Study on the Functions and Effects of European Standards and Standardisation in the EU and EFTA Member States

Part 1: Macroeconomic analysis

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Summary of key findings and conclusions of the macroeconomic analysis

European standards contribute to increased productivity in the EU and EFTA countries. In an analysis of 19 EU and EFTA countries, we find a positive relation between the net stock of European standards and productivity. The result is robust across a variety of model specifications which control for variables such as labour input, capital services, patents, country-fixed effects, time-fixed effects, and recessions. The results indicate that a one percentage point growth increase in the stock of European standards is associated with an increase gross value added of approximately EUR 8.4 billion in the succeeding year for EU and EFTA countries.

The main benefits of standardisation are realised downstream in the value chain. We analyse both the effect of standards in each sector, and the effect downstream in the value chain. The productivity gains from standards seem to be largest in the sectors buying inputs from the sectors that apply the European standards. This is an important finding for policy implications, because it means that the largest benefits appear to be realised by firms which are not the ones undertaking the cost of standardising. This may have implications for the optimal level of subsidies for the development of European standards, and how European standards are priced.

Both harmonised and non-harmonised standards contribute to productivity, but non-harmonised standards are found to contribute more. European standards consist of both harmonised standards and non-harmonised standards. Harmonised standards are created on request from the European Commission – often to fulfil policy-related goals – while non-harmonised standards are developed from market forces, as standards normally are. We find that non-harmonised standards contribute more than harmonised standards do, but that harmonised standards also have a positive effect on productivity. The finding that harmonised standards appear to have a positive contribution on productivity means that they can be a suitable tool both for enhancing productivity and for ensuring other goals of the European Commission. It may be worth examining whether harmonised standards could be used as a tool to an even larger extent than today.

European standards appear to contribute to increased innovation by creating a common platform from which firms can innovate. We use data from the Community Innovation Survey (CIS) and perform a correlational analysis to shed light on how European standards may affect innovation. We find that firms in sectors with more European standards have more innovations that are world leading or new to the market, but fewer innovations that are new only to the firm. This may support two hypotheses. First, that European standards create a common platform, so firms do not need to perform firm level innovations already known to others. Second, that when the European standards push more firms up to the frontier, the number of firms which can make new innovations increases, which again leads to more innovation. This is not a causal finding but indicates that European standards can contribute to increased innovation. When planning on which areas to develop new standards, it may therefore be worth focusing on where European standards can disseminate a "best practice" for firms to innovate from.

European standards develop alongside improvements in sustainability: We examine the relation between European standards and Sustainable Development Goals (SDGs). We map the relevant European standards to each sustainable development goal and examine whether the trends in standardisation coincide with improvements in 13 sustainable development goal indicators. In general, the analysis shows that when the number of relevant European standards increases, the SDG indicator also tends to improve. The findings are in line with a hypothesis that European standards contribute positively to sustainable development.

1. Introduction and reading guide

The macroeconomic is part one out of five that make up the full report on the Functions and Effects of European Standards. It is the first part of the report, and can therefore be read as stand-alone, while it also plays into the other four parts. For reader simplicity, we have split it out as a separate document.

The macroeconomic analysis consists of three parts:

Chapter 2 is a thorough analysis on how European standardisation has affected the productivity of European countries. In **chapters 2.1 and 2.2** we go through the relevant literature on how standards affect productivity and the results of past studies.

In **chapter 2.3** we present the results of our study. **Chapter 2.3.2** shows the results at the economy-wide level, while **chapter 2.3.3** shows the results at the sector and value-chain level.

Chapter 3 examines the relation between European standards and innovation activities, while **chapter 4** analyses how European standards correlate with indicators of societal interests including health, safety, environmental and consumer protection.

Finally, **chapter 5** contains annexes, with robustness tests and descriptive statistics.

2. European standards and productivity

In this section we investigate the impact of European standards on productivity. The analysis integrates and further develops methodology from previous studies to conduct a comparative and comprehensive econometric analysis of the effects of European standards on macroeconomic performance across EU and EFTA Member States. We investigate both economy wide effects and sector specific effects. Moreover, we analyse how European standards impact productivity through sectors' value chains, and whether there are any differences with respect to how harmonised and non-harmonised European standards impact productivity.

2.1 Literature review

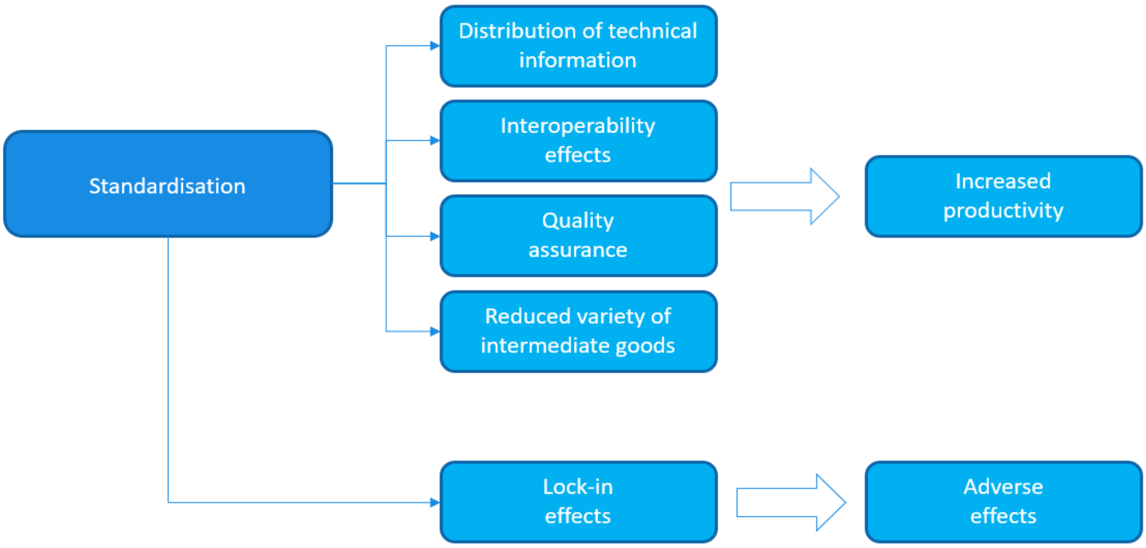
There are several studies that investigate how productivity relates to standards and standardisation. In the following, we first present the channels through which standardisation may increase productivity, and how the impact of standardisation is typically included in macro-economic studies examining explanatory factors of productivity. Following this, an overview of previous empirical studies which have looked at standards as an explanatory variable for productivity is presented.

Potential effects of standards on productivity

As defined by the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC), a standard is a "document, established by consensus and approved by a recognised body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context". Standards play an important role for businesses, citizens and public authorities, as they may contain information such as (but not limited to) guidelines for management, terminology which allows for the use of a common language across value chains and sectors, as well as product and service requirements.

As summarised in the figure below, standards may increase productivity in an economy through several mechanisms.

Figure 1 - Mechanisms for which standardisation may affect productivity[1]



Source: Author's elaboration

One of the most cited mechanisms is the diffusion of knowledge throughout the economy, which is also mentioned as a factor explaining total factor productivity (Organisation for Economic Co-operation and Development (OECD), 2015). This mechanism is captured by "distribution of technical information" in the figure above. To ensure continuous economic growth, creating knowledge through research and development is not sufficient on its own. This knowledge must also be disseminated in the economy at large, enabling companies to make use of it. Jungmittag et al. (2011) point out that standards that are developed in consensus with the participation of companies are particularly suitable for disseminating technical knowledge. Standardisation experts record current practices in documents that can be shared with other companies. Hence, broad diffusion to the market is facilitated. This needs not only be through strictly technological standards, but also for example management standards that spread best practices in how to manage a business. Acemoglu et al. (2010) point out that the standardisation process is costly, and in the short-term new technologies might be complex and require skilled personnel to operate. However, standards facilitate widespread adoption and use of good routines, which in turn enables cheaper production, e.g. through automation.

There are, however, also other channels through which standardisation may influence increased productivity (Swann, 2010). These channels include interoperability effects, reduced variety of intermediate goods and quality assurance. These factors are all likely to be positive for economic productivity. Proper design and implementation of standards may lead to considerable reduction of transaction costs, enhancing trade and, consequently, economic welfare. Reduced variety of intermediate goods enables the exploitation of economies of scale, without reducing the choice of consumers.

There are also possibilities for some adverse effects from standardisation. For example, standardisation could cause companies to choose well-established procedures and solutions instead of investing in research, which aims to develop better solutions. In other words, standards may lead to lock-in effects, where businesses use solutions over a long period of time because they are the most common ones. This might again lead to lower innovation and sub-optimal solutions. This is also pointed out by e.g. Farrell and Klemperer (2006), who emphasise

[1] The figure is inspired by the mechanisms presented and discussed by Swann (2000, 2010).

that switching costs and network effects bind customers to vendors if products are incompatible, locking customers or even markets into potentially suboptimal early choices. That is, there might be a trade-off between lock-in effects, which can have a negative long run effect on productivity, and for example interoperability, which creates positive productivity effects.

2.2 Standardisation and economic models on productivity

All studies related to the effect of standards on productivity that have been reviewed as part of this study model the effect of the stock of standards on output using some variant of the Cobb-Douglas production function, adding standards as an additional explanatory variable. The Cobb-Douglas production function typically takes a shape such as:

$$Y_t = A_t K_t^{\propto} L_t^{\beta}$$

where Y_t is the real output at time t, K_t the capital input, and L_t is the labour input. $\propto$ is the output elasticity of capital, and β is the output elasticity of labour.[2] A_t represents Total Factor Productivity (TFP, sometimes called Multi Factor Productivity or MFP).[3] TFP captures factors which cannot be explained by input factors, traditionally labour and capital, and is often referred to as the Solow residual.[4] This residual represents labour-augmenting technology or "knowledge" and indicates the productivity in these models.

The three most common dependent variables (left hand side variable in the equation) in macro-economic studies on productivity are *gross value added, labour productivity* and *TFP.* The measures are closely related. Gross value added is the total value of output in an economy, or a sector, subtracted the value of the intermediary goods and services in the production process. Labour productivity is the amount of value added produced per labour input, while TFP is a measure of how much is produced for a given level of total factor use in the production, including capital and labour and other input factors. In a regression analysis of gross value added where one controls for input factors, such as capital and labour, the remaining unexplained variation of this model is TFP.

TFP is often referred to as a "measure of our ignorance" (Abramovitz, 1956). While the literature shows examples of how this ignorance has gradually declined over time as the measurement of the quality of input factors has improved, there is still much of productivity growth that remains unexplained. The common approach in empirical analysis of what contributes to economic growth is to replace the productivity variable A_t in the model with variables that are thought to improve productivity. One variable which is particularly relevant to this study is a country's stock of standards. In studies investigating the impact of standards on productivity, the most frequently used variable to replace A_t is the Net Stock of Standards (NSS) in the country. To avoid regression bias, various control variables (X) which may also affect productivity are included. The equations therefore take the shape as:

$$Y_t = K_t^{\propto} L_t^{\beta} NSS_t^{\gamma} X_t^{\delta}$$

[2] The output elasticity is the percentage increase in output from one percent increase in any given explanatory factor.
[3] When it comes to whether labour productivity or total factor productivity should be used to measure economic growth, Sargent and Rodriquez (2000) conclude that both measures have uses. They find that for periods of less than a decade, labour productivity is the preferred measure, but for longer periods total factor productivity is superior. Furthermore, when capital stock estimates are of poor quality – for instance if the time series are too short – it is better to use labour productivity. This is largely in line with the OECD (2001) productivity manual.
[4] The Solow-Swan growth model (Solow, 1956), (Swan, 1956) proposed the addition of technological progress as a third source of economic growth that is external to the other two factors capital and labour. In the model, the rate of technological progress has the only influence on the long-run growth rate of per-capita output and consumption. Romer (1990) builds on these fundamental ideas, showing that technological progress is endogenous to economic growth, i.e. a higher pace of economic activity can raise the pace of process innovation as firms learn from their experience, resulting in a virtuous circle of growth.

Taking the natural logarithm to test it econometrically, the regression becomes:

$$\ln (Y_t) = const + \alpha \ln (\mathrm{K_t}) + \beta \ln(\mathrm{L_t}) + \gamma \ln(NSS_t) + \delta \ln(X_t) + \varepsilon_t$$

where γ is the parameter of interest. γ can be interpreted as the estimate for the effect of standardisation on output. δ is a vector consisting of the elasticity for each control variable in X. ε_t is the error term of the model. This error term can include the part of A_t not captured by the model specification, or measurement errors in any of the independent variables.

Productivity studies including standards as an explanatory factor

Several productivity studies have been carried out which use standards as an explanatory factor. For this study, we have gone through studies from Australia (Standards Australia, 2012), Canada (the Canadian Council of Standards, 2007), France (Afnor, 2009), Germany (*Deutsche Institut für Normung*[5] (DIN), 2011), New Zealand (Business and Economic Research (BERL), 2011), the Nordic countries (Menon, 2018), the UK (Hogan et. al., 2015) and Belgium (Buts et. al., 2020) as well as a combined study on four EU countries (Blind and Jungmittag, 2008). The latter also includes a study at the industry level and a regression analysis including European standards as an explanatory factor, while the Belgian study is at the sectorial level.

Feil! Fant ikke referansekilden. summarises the studies:

[5] German national organisation for standardisation.

Table 1 - Key features of main productivity studies

	Belgium	Nordic countries	UK	Australia	New Zealand	Germany	France	4 European countries	Canada
Year	2020	2018	2015	2012	2011	2011	2009	2008	2007
Dependent variable	Output and labour productivity cross sectors	Labour productivity	Labour productivity	GDP	TFP and labour productivity	GDP	GDP	GDP	Labour productivity
Years studied	1994-2018	1976-2014	1921-2013	1982-2010	1978-2009	1961-2006	1950-2007	1990-2001	1981-2004
Explanatory variables	Capital, employment, patents, recessions, net stock of national standards	Capital-labour ratio, patents, recessions, national stock of standards, time trend	Capital-labour ratio, national stock of standards, recessions, time trend	Capital, employment, stock of national standards, patents, time trend	Capital, employment, domestic patents, licenses, national stock of standards, time trend	Capital, employment, patents, licences, national stock of standards, special events (e.g. recessions)	Capital, labour, national stock of standards, proportion of wages in value added, variation in applications for patents	Capital, labour, patent stock, total stock of standards (national, European, international)	Capital-labour ratio, national stock of standards, time trend
Elasticity of the stock of standards	Positive effects[6]	0.11	0.11	0.17	**TFP**: 0.1 **Labour productivity:** 0.054	0.18	0.12	**Total economy:** 0.079 **UK**:0.52 **Germany**: 0.27 **France**: 0.147 **Italy**: 0.017	0.36

[6]The elasticity estimates represent cross sector averages and are not reported directly in the paper. The estimated economic effect of standards on labour productivity for the Belgian economy (product of elasticity estimate and historic growth rates of stock of standards) is lower than what found for the Nordic countries and UK, while higher than that of Canada.

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	Belgium	Nordic countries	UK	Australia	New Zealand	Germany	France	4 European countries	Canada
	Nordic countries	UK	Australia	New Zealand	Germany	France	4 European countries	Canada	
Year	2018	2015	2012	2011	2011	2009	2008	2007	
Dependent variable	Labour productivity	Labour productivity	GDP output	TFP and labour productivity	GDP output	GDP output	GDP output	Labour productivity	
Years studied	1976-2014	1921-2013	1982-2010	1978-2009	1961-2006	1950-2007	1990-2001	1981-2004	
Explanatory variables	Capital-labour ratio, patents, recessions, national stock of standards, time trend	Capital-labour ratio, national stock of standards, recessions, time trend	Capital, employment, stock of national standards, patents, time trend	Capital, employment, domestic patents, licenses, national stock of standards, time trend	Capital, employment, patents, licences, national stock of standards, special events (e.g. recessions)	Capital, labour, national stock of standards, proportion of wages in value added, variation in applications for patents	Capital, labour, patent stock, total stock of standards (national, European, international)	Capital-labour ratio, national stock of standards, time trend	
Elasticity of the stock of standards	0.11	0.11	0.17	**TFP**: 0.1 **Labour productivity:** 0.054	0.18	0.12	**Total economy:** 0.079 **UK**:0.52 **Germany**: 0.27 **France**: 0.147 **Italy**: 0.017	0.36	

As we can see from the table, the general picture is that standardisation, proxied by the **net stock of national standards, has a positive impact on productivity and economic performance.** The estimated elasticity of the stock of standards does, however, differ from study to study.

One would expect the effect of standardisation to vary across countries and time periods. The studies do, however, differ in several respects, including:

- Country and region: It is reasonable that the effects of standards on productivity differs between countries. Countries differ in many respects, for instance in terms of rules and regulations, culture, and ways of conducting business. This is especially true for the studies outside of the European Union, namely Australia, New Zealand, and Canada. We can see that New Zealand for instance has a substantially lower estimate for labour productivity than other studies, while Canada's is substantially higher.
- Country specialisation: Standards can have a different impact on the economy according to which sector dominates the national economy. The level of available standards varies between sectors. Thus, one should also expect that the economy wide effects vary based on what type of sectors is dominating the country's economy.
- Time period studied: It is generally desirable to use a longer time period when the data are available. On the one hand, this typically reduces the sample's standard error.[7] In the studies above, the time periods studied vary from almost 100 years in the UK study to about 12 years in the 2008 study of the four European economies. On the other hand, economies, and how they function, change over time. One can therefore argue that results based on recent data are more relevant to the current structure of the economy.
- The output measure: Different measures of economic output, the dependent variable, are used across studies. The outcome may be different depending on the output measure used, and the restrictions made on the model estimation. There are for example different methodologies for measuring TFP. Some estimate it themselves, while others use commonly applied coefficients for capital and labour elasticities.
- Capital stock measure: While some of the studies use capital stock, others utilise capital services. For example, the capital stock measure used in the UK study was created by the Bank of England and incorporates asset capital services growth. This differs from the measure used in the German study, where the capital stock is the result of previous investment, defined as assets which are continually used in production, such as machinery and buildings. This can also impact the results of the regression.
- Labour measure: The way labour participation and employment is measured may differ between studies. This could impact the regression results.
- NSS: The NSS differs between countries. Some countries develop more own standards, are more involved in the development of international standards and more efficient in implementing standards in their economies. This may also affect the outcome of the analysis.
- Model specification: Several of the studies include a recession indicator variable, which captures exogenous shocks from recessions. However, this also varies across the studies. Moreover, not all studies include patents as a control variable due to problems with collinearity with the stock of standards.

