

published in: Doluca, H., Holzner, B. & Wagner, M. (2018) Environmental Innovation and Corporate Sustainability: A 15-Year Comparison Based on Survey Data. In: Horbach, J. & Reif, C. (Eds.) New Developments in Eco-Innovation Research. Sustainability and Innovation (pp. 193-217). Springer, Cham. DOI:10.1007/978-3-319-93019-0_9.

Environmental innovation and corporate sustainability: A 15-year comparison based on survey data

Dr. Hüseyin Doluca (University of Augsburg)

Benedikt Holzner (University of Augsburg)

Prof. Dr. Marcus Wagner (University of Augsburg)

Introduction

The political sustainable development agenda initiated by the World Commission on Environment and Development (World Commission on Environment and Development, 1987) has long reached the corporate sector. Consequently, non-financial goals such as environmental and social aspects have been integrated into corporate management, resulting in environmentally-related product or process innovations. Although there exist several databases and related analyses (Wagner, 2007; 2008; Horbach, 2008; Horbach et al., 2012; Schaltegger et al., 2013) the development of environmental innovation and corporate sustainability has not yet been analysed over a long period in high detail. That is why we aim at addressing the research question of how corporate sustainability and environmental innovation activities developed over the past 15 years.

The answer to this question is of interest because environmental protection increasingly gains not only the attention of businesses and politics it also receives significant societal and media attention. Based on a unique dataset containing partly longitudinal survey data from 2001 and 2016, we present the status quo and the development of corporate sustainability efforts among manufacturing firms in Germany and the United Kingdom (UK). We further provide disaggregated results for seven different manufacturing industries while differentiating firm size (small-, medium- and large-sized firms). We find an overall increase of environmental activities and environmental management system (EMS) certification. However, some activities differ across industries and countries. Managerial activities and EMS implementation have overall greater popularity in Germany, while its level of adoption depends on the specific activity. Our results inform practitioners as well as researchers and politicians by providing insights about the development of environmental innovation and corporate sustainability activities across different manufacturing industries in these two countries.

The remainder of our analysis is organized as follows. We start with a brief summary of related research and an explanation of the research approach. Following this, results are presented in three parts: First, we compare corporate ecological sustainability between Germany and the UK as well as over time. Second, the status quo of corporate social sustainability is shown for both countries. Third, we examine corporate ecological sustainability for Germany more in-depth with regard to industry affiliation and firm size. At the end of the chapter, some general conclusions and a discussion of our results are provided.

Literature Review

Environmental innovation has been defined as the application or introduction of new products and processes contributing to the reduction of environmental burdens or to ecologically specified sustainability targets (Rennings, 2000). Corporate sustainability behaviour is more comprehensive and covers all corporate activities related to ecological, economic and social issues aiming at realising a global and long-term sustainable development path. Existing literature suggests that environmental innovation and corporate sustainability behaviour differ depending on different factors such as firm size, the main industry in which a firm is active and the type of environmental innovation. More specifically, since radical technological innovations are less likely pursued by larger firms (Almeida & Kogut, 1997), environmental product and process innovations should be analysed with respect to firm size, since process innovations tend to be more incremental. Analysing product and process innovation separately is additionally necessary because the implementation of environmental management systems is found to be positively associated with environmental process innovation, whereas no empirical association is found with environmental product innovation (Wagner, 2007). Only specific activities such as information of consumers and eco-labelling are shown to positively impact product innovations (Wagner, 2008,), indicating that a detailed activity-based analysis has to be performed.

Extant literature has not much addressed corporate sustainability as concerns of small and medium-sized enterprises (SME), since it either analysed only large firms or the analysis focussed on environmental aspects. Hence, existing analyses either do not provide a fully differentiated view with regard to firm size effects or do not cover all relevant sustainability aspects. For example, Schaltegger et al. (2013) focus on large companies only, yet empirical research indicates that small and SME differ in their approach to corporate sustainability (Wagner & Schrauth, 2014; Wagner and Schaltegger, 2003). By analysing across all different firm sizes, we thus provide a more differentiated analysis and contribute novel insights to the literature. With our study we analyse a longer period than ever before and additionally provide a cross-country comparison of European countries. This enables us to point out national strengths and weaknesses and to assess the development of

corporate sustainability by benchmarking it internationally. Furthermore, we can comment on the status quo of corporate sustainability and environmental innovation with our dataset and thus provides insights on recent trends. In this analysis, we describe the current situation of corporate sustainability and environmental innovation and compare the results with earlier studies.

Data and Method

Building on the European Business Environment Barometer (EBEB) of 2001 survey, to gain more recent insights, we collected data for 2016 in the context of the European Sustainability Management Barometer (ESMB) survey. The ESMB survey was conducted among manufacturing companies and thus continues the work of the EBEB. In the current round of 2016, the ESMB surveyed firms in the UK, Germany, Austria, Switzerland, Italy and Greece. In this report, we focus on a comparison of Germany and the UK, since for these countries sufficient responses were received in both years to make an exploratory statistical analysis feasible. As many questions in the 2016 survey are identical to those from 2001, we can assess the development of sustainability management over a 15-year period, which is unique in the context of large-scale studies on corporate sustainability management.

We distributed the questionnaires to a random sample of manufacturing firms. The pooled dataset contains 783 observations of which 562 are from Germany. Based on this sample, we carry out an exploratory data analysis in order to establish trends and international differences as concerns of corporate sustainability and environmental innovation as well as to identify the status quo in the industrialised countries Germany and UK. We methodologically build on frequency counts and box-whisker plots to assess first and second distributional moments in the data.

The composition of the dataset – especially regarding firm size (and to a lesser degree also with regard to industry structure) is not completely identical in the two countries as well as over time, which should be considered when making comparisons. We define the company size by the number of employees (n). To do so, we follow the European Union recommendation to classify companies into the following aggregate categories: Small (below 50 employees), medium (50 to 249 employees) and large (at least 249 employees). While in 2001 the participants in Germany and the UK had a similar size distribution, this changed for 2016, when 64% of the German companies have at least 250 employees, whereas in the UK only around one-fourth of the responding firms reached this size. However, these differences in size distribution reflect however to a large degree the macro-industrial structure in each country and thus are mostly unavoidable in a comparative survey context such as ours.



Figure 1: Company size by year and country

Analysis

We first describe the results of technological and managerial ecological sustainability and environmental management activities as concerns the differences between Germany and the UK and the development between 2001 and 2016. In a second part, the internal and external social sustainability activities are compared between the two countries. In the final part, the German results are analysed in more depth as concerns company size and industry affiliation.

Ecological sustainability

In this part, we examine the results of 2001 and 2016 for Germany as well as for the UK. Various operational and managerial activities and environmental management system (EMS) adoption are focused upon.

Operational environmental activities

In the survey, 19 operational activities to improve environmental performance were listed and the participants had to state whether or not they implemented them in the prior three years. Three activities premiered in the 2016 survey, for the remaining 16, we show the 15-year comparison. For those operational activities Table 1 shows the adoption rates¹ of the different technological activities in descending order of the 2016 shares in Germany. Overall, the responding firms from the UK have

¹ The adoption level is calculated by dividing the number of firms having undertaken the respective activity by the total number of firms.

made greater progress over the past fifteen years. In 2001, the average responding firm in Germany adopted 41% of the possible technological activities while in the UK it was only 34%. Fifteen years later, in 2016, the direction of this difference was reversed such that the average British firm adopted more technological activities (55%) than its German counterpart (50%). Differences also exist between German and British firms with respect to both the most often adopted and less often adopted activities. In Germany, the top two activities are the reduction of waste and the substitution of hazardous products, while the latter activity increased the most (by 30%) within the last 15 years. In terms of the largest increase, substitution of hazardous products is subsequently followed by the activities reduction of transport energy and substituting non-renewable materials. It is conspicuous that in Germany recycling activities show little change compared with the remaining activities. The adoption of packaging recycling even decreased in the 15-year period analysed. The three activities being evaluated for the first time in 2016, namely emissions offsetting, biodiversity conservation, and biodiversity restoration, all differ markedly in Germany from the activities already covered in 2001, with adoption rates ranging between 29% and 34%. Only the usage of foreign waste streams has been less often adopted overall as an activity.

In contrast to the German respondents, British firms place a stronger focus on recycling. The top three activities are material, packaging and product recycling with almost every company reutilising materials (95%). It is notable that no activity adoption level decreased in the 15-year period but nine out of 16 increased by more than 25%. Similar to Germany, in the UK activities concerning biodiversity restoration, biodiversity conservation and emissions offsetting are adopted by the lowest number of firms and have identical adoption levels of 38%, which are slightly larger than in Germany. Only the substitution of non-renewable materials has been adopted less frequently as in the UK.