It is difficult to pinpoint exactly which of these factors contribute to differences in the estimates across studies. We can see that the European studies looking at labour productivity estimate an

[7] In statistics, the standard error is the approximate standard deviation of a sample population. The term measures the accuracy with which a sample distribution represents a population by using standard deviation. The standard error is a decreasing function of the number of observations in the sample. In statistics, a sample mean deviates from the actual mean of a population—this deviation is the standard error of the mean.

effect from the net stock of national standards of 0.11. Meanwhile, the estimates from other regions give considerably different results – the estimated effect in New Zealand is half of that in the European studies, at 0.05, and that in Canada is more than three times higher. It should also be noted that although the average Nordic estimate was 0.11, the country specific estimates for the five Nordic countries varied from 0.05 to 0.15. One important difference of the Canadian study, compared to that of the Nordic countries and New Zealand, is that it does not control for technological developments, measured by the stock of patents, in the model specification. As we know that the stock of patents and the stock of European standards tend to be correlated, this could explain why this study has a higher coefficient estimate. However, even though patents are not controlled for in the UK study, it investigates a much longer time period, which could also explain differences.

On Gross Domestic Product (GDP), the variations are high also within the European countries. The estimated results from Germany (0.18) and France (0.12) differ by 0.06, which is quite considerable. These differences in results come regardless of the fact that these studies are quite similar in terms of model specification. The estimated time series is, however, 12 years longer in the French study.

Although the coefficients vary in magnitude, all studies find that standardisation is positively related to the productivity of the national economy. The general finding from the literature should, however, be interpreted with caution, in the sense that the estimates do not capture the isolated effect of standards on productivity. Standards are not implemented in a vacuum; they rather play a symbiotic and complementary role with other factors like rules and regulations. Moreover, there may also be an interplay between standards and technological developments, such as the advances in Information and Communication Technologies (ICT). These features are to a limited extent captured by model specifications in the literature, as can be seen in the overview of specifications in **Feil! Fant ikke referansekilden.** above. The mechanisms behind the interplay between standards and other factors are unobservable and therefore hard to account for.

There are also some concerns related to the methodology applied across all of the studies. This includes the robustness of the NSS as a proxy for the influence of standards in the economy, potential multicollinearity between NSS and other control variables, as well as potential issues with non-stationarity of time series in these models. These are issues that will be addressed when investigating the impact of European standards on productivity.

The NSS is a measure of the number of available standards in the economy. A common critique against using the NSS as a proxy for standardisation is that standards presented at a given time are not necessarily equally important in increasing productivity. Moreover, not all standards are implemented, even though they are made available. The same type of critique is also valid for the stock of patents, a commonly used indicator in studies of the innovation process and its impact on productivity. The stock of patents is usually calculated with a factor that takes into account the depreciation of the value of a patent over time. As suggested by Stokes et al. (2011) in their study of productivity effects of standards on the New Zealand economy, a similar approach could be used for the NSS, i.e. modifying the number of standards by their age so as to provide an „age-adjusted" measure of standards. In the later analysis this will be provided as one of many robustness tests with respect to applying the net stock of European standards as a proxy for the development in the influence of European standards.

2.3 Econometric analysis

While there are numerous studies from different countries and time periods on the association between productivity and national standards, a comprehensive estimation of the effects of European standards[8] on economic growth is missing. This study aims to fill that gap.

Several econometric models to investigate the effects of European standards on economic growth are employed, both at the economy wide level, and at the sectorial level. The analysis also goes deeper into the understanding of how European standards function, investigating how European standards impact productivity through the value chain, as well as differences in the impact of harmonised and non-harmonised European standards on productivity.

An important difference from previous studies is that the analysis is based on a panel of EU and EFTA Member States, rather than single countries or regions.[9] Moreover, the study aims at contributing to further development of the methodological approach, addressing issues raised related to the existing literature. The study applies an approach which links European standards to specific sectors, both directly and through their value chain. Moreover, the sector analyses use data sources that adjust for investments in intangible resources and quality of labour. Finally, the study investigates the interplay between European standards and legislation utilising time series data on the development of harmonised standards gathered through systematic searches in the EUR-Lex database.

2.3.1 Data

The econometric analysis on productivity uses two main sources for data on value added, capital and labour: the EU KLEMS productivity and growth accounts database for data at the sectoral level, and the Penn World Table (PWT) for data at the economy-wide level.

In addition, we supplement the analysis with data on specific explanatory variables from European Committee for Standardisation[10] (CEN) and European Committee for Electrotechnical Standardisation[11] (CENELEC) (net stock of European standards), European Patent office (net stock of patents) and Eurostat (Gross capital formation).

KLEMS database

The EU KLEMS database is a widely applied database in productivity studies. In the KLEMS database, output is not modelled as a function of the stocks of capital and labour, but instead from the services that capital and labour provide. Measuring the service rather than the stock reduces the measurement error, which in turn gives better estimates of productivity than what other sources of data on European countries can provide.[12]

However, the KLEMS database has poorer country coverage than other databases. At the total economy level, using KLEMS would not allow us to test all EU and EFTA countries, as it only covers 23 out of 31 countries, starting from the year 2000.[13] At the sectoral level, however,

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[8] By European standards we mean all standards that are adopted by a European standards organisation. This includes all ENs that are implemented as national standards including joint standardisation documents (EN-ISO, EN-IEC and ETSI-EN standards).

[9] To our knowledge the only previous studies on macroeconomic productivity effects of standardisation that have included more than one country are Blind and Jungmittag (2008) for Germany, UK, Italy and France, as well as Menon et al. (2018) in their study of the five Nordic economies.

[10] In French: *Comité Européen de Normalisation*.

[11] In French: *Comité Européen de Normalisation Électrotechnique*.

[12] The importance of using capital and labour *services* rather than stocks is highlighted in the OECD manual of productivity. http://www.oecd.org/sdd/productivity-stats/2352458.pdf.

[13] At the total economy level KLEMS has data on GVA, capital stock and hours worked from the year 2000 up through 2017.

KLEMS is the preferred database since the country coverage is in line with other relevant databases such as the OECD Structural Analysis Database (STAN).

Penn World Table

The PWT contains consistent national accounts data for countries across the world, including the 31 EU and EFTA countries. The database contains national accounts data collected from individual countries, supplemented with additional data where necessary. Using the PWT allows us to analyse all EU and EFTA countries which have been members of CEN-CENELEC-European Telecommunications Standards Institute (ETSI) over the past 23 years. Robustness tests show that the estimated coefficients are highly similar when running regressions at the total economy level for the same sample of countries with data from the Penn World Table and the EU KLEMS database, respectively. We therefore consider that for the total economy model, it is preferable to utilise the PWT due to its wider country coverage, as well as more recent time series.

Stock of European standards

We use data on the stock of European standards from the European standardisation bodies (CEN-CENELEC and ETSI). The data includes information on when the standards were introduced, which ICS they belong to, and (when relevant) the date they ceased to be active. These data are accompanied by data on ICT-standards from ETSI (the European Telecommunications Standards Institute).

The NSS is a widely applied proxy for the impact of standards over time. We calculate the net stock of European standards (NSES) per year as all European standards active in that year. That is, we calculate all new standards and subtract all standards that expire within one given year. This is the same methodology as other studies investigating the relation between stock of standards and productivity.

Using the ICS-codes, we map which standard belongs to which KLEMS sector and NACE a64 sector. The standards are mapped connecting each ICS level 3 (7-digit ICS-code) to which NACE and KLEMS sectors it belongs to. This creates a stock of European standards per sector.

In addition, we calculate the *effective NSS*. This is done by weighing the stock of European standards for each sector with respective sector sizes in each country. In this way, the standards which are more relevant to each economy are given a higher weight, and we get a more precise proxy of the impact of different European standards on each economy.

European Patent Office

Patents are commonly used in the standardisation literature as a proxy for a country's innovation activity. As our estimate for new patents in each country, we use the stock of patents granted to inventors with residence in different countries by the European Patent Office. The net stock of patents is then calculated by using a perpetual inventory model. That is, the stock of patents on year *t* is the stock of patents the year before depreciated, plus the number of new patents granted in the year. We employ a commonly used depreciation rate for patents of 15%.[14]

Input-output tables

To determine the number of standards in the value chain, we use input-output tables and data on gross capital formation by asset type, collected from Eurostat. Input-output tables describe sales and purchases of goods and services between industries within each country. We utilise this, together with the stock of European standards and the sector-mapping, to calculate the NSUS in the value chain.

[14] See for instance Derek Bosworth and Gregory Jobome (2003).

Time period

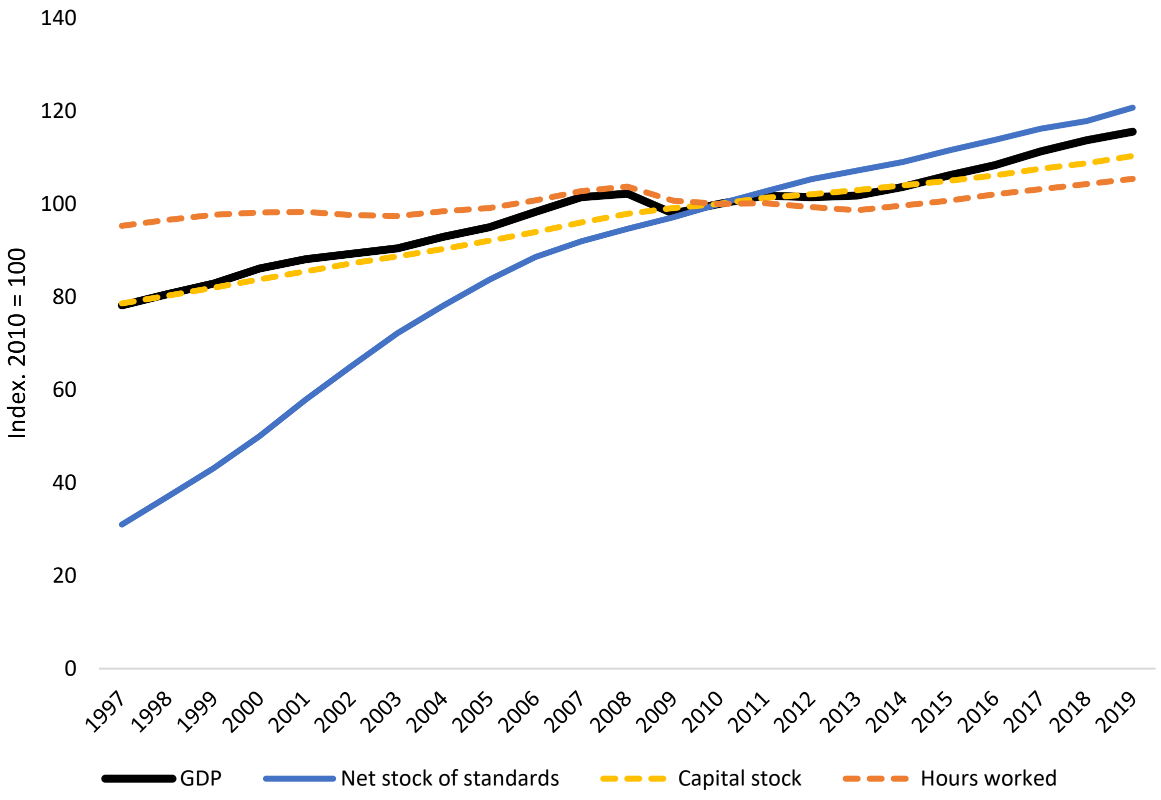
Our analysis at the economy wide-level uses data from the period from 1997 to 2019, while the sector-models rely on more granular data which is only available up through 2017.

This is shorter than previous productivity studies on standards which typically estimate models based on a 40-100-year time span. There are two main reasons for narrowing down the time span. Firstly, during most of the 1990s the growth in European standards was "artificially" high due to the New Approach (1985). This artificially high growth would pose problems in the estimation of productivity effects when using the stock of standards as an explanatory variable. Secondly, as this study is orientated towards what effect we can expect from European standards forward in time, we want to base the estimates on the most recent time period possible while at the same time having a sufficient amount of data to get precise estimates.

Descriptive statistics

The figure below shows how the net stock of European standards has grown significantly during the estimation period. At the start of 1997, the net stock of European standards was just under 6 000. By 2002, it had more than doubled to more than 13 000, and by 2019 it doubled again to about 26 500.[15] This corresponds to an annualised growth rate in the stock of European standards over the time period of 6.4 percent per year, far exceeding the growth rate of GDP, capital or hours worked (as illustrated in the figure below). Real GDP in the EU + EFTA has grown by an average of approximately 1.8 percent per year, slightly faster than the capital stock, and much faster than hours worked, which grew by an annualised 0.5 percent.

Figure 2 - Index of Real GDP, the stock of standards, capital and hours worked in EU + EFTA countries. Index: 2010 = 100



[15] Some of the documents created by the European Standardisation Organisations are multi-part documents. This means that each document contains many sub-parts which focus on different, related topics. For the macroeconomic analysis, we count each (active) part as a separate standard.

Source: PWT for Real GDP, capital stock and hours worked. CEN-CENELEC and ETSI for standards

The net stock of European standards is identical for all countries with membership in CEN-CENELEC-ETSI. Thus, the net stock of European standards does not vary between the countries. This is not the case for GDP, for which there have been rather large variations in growth rates across EU and EFTA countries the past 20 years. Approximately one third of the countries in EU + EFTA had an average annualised growth rate of over 3 percent over the analysed period, while one third had a growth rate of 2-3 percent, and one third had a growth rate of under 2 percent. The largest countries tended to have a lower growth rate over the period, which means that the average EU and EFTA country saw higher growth than the total growth rate of EU and EFTA. While the annualised growth rate for EU + EFTA overall was approximately 1.8 percent, the average growth rate of the individual countries was 2.5 percent.

2.3.2 Economy-wide model

The descriptive statistics clearly show that **capital, labour, output and the stock of standards have all trended upwards in recent history.** Performing tests for stationarity confirms that all variables in our dataset are non-stationary.[16] Non-stationarity is problematic as estimation of the standard productivity model on log form, as specified in the literature review Section 2.1, could lead to spurious results.

To solve the problem of non-stationarity, we take the first difference of the natural logarithm of each variable. This means that rather than looking at output levels, we look at **output growth**.[17]

To model the effects of standards on GDP growth we estimate the following model:

$$\Delta \ln Y_{i,t} = const + \alpha\, \Delta\ln\left(K_{i,t}\right) + \beta\, \Delta\ln\left(L_{i,t}\right) + \gamma\, \Delta\ln(NSES_{t-1}) + \delta\, \Delta\ln\left(X_{i,t}\right) + \varepsilon_t$$

where Δ is the first difference operator, $Y_{i,t}$ is real gross value added *(GDP)* of country *i* at time *t*, $K_{i,t}$ is the capital input, and $L_{i,t}$ is the labour input, represented by hours worked. $\Delta\ln(NSES_{t-1})$ is the change in the net Stock of European standards in year *t-1, and* ε_t is the error term. $X_{i,t}$ is a vector of control variables. The vector includes the net stock of patents granted by the European Patents Office to inventors with residence in country *i* (pat_{it}). The net stock of patents is calculated using a perpetual inventory method.

The regression also includes controls for whether the country is in a recession (rec_{it}), where a recession is defined by a drop in real GDP from one year to the next.

All variables in the regression are demeaned, to control for country-fixed effects.[18] In this way, we control for unobserved factors that lead to different average growth rates across countries. Tests of the first-differenced variables indicate that they are stationary.[19] This means that performing the regression on the first-differenced variables does not risk producing spurious

[16] For a variable to be stationary it needs to have time-invariant mean, variance, and autocovariance. A panel Breitung test for stationarity was employed, and all tests fail to reject the null hypothesis that the panels contain unit roots, i.e. are non-stationary. This holds regardless of if variables are demeaned or a trend is added. The same test shows that all first differenced variables are stationary. (Reference: Breitung, J. 2000. The local power of some unit root tests for panel data. In Advances in Econometrics, Volume 15: Nonstationary Panels, Panel Cointegration, and Dynamic Panels, ed. B. H. Baltagi, 161-178. Amsterdam: JAI Press.).

[17] Taking the first difference of the logged variables is what is typically done in modern productivity studies, such as Sichel (2019) and is broadly done in the OECD manual of productivity.

[18] Tests for fixed vs. random effects confirm that a random effects approach would lead to biased results. This holds for all economy wide models. (Reference: Schaffer, M.E., Stillman, S. 2010. xtoverid: Stata module to calculate tests of overidentifying restrictions after xtreg, xtivreg, xtivreg2 and xthtaylor .http://ideas.repec.org/c/boc/bocode/s456779.html.).

[19] The stationarity is tested using panel unit root tests of Breitung for all variables that vary between countries. The stationarity in the country-invariant NSES is examined using the Augmented Dickey Fuller procedure (ADF). (Reference: Breitung, J. 2000. The local power of some unit root tests for panel data. In Advances in Econometrics, Volume 15: Nonstationary Panels, Panel Cointegration, and Dynamic Panels, ed. B. H. Baltagi, 161-178. Amsterdam: JAI Press.)

results. As the model is specified in terms of growth rates, rather than levels, the results are not directly comparable to past studies on national standards.

We use the panel data cointegration test developed by Westerlund (2007), and the tests fail to reject the null hypothesis of no cointegration. These results indicate that we do not have a cointegrating relationship in our model.[20]

The cointegration tests do, however, not strongly reject the alternative hypothesis that the model is cointegrated. Moreover, previous studies have found similar models to be cointegrated (Centre for Economics and Business Research (CEBR), 2015). For this reason, we therefore add a robustness test in Annex 2.1 which performs the regression at levels instead of first-difference.

The coefficients in this regression can be interpreted as the estimated effect on GDP growth of a one percentage point increase in the growth of the explanatory variables: A one percentage point increase in growth in the net stock of European standards yields a γ percentage points change in GDP growth.

The results from the model where the variables are first differenced are shown in Table . Model (1) shows how the NSS is associated with the Gross Value Added (GVA (Gross Value Added), controlling for the capital stock and total hours worked in each country, as well as country fixed effects. Model (2) adds the net stock of patents as a control, model (3) additionally controls for year where the change in output in the country is negative, and model (4) also controls for human capital formation. Finally, model (5) adds time-fixed effects, in addition to the controls of model (4).

Table 2 - Regression results for economy wide model with first differences. Dependent variable growth of GVA, all controls first differenced, variables are stationary

	Model 1	Model 2	Model 3	Model 4	Model 5
Stock of standards elasticity	0.081*** (0.0153) t: 5.33 p: 0.000	0.082*** (0.0156) t: 5.24 p: 0.000	0.061*** (0.0116) t: 5.27 p: 0.001	0.061*** (0.0117) t: 5.25 p: 0.001	0.1162*** (0.0211) t:5.55 p: 0.001
Controls					
Capital stock and hours worked	Yes	Yes	Yes	Yes	Yes
Stock of patents	No	Yes	Yes	Yes	Yes
Negative change in output dummy	No	No	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes	Yes
Human capital	No	No	No	Yes	Yes
Time-fixed effects	No	No	No	No	Yes
N	437 (23 years and 19 countries)	437 (23 years and 19 countries)	437 (23 years and 19 countries)	437 (23 years and 19 countries)	437 (23 years and 19 countries)

*Cluster robust standard error (at the country level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2019*

The table above shows that the **results are stable independent of model specification**. All models show a **positive significant relationship between the growth rate of the stock of European standards and GVA**.

Depending on the model specification (1-5) a one percentage point increase in the growth rate of the stock of European standards is associated with a 0.06-0.12 percentage points increase in the growth rate of GVA. Of the five models we argue that specification (4) has the most reliable

[20] We use the Stata function xtwest as created by Persyn, D., & Westerlund, J. (2008).

estimates for the net stock of European standards, as these specifications control for country specific recessions, human capital formation and Europe-wide common shocks to GVA. Specification (5) includes time-fixed effects, which controls further for year-specific shocks, but introduces some multicollinearity with the stock of European standards. The multicollinearity is within acceptable levels, but still increases uncertainty of the estimate, as seen by the level of the standard errors.[21] Model 4, which represent results in the lower end of the coefficient estimate interval, may therefore provide the most reliable coefficient estimate of the effect of European standards on GVA growth.

The model is estimated for the 19 EU and EFTA countries which have been members of CEN-CENELEC during the entire period of analysis from 1997 through 2019.[22] Countries which have not been members of CEN-CENELEC for the entire period of estimation differ in many aspects from the countries which have been members since before 1997. Importantly, they are often also granted EU membership at the same time, which could lead to significant unobserved changes in the economy. Furthermore, these countries may have adopted European standards prior to entering CEN-CENELEC, which might also be a confounding factor.

The regression results imply that **if the growth rate of European stock of standards increases by 1 percentage point, the growth in output would increase by about 0.06 percentage points** (Model 4). In comparison, the growth rate of the stock of European standards in the 2010s was approximately 2.1 percent per year. If this growth one year were to increase by one percentage point, to 3.1 percentage points, we would expect the output growth to increase by 0.06 percentage points. This would in this case lead to an approximate increase in EU output of EUR 8.4 billion.[23]

While the causal direction of the relationship is unproven, it appears more likely that it goes from European standards to output than the other way around. Increased economic activity may increase the number of standards developed, but creating standards takes a long time – often up to five years. It is therefore unlikely that changes in output growth from one year to the next will affect the growth in the stock of European standards. Standards, however, are likely to influence productivity as soon as the standards start being used.

As described in the literature review, there are some potential issues with using the stock of standards as the explanatory variable. One problem is that the NSES is equal across all EU and EFTA countries, which means that it does not take into account that the availability of European standards varies across countries depending on sector composition. Secondly, the stock of standards is not adjusted to the age of the standards. We robustness test the results with respect to these concerns by applying an *effective* stock of standards which control for the individual country's sector composition in the next sub-section, and an *age-adjusted* stock of standards in Annex 2.3.

Robustness test of economy wide model: effective standards

European standards apply to all countries which are CEN-CENELEC members. All countries are not necessarily affected the same way by a new standard, however. Certain standards affect mostly some industries, and countries which specialise in those industries are therefore more likely to be affected by that standard. For example, standards affecting car manufacturers may influence big car manufacturing countries, such as Germany, more than they may influence

[21] The Variance Inflation Factor is 5.5. This is below the commonly used rule of thumb of 10, but it increases the uncertainty of the coefficient estimates.
[22] Austria, Belgium, Denmark, Germany, Greece, Spain, Finland, France, Ireland, Italy, Iceland, Luxemburg, Netherlands, Norway, Portugal, Sweden, Switzerland and the UK have been members of CEN-CENELEC for the entire period of interest.
[23] The EU27 GDP was approximately 14 trillion EUR in 2019, and an increase in output growth by 0.06 percentage points would therefore increase the GDP by approximately 8.4 billion EUR.

another country, e.g. Austria, since car manufacturers make up a much larger share of the German economy than they do of the Austrian economy.

This means that **while the stock of standards is identical for all EU and EFTA countries, it affects countries in different ways depending on the respective country's sector composition**. We therefore calculate an *effective stock of European standards*, which takes sectoral composition into account. The effective stock of standards is calculated as:

$$ENSES_{i,t} = \sum_{j=1}^{40} NSES_{j,t} * \frac{\overline{VA_{i,j}}}{\overline{VA_{i,tot}}}$$

where $ENSES_i$ is the effective net stock of European standards (ENSES) in country i. $NSES_j$ is the net stock of European standards in sector j. $\overline{VA_{i,j}}$ is the average value added in country *i* in sector j over the sample period. $\overline{VA_{i,tot}}$ is the average total value added in country *i*. $\frac{\overline{VA_{i,j}}}{\overline{VA_{i,tot}}}$ is thereby sector j's share of the total value added in country *i* for the sample period. Further, $ENSES_i$ is the weighted sum of European standards in all sectors in country *i*.

When country A′s effective stock of European standards grows faster than country B's, that is because, in that year, there were more new European standards made available in sectors in which country A has specialised, than in sectors in which country B has specialised. This is a form of natural variation between countries which we can use to further examine the productivity effects of European standards.

If European standards truly have an effect on productivity, we would expect to see that when country A's effective stock of European standards increases more than country B's, that will lead to country A's productivity rising more than country B's.

We perform a regression with the same setup as the baseline first difference model, but with the *effective* stock of standards as the explanatory variable. Specification 5, which has both time-fixed and country-fixed effects, utilises the natural variation in sector compositions between countries to perform a type of difference-in-difference model setup. In this specification, γ is an estimate of how much a higher than average growth in the effective stock of standards affects that country's output the next year. The results are displayed in the table below.

Table 3 - Results of regression analysing the productivity effects of having a higher than average growth in the effective stock of standards

	Model 1	Model 2	Model 3	Model 4	Model 5
Effective stock of standards elasticity	0.0574*** (0.0099) t:5.78 P:0	0.0534*** (0.009) t:5.94 P:0	0.0428*** (0.0082) t:5.23 P:0.0001	0.0429*** (0.0081) t:5.30 P:0.0001	0.0959* (0.0499) t:1.92 P:0.07
Controls					
Capital stock and hours worked	Yes	Yes	Yes	Yes	Yes
Stock of patents	No	Yes	Yes	Yes	Yes
Negative change in output dummy	No	No	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes	Yes
Human capital	No	No	No	Yes	Yes
Time-fixed effects	No	No	No	No	Yes

	Model 1	Model 2	Model 3	Model 4	Model 5
N	315 (21 years and 15 countries)	315 (21 years and 15 countries)	315 (21 years and 15 countries)	315 (21 years and 15 countries)	315 (21 years and 15 countries)

*Cluster robust standard error (at the country level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2017.*[24]

The results of this robustness test are similar to the baseline model and support its conclusions. Specification 4 of the baseline model suggested that a 1 percent increase in the stock of European standards yielded an average 0.061 percent increase in output for European countries, while the regression with effective standards suggests the coefficient is 0.043. The fact that we find estimates within the same magnitude applying two different measures for the evolution of European standards **strongly supports the findings of the baseline model**.

Specification 5 controls for both time-fixed effects and country-fixed effects. The interpretation of the coefficient is therefore that when one country has a 1% higher growth in effective standards than another, that leads to an estimated 0.096 percent higher growth in output the next year. In simple terms, this regression indicates that **when new European standards are created in one sector, then the productivity of countries with relatively higher dependence of that sector increases the following year**, and increases less in countries with relatively less dependence of that sector.

2.3.3 Sector model

The results of the effective standards model indicate that cross country variation in the effective stock of European standards causes increased output. If there are more European standards in sectors a country specialises in, that country sees increased growth. This result is particularly convincing as it exploits the variation of available European standards, which depends on the sector composition of the respective EU and EFTA country.

In this Section we try to disentangle the economy wide effect by looking at how productivity developments within specific sectors are associated with the developments in standards relevant for this sector. Moreover, we also investigate how gains from European standards are distributed through the value chain.

In Figure 1 in the literature review (Section 2.1), we introduced four main channels through which standards are expected to have a positive effect on productivity: interoperability effects, reduced variety of intermediate goods, quality assurance, and distribution of technical knowledge. While distribution of technical knowledge is most relevant for productivity effects within the sector, the other channels are just as likely to provide productivity effects further down the value chain.

For example, if all potential suppliers of an intermediate good apply the same standard it will increase the number of compatible suppliers, which in turn might increase productivity for the downstream final good producer. This is not only true for goods, but also for systems and services. Different systems from different suppliers can work together by adhering to the same standards, but without good standards, it would be difficult for the systems to do so. The standards therefore increase the number of compatible suppliers of systems. This provides an illustration of how interoperability effects and a reduced variety of intermediate goods may particularly benefit the downstream firm. The quality assurance effect could have a positive impact both within the sector and through the value chain. Within the sector, quality assurance could create markets for high quality suppliers which otherwise would not have a market for

[24] The time period is from 1997-2017 in this regression, as calculating the effective net stock of standards requires value added data from the KLEMS database which is only available up to 2017.

their product as consumers could not separate their product from that of low-quality suppliers. It could also create productivity effects downstream as buyers of the products would need to use less resources on verifying the quality of products and services, in addition to reducing risk related to low quality supplies in production.

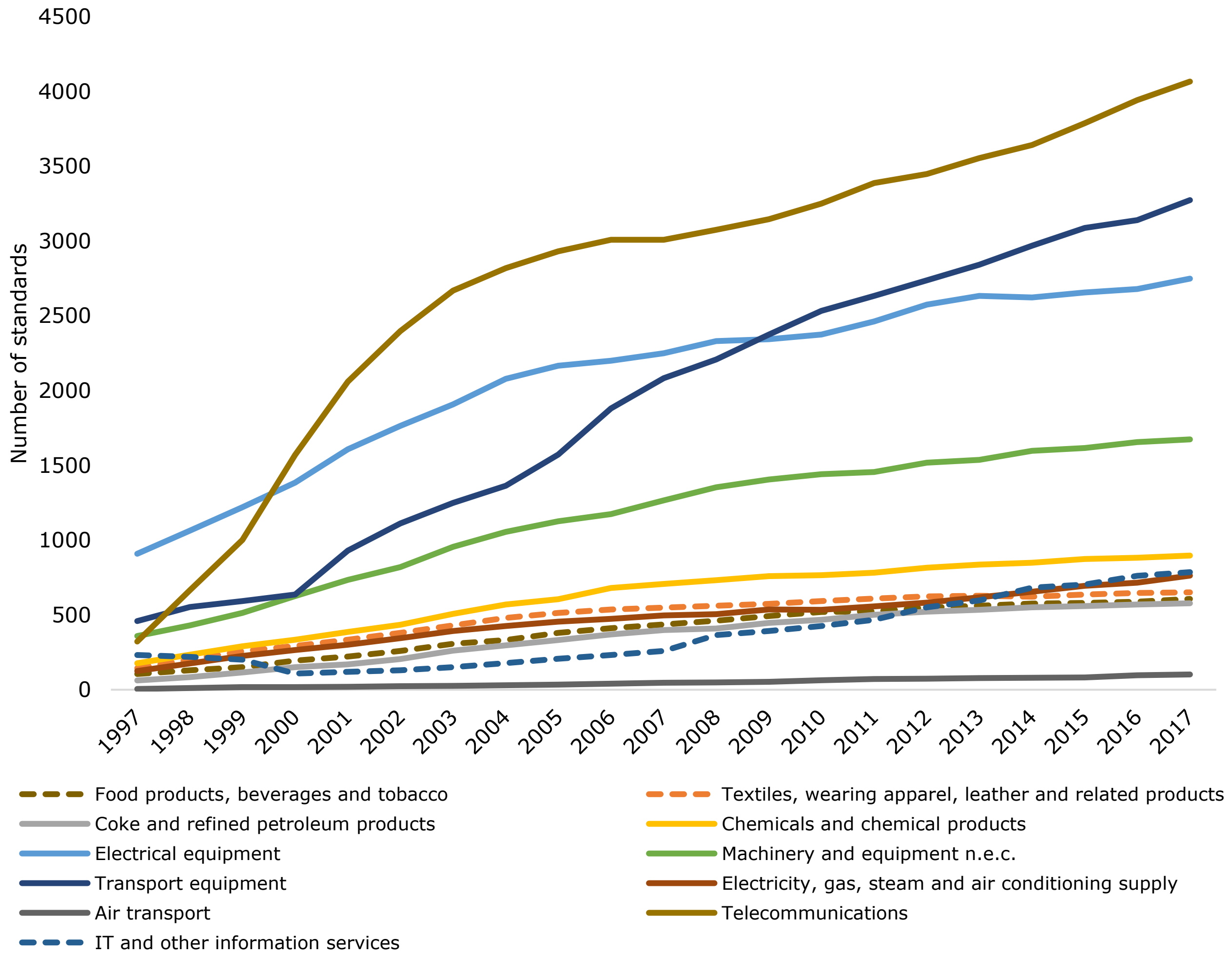
In task 2, we perform sector analysis of the presence and relevance of European standards within 10 selected industries. In the following Section we investigate productivity effects and value chain effects both across these sectors, as well as for each sector individually.[25] Figure 3 below displays the development in the stock of European standards for each of the 10 sectors during the period 1997 to 2017.[26] The sector with most standards is the telecommunications sector, followed by transport equipment, electrical equipment, and machinery. At the other end of the scale, we find European standards related to air transport.[27] Sector growth rates are generally more volatile than in the economy-wide model. Certain periods have higher growth rates. While the average growth rate in the net stock of European standards at the economy wide level was 6.6% per year over the period, the selected sectors tend to have a slightly higher one, with the telecommunications, transport equipment and coke and petroleum sectors having annualised growth rates of more than 10%. Certain sectors grew slower than the national average, for instance the stock of standards for Electrical equipment, which grew at an average of 5.7%.

[25] The sectors in task 1 and task 2 are not fully overlapping as the statistical analyses on productivity is limited to the level of granularity of official statistics available. Certain sectors in task 2 are therefore not feasible to analyse in the productivity study in task 1. See Annex 1.1.1 and Annex 1.2.1 for the correspondence of sectors in task 1 and task 2. The digital society sector in Task 2 contains both "IT and other information services" and "Telecommunications", therefore Task 1 focuses on 11 sectors, while Task 2 on 10.

[26] The number of standards here include the different parts in a European multi-part document. A multi-part document with 10 different parts is therefore counted as 10 standards. This is done since the scope of the individual parts are more similar to other standards, than the scope of the full multi-part documents is.

[27] Air transport does not include standards related to manufacturing, which is part of transport equipment.

Figure 3 - Descriptive statistics of number of European standards per sector over time



Source: Data from CEN, CENELEC and ETSI, mapping by Menon Economics and EY

In Annex 2.2., we display the development of standards along with TFP in the analysed countries in each of these sectors. Sector TFP growth differs, often substantially, between the different sectors and countries, and is quite volatile.

Value chain analysis

In this sub-section we investigate productivity effects and value chain effects across the 11 sectors. We perform a similar regression to the baseline regression, with the core difference that we perform the regression at a sectoral level. See Annex 1.1.1 for further details on productivity data at the sectorial level.

For this regression, we need data at the sector level, which reduces the number of countries with available data to 11.[28] Moreover, the KLEMS sector level data has a two year shorter time series compared to the economy wide model. The countries with data at the sector level also have statistics on TFP per sector. Data on TFP allows us to examine productivity directly, and we therefore use TFP as the dependent variable in this analysis.[29]

To analyse value chain effects, we create a variable for the net stock of upstream European standards (NSUS). NSUS is the sum of European standards affecting suppliers in sectors

[28] The countries are Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden and the UK.

[29] As a robustness test, we also examine with value added as the dependent variable, and this results in coefficients of similar magnitude.

upstream in the value chain, weighted by the share of input provided by the respective upstream sectors. This means that a sector which purchases goods, services and investment goods from sectors with more available European standards will have a higher net stock of upstream standards.

The NSUS is calculated as:

$$NSUS_{j,y,i} = \sum_{n=1}^{N} \frac{I_{j,n,i}}{I_{j,tot,i}} * NSES_{n,y}$$

where j is the KLEMS-sector, n is the NACE A64-industry, y is year, and g is country. $I_{j,n,i}$ is the input from A64-industry n into KLEMS sector j in country i. $I_{j,tot,i}$ is the total upstream input into KLEMS sector j in country *i*. $NSES_{n,y}$ is the net stock of European standards for a given A64-industry n in year y. We exclude inputs internally in the same sector from the estimates, as we do not want the stock of standards in the sector to affect the upstream standards. For a further description of the calculation of the NSUS, see Annex 1.1.2.

The regression model is as follows:

$$\Delta \ln TFP_{i,j,t} = const + \gamma \Delta \ln NSES_{j,t-1} + \lambda \Delta \ln NSUS_{i,j,t-1} + \delta \Delta \ln X_{i,j,t} + \varepsilon_{i,j,t}$$

where $TFP_{i,j,t}$ is the total factor productivity in country i in sector j in year t, $NSES$ is the net stock of European standards in sector j, and $NSUS$ is the stock of upstream standards in country i and sector j. $X_{i,j,t}$ is a vector of control variables. These control variables are: pat_{ijt}, the net stock of patents, rec_{it}, a dummy for whether the country is in a recession, K_{ijt}, and the capital services, L_{ijt}, the labour services.[30]

We perform the regression with three combinations of explanatory variables related to European standards. One with only the stock of sector standards, one with only the stock of upstream standards, and one with both variables in the same model. The results of the different model estimations are displayed in the table below, altogether 12 different regression analyses based on data for the 10 selected sectors for EU and EFTA countries with available data.

Table 4 - Results of regressions analysing the value-chain effects of European standards[31]

Regression	Coefficient	Model 1	Model 2	Model 3	Model 4
Only sector	Stock of sector standards	0.0329* (0.017)	0.038** (0.0164)	0.0372** (0.0165)	0.0231* (0.0134)
Only upstream	Stock of upstream standards	0.0679*** (0.0226)	0.086*** (0.0234)	0.085*** (0.0236)	0.0469** (0.0196)
Sector and upstream	Stock of sector standards	0.0118 (0.0179)	0.0104 (0.0181)	0.0104 (0.0181)	0.0093 (0.0161)
	Stock of upstream standards	0.0588** (0.0232)	0.0779*** (0.026)	0.0769*** (0.0259)	0.0396* (0.0235)
Controls					
	Fixed effects (country -sector)	Yes	Yes	Yes	Yes
	Capital and labour	No	Yes	Yes	Yes
	Patents	No	No	Yes	Yes

[30] Capital services and labour services should in theory be controlled for in the TFP measure. However, as the conventional elasticity of capital and labour in creating the TFP measures do not necessarily hold for the time period and countries we are looking at, we include them also in the TFP regression.

[31] Performing this regression with time-fixed effects is not feasible, as multicollinearity would be very high. With time-fixed effects and country-sector-fixed effects, the VIF is over 10.