The activities around the implementation of cleaner technologies in the production process and “Green” design of new products reflects the environmental innovation performance of a company, corresponding to process and product innovation, respectively. Although the activities’ adoption rates did increase in the 15-year period to a greater extent in the UK than they did in Germany, on average more German firms adopted innovation activities. In 2016, 50% of the German and 38% of the British firms had undertaken a “Green” product innovation activity within the past three years. A cleaner technology was applied by 63% in Germany and 57% in the UK. In 2001, for almost every activity the share of adopting companies is higher in Germany. The only exceptions are material recycling, the use of foreign waste streams and the substitution of hazardous products. However, over the period considered, British companies achieved higher adoption rates for almost every activity. Hence, in 2016 a differentiated picture is observed with regard to the leadership of the respective activities between the two countries. Firms in the UK seem to focus on recycling rather

than focusing on more efficient production, the latter predominantly being done by German firms (which lead in substituting hazardous input as well as in reducing output in terms of waste).

Table 1: Operational activities by country and year

Operational Activity	GER 2001	GER 2016	UK 2001	UK 2016
Reduce Waste	65%	78%	34%	57%
Substitution of hazardous input	46%	76%	35%	62%
Reduce material per unit	48%	69%	34%	64%
Reduce water use	52%	69%	32%	68%
Reduce air emission	53%	66%	39%	52%
Cleaner production technology	53%	63%	38%	57%
Packaging recycling	66%	60%	53%	81%
Reduce noise emission	46%	58%	34%	48%
Reduce transport energy	31%	53%	27%	52%
Material recycling	46%	51%	66%	95%
"Green" new product design	42%	50%	26%	38%
Product recycling	38%	47%	36%	76%
Reduce packaging per unit	46%	38%	30%	62%
Substitution of non-renewable materials	16%	36%	19%	36%
Reduce water emission	29%	34%	29%	38%
Biodiversity conservation		34%		38%
Emissions offsetting		30%		38%
Biodiversity restoration		29%		38%
Use of foreign waste streams	9%	17%	16%	50%

Managerial environmental activities

We also surveyed 20 managerial environmental activities in the same manner as described for the operational activities. shows the managerial activities covered, sorted in descending order by the 2016 results for German respondents. Overall, the managerial activities have higher adoption rates. Two-thirds of the activities have been adopted by at least two-thirds of the respondents in Germany and half of them in the UK. Clearly defined responsibilities are most often adopted in Germany (90%), followed by environmental goals being part of a continuous improvement process and having measurable environmental goals (both 84%). In the UK, procedures to handle legal requirements (95%) and written environmental policies have the highest adoption rates (90%).

Manufacturing companies in both countries rarely benchmark their own environmental performance with other companies. Furthermore, market research for specifically environmental-friendly ("Green") products is also rare (19% and 27%, respectively). Eco-labels show a growing popularity in Germany (44%). In the UK, they are less widespread (19%). Reviews of EMS efficiency, environmental performance indicators and placing a demand on suppliers to take environmental activities are also topics, that get substantially more attention from German companies. They also publish a separate environmental report more often (+ 32%). In comparison, British companies put this information in the annual report more often (+ 10%), which makes the difference less pronounced. Except for this

and procedures for identification and evaluation of relevant legal requirements, managerial activities are generally adopted to a greater degree by German companies, as compared to firms in the UK.

Table 2: Managerial activities by country and year

Managerial Activity	GER 2001	GER 2016	UK 2001	UK 2016
Clear responsibilities	74%	90%	53%	86%
Improvement process for environm. goals	54%	84%	44%	81%
Measurable environm. Goals	52%	84%	41%	81%
Procedure to handle legal requirements	57%	84%	70%	95%
Written environm. policy	53%	83%	69%	90%
Programs for environm. goals	47%	83%	38%	81%
Environm. performance indicators	38%	82%	26%	62%
Environm. program audit	43%	81%	38%	67%
Review EMS efficiency	40%	77%		38%
Separate environm./ HSE report	42%	75%	25%	43%
Environm. staff trainings	54%	71%	36%	67%
Initial environm. review	57%	70%	62%	67%
Supplier selection by environm. performance	51%	66%	39%	62%
Environm. data in annual report	38%	66%	30%	76%
Demand suppliers to take environm. actions	45%	64%	32%	43%
Consumer information about environm. effects	33%	48%	32%	43%
Eco-labelling	16%	44%	14%	19%
Life cycle assessment for products	18%	39%	13%	48%
Benchmarking with other companies	16%	27%	22%	19%
Market research on 'Green' products	15%	23%	18%	24%

Environm. = environmental

HSE = Health and Safety Executive

Environmental management systems

In this section, we show the trend of implementing an EMS for Germany and the UK. EMS cover the implementation, organisation, and advancement of operational environmental management.

Besides, a certified EMS can signal the level of environmental performance to outside parties, which is used to reliably assess the benefits that result from corporate environmental activities.

Furthermore, we show the relation between environmental activities other than EMS and the implementation of an EMS.

The diffusion of EMSs has grown over the past 15 years (). German manufacturers tend to implement them rather more frequently than UK ones. In 2016, 79% of the responding firms had implemented an EMS in Germany, compared to 52% in the UK. Even in 2001, the German share was bigger: with 45% of the firms having implemented an EMS, they were 17% higher. Non-certified systems are very rare in both countries.

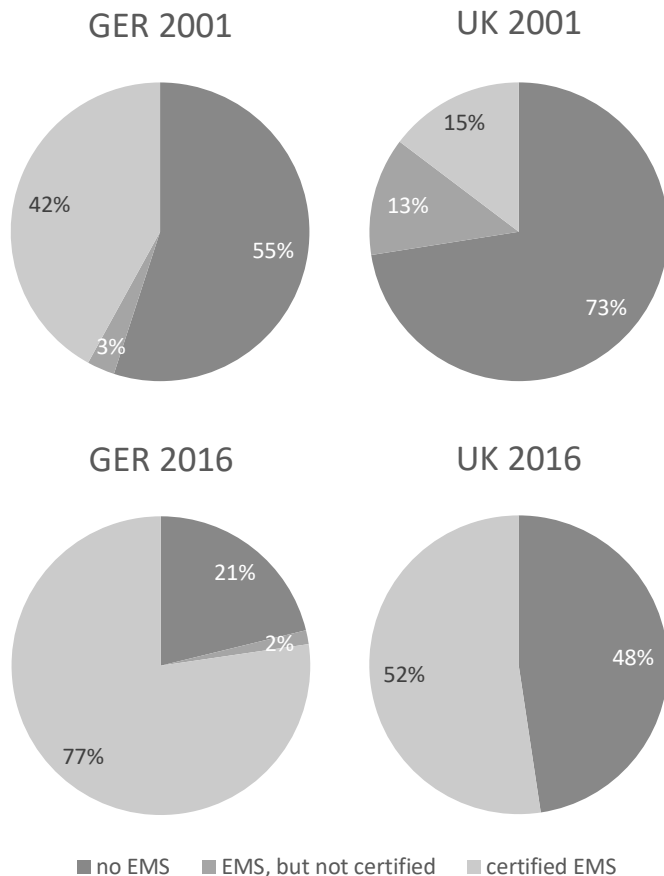


Figure 2: Adoption of EMS

EMS theoretically should support the implementation of environmental activities. Therefore, it is expected that companies with an EMS perform more activities. We can further assume companies have a stronger motivation for environmental protection if they are willing to implement an EMS. We present the relation between the presence of an EMS and the number of managerial and operational activities for German and British companies in this section. We do not differentiate between the different types of certification. The box-and-whisker plot represented in confirms our expectations and shows further information about the distribution of the number of implemented activities: Companies with an EMS are found to have implemented more operational environmental activities. In 2001 and in 2016, the number of activities was clearly higher, even though there were some time- and country-specific peculiarities.

For German companies with an EMS, the median remained almost unchanged.² The overall increase above discussed is due to the increase of both the lower and upper quartiles. In 2016, the number of implemented activities was on average higher in the UK, where the median reached a value of 11 for

² Note that also we have checked for outliers, for robustness reasons we prefer using the median instead of using the mean.

companies with EMS and nine for companies without one. Surprisingly, the firms without an EMS raised both the median and the quartile values in both countries. This suggests a somewhat limited role of certification, since evidently other factors such as regulations or increased public awareness must have driven the average number of technological activities up in firms without a certified EMS, a finding that is consistent with earlier research (Hertin et al., 2008; Tyteca et al., 2002).