Regression	Coefficient	Model 1	Model 2	Model 3	Model 4
	Negative value added in sector in year dummy	No	No	No	Yes

*Cluster robust standard error (at the country-sector level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2017. Number of observations is 2193 for each regression*

We observe that **the result is relatively robust for model specification**. We do, however, consider that model specification 4 has the most precise estimate, as it controls for sector fixed effects, capital and labour changes, patents and includes a dummy for years with negative value added in the sector.

In the model with only sector standards, the result from model specification 4 indicates that a one percent increase in the growth rate of European standards results in a 0.023 percent increase in productivity growth rates. The result is significant at the 10% level. In the model with only upstream standards, the estimate is higher, at 0.047, and significant at the 5% level. This indicates that **firms' productivity is more affected by European standards available upstream in the value chain, compared to European standards available in the part of the value chain they operate themselves**

We find the same indication from the model with both sector standards and upstream standards included. **Upstream standards have a higher coefficient**, which is significant at the 10% level. With this model specification, sector standards are not significantly different from zero. A potential challenge of running with both variables in the same regression is that the same process generates an increase in both sector and upstream standards. This is investigated using a variance inflation factor (VIF) test, which indicates that multicollinearity is not an issue.[32,33] Still, the fact that we get significant results for both explanatory variables when they are included separately, but not when they are run together, indicates that we should be careful with interpreting a non-significant coefficient on sector standards as if sector standards did not have any effect on productivity within the sector. In particular, as the individual sector analysis below shows, these effects may vary across sectors.

Nevertheless, the results indicate that **the strongest effects of European standards on productivity may be related to interoperability effects and a reduced variety of intermediate goods which improves productivity** through the value chain. In turn, this means that a large portion of the benefits from European standards on productivity are received by other companies than those using them. This could have implications for the optimal level of subsidies of the development of European standards, and how European standards are priced.

Sector-specific coefficients

The value-chain regression is the aggregated analysis for the case sectors combined. It is possible to perform the regression for each sector as well, but at the individual sector level, estimates are more uncertain. They are more uncertain due to fewer data points in the data set (11 countries over 21 years per sector). Moreover, sector level TFP and GDP data are more "noisy"[34] than data at the national level. The fact that each sector has around half the same number of observations as the economy wide model, combined with productivity data being more noisy at the sectorial level, makes it harder to identify systematic patterns at the individual

[32] We also test sensitivity for the selection of start-year and find that starting the regression a year or two later would not substantially impact the results. Coefficients would be slightly higher, as would uncertainty.
[33] Stationarity is tested using panel unit root tests of Breitung for NSES and NSUS, allowing for cross-sectional dependence.
[34]By "noisy" we do not mean that the data are wrong, but rather that they contain variations over time that, based on our model, we cannot understand and interpret correctly.

sector level as much of the variations are explained by factors outside the model. In Annex 1.1.3, we provide descriptive statistics of how the TFP has developed per country in each sector. There are large differences in TFP developments at the sector level per country, which contributes to the **higher level of uncertainty in the estimates**.

Due to the lower number of data points, it is not feasible to perform the regression with both sector and upstream standards in the same regression. We therefore only run them separately.

Table 5 - Results of regression between standards and productivity at the sector level, for individual sectors

Sector	Model 4 – sector standards	Model 4 – upstream standards	Number of observations
Food products, beverages and tobacco	-0.008 (0.0166)	-0.007 (0.0177)	224
Textiles, wearing apparel, leather and related products	0.0588** (0.0259)	0.0581 (0.035)	224
Coke and refined petroleum products	0.0857 (0.1563)	0.1926 (0.1443)	194
Chemicals and chemical products	0.0068 (0.0253)	0.0191 (0.0302)	184
Manufacturing of Electrical equipment	-0.0679 (0.0478)	-0.0249 (0.0589)	204
Machinery	-0.0176 (0.0312)	-0.0147 (0.0443)	224
Transport equipment	0.0831** (0.0367)	0.0037 (0.0382)	224
Electricity, gas, steam and air conditioning supply	0.0313* (0.0158)	0.0547** (0.024)	204
Air transport	0.1483 (0.1124)	-0.0335 (0.3296)	63
Telecommunications	0.0926*** (0.0251)	0.146** (0.0653)	224
IT and other information services	-0.0158 (0.0261)	0.0962* (0.0494)	224
Controls			
Fixed effects	Yes	Yes	
Capital and labour	Yes	Yes	
Patents	Yes	Yes	
Negative value added in sector in year	Yes	Yes	

*Cluster robust standard error (at the country level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2017. Reported R-squared is R-squared within. N is less than 242 since certain countries lack data for certain sectors and certain years*

The table above displays that **four sectors are found to have significant, positive coefficients** on productivity from the availability of sector specific European standards. These sectors are "Textiles, wearing apparel, leather and related products", "Transport equipment", "Electricity, gas, steam and air conditioning supply" and "Telecommunications". For the remaining sectors most of the estimates are either close to zero, or positive but statistically insignificant. The only sector with substantial negative results is the manufacturing of Electrical equipment, but this is not statistically significant. (p=0.19).

For upstream standards, we see that the "electricity, gas, steam and air conditioning supply" sector, telecommunications sector, and the Information technology (IT) and other information services sector have positive coefficients, while "Textiles, wearing apparel, leather and related products" is almost significantly positive (p=0.13).

Previous reports, such as Blind and Jungmittag (2008) have, like us, found that when analysing individual sectors, the results are only partly satisfactory. As mentioned, we warn that one should be careful in overinterpreting the estimates for the individual sector. Within some sectors, such as "coke and petroleum" and "air transport services", there are large variations in productivity over time that cannot be explained by any of the factors in the model, see Annex 2.2. Thus, we cannot exclude that non-significant results are false negatives, i.e. that European standards could have a positive impact on the productivity in that sector even though we do not find a significant positive relationship in our data.

The fact that we find positive significant average effects when we analyse the 10 sectors combined indicates that for **some sectors there is too much noise and too few observations to get significant results**. Still, some sectors seem to have a stable but low, or even negative, growth in productivity over large parts of the time period. This is the case for sectors like "Food products, beverages and tobacco", "Manufacturing of Electrical equipment" and "Machinery". In the same time period, all these sectors have had a fairly stable growth in European standards available to them directly, or to their suppliers. From this one can at least draw the conclusion that the availability of new European standards over the time period has not been sufficient to improve the aggregate productivity of these sectors. From the results of the regression analysis it is also apparent that other factors such as the development in capital and labour inputs, or demand shocks related to recessions, can explain why we do not see a significant increase in productivity even though there is a positive development in the availability of European standards.

It is interesting that we, in the value chain analysis, find that the stock of sector standards has a weak effect, but that we, in the sector-specific analysis, find that it has a more substantial effect in the individual sectors. One possible explanation is that the sector standards affect the sector they are in differently between the sectors, and that an attempt to find the average effect by looking at the sectors together therefore results in a weak effect. If sector standards in some sectors have a positive effect, some have a neutral effect, and some potentially a negative effect, then that aggregated together may be close to zero.

For upstream standards, there is no such indication that some sectors may have negative effects from increased standards upstream, and the average effect of upstream standards is therefore positive in aggregate.

If this interpretation is correct, it may mean that **the value-chain effect works more generally, while the in-sector effect only happens in certain sectors**. It is then interesting to examine the characteristics of which sectors experience in-sector productivity effects of standardisation. .

Harmonised European standards

Standards have many roles. As mentioned, they may contribute to distribution of technical knowledge, interoperability, a reduced variety of intermediate goods and quality assurance. These are the main roles of non-harmonised standards, which tend to be created by an industry in a market-driven approach. Harmonised standards, however, are created based on a request from the European commission and are usually intended to support European regulations. The effects of harmonised standards may therefore differ from that of non-harmonised standards.

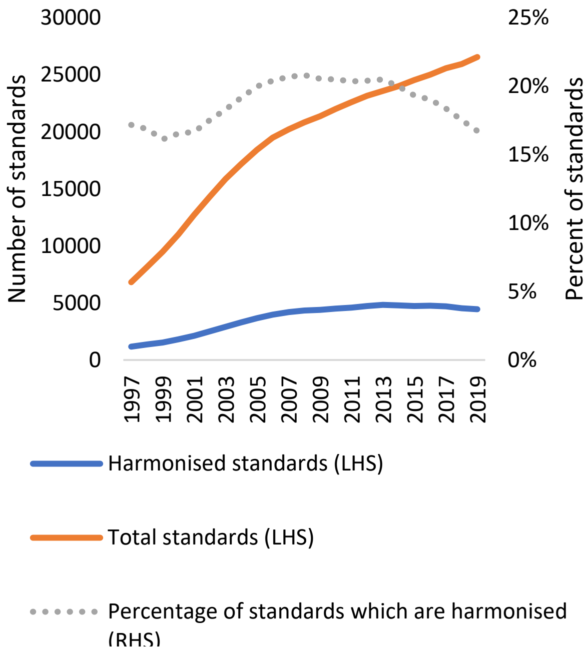
As noted by previous studies, regulations are generated by more of a top-down approach than standards are (see e.g. Blind et al. 2017). The harmonised standards which support the regulations are less top-down than the regulations, but more so than the non-harmonised standards. Harmonised standards may therefore constitute a softer approach than pure regulation without harmonised standards would constitute.

To estimate the stock of harmonised standards per year, we have used the EUR-Lex database as a reference. We have identified all Commission communications referring to harmonised standards until 2019 and extracted all harmonised standards that were mentioned in these. We have then matched these standards with the standards received from CEN-CENELEC and ETSI to create a stock of harmonised standards per year. The standards are not always referred to in precisely the same way in EUR-Lex and by CEN-CENELEC-ETSI, so some harmonised standards may be unmatched. We estimate that our methodology may miss around 10% of harmonised standards, but this number is uncertain. Even with this uncertainty, it is to our knowledge the best available estimate of the number of harmonised standards over time.

The figures below show that the relative growth in the number of harmonised standards was slightly higher than the relative growth of non-harmonised standards from 1997 to 2005. The share of European standards which were harmonised therefore grew in this period. From 2011 through 2017, the number of harmonised standards is approximately flat, while the number of non-harmonised standards has grown. In the later years the share of European standards which are harmonised has therefore decreased. Currently we find that approximately one out of six European standards are harmonised.

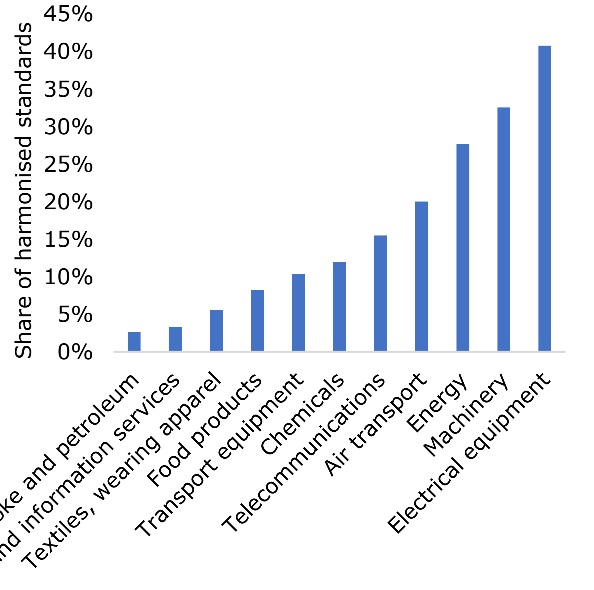
Among the case sectors, the industries with the most harmonised standards are "Manufacturing of Electrical equipment", "Machinery", and "Electricity, gas, steam and air conditioning supply", while "Coke and petroleum" and "IT and information services" have the fewest.

Figure 5 - Number of harmonised standards, and share of standards which are harmonised per year



Source: Author's elaboration based on the EUR-Lex database, CEN-CENELEC-ETSI

Figure 4 - Percentage of standards in each sector which are harmonised at the end of 2017



Source: Author's elaboration based on the EUR-Lex database, CEN-CENELEC-ETSI

In order to estimate the effects of harmonised standards on productivity, we perform the same regression as we did in the baseline model and sector models, but with the stock of harmonised standards and non-harmonised standards as the explanatory variables. Due to the number of tests, we only present the results of specification 4, with all control variables. The time period analysed is 1997-2017, which is the time period for which we have sector level data.[35] The

[35]At the economy wide level there are two years of additional time series data available. For reasons of comparability we do, however, use the same time period for both economy wide and sector level estimations in this analysis.

results of these regressions are displayed in the table below. Each row represents a separate regression, while the columns represent different explanatory variables.

Table 6 - Results of regressions analysing the effects of harmonised standards. The rows show the model specification, while the columns show the different explanatory variables. The first three rows use only the stock of harmonised standards, the next three only the stocks of non-harmonised standards, and the final three both in the same regression

Regression	Harmonised	Non-harmonised	Number of observations
1 - Economy wide	0.0278** (0.0109)		399
2 - Sector-specific	0.008 (0.0081)		2193
3 - Upstream	0.0291** (0.0126)		2193
4 - Economy wide		0.0493*** (0.0114)	399
5 - Sector-specific		0.0203 (0.0135)	2193
6 - Upstream		0.0483** (0.0217)	2193
7 - Economy wide	-0.0378 (0.025)	0.0899*** (0.0274)	399
8 - Sector-specific	0.0046 (0.0089)	0.0208 (0.0155)	2193
9 - Upstream	0.0099 (0.0387)	0.035 (0.0633)	2193

*Cluster robust standard error in parentheses. Clustered at the country level for the economy-wide regressions, and at the country-sector level for the sector and upstream regressions. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2017*

The first three rows display the results of the regression with only the harmonised standards at the economy wide, sector-specific and upstream levels. The next three rows display the same for the non-harmonised standards. The results indicate that harmonised standards have a productivity effect at the economy-wide level and through value chains, but we find no such indication at the sector-specific level. The coefficients for the harmonised standards are also lower for each regression than those for non-harmonised. In other words, it appears that harmonised standards have a productivity effect, but that non-harmonised standards have a stronger productivity effect.

Specifications 7 through 9 show the results of a regression with the harmonised and non-harmonised versions of the same variable together in the same model. The economy-wide regression (7) has increased uncertainty in the estimates due to multicollinearity.[36] The insignificant coefficient for the harmonised standards should therefore be taken with a grain of salt, as should the high coefficient for the stock of non-harmonised standards. Specification 9 similarly has inflated standard errors, which means that not too much emphasis should be put on the exact coefficients in these three specifications. Their main implication is that they support the notion of specifications 1 through 6, that non-harmonised standards have a stronger productivity effect than harmonised standards do.

[36] The VIF is 6.8 for the stock of harmonised standards in specification 7. For specification 9, it is 4.3. For the other specifications, the VIF is below 4.

As another test, we perform the value-chain regression with only harmonised and only non-harmonised standards, and find similar trends as in the regression with both.

Table 7 - Results of the value-chain regression, using only harmonised standards and only non-harmonised standards. Regression is same as in for the value chain analysis with control variables of specification 4

Explanatory variable	Sector standards	Upstream standards	Number of observations
10 - Harmonised standards	-0.0022 (0.0098)	0.0368** (0.0168)	2193
11 - Non-harmonised standards	0.0084 (0.0153)	0.0422* (0.0245)	2193

*Cluster robust standard error (at the country-sector level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2017. Number of observations is 2193 for each regression*

Specifications 10 and 11 show similar results as the third specification in the value-chain analysis: European standards appear to have a higher productivity effect downstream in the value chain for both harmonised and non-harmonised standards.

Harmonised standards are intended to fulfil many goals apart from productivity, some of which may be contrary to productivity growth. On average, they still appear to contribute to productivity growth, albeit less than what non-harmonised standards do.

3. European standards and innovation activities

Standardisation may encourage innovation through creating a common platform from which to develop new innovations. Standards may also disseminate knowledge which can lead to company-specific innovations, but may also hamper innovation by causing companies to choose well-established procedures and solutions over new ones.

Recent empirical research underlines these ambiguous effects. A survey of Nordic companies using national standards seems to reject the notion that standardisation is an impediment to innovation (Menon Economics et al., 2018). When asked whether standards prevent their company from developing innovative technology, only 14 percent of the companies respond positively to this claim, while six out of ten respondents emphasize standards as a good means of following technical developments. A study based on the German CIS from 2011 finds that the impact of standards on innovation efficiency depends on characteristics of the market (Blind et al. 2017). They find that in markets with a high degree of technological uncertainty, standards lead to lower costs of innovation, while standards lead to higher costs of innovation in markets with low uncertainty. For regulations they find the opposite pattern. The rationale for the result is that in markets with a high degree of technological uncertainty it is more difficult to strategically influence consensus-based standardisation processes for your own benefit, e.g. standards with very strict specific technical specifications or purposeful inclusion of intellectual property.

In this analysis we investigate whether there are systematic patterns between innovation activities and European standards, both harmonised and non-harmonised. On innovation activities we use CIS data from 2016.[37] The CIS has several variables that may be affected by European standards, which allows us to examine two fields: the diffusion of knowledge from standardisation, and the interplay between standardisation, legislation and innovation.

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[37] CIS is carried out across the European union and EFTA countries at two-year intervals. As the survey has gone through major revisions over time, both with respect to coverage and questions asked, the time series are typically short, and the panel coverage is unbalanced. We therefore prefer to employ cross-sectional data for this analysis. Blind et al. (2017) also use cross sectional CIS data for their analysis.

We examine two variables focusing on the numbers of firms that innovate per sector, and two variables focusing on the interplay between standardisation, legislation and innovation.

3.1 Share of innovative firms

As introduced in Figure 1 in the literature review, one of the key productivity effects of standardisation is the diffusion of knowledge. Through diffusion of knowledge, standards can help firms achieve a close to best practice in the industry. Initially, this may yield a productivity effect, as we examined in Section 2.3. In the longer run, this dissemination of knowledge may contribute to increased innovation. If standardisation contributes to a larger number of firms being at the technological forefront, then this will increase the number of firms that may push the frontier and create new innovations. This would mean that sectors with many standards should see more innovation.

Adapting of modifying existing knowledge

We examine how European standards affects the share of firms that innovate by "adapting or modifying products and/or processes originally developed by other enterprises or organisations". Firms which perform these types of innovations build on existing knowledge, and create improvements based on that knowledge. Standards comprise one key basis of knowledge on which those companies may innovate.

We utilise our sector-specific stock of standards and examine whether sectors with a higher stock of European standards innovate more. We run the regression:

$$ADP_{i,j} = \alpha + \beta\ NSES_j + e_{i,j}$$

where $ADP_{i,j}$ is the percentage of firms in country i in sector j which innovate by adapting or modifying products and/or processes originally developed by other enterprises or organisations, $NSES_j$ is the stock of sector-specific European standards in sector j.[38] β is thereby the effect one additional standard in sector j has on the percentage of firms that innovate.

The CIS has data regarding the percentage of firms that perform the relevant form of innovation within goods, services and process innovation, respectively. We run the regression on each of these as the dependent, in addition we run a regression with all three indicators combined into a single variable.