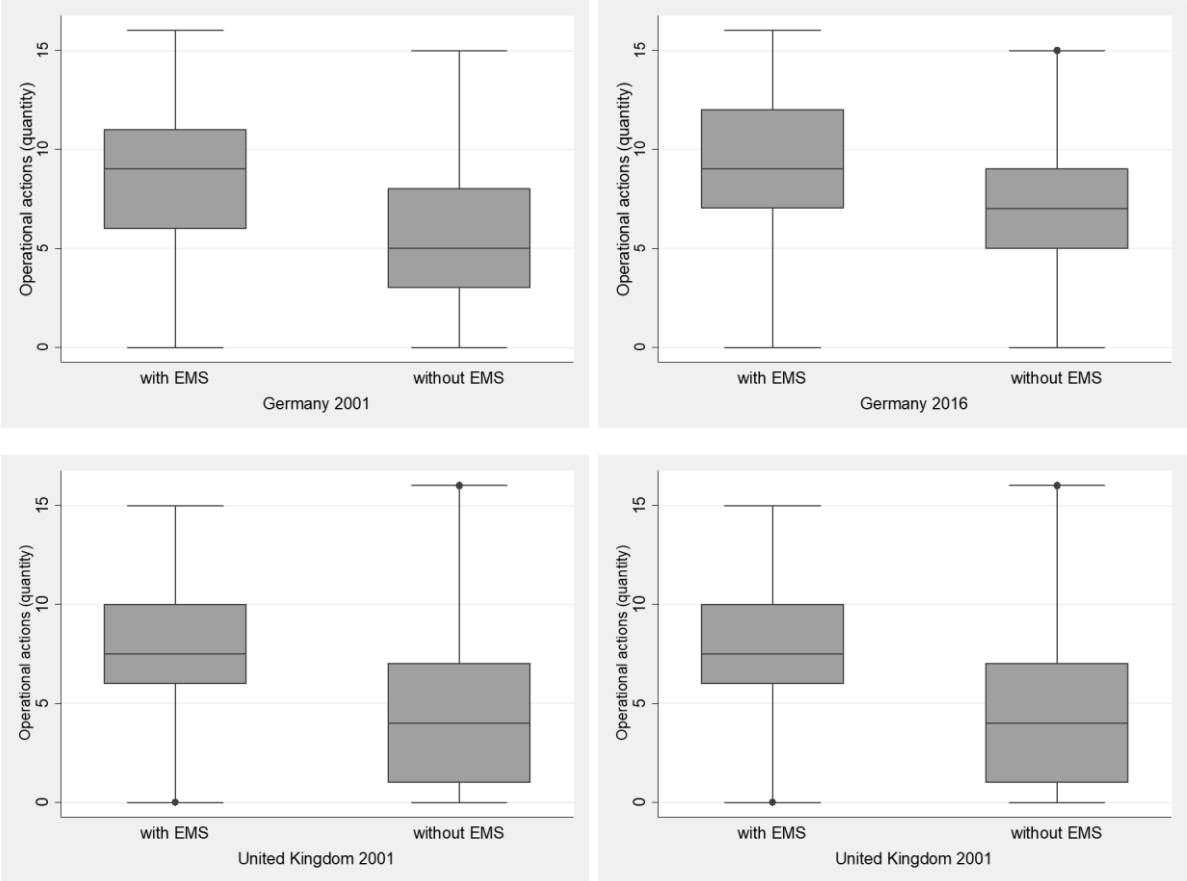


Figure 3: Boxplots of operational activities vs. EMS

For managerial activities, the existence of an EMS makes a bigger difference (). In all surveys, the median of participants with an EMS is at least 14. For those without an EMS, only the UK 2016 survey reached a value above four. It is worth mentioning, that some of the activities enquired about are required to certify an EMS. Therefore, their adoption rate is 100% in the companies with an EMS.

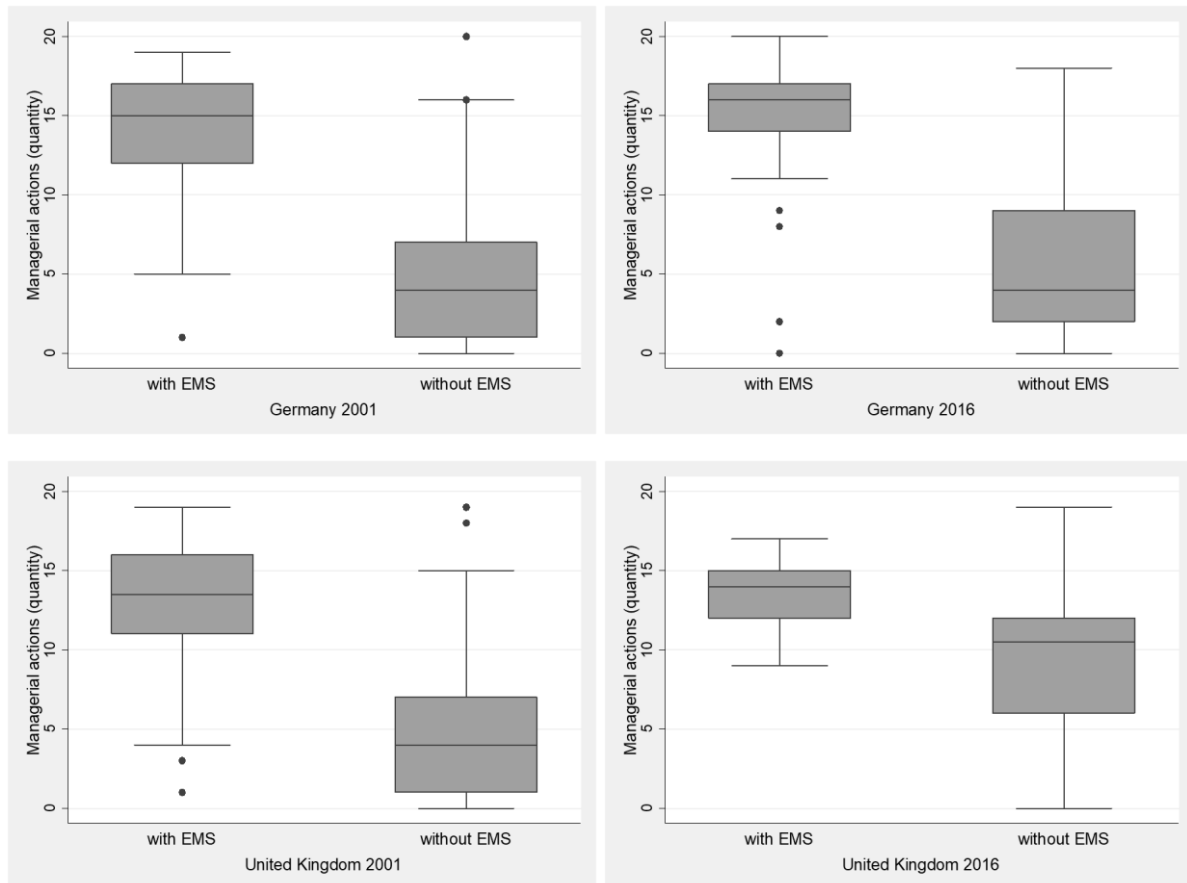


Figure 4: Boxplots of managerial activities vs. EMS

Internal and external social sustainability

Alongside the ecological activities, companies are also concerned by social issues. This section examines what internal and external efforts companies make in support of social sustainability. We describe the current dissemination levels of 17 internal and 21 external activities in total. The results are presented for Germany and the UK in 2016.

The results show the internal activities in descending order for the share in Germany. The most frequent activities in both Germany and the UK are offers for health protection and general education and training programmes for employees, followed by an employee suggestion scheme. While in Germany nearly every company is implementing those activities (91-93%), in the UK, about two-thirds of the participants do so. These activities bring direct benefits such as less sick days or a better qualification of employees for the companies. However, British firms lead in terms of support for the childcare of employees and support of gender diversity. Other activities for the equal treatment of all employees like ethnic diversity plans (77% vs. 56%) or the fair distribution of wages (68% vs. 53%) have an average adoption level across all activities: In Germany and the UK, respectively 51% and 33% of the participants apply social standards like “Recommendation 146” of the International Labour Organisation (ILO). A balanced scorecard incorporating sustainability

aspects was implemented by 28% and 19% of the responding, respectively. The UN Global Compact is an initiative for socially responsible business policies. With its ten principles, it is meant to promote a sustainable economy worldwide. 19% of the German manufacturers and 13% of the British ones joined this agreement. Among the firms in Germany and the UK, 26% and 19% respectively use a quality management system based on the European Foundation for Quality Management (EFQM) model that includes societal and employee welfare goals. Only 10% of the German and none of the UK companies implemented the ISO 26000 standard for social responsibility.

Table 3: Internal social sustainability activities

	GER	UK
Health protection	93%	76%
General education programme	92%	76%
Employee suggestion scheme	91%	76%
High level social benefits	85%	41%
Individual work time models	83%	71%
Ethnic diversity plans	77%	56%
Qualification activities for job returners	76%	38%
Flexible work place design	70%	65%
Fair distribution of wages	68%	53%
Gender diversity support	68%	75%
Social standards (e.g. ILO 146)	51%	33%
Time for education on issues relevant for society at large	49%	38%
Support with child care by the company	47%	59%
Sustainability balanced scorecard	28%	19%
EFQM-based management system	26%	19%
UN Global Compact membership	19%	13%
ISO 26000 implementation	10%	0%

Most of the firms surveyed offer apprenticeship positions under their external social sustainability activities. Fair trading relationships are especially supported in Germany (87%). Sport and cultural sponsoring is also more popular in Germany with shares being around twice the level of those in the UK. Support for the local community is important in both countries (71% and 65%, respectively). A company's regional integration has a positive effect when it comes to recruiting or retaining employees, but also with regard to support for sustainable regional development. This might explain the support for the region in which the firms' operations are located (67% and 47%). 64% support justice-marked commodities (i.e. commodities for which just trading relations with customers, suppliers and other business partners exist), while only 13% declare their own products to be "Fair Trade" certified. Apart from this, only the adoption of the Social Accountability 8000 standard, which deals with social accounting in general and social marketing, is less than or equal to 15% in both countries that were analysable.

Table 4: External social sustainability activities

	GER	UK
Apprenticeship positions	93%	71%
Fair trading relationships	87%	41%
Support/sponsoring of sport events	76%	35%
Community support	71%	65%
Support for regions of company's locations	67%	47%
Justice-marked commodities	64%	24%
Cultural sponsoring	56%	29%
Social issues reporting or sustainability reporting	54%	44%
Support of education initiatives	50%	19%
Stakeholder dialogue initiatives	43%	47%
Social performance indicators	43%	40%
Promotion of Human Rights	42%	41%
Corporate volunteering	41%	47%
Corporate citizenship activities	34%	35%
OECD guidelines for multinational enterprises	30%	7%
Social justice programmes abroad	30%	31%
Aid to homeless	19%	12%
Social marketing	16%	27%
Social accounting	16%	20%
Social Accountability (SA) 8000 standard	15%	6%
"Fair Trade" declaration of products	13%	14%

Detailed analysis by industry and size for Germany

In this third part, the results for Germany will be analysed in more depth with respect to effects of the participating companies' size and industry. Further, we will examine which companies cooperate during product planning and development as concerns environmental aspects. Since some questions were not asked in the UK in 2001, we can no longer consider British firms in this part of the analysis.

Categorizations via industry and company size

In order to provide improved comparability, we defined 7 industry classes out of 21 options offered to the participants for identifying their main industry at a detailed level. These aggregate industry classes are "Consumer industry", "Wood, paper, publishing and printing products", "Chemical industry", "Glass, ceramic and metal products", "Engineering and vehicle construction", "Electric and electronic devices", with the industries included being self-explanatory. Additionally, there is the class of "Other manufacturing industries", which contains firms assigning themselves to this class as well as firms of the utilities, transport and recycling sectors. These are assigned here due to a low number of participants in these sectors in order to remain parsimonious.

The distribution of the participants across the so-defined aggregate industry classes is as follows. In 2001 "Glass, ceramic and metal products" together with the "Consumer industry" had the biggest shares each with 18% of the participants. In the 2016 survey, most companies were part of the "Chemical industry", representing 16%. At the expense of all remaining industry classes, the other manufacturing companies have a larger representation in 2016 (30% against 16%). Apart from this, the structure is similar in both surveys, enabling a meaningful comparison over time. As concerns the

distribution in the total population of German manufacturing firms, in 2014, the largest industry in terms of the number of companies was “Glass, ceramic and metal products”, followed by “Consumer goods” and “Engineering and vehicle construction” (Statistisches Bundesamt, 2016). These three industries represent the second, third, and fourth largest industries in our responses. Therefore, the results reported in the following are broadly representative for the German manufacturing sector as a whole as concerns industry distribution.

We further aggregated the companies by size, based on the categories reported in the introduction for the number of employees. Overall, the size of respondents ranges from 6 to 610.000 employees. Whilst in 2001 half of the participants had between 50 and 250 employees, in 2016 firms with more than 250 employees are having the largest share (47%). Small companies with less than 50 employees were represented only in smaller numbers in 2001. In the 2016 survey, they account for 10%. This change in size composition in our responses may affect the results. The distribution in each size category based on the aggregated categories is displayed in Table 5.

Table 5: Firm size distribution by aggregate industry category

Industry	Year		2001			2016		
	01-49	50-249	>=250	01-49	50-249	>=250		
Consumer industry	80%	19%	17%	18%	11%	11%		
Wood, paper, publishing, and printing	0%	14%	6%	14%	14%	6%		
Chemical industry	0%	13%	13%	23%	14%	16%		
Glass, ceramic and metal products	20%	21%	15%	0%	19%	12%		
Engineering and vehicle construction	0%	12%	17%	0%	0%	17%		
Electric and electronic devices	0%	11%	10%	14%	13%	8%		
Other manufacturing industries	0%	10%	20%	32%	29%	31%		

Operational environmental activities

We now take a closer look at the operational activities taken to diminish or prevent negative environmental impacts. As can be seen from Figure 5, all the three aggregate size categories considered more activities which have been implemented over time. Furthermore, in both periods analysed, the quantity of operational activities rises with the size of the company. In 2016, the median of the medium-sized firms is approaching that of large firms. Some large firms implemented all 16 activities for the first time in 2016. The influence of size is particularly visible when examining the small firms. Small firms turn out to implement a distinctively smaller amount of activities. This is likely the case because, typically, they have less resources and thus activity pursuance is more challenging. However, even for the small firms, the maximum number of activities implemented increased from 7 to 15, in doing so catching up remarkably with the maximum number of activities of the medium-sized firms in 2016 versus 2001 and again underscoring the considerably increased relevance of sustainable operations in every size category in 2016.

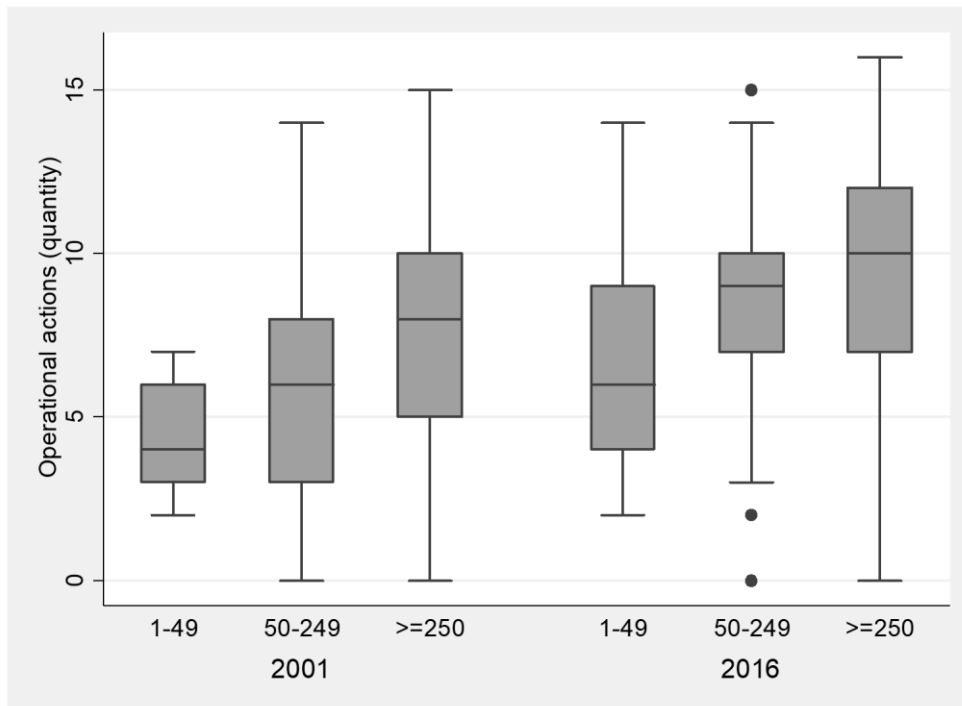


Figure 5: Boxplot of operational activities by aggregate size category in Germany

As can be seen from Figure 5 these size-specific results are essentially determined by the adoption of individual activities: In most cases, larger companies are more likely to implement operational activities. Nevertheless, there are exceptions, especially that small enterprises have the biggest share in product recycling and in reducing the packaging per unit of product and have generally caught up very strongly over the years. Overall, medium-sized companies have as well caught up with large enterprises over the past 15 years, as signified by the gap for many activities getting smaller. However, as concerns the implementation of cleaner production technologies and “Green” new product designs as crucial activities for environmental innovation large firms have kept their lead from 2001 to 2016. Thus, whilst encouragingly overall aggregate size categories interest in environmental innovation has considerably increased between 2001 and 2016, large companies keep their leading edge. As concerns the newly introduced items on ecosystem services, small and large enterprises interestingly engage more often in the restoration or conservation of biodiversity than medium-sized ones. Opposed to this, emissions offsetting as a comparatively new tool, is to date much more often implemented by larger companies.