Table 8 - Results of regression between the stock of European standards and the dependent variable. Standard errors in parentheses

	Process innovations	Production of goods innovations	Production of services innovations	All three types of innovations
Coefficient	0.0014**	0.0006	0.0005	0.0008**
	-0.0006	-0.0004	-0.0007	-0.0004
N	752	717	701	2170

*Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

The results show that sectors with more European standards also have a higher level of process innovations, which indicates that European standards have a positive impact on process innovation. There are similar indications in goods innovations and services innovations, but these results are not significant. When examining all types of innovations together, the results indicate that European standards have a positive impact on innovation within the sector.

[38] The Community Innovation dataset consists of 42 NACE sectors. The regression is run for all countries that were CEN-CENELEC members in 2016 and had available data.

The dependent variable in the regression is denominated in percentage from 0-100. The interpretation of this coefficient is therefore as follows: Adding one standard to a sector increases the share of firms in that sector which innovate by adapting or modifying products/processes by 0.0008 percentage points. The average A64-sector has approximately 500 standards. This regression therefore suggests that in an average sector, a one percent increase in European standards contributes to 0.4 percentage points more firms innovating by adapting or modifying an existing product/process each year.

Product innovation types

As mentioned, if standardisation contributes to a larger number of firms being at the technological forefront, then this may increase the number of firms that may push the frontier and create new innovations. We therefore examine whether European standards are associated with more advanced innovations.

The CIS has data differentiating by whether product innovations are the first in the world, new to the market, or new only to the firm.[39] We examine how European standardisation affects each of these by running a regression similar to the one in the previous Section. We run:

$$Inn_{i,j} = \alpha + \beta \ NSES_j + e_{i,j}$$

where $Inn_{i,j}$ is the number of firms in country i in sector j that perform each type of innovation.

Under the hypothesis that Europeans standards contribute to more firms pushing the technological frontier, we would imagine that the stock of European standards in a sector should have a positive relation with the number of "world first" innovations and innovations which are new to the market.

The results are as follows:

Table 9 - Results of regression between stock of European standards in sector and percentage of firms which innovate. Standard errors in parentheses

	At least one 'world first' product innovation	New or significantly improved products that were new to the market	New or significantly improved products that were only new to the firm
Coefficient	0.00266***	0.003303***	-0.000898*
	(0.0009)	(0.0007)	(0.0005)

*Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

We find that sectors with more European standards have more "World first" innovations and more innovations which are new to the market. This is in line with the hypothesis that standards create a common ground from which to innovate. Moreover, the results show that sectors with more European standards have fewer innovations which are new only to the firm. A possible explanation for this is that European standards lead to more knowledge being disseminated within the sector, in turn leading the firm not to spend resources on making innovations that others already know, as the information is made available through European standards.

3.2 The interplay between European standardisation, legislation and innovation

We have in Section 2.3 seen indications that harmonised standards have a productivity effect, but one that is weaker than that of non-harmonised standards. Harmonised standards contribute towards sets of goals that may at times be contradictory: productivity and innovation on the one

[39] An innovation being new only to the firm means that the business made an innovation that was new to the firm, but already known by a competitor in the market.

side, and supporting legislation covering alternative set of purposes, on the other. We use CIS-data in an attempt to examine the total effect of harmonised standards on innovation.

The CIS has several indicators on how legislation affects innovation. Primarily, these indicators focus on how legislation and regulation may adversely affect innovation. Harmonised standards often supplement legislation. It may therefore be that harmonised standards contribute to reducing innovation. On the other hand, harmonised standards are a softer way of legislating, which may make harmonised standards a way of achieving government goals with less damage to innovation. Additionally, as previously mentioned, harmonised standards may contribute to creating a common ground from which to innovate.

To analyse how harmonised standards may affect innovation, we use data from CIS on how many firms state that their "innovation activities have been affected by legislation or regulations" by subject of the regulation/legislation that affects them. The legislation is divided into several subjects, of which four are relevant for this analysis: "Employment, worker safety or social affairs", "Environment", "Operational and worker safety" and "Product safety, consumer protection".

For each of these, there is data on how big a percentage of firms answer that legislation/regulations result in "Stimulation of innovation", "Creation of uncertainty", "Generation of an excessive burden", "Lack of consistency across the EU", "No major problems caused" and "No impact".

There are two main hypotheses for how harmonised standards should affect whether firms are affected by legislation. The first is that harmonised standards constitute a form of regulation, and that sectors with more harmonised standards should therefore have more firms answering they are affected by legislation. Under this hypothesis, we would expect that a higher level of harmonised standards in a sector would correlate with more firms answering that legislation creates uncertainty and a burden.

The second hypothesis is that while harmonised standards are related to legislation, they are a softer approach than the alternative, and allow firms more freedom to find individual solutions and innovate. Under this hypothesis, we would expect that sectors with many harmonised standards would see smaller adverse effects of regulation than sectors with few harmonised standards do. We would therefore expect that in sectors with many harmonised standards, fewer firms would answer that legislation creates uncertainty, or an excessive burden. Further, fewer firms would answer that legislation creates a major problem.

We run the following regression for each combination of legislation and type of effect:

$$LegEff_{i,j} = \alpha + \beta \, NSHES_j + e_{i,j}$$

where $LegEff_{i,j}$ is the share of firms which answer that their innovation activities have been affected with <effect> by regulation/legislation within <subject>. The following table shows the coefficients of the regression, where the rows are the subject of the legislation ("<subject>"), and the columns are the effect the firms experience ("<effect>").

Table 10 - Results of regression between stock of harmonised European standards in sector, and the share of firms that answer that their innovation activities have been affected with <column> by regulation/legislation within <row>. Robust standard errors in parentheses

	No impact	No major problems	Creation of uncertainty	Generates an excessive burden	Lack of consistency in the EU	Stimulate innovation
Employment, worker safety or social affairs	-0.0068** (0.0031)	0.008*** (0.0031)	0.003* (0.0016)	-0.0014 (0.0012)	-0.0002 (0.0004)	-0.001 (0.0007)
Environment	-0.0109*** (0.0025)	0.0086*** (0.0033)	0.0008 (0.0013)	-0.0024** (0.0012)	0.0001 (0.0004)	0.0004 (0.0018)

Operational and worker safety	-0.0105*** (0.0031)	0.0072** (0.0034)	-0.0016 (0.0016)	0.0015 (0.0019)	0.0002 (0.0003)	0.0015 (0.0018)
Product safety, consumer protection	-0.0095*** (0.0035)	0.0035 (0.0029)	-0.001 (0.0011)	0.0017 (0.0018)	0.0007 (0.0011)	0.0035** (0.0016)

*Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

The coefficient here shows the effect one additional harmonised standard has on the percentage of firms answering that the legislation in the row has the respective effect.

In sectors with more harmonised standards, fewer firms answer that legislation/regulation has "no impact" than in sectors with fewer harmonised standards. Similarly, they are more likely to answer that legislation causes "No major problems". In other words, these results indicate that firms in sectors with more harmonised standards are more affected by legislation/regulation, but less likely to be majorly negatively affected by legislation. This would fit the first mentioned hypothesis: that harmonised standards are a "soft" alternative to legislation, with less adverse effects on innovation.

For the four specific effects, we find no clear systematic indications. The coefficients are low, and only 3 out of 15 regressions yield significant results. Those relations could well be spurious, and we can therefore say little about those effects.

Overall, the results indicate that harmonised standards cause some impact on firms, but that this impact is weaker than regulating directly.

4. European standards and sustainable development

To complement the analysis on European standards and productivity, we have conducted a correlation study on the relation between European standards and macro-economic variables related to the UN Sustainable Development Goals.

4.1 Methodological approach

This study is conducted by reviewing all the SDG indicators reported by Eurostat.[40] To identify which macroeconomic indicators are suitable for a correlation analysis, we classify the SDG indicators into the following four categories:

1. Indicators without link to any specific category of European standards;
2. Indicators with link to specific categories of European standards, but the availability of European standards in the specific category is limited;
3. Indicators with few observations over time and across countries;
4. Indicators with link to European standards and sufficiently many observations over time and across countries.

Indicators which are classified in category 1-3 are not used in this study. Indicators falling in category 4 are used and matched with relevant European standards.

The classification effort yields 16 Eurostat indicators deemed feasible for looking at the relationship between the SDGs and standards.[41] Some of the indicators are linked to several SDGs. When linking standards and indicators, the same approach as in the sector model is used, where the standards are categorised according to ICS codes, and ICS codes are in turn used to link indicators and standards. This approach produces an indicator-specific stock of standards

[40] https://ec.europa.eu/eurostat/web/sdi/indicators.

[41] The SDGs being measured are the following: SDG 1 (no poverty); SDG 3 (Good health and well-being); SDG 6 (Clean water and sanitation); SDG 7 (Affordable and clean energy); SDG 8 (Decent work and economic growth); SDG 9 (Industry, innovation and infrastructure); SDG 11 (Sustainable cities and communities); SDG 12 (Responsible consumption and production); SDG 15 (Life on land); SDG 16 (Peace, justice and strong institutions).

containing European standards which are deemed relevant to a specific indicator. The link between SDG indicators and ICS codes is shown in the table below.

Table 11 - Overview of indicators and their relevant SDG and ICS codes

Indicator	ICS codes mapped to indicator	Relevant SDG(s)
Share of renewable energy in gross final energy consumption[42]	Hydraulic energy engineering (27.140) Solar energy engineering (27.160) Wind turbine energy systems (27.180) Biological sources and alternative sources of energy (27.190) Hydrogen technologies (27.075)	Affordable and clean energy (SDG 7), Climate action (SDG 13)
Greenhouse gas emissions intensity of energy consumption	Energy and heat transfer engineering (27.) Electrical engineering (29.) Thermal insulation of buildings (91.120.10)	Affordable and clean energy (SDG 7), Climate action (SDG 13)
Average CO_2 emissions per km of new passenger cars	Transport exhaust emissions (13.040.50) Internal combustion engines for road vehicles (43.060) Road vehicle systems (43.040) Road vehicles in general (43.020)	Industry, innovation and infrastructure (SDG9), Responsible consumption and production (SDG12)
Greenhouse gas emissions	Pollution, pollution control and conservation (13.020.40) Transport exhaust emissions (13.040.50) Thermal insulation and energy efficiency of buildings (91.120.10) Energy and heat transfer engineering (27.)	Climate action (SDG13)
Population unable to keep home adequately warm	Energy efficiency standards (27.015), Thermal insulation standards (27.220), Thermal insulations in building standards (91.120.10)	No Poverty (SDG 1), Affordable and clean energy (SDG 7)
People living in households suffering from noise	Noise with respect to human beings (13.140), Sound insulation (91.120.20)	Good health and well-being (SDG 3), Sustainable cities and communities (SDG 11)
Exposure to air pollution	Pollution, pollution control and conservation (13.020.40), Air quality (13.040)	Good health and well-being (SDG 3), Sustainable cities and communities (SDG 11)
People killed in road accidents	Road vehicle systems (43.040.80), Road engineering (93.080), Tunnel construction (93.060)	Good health and well-being (SDG 3), Sustainable cities and communities (SDG 11)
People killed in accidents at work	Workplace safety (13.100), safety of machinery (13.110)	Good health and well-being (SDG 3), Decent work and economic growth (SDG8)
Recycling rate of municipal waste	Wastes and recycling (13.030)	Sustainable cities and communities (SDG11)
Corruption Perceptions Index	Organisation and management systems (03.100)	Peace, justice and strong institutions (SDG16)
Resource productivity	Full stock of European standards (Similar to A1/A2-model in this study)	Decent work and economic growth (SDG8), Responsible consumption and production (SDG12)

[42] Unlike the other indicators, the share of renewable energy in gross final energy consumption is not taken logs of before the regression. Rather the regression is: $share\_of\_renwables_t = const + \beta_1 ln(ISSES_t) + \beta_2 \ln(X_t) + \epsilon_t$.

Indicator	ICS codes mapped to indicator	Relevant SDG(s)
Generation of waste excluding major mineral wastes by hazardousness	Wastes and recycling (13.030)	Responsible consumption and production (SDG12)

The indicators looked at are divided into three different categories: Biosphere (SDG 6, 13, 14, 15), society (SDG 1, 2, 3, 4, 5, 7, 11, 16) and economy (SDG 8, 9, 10, 12).[43]

Overall, we find that **the development in European standards and the identified SDG indicators are correlated, and that the correlation direction is as expected**, i.e. that when the stock of relevant standards increases, SDG indicators also improve.

Generally, this relationship holds also when controlling for some few control variables, such as GDP per capita.

However, all these results should be interpreted with caution, as we have not developed regression models which control for confounding factors when running these correlation analyses. Hence, we should not interpret from these results that more European standards necessarily cause achievement of the SDGs.

For example, one very important confounding factor is that there is a large political push towards achieving the SDGs which would at the same time increase the performance on the indicator as well as increase the number of European standards related to the indicator of interest.

It is beyond the scope of this analysis to control for these confounding variables. Still, the results are interesting as they reveal a systematic pattern regarding the development of European standards and relevant SDG indicators.

In the sub-sections below, we will go through each of the three SDG categories one by one. Please see annex 2.4 for a review of each individual indicator.

4.2 Biosphere

We examine four indicators related to sustainability in the biosphere, encompassing SDG 13 – climate action, SDG 14 – life below water, and SDG 15 – life on land.[44] The indicators looked at are greenhouse gas emissions, the emission intensity from greenhouse gas emissions, the share of renewables, and carbon dioxide (CO_2) emissions of new cars.

There have been strong improvements on all four biosphere indicators the past 20 years, both for the EU as a whole as well as for most of the individual countries in recent years. There has also been an increase in the number of available European standards related to each of these indicators.

The table below sums up the analysis related to biosphere SDGs.

It shows the relevant SDGs for each indicator, as well as the indicator that has been used in the correlation analysis, the standards which we have mapped towards the indicator, relevant control variables, as well as the direction and level of significance of the correlation coefficient.

It is important to point out that these are not causal analyses. Hence, a significant relationship merely implies correlation, and not necessarily causality.

Table 12 - Results from the correlation analysis of indicators related to the biosphere

Indicator	Controls[45]	Coefficient direction
	None	Positive***

[43] As classified by the Stockholm Resilience Centre: https://www.stockholmresilience.org/research/research-news/2017-02-28-contributions-to-agenda-2030.html.

[44] SDG 6, clean water and sanitation, is also categorised as a "biosphere" SDG. However, we do not look at any indicators encompassing SDG 6.

[45] Controls that are percentages of a total are not taken logs of before inclusion in the regression. All other controls are logged.

Indicator	Controls[45]	Coefficient direction
Share of renewable energy in gross final energy consumption[46]	GDP per capita, implicit tax rate on energy	Positive***
Greenhouse gas emissions intensity of energy consumption	None	Negative ***
	GDP per capita	Negative ***
Average CO_2 emissions per km of new passenger cars	None	Negative ***
	GDP per capita	Negative ***
Greenhouse gas emissions	None	Negative **
	GDP per capita, population, industry share of economy, agriculture share of economy	Negative ***

*Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

In the table above, we see that the coefficient direction is significant and in the expected direction for all indicators studied. This could, arguably, support the case that there is a relationship between the indicators and European standards. For example, in the correlation analysis, we regress the change in CO_2 emissions on the stock of available European standards within pollution control, transport emissions, house insulation and energy production. The correlation analysis of the given stock of European standards on total greenhouse gas emissions yields, as can be seen from the table above, a strongly significant negative relationship between emissions and the number of available relevant European standards. This result remains after controlling for GDP growth and the economy's sector composition.

European standardisation can work to reduce CO_2 emissions in several ways, most particularly through more effective energy production, and more effective utilisation of resources. One could expect that an increase in the relevant European stock of standards could lead to a decrease in indicators measuring CO_2 emissions. In this lays the assumption that standards lead to higher energy efficiency in components that emit CO_2, such as engines. The sectoral productivity analysis reinforces this assumption, as we found indications that standardisation upstream in the value chain from energy producers had contributed to increased productivity in energy producing companies. Thus, the correlation analysis supports a hypothesis that European standards have a positive impact on greenhouse gas emissions. In the same period, there has been an intense focus on decreasing greenhouse gas emissions in the EU, and we are not able to control for all these factors in the analysis.

4.3 Society

We examine ten indicators related to societal sustainability, encompassing SDG 1 – no poverty, SDG 3 – good health and wellbeing, SDG 7 – affordable and clean energy, SDG 11 – sustainable cities and communities, and SDG 16 – peace, justice and strong institutions. The indicators include: Population unable to keep their home adequately warm, people living in households suffering from noise, exposure to air pollution, people killed in road accidents, share of renewable energy in gross final energy consumption, greenhouse gas emissions intensity of energy consumption, people killed in accidents at work, recycling rate of municipal waste, and the corruption perceptions index.

Of these indicators, the share of renewable energy in the gross final energy consumption and the greenhouse gas emissions intensity of energy consumption are already mentioned in the

[46] Unlike the other indicators, the share of renewable energy in gross final energy consumption is not taken logs of before the regression. Rather the regression is: $share\_of\_renwables_t = const + \beta_1 ln(ISSES_t) + \beta_2 \ln(X_t) + \epsilon_t$.

previous sub-section in relation to the biosphere, as these indicators are also related to SDGs falling into this category.

As we can see from the table below, there have been significant correlations between all SDG indicators related to society and relevant European standards, except for the corruption perceptions index. For example, we find significant correlations between the stock of available European standards and the indicators related to health and safety, such as people killed in accidents at work and people killed in road accidents. Both these indicators are areas where we would expect standards to play a role. Approximately two thirds of the standards relating to people killed in accidents at work are harmonised. This is the highest share out of all the SDG indicators looked at. This indicates that health and safety is a larger focus of harmonised standards than of non-harmonised standards. It seems reasonable that health and safety standards related to workplaces are harmonised, as these are issues which are mostly regulated by workplace legislation. Harmonised standards can therefore help to meet requirements in legislation, but also help uphold the EU's commitments in the SDGs.

The same argument could also be valid for the other indicators under this category. Arguably, both exposure to air pollution, noise affecting households, and the recycling of municipal waste carry negative externalities which are not regulated through the open market. A fair number of the standards which have been matched to these indicators are also mentioned in EU legislation. This could indicate that European standards play a role in achieving improvements in these indicators.

Table 13 - Results from the correlation analysis of indicators related to society

Indicator	Controls[47]	Coefficient direction
Population unable to keep home adequately warm	None	Negative ***
	GDP per capita, population, unemployment rate	Negative **
People living in households suffering from noise	None	Negative ***
	GDP per capita, population, urban population share	Negative ***
Exposure to air pollution	None	Negative ***
	GDP per capita, population, urban population share, industry share of economy	Negative ***
People killed in road accidents	None	Negative ***
	GDP per capita, population, cars per 1000 people	Negative ***
Share of renewable energy in gross final energy consumption [48]	None	Positive ***
	GDP per capita, implicit tax rate on energy	Positive ***
Greenhouse gas emissions intensity of energy consumption	None	Negative ***
	GDP per capita	Negative ***
People killed in accidents at work	None	Negative ***

[47] Controls that are percentages of a total are not taken logs of before inclusion in the regression. All other controls are logged.