Table 6: Adoption of operational activities by aggregate size category in Germany

	small enterprises			medium enterprises			large enterprises		
	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ
Reduce water consumption	40%	37%	-3%	42%	62%	20%	59%	78%	19%
Reduce material per unit	40%	50%	10%	43%	70%	27%	48%	75%	27%
Material recycling	40%	41%	1%	34%	44%	10%	54%	53%	-1%
Use of foreign waste streams	20%	14%	-6%	8%	12%	4%	7%	15%	8%
Substitution of non-renewable materials	0%	23%	23%	10%	40%	30%	20%	40%	20%
Substitution hazardous input	20%	41%	21%	29%	76%	47%	59%	83%	24%
Reduce air emission	0%	36%	36%	40%	56%	15%	66%	76%	10%
Reduce water emission	40%	18%	-22%	17%	27%	10%	38%	40%	2%
Reduce noise emission	20%	36%	16%	40%	62%	22%	50%	59%	9%
Reduce waste	20%	82%	62%	51%	75%	24%	74%	77%	3%
Product recycling	20%	59%	39%	26%	48%	21%	47%	47%	0%
Packaging recycling	60%	68%	8%	61%	65%	4%	66%	59%	-7%
Reduce packaging per product unit	40%	50%	10%	40%	33%	-7%	48%	42%	-6%
Reduce transport energy	40%	41%	1%	25%	43%	18%	35%	61%	26%
Cleaner technology	0%	46%	46%	38%	54%	16%	55%	73%	18%
“Green” new product design	40%	41%	1%	32%	46%	14%	48%	60%	12%
Biodiversity restoration		32%			21%			34%	
Biodiversity conservation		36%			24%			41%	
Emissions offsetting		14%			19%			36%	

Differences bigger 25% in bold

To consider industry-specific differences in operational environmental activities, we compare the seven aggregated industry categories defined above. In all of them, the number of implemented operational activities in 2016 is higher than 15 years ago. The “Chemical industry” and the engineering and vehicle-constructing sector are leading in both periods. They only swapped their position over time. Except for the “Other manufacturing industries”, all remaining aggregate industries share the same median of 6 operational activities in 2001. In 2016, they still share a median, but now it is at 9 activities in which firms are engaged. Together with the second quartile now being at no less than 5 activities, the progress to a higher operational level is unambiguously visible across all industries.

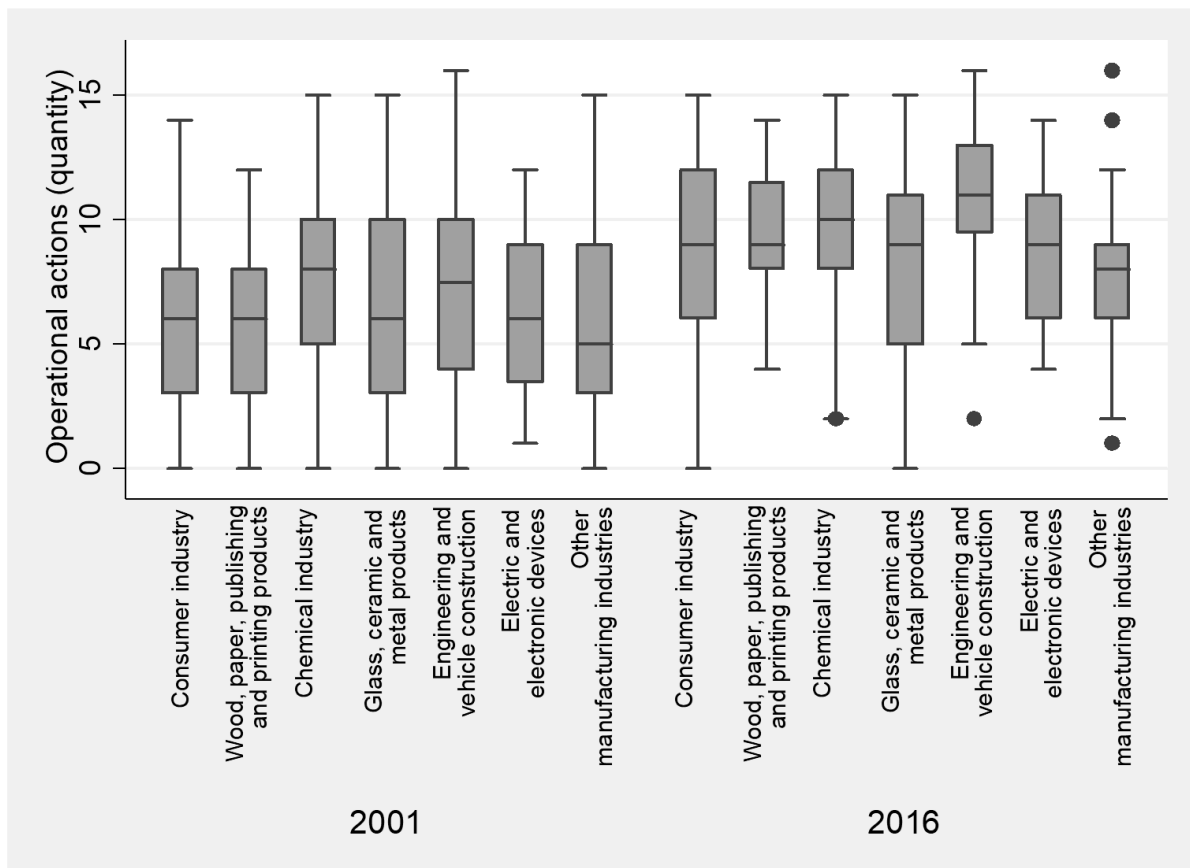


Figure 6: Boxplots of operational activities by aggregate industry category in Germany

To reveal differences between the aggregate industries, their specific adoption level for every activity is shown in Table 7. “Engineering and vehicle construction” has most often the highest level of adoption, especially as concerns the reduction of various emissions. However, every aggregate industry is leading in terms of adoption for at least one activity, this confirms that environmental exposure is industry-specific. The “Consumer industry”, for example, is most concerned about recycling issues. The reduction of transport energy is an activity of increasing importance across all aggregate industries. Other activities, like packaging-related ones, show less consistent patterns. While gaining larger shares in the “Wood, paper, publishing and printing products” industry, they lose shares in many other aggregate industries. Overall, companies in the “Wood, paper, publishing and printing products” industry, followed by firms in the “Consumer industry”, have made the biggest progress over the last 15 years resulting in average adoption rates of 53.9% and 51.7%, respectively, across all activities. Firms in the “Engineering and vehicle construction” industry (60.5%) and the “Chemical industry” (56.0%) have even higher values and thus the best environmental performance in 2016. In contrast in the “Glass, ceramic and metal products” industry, the average adoption rate per activity is 46.8% and is thus the lowest one across all aggregated sectors.