[48] Unlike the other indicators, the share of renewable energy in gross final energy consumption is not taken logs of before inclusion, the regression is therefore $share\_of\_renwables_t = const + \beta_1 ln(ISSES_t) + \beta_2 \ln(X_t) + \epsilon_t$.

Indicator	Controls[47]	Coefficient direction
	Agriculture share of economy, industry share of economy	Negative ***
Recycling rate of municipal waste	None	Positive ***
	GDP per capita, share of economy value added in industry	Positive ***
Corruption Perceptions Index	None	0
	GDP per capita, GINI coefficient	Positive *

*Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

4.4 Economy

We examine five indicators related to economic sustainability, encompassing SDGs 8 – decent work and economic growth, 9 – industry, innovation and infrastructure, 10 – reduced inequalities and 12 – responsible consumption and production. The indicators examined are people killed in accidents at work, resource productivity, average CO_2 emissions per km of new passenger cars, and the generation of waste, excluding major mineral wastes, by hazardousness.

Of these indicators, average CO_2 emissions and the people killed in accidents at work are already examined.

As we can see from the table below, there have been significant correlations in the development of all indicators and European standards over time. Hence, even though the correlation analysis says little about the causal relationship between standard and the SDG indicators, this could be an indication that there could be such a relationship.

One of the indicators examined is resource productivity. Resource productivity measures the total output per kilogram of material used. It is a measure of how much output can be produced for a given level of materials consumed, and thereby whether countries are successfully decoupling economic growth from the use of natural resources. For this study, we have matched resource productivity with the full stock of European standards, as the resource productivity indicator measures approximately the same as the full model. Finding a positive and significant relationship between resource productivity and standards is therefore as expected, as it underpins the findings in the main analysis.

Table 14 - Results from the correlation analysis of indicators related to the economy

Indicator	Controls[49]	Coefficient direction
People killed in accidents at work	None	- ***
	Agriculture share of economy, industry share of economy	- ***
Resource productivity	None	+ ***
	Share with tertiary education, agriculture share of economy, industry share of economy	+ ***
Average CO_2 emissions per km of new passenger cars	None	- ***
	GDP per capita	- ***
Generation of waste excluding major mineral wastes by hazardousness	None	- **
	GDP per capita, population, industry share of economy, agriculture share of economy	- **

*Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

[49] Controls that are percentages of a total are not taken logs of before inclusion in the regression. All other controls are logged.

5 Annexes

5.1 Robustness test: Economy wide model at levels

In our model we take first differences of all variables. The reason for this is that tests for stationarity confirm that all variables in our dataset are non-stationary, which may lead to spurious results in the model estimation.

If the model with all control variables is cointegrated, however, it may be more appropriate to run the regression at levels. In this case the regression analysis on the level model will produce "super consistent" results, which means that the coefficient estimates will converge to its true value with fewer observations than in a model where the variables are stationary.

As described in chapter **Feil! Fant ikke referansekilden.**, a Westerlund (2007) test indicates that the economy wide model is not cointegrated, but previous literature has analysed similar models and indicated they were cointegrated. We therefore provide a robustness test of the results by estimating the model at levels, meaning that we do not take first differences. If the model in levels gives qualitatively similar results as the first differenced model with growth rates, this assures us that the finding that European standards are positively associated with productivity growth is independent of the assumption on whether the model is cointegrated or not.

From the literature review we identified the most common model used in investigating the relationship between output and standards. To estimate the Cobb-Douglas model empirically, we take the natural logarithm of the variables and estimate the following model:

$$\ln Y_{i,t} = const + \alpha \ln\left(K_{i,t}\right) + \beta \ln\left(L_{i,t}\right) + \gamma \ln(NSES_{t-1}) + \delta \ln\left(X_{i,t}\right) + \varepsilon_{i,t}$$

where $Y_{i,t}$ is real gross value added *(GDP)* of country *i* at time *t*, $K_{i,t}$ is the capital input, and $L_{i,t}$ is the labour input, represented by hours worked. $NSES_{t-1}$ is the stock of European standards on January 1st of year *t, and* ε_t is the error term. $X_{i,t}$ is a vector of control variables. The vector includes the net stock of patents granted by the European Patents Office to inventors with residence in country *i* (pat_{it}). The regression also includes controls for whether the country is in a recession (rec_{it}), where a recession is defined by a drop in real GDP from one year to the next. All variables in the regression are demeaned, to control for country-fixed effects.[50]

The coefficients of each term can be interpreted as the estimated effect on growth of output of a 1 percent increase in the explanatory variable. A one percent increase in variable K yields an α percent increase in Y, and similarly a one percent increase in $NSES$ yields a γ percent increase in Y.

The table below shows the results for the Cobb-Douglas model at levels, i.e. without taking first difference. Model 1 controls for the capital stock and total hours worked in each country, as well as country fixed effects. Model 2 adds the net stock of patents as a control, model 3 additionally controls for recessions, model 4 also controls for human capital formation, and finally, model 5 controls for time-fixed effects.

Table 15: Regression results for Model A1. Dependent variable GVA, variables are non-stationary. N=399 – only countries which were CEN-CENELEC members for the full period.

	Model 1	Model 2	Model 3	Model 4	Model 5

[50] Tests for fixed vs. random effects confirm that a random effects approach would lead to biased results. This holds for all economy wide models. (Reference: Schaffer, M.E., Stillman, S. 2010. xtoverid: Stata module to calculate tests of overidentifying restrictions after xtreg, xtivreg, xtivreg2 and xthtaylor http://ideas.repec.org/c/boc/bocode/s456779.html.).

Stock of standards elasticity	0.0598 (0.0346) t:1.73 P:0.1	0.0535 (0.0322) t:1.66 P:0.111	0.0583* (0.034) t:1.84 P:0.08	0.0725** (0.0291) t:2.49 P:0.02	0.0917* (0.0463) t: 1.98 p: 0.063
Controls					
Capital stock and hours worked	Yes	Yes	Yes	Yes	Yes
Stock of patents	No	Yes	Yes	Yes	Yes
Recession dummy	No	No	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes	Yes
Human capital	No	No	No	Yes	Yes
Time-fixed effects	No	No	No	No	Yes

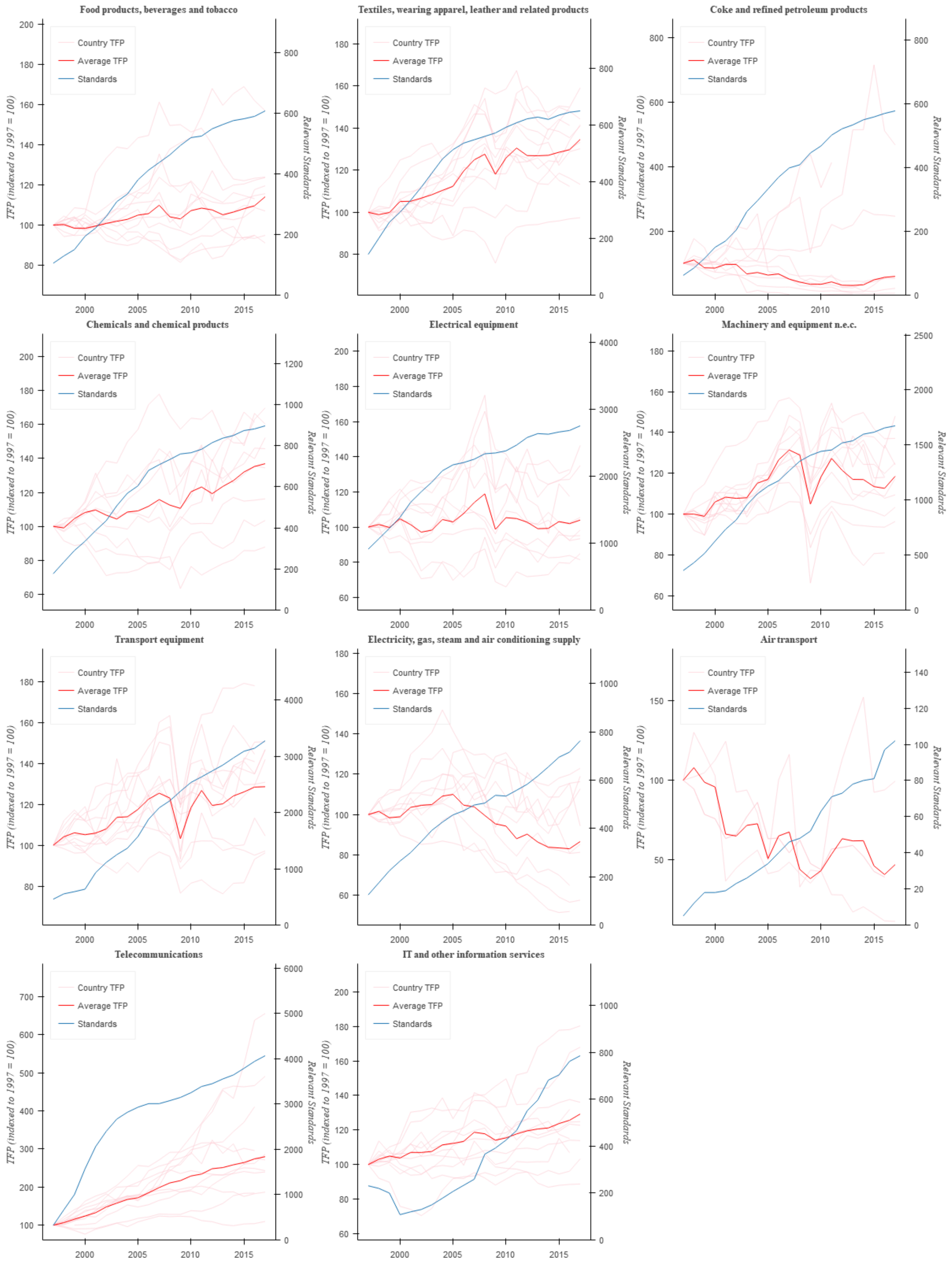
*Cluster robust SE (at the country level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The time period is 1997-2019.*

The elasticity of stock of standards estimated on output is stable across models, and ranges from 0.05 to 0.07. The effect is statistically significant in model 4, after controlling for human capital. The results suggest that a 1 percent increase in the stock of standards is associated with a 0.07 percent increase in output, which is slightly higher than the estimate in the first-differenced economy wide model. Model 5, with time-fixed effects, has a coefficient of 0.09, but also higher standard errors, and is therefore only significant at the 10 percent level. Model 5 has the problem of multicollinearity between the time-fixed effects and the stock of standards: the VIF test is 14, well above rule-of-thumb of 10, which contributes to the high uncertainty.

We repeat, however, that since the Westerlund (2007) test indicates variables are not cointegrated, this test will yield biased results, and it is therefore only included as a robustness test.

5.2 Development of TFP and standards per case sector

Figure 6: Graphs of stock of standards and TFP developments for each case sector



5.3 Robustness test: Age-adjusted stock of standards

As mentioned in the literature review, there are some known potential weaknesses of using the stock of European standards. Firstly, not all standards are necessarily equally important, and they may not be perpetually important. Secondly, if a new standard replaces an old one, that does not increase the stock of standards, despite standardisation progress having been made.

We build on suggestions by Stokes et al. (2011) to create an age-adjusted stock of European standards. Old standards are likely not as important for productivity as newer standards are, and age-adjusting takes account of this. Age-adjusting the standards also helps with the second problem, as it means that a newer standard replacing an older one will result in an increased stock of standards.

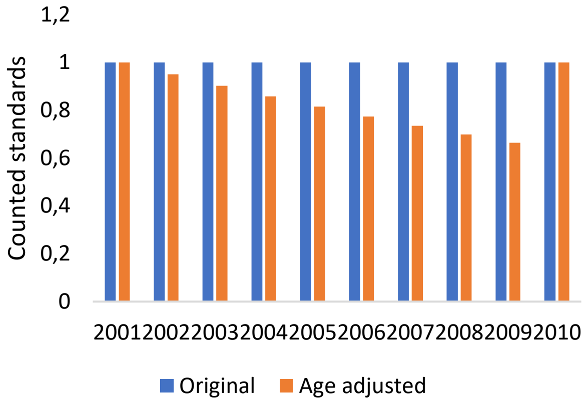
The age-adjusted stock of standards is created by depreciating standards by 5 percent per year for each year until they are withdrawn. When withdrawn, the remainder of the original standard is removed from the stock of standards. Before showing the regression results, we briefly outline the potential benefits of this approach with an example.

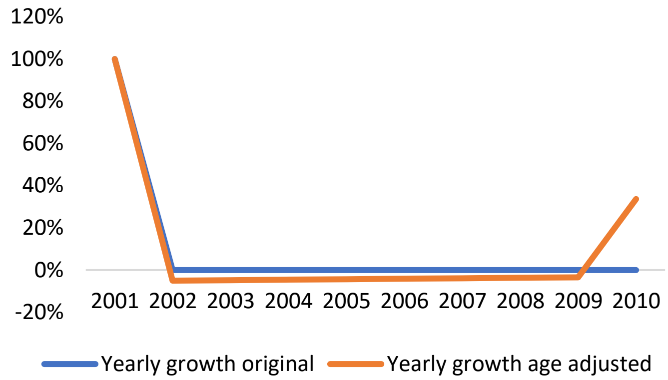
A standard is created in 2001, in a field where there previously existed no standards. It is logical to assume that this standard then has some positive effect on productivity, and this is picked up on in the stock of standards: where there were no standards in the field in 2000, there is now one.

Over the next 9 years, the effect of this standard is counted as constant. Then, in 2010, the standard is replaced with a new, improved standard. There is now still only one standard within the field, as the standard from 2001 was removed. The traditional way of counting the stock of standards therefore counts this as no change occurring in 2010.

With the age adjusted stock of standards, the effects are different. When the standard is created in 2001, the field still goes from having 0 to 1 standard. But if no new standards are created, then the stock of standards will decrease by a depreciation rate every year, for instance 5 percent. Every year, the impact on the stock of standards is therefore slightly negative, if no new standards are created. In 2009 in our example, the original standard will have only 66 % of its original contribution to the stock of standards left. When the new standard arrives in 2010, the stock of standards loses the 63% remainder, but gains a new, fully counted standard. The new standard replacing the old one therefore increases the stock of standards, by 34% of a full standard. We display the effects in the figures below.

Figures 7 and 8: Example: A standard is introduced in 2001, and then replaced with an updated standard in 2010. To the left, figure 7 shows the total contribution on the stock of standards. To the right, the change in stock of standards per year.

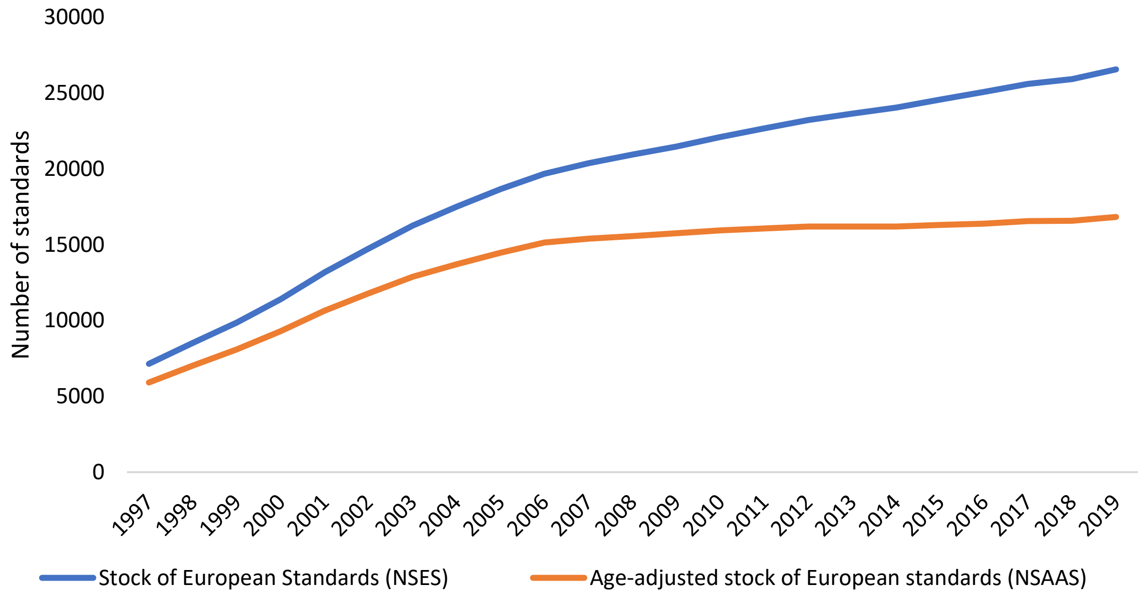




By using this methodology, all standards are not considered equally important, and new standards replacing old ones will be counted as increasing the stock of standards. This may therefore be a more refined measure than the traditional stock of standards. It is, however, more experimental, and there is no definitive way to determine the appropriate depreciation rate. We therefore keep this as a robustness test, but consider it a highly interesting topic to look further into.

Stock of European standards and stock of age-adjusted European standards over timeFigure 9 shows the development of the age-adjusted stock of European standards over time, plotted together with the baseline stock of European standards.

Figure 9: Stock of European standards and stock of age-adjusted European standards over time



We perform the baseline regression with the stock of age-adjusted standards, with a depreciation rate of 5%. That is:

$$\Delta\ln Y_{i,t} = const + \alpha\,\Delta\ln(K_{i,t}) + \beta\,\Delta\ln(L_{i,t}) + \gamma\,\Delta\ln(NSAAS_{t-1}) + \delta\,\Delta\ln(X_{i,t}) + \varepsilon_t$$

where the variables are as in the baseline model, and NSAAS is the net stock of age-adjusted standards.

The results of this regression are as follows:

Table 16: Results of regression with the stock of age-adjusted standards

	Model 1	Model 2	Model 3	Model 4	Model 5
Stock of age-adjusted standards elasticity	0.0796*** (0.0144)	0.080*** (0.0148)	0.059*** (0.011)	0.059*** (0.011)	0.112*** (0.02)
Capital stock and hours worked	Yes	Yes	Yes	Yes	Yes
Stock of patents	No	Yes	Yes	Yes	Yes
Negative value added in country	No	No	Yes	Yes	Yes
Country-fixed effects	Yes	Yes	Yes	Yes	Yes
Human capital	No	No	No	Yes	Yes
Year dummy	No	No	No	No	Yes

*Robust SE in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.*

The results are broadly similar using the age-adjusted stock of European standards as with the stock of European standards. This robustness test therefore indicates that controlling for the aging of standards over time would not substantially affect the results.

5.4 European standards and sustainable development goals (SDG)

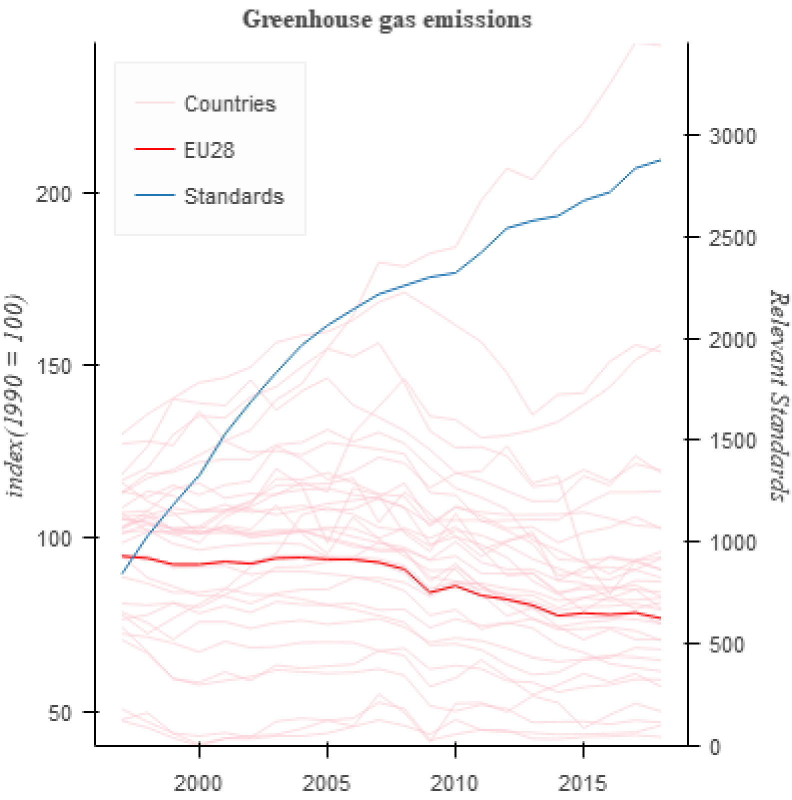
In the following we present a detailed analysis for each of the sustainable development goal indicators and how it has co-development with the availability of European standards. For each of the indicators we present examples of European standards that are relevant for the development of the respective indicator.

5.4.1 Biosphere

The following indicators are analysed:

- Greenhouse gas emissions
- Share of renewable energy in gross final energy consumption
- Greenhouse gas emissions intensity of energy consumption
- Average CO2 emissions per km of new passenger cars

5.4.1.1 Greenhouse gas emissions



Total greenhouse gas emissions in the EU have fallen by 23 percent since 1990, and by 17 percent since 2000. There are several relevant European standards that may have contributed to this development. In this correlation study, we have linked greenhouse gas emissions with standards within pollution, pollution control and conservation, transport exhaust emissions, thermal insulation and energy efficiency of buildings, as well as energy and heat transfer engineering.

Out of the 31 EU + EFTA countries, 24 countries had lower emissions in 2018 than in 2000. Total CO_2 emissions are affected by many factors, but two of the most prominent are the energy and transport sectors. The energy sector – both production and use – accounts for approximately 75 percent of the EU's greenhouse gas emissions.[51]

European standardisation can work to reduce CO_2 emissions in several ways, most particularly through more effective energy production, and more effective utilisation of resources. We expect that an increase in the European stock of standards led to a decrease in indicators measuring CO_2 emissions. In this lies the assumption that standards lead to higher energy efficiency in components that emit CO_2, such as engines. The sectoral productivity analysis reinforces this assumption, as we found indications that standardisation upstream in the value chain from energy producers had contributed to increased productivity in energy producing companies.

Some of the European standards most mentioned in European legislation are related to heat pumps and air conditioning. Air conditioners are known[52] for contributing considerably to climate change. Room air conditioners alone – the typical window and split units used in most homes – are set to account for over 130 gigatons (GT) of CO_2 emissions between now and 2050. That would account for 20-40% of the world's remaining "carbon budget". Standards which increase the energy efficiency of air conditioners might therefore help lower their climate impact.

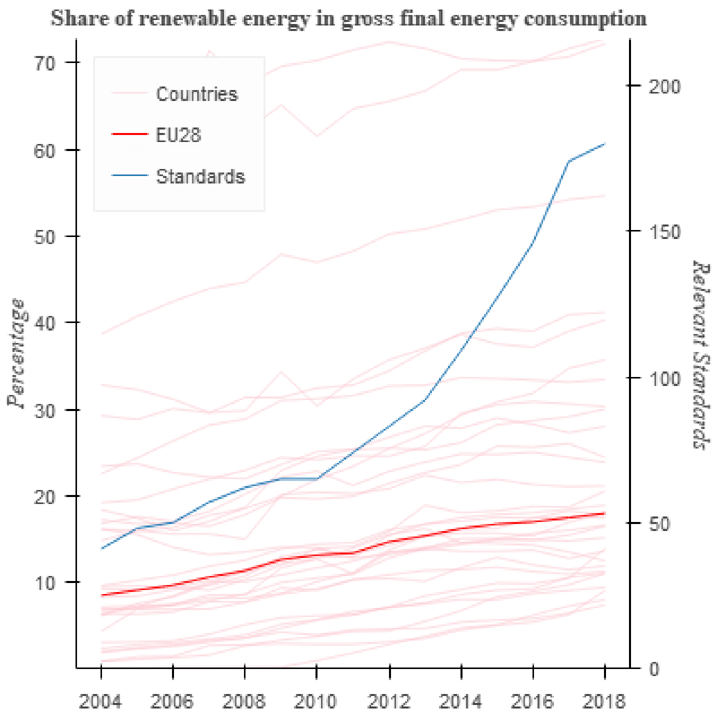
In the correlation analysis, we regress the change in CO_2 emissions on European standards within pollution control, transport emissions, house insulation and energy production. The correlation analysis of the given stock of standards on total greenhouse gas emissions yields a strongly significant negative relationship between emissions and the number of available relevant European standards. This result remains after controlling for GDP growth and the

[51] According to the international energy agency, https://www.iea.org/reports/european-union-2020

[52] See for instance Sachar, Sneha, Iain Campbell, and Ankit Kalanki, Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners. Rocky Mountain Institute, 2018. www.rmi.org/insight/solving_the_global_cooling_challenge.

economy's sector composition. Thus, the correlation analysis supports the hypothesis that European standards have a positive impact on greenhouse gas emissions. In the same period, there has been an intense focus on decreasing greenhouse gas emissions in the EU, and we are not able to control for all these factors in the analysis.

5.4.1.2 Share of renewable energy in gross final energy consumption



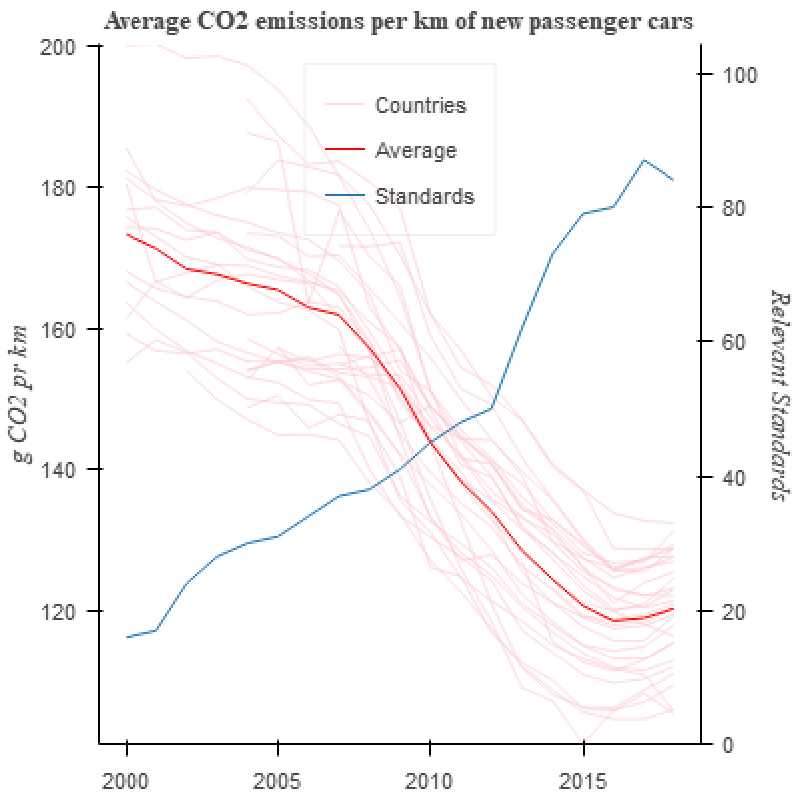
Renewable energy is a high-tech industry, and European standards may contribute to the dissemination of best practices among producers. There is a large number of European standards which link to renewable energy sources. We have linked the renewable energy share with standards for engineering in hydraulic and solar energy, wind turbine energy systems, biological and alternative sources of energy and hydrogen technologies.

As shown in the figure, renewable energy has been a recent growth area for standardisation – the stock of standards related to this area has increased by over 150 percent since 2010. In the same period, the share of renewable energy in gross final energy consumption has increased far more modestly, as can be seen from the figure. Consequently, the growth in standards within renewable energy has been considerably higher than the growth share of renewable energy in the final energy consumption in the EU.

European standards might help develop the renewable energy sector through several channels. For example, standard EN 61400 is a comprehensive standard for wind turbines. Standard 61400 is a set of design requirements made to ensure that wind turbines are appropriately engineered against damage from hazards within the planned lifetime. The standard concerns most aspects of the turbine life from site conditions before construction to turbine components being tested, assembled and operated. This standard is likely to increase product quality as the turbines will have a longer lifetime with less damage, reduce the variety of intermediate goods as the standard includes design specifications, as well as increase the diffusion of knowledge as technical information about all parts of the assembly process is distributed.

In the correlation analysis, we find a positive and significant relationship between an increased stock of standards in the renewable energy sector and the share of renewable energy in the energy mix. This relationship holds also when we control for GDP per capita and the implicit tax rate. These results support a hypothesis that European standards are positively associated with increasing the share of renewable energy in European energy consumption.

5.4.1.3 Average CO_2 emissions per km of new passenger cars



The average CO_2 emissions per km of new passenger cars has decreased substantially in all EU and EFTA countries the past 20 years, as shown in the figure.[53] The decrease was especially prominent between 2005 and 2015. From the figure, we can see that this has been accompanied by a sharp increase in the stock of standards related to the CO_2 emissions of passenger cars. In this project, we have linked this indicator to standards regarding transport exhaust emissions, internal combustion engines for road vehicles, road vehicle systems and road vehicles in general. We would expect an increased stock of standards within these areas to be accompanied by a decrease in the average CO_2 emissions per km of new passenger cars.

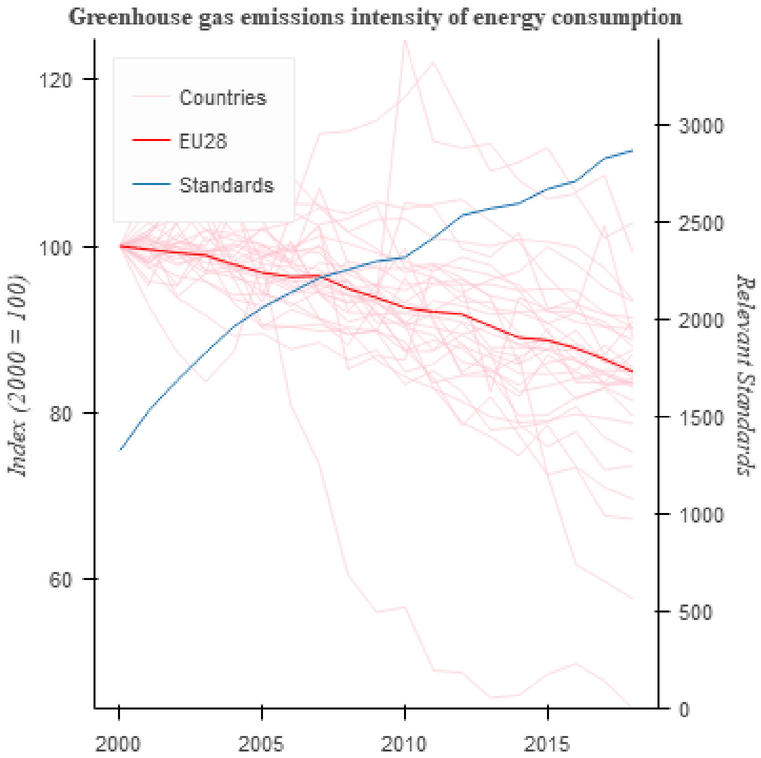
CO_2 emissions of passenger cars has also been an area of particular focus in European regulation, and many of the European Standards related to car emissions support European legislation. For instance, EU regulation 692/2008 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles refers to over 20 different European standards.[54] The standards here play a vital part in ensuring that the regulations are fulfilled.

In the correlation analysis, we find a negative and significant relationship between an increased stock of standards and the CO_2 emissions from passenger cars. This relationship holds when controlled for GDP per capita.

[53] In this figure, Eurostat has no data for the EU28 for the majority of the years, and we therefore plot the average of the countries with data instead

[54] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008R0692&from=EN#d1e32-27-1

5.4.1.4 Greenhouse gas emissions intensity of energy consumption



The indicator Greenhouse gas emissions intensity of energy consumption measures the greenhouse gas emissions of a country per unit of consumed energy. European standards may contribute to disseminating best practices in this regard. We have linked this indicator with standards regarding energy and heat transfer engineering, electrical engineering, and thermal insulation of buildings. We would expect that an increase in the stock of these standards would result in a decrease in the emission intensity of greenhouse gases in the energy consumption.

Every EU and EFTA country has seen a reduction in CO_2 emissions per produced unit of energy since 2000, as shown in the figure. In 2018, the stock of European standards was about double of what it was in 2000. In the same period, the greenhouse gas emissions intensity of energy consumption has decreased.

Most standards mentioned in legislation associated with this indicator are related to Electrical and electronic applications for railways. The transport sector is a substantial consumer of energy in the EU. Hence, increased standardisation in the energy consumption of railways is also one of the key components in delivering the European Green Deal objectives in the transport field.

Greenhouse gas emissions intensity of energy consumption" is the SDG indicator with the second highest share of harmonised standards, after "People killed in accidents at work". Slightly over a third of standards related to this indicator are harmonised. This highlights that energy efficiency is a particular focus of harmonised standard and that energy efficiency is a focus area of legislation.

In the correlation analysis, we find a negative and significant relationship between an increased stock of standards and the greenhouse gas emissions intensity of energy consumption. This relationship holds also when we control for GDP per capita. These results strengthen our hypothesis that European standards are positively associated with decreasing greenhouse gas emissions from energy consumption.

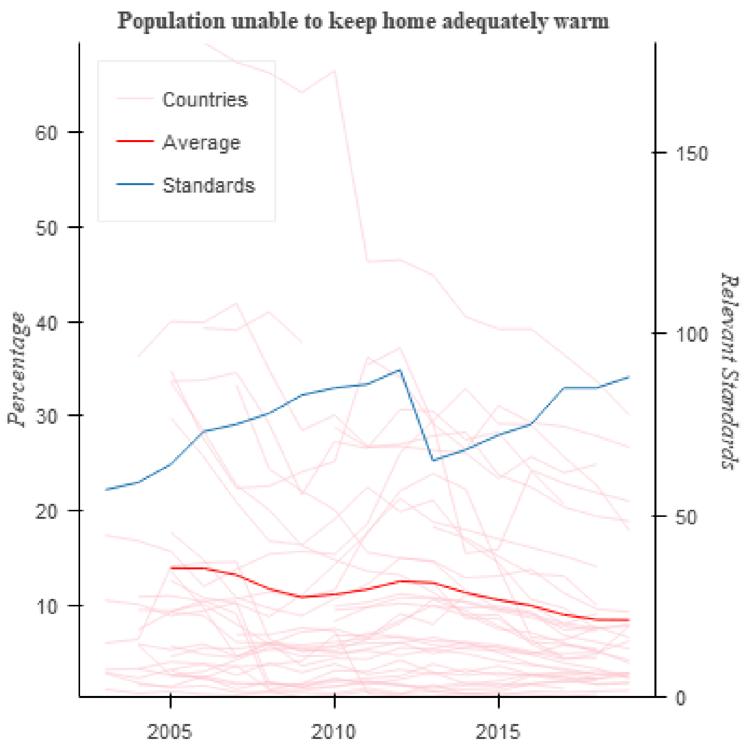
5.4.2 Society

The following indicators are analysed:

- Population unable to keep home adequately warm
- People living in households suffering from noise
- Exposure to air pollution
- People killed in road accidents

- Share of renewable energy in gross final energy consumption
- Greenhouse gas emissions intensity of energy consumption
- People killed in accidents at work
- Recycling rate of municipal waste
- Corruption Perceptions Index

5.4.2.1 Population unable to keep their home adequately warm



European standards can contribute to the warming of housing in several ways. They can make sure buildings are built with adequate insulation, which will ensure they leak less heat. They can also help making warming more affordable, through increasing energy efficiency. The indicator for the population unable to keep their houses adequately warm is linked with the following standards: Energy efficiency standards, thermal insulation standards, and thermal insulation in building standards.

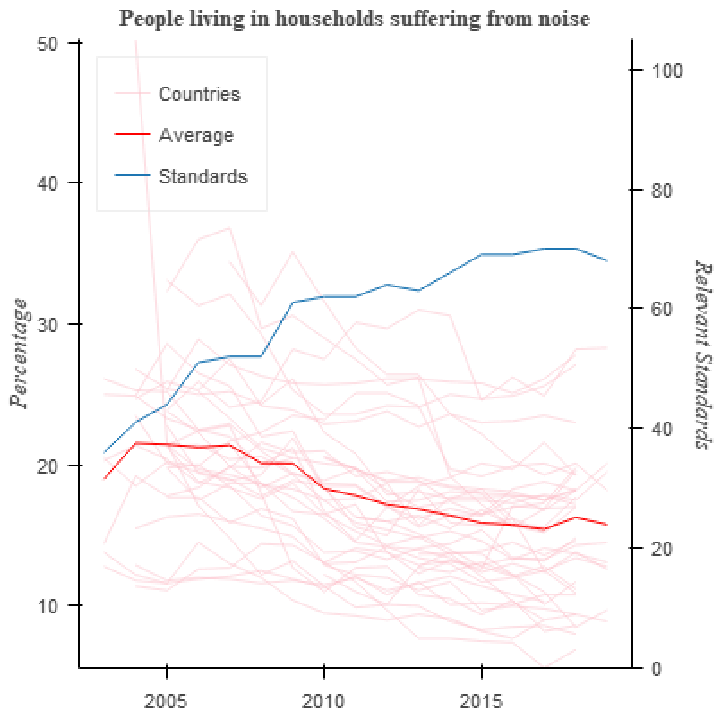
As shown in the figure, the number of relevant standards has increased slightly overall during the period, with a significant fall in the early 2010s. At the same time, the percentage of the population unable to keep their home adequately warm has decreased steadily over the period. [55]

Among the standards which are matched with this indicator, we find standard ISO 10077-1 which is mentioned several times in legislation. ISO 10077-1 gives standards for thermal performance of windows, doors and shutters. Increasing the quality of these components may contribute substantially to keeping houses adequately warm.