Table 7: Adoption of operational activities by aggregate industry category in Germany

	Consumer industry			Wood/ Paper/ Publishing/ Printing			Chemical industry		
	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ
Reduce water consumption (1)	52%	74%	22%	51%	60%	9%	55%	76%	21%
Reduce material per unit (2)	40%	63%	23%	43%	90%	47%	62%	76%	14%
Material recycling (3)	33%	44%	11%	40%	60%	20%	48%	65%	17%
Use of foreign waste streams (4)	0%	7%	7%	8%	20%	11%	10%	14%	4%
Substitution non-renewable materials (5)	8%	52%	44%	17%	50%	33%	21%	46%	25%
Substitution hazardous input (6)	35%	63%	28%	49%	80%	31%	56%	70%	16%
Reduce air emission (7)	44%	70%	26%	40%	65%	25%	62%	62%	0%
Reduce water emission (8)	27%	26%	-1%	17%	30%	13%	45%	35%	-10%
Reduce noise emission (9)	41%	52%	11%	49%	65%	16%	43%	65%	22%
Reduce waste (10)	56%	59%	0%	43%	90%	47%	83%	92%	9%
Product recycling (11)	25%	63%	38%	46%	45%	-1%	36%	60%	24%
Packaging recycling (12)	59%	74%	15%	46%	65%	19%	64%	65%	1%
Reduce packaging per unit (13)	49%	44%	-5%	26%	55%	29%	50%	51%	1%
Reduce transport energy (14)	46%	63%	17%	17%	35%	18%	26%	60%	34%
Cleaner technology (15)	40%	70%	16%	43%	70%	27%	55%	76%	22%
“Green” new product design (16)	32%	56%	24%	31%	55%	39%	50%	65%	15%
Biodiversity restoration (17)		37%			20%			27%	
Biodiversity conservation (18)		37%			30%			38%	
Emissions offsetting (19)		26%			40%			24%	

	Glass/Ceramic/Metal products			Engineering/Vehicle construction			Electric/Electronic devices			Other manufacturers		
	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ
(1)	59%	63%	4%	50%	88%	38%	39%	52%	13%	40%	70%	30%
(2)	43%	77%	34%	54%	80%	25%	53%	70%	17%	38%	61%	24%
(3)	43%	40%	-3%	52%	54%	2%	44%	57%	13%	45%	41%	-4%
(4)	18%	20%	2%	12%	17%	5%	3%	0%	-3%	9%	16%	6%
(5)	14%	20%	6%	17%	25%	8%	8%	48%	40%	23%	36%	13%
(6)	30%	87%	57%	56%	92%	36%	50%	78%	28%	43%	77%	34%
(7)	66%	73%	7%	39%	83%	45%	44%	57%	12%	57%	63%	6%
(8)	31%	30%	-1%	25%	54%	29%	14%	26%	12%	32%	36%	4%
(9)	51%	70%	19%	54%	71%	17%	14%	39%	25%	49%	48%	-0%
(10)	59	60%	1%	64%	92%	28%	66%	91%	25%	57%	69%	12%
(11)	36%	43%	7%	52%	58%	6%	44%	61%	17%	25%	33%	8%
(12)	69%	57%	-12%	77%	71%	-6%	75%	70%	-5%	51%	49%	-2%
(13)	38%	30%	-8%	56%	50%	-6%	55%	44%	-11%	32%	30%	-2%
(14)	21%	50%	29%	32%	63%	31%	17%	48%	31%	34%	54%	20%
(15)	54%	63%	-1%	48%	80%	32%	33%	78%	45%	43%	50%	-7%
(16)	33%	53%	31%	60%	75%	15%	61%	65%	4%	23%	37%	14%
(17)		13%			29%			26%			40%	
(18)		10%			41%			26%			49%	
(19)		30%			29%			22%			33%	

Differences greater than 25% in bold

Managerial environmental activities

The following section analyses in more depth the managerial activities in terms of size and industry differences. As Figure 7 shows, the number of managerial activities implemented increased in all three size categories over the 15-year period from 2001 to 2016. Especially the mid-sized companies increased their median from 4 to 15 activities. While the number of implemented activities differed strongly between the company sizes in 2001, the median now is almost equal across all three size

categories and the differences manifest mostly in the quartile values. Still, large companies implement more activities and only outliers in this size category implement less than 11 of the managerial activities as Figure 7 shows. This also implies that competitive differentiation based on managerial activities becomes increasingly difficult for large firms.

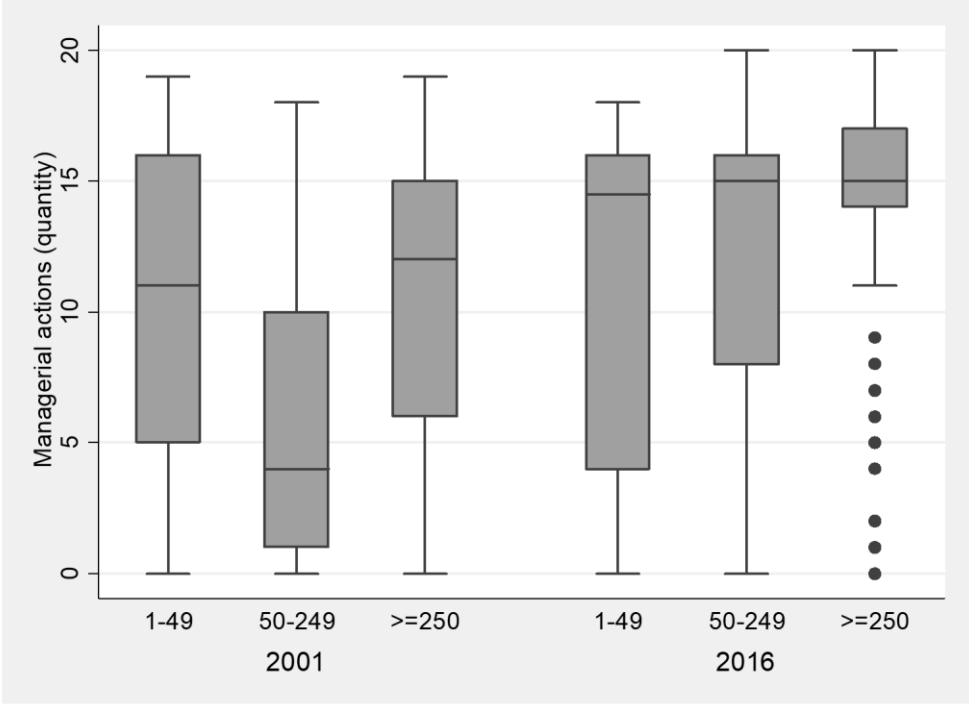


Figure 7: Boxplot of managerial activities by aggregate size category in German

This development can also be seen in Table 8. The adoption share of almost every activity increased for medium-sized and large enterprises. Environmental performance indicators, reviews of the EMS efficiency or an audit of the environmental program have been activities which are rarely adopted in manufacturing companies with 50-249 employees in 2001 (23% to 25% adoption rates). Over time, these activities have become more common in this size category as evidenced by higher adoption shares in 2016 (71% to 78% adoption rates). Measurable environmental goals and a separate report for environmental, health and safety topics evolved similarly. In large firms, eight activities are essentially standards in practice with about 9 out of 10 firms implementing them, partly because they are mandatory elements required for EMS certification. Eco-label usage increased massively in companies with more than 50 up to 250 employees where it now has an adoption share of 59%, which is the highest across all three size categories. As in 2001, the adoption share of medium-sized companies for this activity is a little higher than the one of large companies (46% versus 43%). One explanation for this may be that eco-labelled products are often more regional products and therefore more produced by smaller companies. It is possibly also harder for large companies to establish the environmental quality level required for an eco-label uniformly over a much larger volume of inputs, as it is the case in food production and paper manufacturing.

Table 8: Adoption of managerial activities by aggregate size category in Germany

	small enterprises			medium enterprises			large enterprises		
	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ
Supplier selection by environm. performance	60%	55%	-5%	42%	62%	20%	59%	70%	11%
Demand suppliers to take environm. actions	40%	32%	-8%	31%	54%	23%	58%	72%	15%
Written environm. policy	60%	68%	8%	36%	78%	42%	70%	92%	22%
Procedure to handle legal requirements	80%	64%	-16%	39%	78%	39%	74%	93%	19%
Initial environm. review	40%	68%	28%	43%	64%	21%	73%	73%	0%
Measurable environm. goals	80%	73%	-7%	33%	79%	46%	70%	90%	20%
Programs for environm. goals	60%	68%	8%	31%	75%	44%	63%	90%	27%
Clear responsibilities	80%	77%	-3%	63%	91%	28%	87%	93%	6%
Environm. staff trainings	40%	73%	33%	35%	62%	27%	73%	77%	4%
Improvement process for environm. goals	60%	77%	17%	41%	78%	37%	68%	90%	22%
Environm. data in annual report	60%	50%	-10%	24%	64%	40%	52%	70%	18%
Separate environm./HSE report	60%	68%	8%	28%	73%	45%	56%	80%	24%
Environm. program audit	60%	68%	8%	25%	78%	53%	60%	88%	28%
Review EMS efficiency	60%	64%	4%	24%	76%	53%	56%	82%	26%
Environm. performance indicators	60%	73%	13%	24%	71%	47%	51%	89%	38%
Benchmarking with other companies	20%	9%	-11%	11%	24%	13%	19%	30%	11%
Eco-labelling	0%	59%	59%	17%	46%	29%	16%	43%	27%
Consumer information about environm. effects	40%	59%	19%	25%	41%	16%	39%	51%	12%
Market research 'Green' products	20%	9%	-11%	11%	16%	5%	18%	28%	10%
Product Life Cycle Assessment	40%	23%	-17%	8%	27%	19%	26%	46%	20%