In the correlation analysis, we find that there is a significant and negative relationship between the amount of people unable to keep their home adequately warm and the availability of relevant European standards. This relationship holds when controlling for GDP per capita, population and the unemployment rate.

[55] For population unable to keep house sufficiently warm and household noise, Eurostat has no data for the EU28 for the majority of the years, and we therefore plot the average of the countries with data instead

5.4.2.2 People living in households suffering from noise



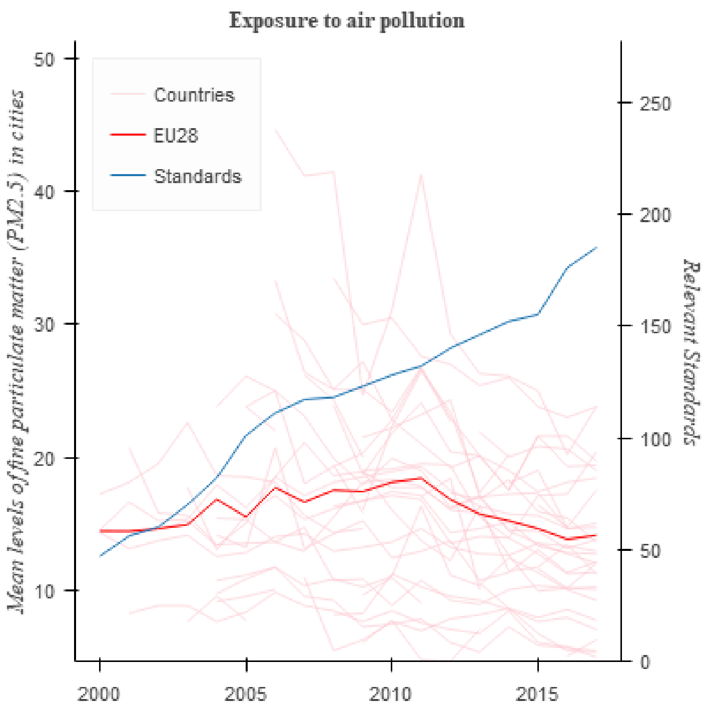
Two groups of standards are mapped to the indicator for the amount of people living in households suffering from noise. These groups of standards are noise with respect to human beings and sound insulation.

As shown in the figure, the percentage of people living in households suffering from noise has decreased over the period. Meanwhile, the stock of standards has increased over the period, following a curvature slightly similar to the indicator of interest.

We find no European standards related to noise and sound insulation which are mentioned in legislation. There are, however, several European standards developed for reducing noise between apartments in apartment buildings, and from the outside and into apartments. These standards could spread knowledge and best practices and increase the quality of buildings with respect to sound proofing.

In the correlation analysis, we find that there is a negative and significant correlation between the people living in households suffering from noise and the availability of relevant European standards over time. This relationship holds when controlling for GDP per capital, population and the urban population share.

5.4.2.3 Exposure to air pollution



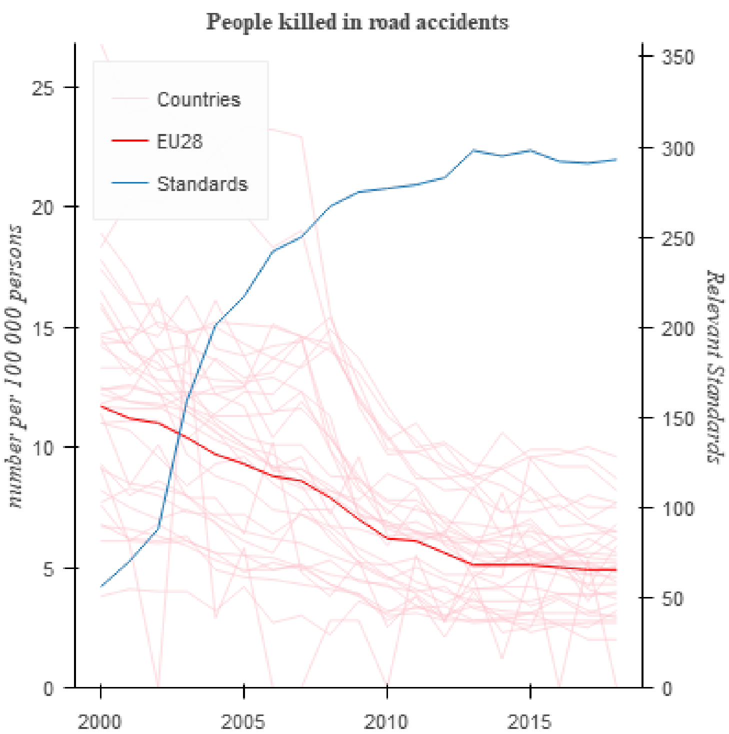
There are several standards related to air pollution. Air pollution could have a substantially adverse effect on health, and European standards can therefore contribute significantly to sharing best practices in reducing the emission of pollutants. With the exposure to air pollution indicator, we have mapped standards related to pollution, pollution control and conservation, and air quality. The indicator is related to SDG 3, good health and well-being, as well as SDG 11, sustainable cities and communities.

As we can see from the figure, the mean levels of particulate matter have been relatively stable over the period from 2000. At the same time, standards related to this indicator ha increased, especially between 2000 and 2005, and from 2010 onwards.

There are several relevant European standards with a number of mentions in legislation. Many of these standards are related to methods for sampling and determining the concentration of pollutants which are emitted from various processes. This is expected to carry advantages for good health and well-being, as well as sustainable cities and communities.

From the correlation analysis, we find a significant and negative relationship between standards and the exposure to air pollution in the population. This relationship holds also when controlling for GDP per capita, population, the urban population share as well as the industry share of the economy.

5.4.2.4 People killed in road accidents



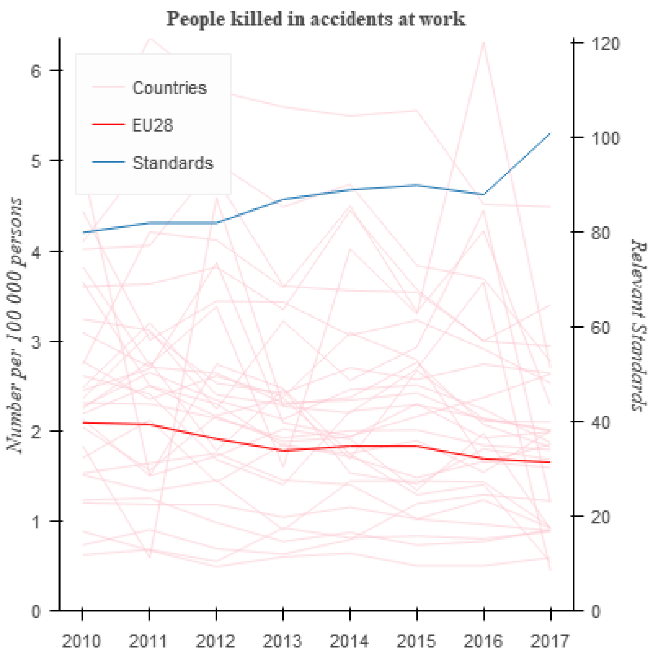
The standards related to road accidents measure societies' ability to protect people from accidents, and are likely to be affected by legislation, regulation and standardisation which increase safety measures in roads and vehicles. We have mapped European standards related to road vehicle systems, road engineering, and tunnel construction to this indicator.

In the figure, we can see from the development of both the European standards related to road accidents and the number of people killed in road accidents that the curvature is quite similar. In the beginning of the period, there is a steeper rise in European standards, while there is a steeper decline in accidents. Later, both the increase in standards and the decrease in accidents subside. This could indicate that there is a relationship between the two. However, it could also reflect the fact that there has been a larger development of standards in a period when the reduction of accidents has been a priority. Hence the two variables could be affected by the same external factors.

Some of the standards related to road accidents are mentioned several times in legislation. Notable is EN 1991-2:2003/AC:2010 which is related to the traffic load on bridges. Poor bridge construction could lead to the bridge failing under large traffic loads. This could again lead to traffic disasters. The mentioned standard is likely to increase the safety of bridges, as well as the diffusion of knowledge and technical information.

From the correlation analysis, we find a significant and negative relationship between standards and the people killed in road accidents. This relationship holds also when controlling for GDP per capita, population, and cars per 1000 people.

5.4.2.5 People killed in accidents at work



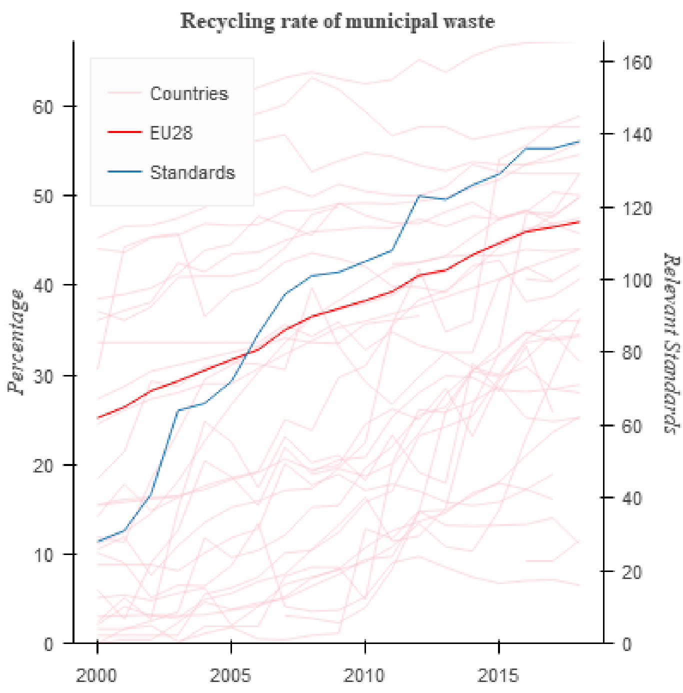
As with people killed in road accidents, standards related to people killed in accidents at work measure societies' ability to protect people from accidents, and are likely to be affected by legislation, regulation and standardisation which increase safety measures at workplaces. To this indicator, we have mapped European standards related to workplace safety, as well as safety of machinery.

Since 2010, the amount of accidents at work has fallen only slightly in the EU28, while the corresponding stock of standards has risen only slightly. The rate by which they vary is, however, quite similar, as can be seen from the figure. However, we can also see from the country graphs that there are significant differences between countries in the development in people killed in accidents at work. This could be due to the fact that larger accidents occur at random, and that the rate at which accidents occur is not stable from year to year.

Approximately two thirds of the standards relating to people killed in accidents at work are harmonised. This is the highest share out of all the SDG indicators looked at. This indicates that health and safety is a larger focus of harmonised standards than of non-harmonised standards. It seems reasonable that health and safety standards related to workplaces are harmonised, as these are issues which are mostly regulated by workplace legislation. Harmonised standards can therefore help to meet requirements in legislation, but also help uphold the EU's commitments to the SDGs.

From the correlation analysis, we find a significant and negative relationship between the development in available European standards and the people killed in accidents at work. This relationship holds also when controlling for the agriculture and industry share of the economy.

5.4.2.6 Recycling rate of municipal waste



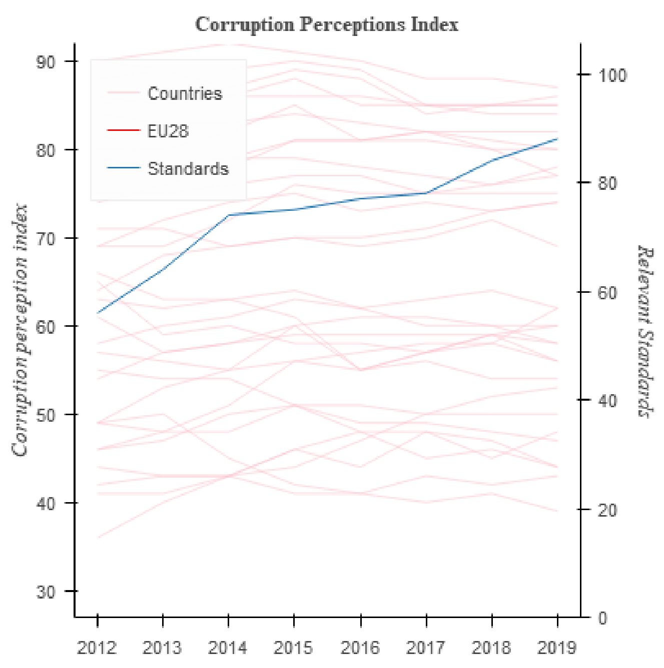
For the recycling rate of municipal waste, we have mapped European standards related to waste and recycling.

When looking at the figure, we see that both European standards related to waste handling and the recycling rate are increasing over the period of interest.

There are some standards related to this indicator which are mentioned in legislation. Most of these are related to packaging. Improved packaging could ease the process of recycling waste, for example as it is hard to recycle packaging made from both plastic and paper if the two materials cannot be separated from each other easily prior to recycling.

From the correlation analysis, we find a significant and positive relationship between European standards and the recycling rate of municipal waste. This relationship holds also when controlling for GDP per capita, and the share of economy value added in industry.

5.4.2.7 Corruption perceptions index



Lastly under this category, we have looked at Transparency International's corruption perceptions index, which is used to measure progress on SDG 16. We have linked this index with management standards, under the assumption that standards on management might lead to higher transparency and more streamlined systems in organisations. It is important to note in this regard that an increase in the corruption perceptions index means that a country has a lower *perceived* level of corruption. The index is compiled from survey data, asking about how a population perceives corruption levels in its society.

As can be seen from the figure, relevant standards have increased by about 50% between 2012 and 2019, but the corruption level seems relatively stable in most countries.

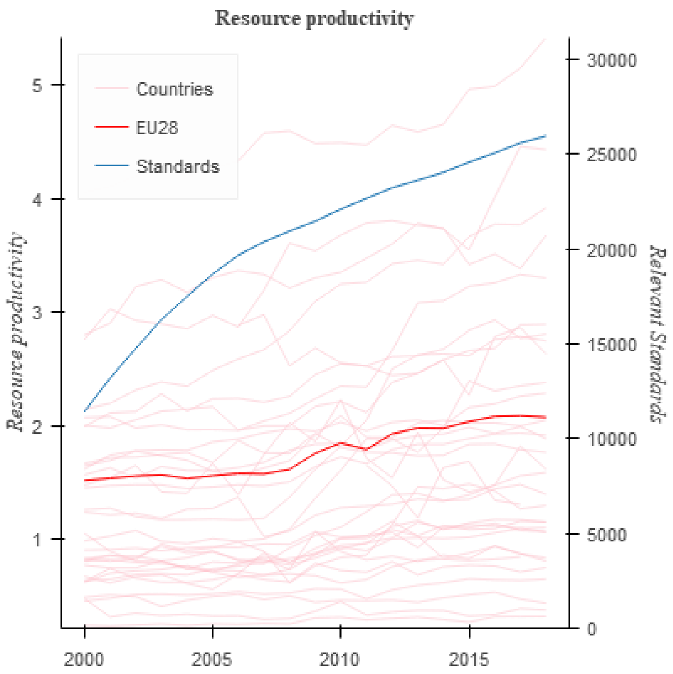
The correlation analysis finds no relationship between the chosen European standards and the corruption index when no control variables are included. However, when we control for GDP per capita and the GINI coefficient, we find a positive correlation relationship which is significant at the 10 percent level.

5.4.3 Economy

The following indicators are analysed:

- Resource productivity
- Generation of waste excluding major mineral wastes by hazardousness

5.4.3.1 Resource productivity

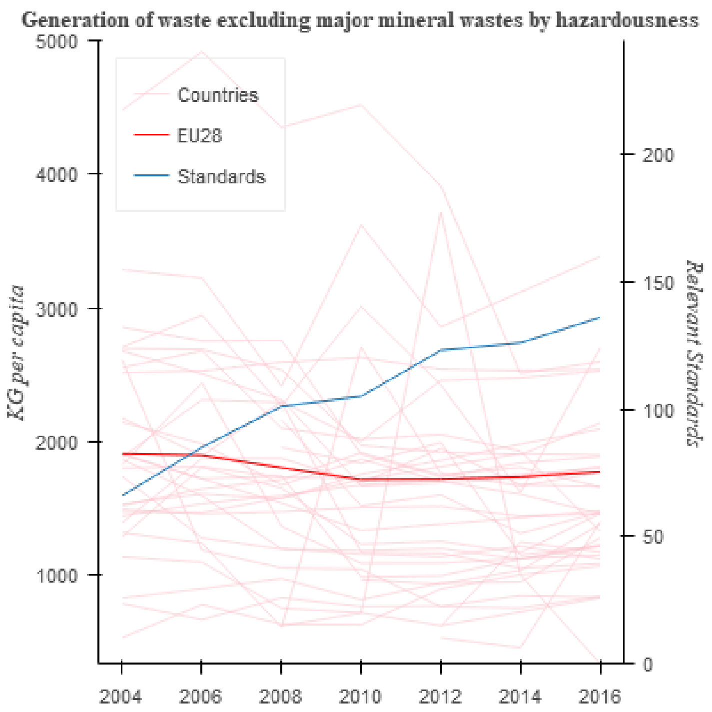


Resource productivity measures the total output per kilogram of material used. It is a measure of how much output can be produced for a given level of materials consumed, and thereby whether countries are successfully decoupling economic growth from the use of natural resources. For this study, we have matched resource productivity with the full stock of European standards, as the resource productivity indicator measures approximately the same as the full model.

As can be seen from the figure, both resource productivity and standards have increased during the period from 2000 to 2019.

From the correlation analysis, we also find a positive and highly significant relationship between standards and resource productivity. This relationship holds also when controlling for the agriculture share of the economy, the industry share of the economy and the urban population share.

5.4.3.2 Generation of waste, excluding major mineral wastes, by hazardousness



We examine the relation between European standards and the generation of waste, excluding major mineral wastes. This indicator is linked with European standards under ICS 13.030 which focus on increasing recycling, reducing waste and improving packaging.

As seen from the figure, since 2004 the generation of waste per capita has fallen by approximately 7% in the EU28, but this fall happened mostly from 2004 to 2010, and many countries have individually seen an increase. This is in other words an indicator where relatively little progress has been made.

There are some European standards related to this indicator which are mentioned in legislation. Most of these are related to packaging. Improved packaging could ease the process of recycling waste. In the correlation analysis, we can see that there is to some degree a relationship, where the increase in standards leads to a decrease in the generation of waste.

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