Differences greater 25 % in bold
 environm. = environmental
 HSE = Health and Safety Executive

Finally, as Figure 8 shows that the differences across aggregate industry categories decreased in a way that the median of almost every industry is the same and at a level of 15 implemented managerial activities in 2016. The “Wood, paper, publishing and printing product” industry’s median is with a median value of 16 even a bit higher. 15 years ago, the average value for this sector was 4 and thus the lowest across all aggregate industries, which witnesses a remarkable improvement. The “Electric and electronic devices” industry and the “Consumer industry” have a larger quartile spread than the other five aggregate industries, which suggests that in the former the variability with regard to environmental management is considerably bigger. This suggests that some firms in these two industry categories still lag more behind, in particular since 15 years ago, they already had the second and third lowest median across all seven aggregate industries. Still, for the manufacturing sector in Germany overall, we see a remarkable shift towards increased adoption of managerial activities supporting environmental protection. However, it is somewhat less evident that this has resulted in a complementary increase in the adoption of operational and technological activities to protect the environment. Neither can we ascertain from our survey, that this increase in activities has also improved actual environmental performance in terms of lower emissions and resource

consumption. This is particularly difficult to establish since in the last two decades globalisation processes have continued to fragmentize value chains by means of outsourcing and offshoring. This makes a reliable assessment of actual environmental performance very difficult since this would require to account for a shift of polluting activities which increasingly move outside of the direct firm boundaries, which is highly challenging due to constraints in data availability.

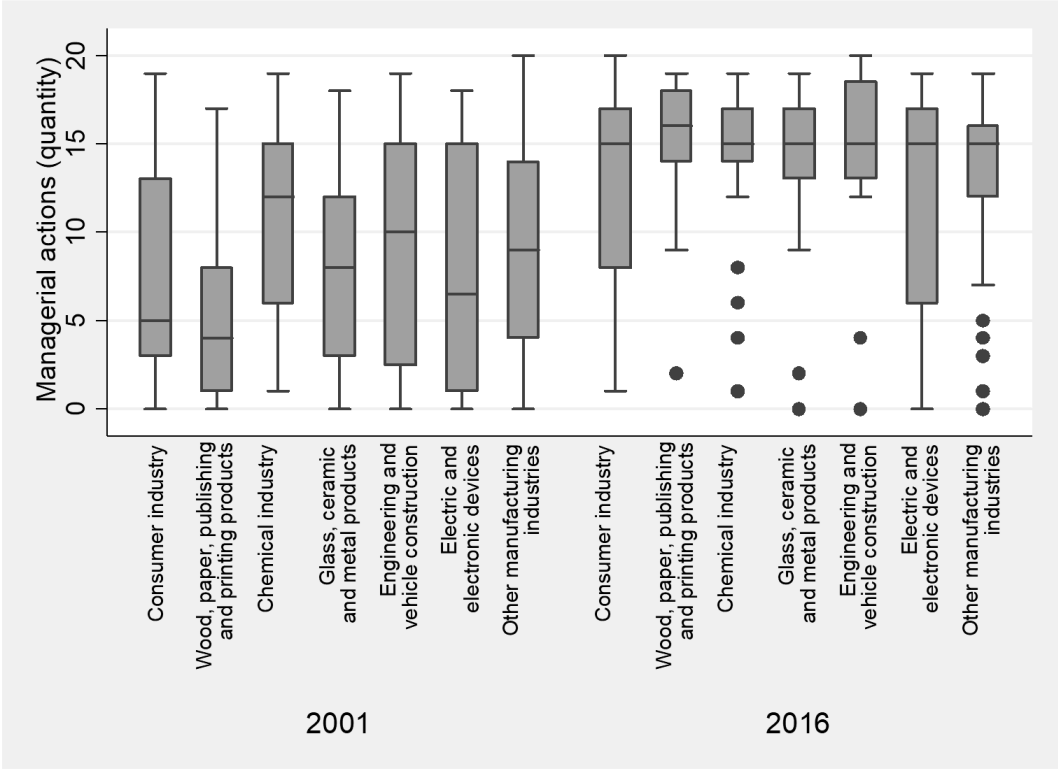


Figure 8: Boxplots of managerial activities by aggregate industry category in Germany

Table 9 shows the adoption shares by aggregate industry for individual managerial activities in detail, which supports the results derived from the Box-Whisker plots in Figure 7. All activities have (often significantly) increased adoption shares in all industries. However, there are still industry-specific differences. The companies in the “Wood, paper, publishing and printing products” industry raised their shares the most, which corresponds to the earlier observation in this respect. More specifically, for 15 out of the 20 activities surveyed, the firms increased their adoption share by more than 25%. “Chemical industry” companies and firms in the “Glass, ceramic and metal products” industry have most often the largest adoption share. Manufacturers of “Electric and electronic devices” show the least improvement. In half of the activities surveyed, they have a lower adoption share than in any of the other aggregate industries. The definition and introduction of measurable environmental goals, as well as the publication of environmental reports, are examples of activities in which the industry lags behind. Some activities are still not broadly implemented by manufacturing firms in Germany, as for example conducting market research for “Green” products, is an activity with relatively low adoption rates across all industries. In only three aggregate industries, more than a quarter of the

participants stated that they pursue this type of research. As stated before, the overall trend is that companies adopt more environmentally-related managerial activities and have used the past 15 years for the implementation of a growing number of different activities. There are still industry-specific differences though, and in future, the focus needs to be on implementing more of those activities that only received minimum attention so far, because these are sometimes also qualitative game-changers in terms of contributors to sustainable development as well as in terms of enabling competitive differentiation. Furthermore, it has to be assured that the actual environmental performance is raised as clearly as the number of activities is.

Table 9: Adoption of managerial activities by aggregate industry category in Germany

	Consumer industry			Wood/Paper/ Publishing/ Printing			Chemical industry		
	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ
Supplier selection by environm. performance (1)	52%	63%	11%	52%	65%	13%	57%	65%	8%
Demand suppliers to take environm. actions (2)	48%	59%	11%	46%	70%	24%	50%	68%	18%
Written environm. policy (3)	44%	78%	34%	29%	85%	56%	74%	95%	21%
Procedure to handle legal requirements (4)	50%	89%	39%	28%	90%	62%	81%	83%	3%
Initial environm. review (5)	46%	70%	25%	47%	60%	13%	76%	65%	-11%
Measurable environm. goals (6)	45%	82%	36%	32%	90%	58%	62%	92%	30%
Programs for environm. goals (7)	40%	78%	38%	29%	90%	61%	62%	81%	19%
Clear responsibilities (8)	71%	82%	11%	65%	95%	30%	86%	92%	6%
Environm. staff trainings (9)	40%	70%	30%	32%	75%	43%	69%	81%	12%
Improvement process for environm. goals (10)	56%	74%	18%	43%	90%	47%	65%	95%	30%
Environm. data in annual report (11)	30%	56%	26%	26%	55%	29%	58%	78%	20%
Separate environm./ HSE report (12)	38%	70%	32%	32%	80%	48%	57%	87%	30%
Environm. program audit (13)	36%	74%	38%	23%	90%	67%	61%	89%	28%
Review EMS efficiency (14)	37%	63%	26%	16%	85%	69%	57%	81%	24%
Environm. performance indicators (15)	38%	86%	47%	23%	85%	62%	56%	89%	33%
Benchmarking with other companies (16)	15%	22%	7.0%	21%	45%	24%	22%	27%	5%
Eco-labelling (17)	32%	67%	35%	17%	80%	63%	17%	38%	21%
Consumer inform. about environm. effects (18)	37%	56%	19%	26%	55%	29%	46%	46%	0%
Market research 'Green' products (19)	23%	33%	10%	13%	40%	27%	22%	24%	2%
Product Life Cycle Assessment (20)	10%	22%	12%	22%	40%	18%	31%	60%	29%

	Glass/Ceramic/Metal products			Engineering/Vehicle construction			Electric/Electronic devices			Other manufacturers		
	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ	2001	2016	Δ
(1)	50%	63%	13%	55%	79%	24%	60%	78%	18%	40%	63%	23%
(2)	39%	80%	41%	53%	75%	22%	46%	61%	15%	39%	51%	13%
(3)	54%	90%	36%	58%	88%	30%	53%	70%	17%	65%	87%	22%
(4)	61%	90%	29%	58%	92%	34%	63%	83%	20%	67%	83%	16%
(5)	66%	70%	4%	64%	58%	-6%	50%	70%	20%	65%	80%	15%
(6)	57%	87%	30%	62%	88%	26%	50%	70%	20%	54%	87%	33%
(7)	51%	87%	36%	60%	88%	28%	44%	70%	25%	46%	89%	42%
(8)	72%	90%	18%	82%	92%	10%	72%	87%	15%	81%	94%	13%
(9)	46%	63%	17%	70%	79%	9%	58%	65%	7%	67%	73%	6%
(10)	59%	90%	31%	71%	88%	16%	58%	65%	7%	58%	87%	29%
(11)	34%	70%	36%	51%	63%	12%	33%	52%	19%	52%	70%	18%
(12)	33%	87%	54%	46%	67%	21%	46%	52%	7%	52%	80%	28%
(13)	41%	90%	49%	50%	88%	38%	44%	61%	16%	53%	84%	31%
(14)	36%	90%	54%	46%	88%	42%	46%	61%	15%	47%	80%	33%
(15)	33%	90%	57%	48%	88%	40%	34%	61%	27%	40%	80%	40%
(16)	16%	20%	4%	16%	50%	34%	3%	22%	19%	19%	20%	1%
(17)	12%	30%	18%	10%	33%	23%	9%	30%	21%	16%	47%	32%
(18)	34%	40%	6%	29%	42%	13%	26%	52%	26%	37%	53%	16%
(19)	10%	20%	10%	8%	33%	25%	12%	22%	10%	17%	11%	-6%
(20)	21%	27%	6%	21%	50%	29%	11%	48%	36%	16%	31%	16%

Differences greater 25% in bold
 environm. = environmental
 HSE = Health and Safety Executive

Summary and Discussion

In our analysis, we found an overall increase of environmental activities and of EMS implementation levels in both countries, Germany and the UK. Our 15-year comparison shows an increasing effort of manufacturing firms regarding environmental concerns. Nevertheless, some environmental activities are actually less widely diffused than they were 2001. Managerial activities and EMSs are more popular in Germany, while operational activities have to be analysed individually to observe in which region they are implemented more often. Although EMS implementation increased over time, its positive impact on the probability of operational activities decreased while the impact on managerial ones remained unchanged. In terms of the distinguishing sub-classes of different manufacturing industries, the differences in implementing managerial ecological activities disappeared mostly within the last 15 years. Nevertheless, operational activities are still predominantly performed by engineering and vehicle constructing firms.

Moreover, we find that ecological sustainability increases with company size, most likely because of higher availability of resources. In addition to this, the differences between the different firm sizes regarding managerial activities have decreased over time. The influence of both size and industry is low for those activities. It is noticeable that the presence of an EMS influences the environmental performance in Germany more than in the UK. Regarding social activities, the picture is different: Social activities are very widespread across firms. Especially in Germany, some social activities have become standards. However, in both countries there is still potential to improve the companies' social performance. When it comes to topics which are more distant to the core business adoption rates decrease, likely because of missing incentives.

Contrary to Schaltegger et al. (2013), overall we found higher adoption rates in Germany than in the UK. Schaltegger and colleagues stated the corporate sustainability performance of UK firms to be above whilst that of German firms was rated to be below the international average. The difference in our findings can possibly be explained by our broader sample, which contains firms of all size categories. Given the comparable firm structure, our results are similar to those of Wagner and Schrauth (2014) who cover data for only 10 years, thus suggesting that our findings indeed represent long-term trends. Nevertheless, our dataset covers 5 more years and thus our analysis certainly captures the status quo better and provides a more comprehensive and current overview of the development as well as status quo of corporate sustainability and environmental innovation in German manufacturing firms.

Our findings can serve as impulse for future research in terms of calling for further examination of a number of phenomena. To start with, the lack of interest in environmental benchmarking with other companies could imply that the environmental activities are not implemented to differentiate from competitors. This could support the argument that fulfilling regulations or consumer expectations could be the main motivation for environmental activities. Moreover, country-specific differences can at least partly be attributed to national regulations and practices. For example the British firms' focus on recycling or their effort for the childcare of employees can at least partly be attributed to waste regulations or the existence of a governmental childcare system. Although European legislation is the same for Germany and the UK as EU member states, the precise implementation is often left to the individual member state. Hence, it is national legislation as well as a path dependent and country specific corporate culture that can cause the differences.

Our findings, therefore, provide useful insights to practitioners as well as for researchers and politicians. Knowing the sustainability behaviour in a specific industry helps practitioners to determine own strengths and weaknesses to remain competitive. Policymakers interested in a better understanding of the variation between individual firms with regard to environmentally related and socially beneficial innovation activities can use our findings to substantiate and ameliorate policy initiatives. Specifically, they may use the detailed information about firms' behaviour to set incentives in favour of those activities being less adopted but relevant for achieving sustainable development. Especially our analysis equips them with detailed information regarding the specific conditions for a different size or industry categories.

Finally, our findings also have implications for researchers. Analyses on corporate sustainability and environmental innovation should be interpreted with reference the time when as well as to the spatial scope of the data gathered. Moreover, our findings suggest that generalising results from an

analysis being based on one industrialized country to other industrialized countries is not always possible and thus such transfers need to be considered with heightened care.

References

- Almeida, P., & Kogut, B. (1997). The exploration of technological diversity and geographic localization in innovation: Start-up firms in the semiconductor industry. *Small Business Economics*, 9(1), 21-31.
- Bradford, D. (2000). Motivating SMEs Towards Improved Environmental Performance. IPTS Report, 41, 25-29.
- Hertin, J., Berkhout, F., Wagner, M., & Tyteca, D. (2008). Are EMS environmentally effective? The link between environmental management systems and environmental performance in European companies. *Journal of Environmental Planning and Management*, 51(2), 255-280.
- Horbach, J. (2008). Determinants of Environmental Innovation – New Evidence from German Panel Data Sources. *Research Policy*, 37, 163-173.
- Horbach, J., Rammer, C., Rennings, K. (2012). Determinants of Eco-innovations by Type of Environmental Impact – The Role of Regulatory Push/Pull, Technology Push and Market Pull. *Ecological Economics*, 78, 112-122.
- Tyteca, D., Carlens, J., Berkhout, F., Hertin, J., Wehrmeyer, W., & Wagner, M. (2002). Corporate Environmental Performance Evaluation: Evidence from the MEPI Project. *Business Strategy and the Environment*, 11, 1-13.
- Rennings, K. (2000). Redefining innovation—eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32(2), 319-332.
- Schaltegger S., Harms D., Hörisch J., Windolph S.E., Burritt R., Carter A., Truran S., Crutzen N., Ben Rhouma A., Csutora M., Tabi A., Kokubu K., Kitada H., Haider M.B., Kim J-D., Lee K-H., Moneva J.M., Ortas E., Álvarez-Etxeberria I., Daub C.-H., Schmidt J., Herzig C., & Morelli J. (2013). International Corporate Sustainability Barometer: A Comparative Study of 11 Countries. Centre for Sustainability Management, Lüneburg.
- Wagner, M. (2007). On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms. *Research Policy*, 36(10), 1587-1602.
- Wagner, M. (2008). Empirical influence of environmental management on innovation: evidence from Europe. *Ecological Economics*, 66(2-3), 392-402.
- Wagner, M., & Schaltegger, S. (2003). How does sustainability performance relate to business competitiveness?. *Greener Management International*, 5-16.

Wagner M. & Schrauth, F. (2014). Umwelt- und Nachhaltigkeitsmanagement in deutschen Unternehmen: ein Zehnjahresvergleich unter besonderer Berücksichtigung von kleinen und mittelständischen Unternehmen und Branchenunterschieden. Lehrstuhl für Betriebswirtschaftslehre, Innovation und Internationales Management, Augsburg.

Statistisches Bundesamt (2016). Beschäftigung und Umsatz der Betriebe des Verarbeitenden Gewerbes,
<https://www.destatis.de/DE/Publikationen/Thematisch/IndustrieVerarbeitendesGewerbe/ThemaIndustrie.html> [29 January 2018].

World Commission on Environment and Development (1987). Our Common Future. Oxford University Press: Oxford.