Measuring industrial sustainability performance: Empirical evidence from Italian and German manufacturing Small & Medium Enterprises

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Abstract

Measuring industrial sustainability performance in manufacturing firms is still a major challenge for both policy and industrial decision makers, with many firms, particularly small and medium enterprises, struggling to properly engage with them. Hence, to understand the level of adoption of industrial sustainability indicators and the issues preventing their effective measurement, and stimulate further research in this area, a multiple case analysis of 26 small and medium manufacturing enterprises across Germany and Italy operating in the chemical and metalworking sectors was conducted. The findings show that only 18 indicators are in place on average. Furthermore, too many firms still focus almost exclusively on the economic pillar of sustainability, while social and environmental pillars are addressed almost exclusively for compliance with legislation. Moreover, the research suggests that contextual factors may influence the firms' perspective on sustainability and the way it is managed, as well as the certifications held by firms, influencing, in turn, the number and types of indicators considered. An exploratory investigation allowed identification of several important open issues, leading to future research avenues, and in particular towards the development of a novel model to gauge sustainability in industrial activities,

as well as adoption of policy-making measures for further emphasis on environmental and social pillars when promoting the adoption of sustainability indicators.

Keywords

Sustainability performance measurement, sustainability performance indicators, industrial sustainability, small and medium enterprises, manufacturing

1 Introduction

Measuring sustainability performance is very important for industrial firms for several reasons, also considering the overall impact of sustainability agendas, in both economic terms and for future policy (European Union, 2017a).

Firms receive strong pressures towards increased sustainability and transparency about the results achieved (Lozano and Huisingh, 2011; Stacchezzini et al., 2016) by external stakeholders (Staniškis and Arbačiauskas, 2009), to whom firms communicate their sustainability practices and performance (Székely and Vom Brockem, 2017). By improving the relationship with external stakeholders (Fuente et al., 2017), companies aim to enhance and protect their reputation (De Villiers et al., 2016). External communication plays a relevant role in influencing the indicators measured by a firm (Nordheim and Barrasso, 2007), leading to a focus on external rather than internal reporting (De Villiers et al., 2016). However, sustainability and its measurement should be included in industrial firms at a plant level (Neri et al., 2018) to effectively understand where specific actions should be taken (Collins et al., 2016; Singh et al., 2012). Measuring performance, indeed, helps raise awareness, guide decisions and evaluate the achievements of established goals (Paju et al., 2010): therefore, performance measurement should be tailored on the firm's needs (Clarke-sather et al., 2011; Singh et al., 2016). Focusing on performance, benchmarking activities are crucial, by conducting a closer and continuous comparison with peers and competitors (Ferrari et al., 2019), also with respect to its specific sustainability three pillars – economic, environmental, and social - known as the triple bottom line (TBL), as recent research shows (Ghadimi et al., 2012). Despite the traditional view of benchmarking as a "*systemic learning process based on the continuous comparison*" among "*operators in the same or related sectors*" (Ferrari et al., 2019), the importance of other contextual factors such as the geographical area (Apaydin et al., 2018; Tanzil and Beloff, 2006) and firm size (Siebert et al., 2018) is increasingly emerging. Nevertheless, to compare different firms, research suggests that the selected indicators should be standardized (Ferrari et al., 2019) and be adaptable to different contexts (Paju et al., 2010).

While the need for effective measurement of sustainability in plant performance has been underlined for some time (Globerson, 1985), the EU manufacturing sector is lagging in several aspects (Johnson and Schaltegger, 2016) since, despite the claimed evolution of the manufacturing system towards sustainability, e.g. standardized methods for assessing sustainability performance, are still missing (Harik et al., 2015; Helleno et al., 2017).

Research shows that a proper selection of sustainability performance indicators can lead to improved firm management (Staniškis and Arbačiauskas, 2009). Literature abounds with methods for performance evaluation, but firms often present difficulties in selecting relevant indicators for their specific goals (Lee and Lee, 2014), since the available methods are deemed to be too generic for application in specific contexts (Hallstedt et al., 2015), without sufficient guidance for the selection of performance indicators (Salvado et al., 2015). Research in this area is scarce, with the development of sustainability performance indicators for industrial firms based mainly on literature reviews (Helleno et al., 2017; Huang and Badurdeen, 2018) and theoretical frameworks (Fang et al., 2016), and not sufficiently grounded on a firms' perspective and needs (Delai and Takahashi, 2011; Salvado et al., 2015). Hence, firms may either adopt the developed methods or develop their own. In the first case, even if benchmarking is allowed, such methods have been recognized to be excessively time consuming and not properly applicable in specific contexts (Hallstedt et al., 2015). In the second case, even when starting from an available generic model (Staniškis and

Arbačiauskas, 2009), further specification may be too resource intensive and might jeopardize benchmarking activities.

Sustainability measurement is a relevant problem particularly for industrial small and medium enterprises (SMEs) (Arena and Azzone, 2012). They are crucial for sustainability objectives in the manufacturing sector (Singh et al., 2016), but often unaware of their relevance (Feil et al., 2017). In addition, SMEs often lack their own sustainability performance measurement systems (Arena and Azzone, 2012), or sufficient resources to properly and effectively measure performance (Tremblay and Badri, 2018). In particular, research has suggested that the large amount of information often required for performance assessment may be unsustainable for SMEs (Laurinkevičiute and Stasiškiene, 2011; Winroth et al., 2016), given their characteristics (Singh et al., 2016).

Previous empirical contributions have selected and prioritized indicators basing on the perspective of external stakeholders (Basu and Kumar, 2004; Naderi et al., 2017) and researchers (Feil et al., 2015). However, by specifically selecting performance indicators according to the needs of the single firm, the effectiveness of the measurement can be increased, as preliminary research on the European aluminium sector has shown (Nordheim and Barrasso, 2007).

So far, the empirical discussion over the adoption of sustainability indicators in manufacturing firms has been quite scarce, being limited to offering firms the adoption of previously developed models. The application of such models is also scarce, with too few empirical contributions either at the sectorial level – e.g., cement (Amrina et al., 2016), automotive (Salvado et al., 2015), steel (Singh et al., 2007) - or with evaluation in a specific country – e.g., China (Long et al., 2016), Taiwan (Hsu et al., 2017), Sweden (Winroth et al., 2016). As a research gap, there is thus a lack of empirical evidence on how manufacturing SMEs measure sustainability performance, how indicators are selected according to their specific needs, and whether the developed sustainability performance measurement systems are actually suitable to them.

To offer a contribution to the research discussion in this area, an explorative multiple case study was conducted by focusing on German and Italian manufacturing SMEs operating in the chemical and the metalworking sector, given the relevance of these two sectors and countries for the European economy (Eurostat, 2013), with the aim of understanding possible issues that prevent effective measurement through the adoption of previously developed methods for assessment of performance, and the characteristics these methods should have to be both helpful and appropriate for firms. To the authors' knowledge, this study represents one of the first empirical contributions exploring the adoption of sustainability indicators among SMEs – with an extensive focus on its three pillars – and also gathers empirical evidence of the limits of the available systems, simultaneously analysing two sectors and two countries in major European economies, and considering the differences that emerge from the analysis of micro- and small firms compared to medium-size firms, as suggested, for example by Micheli and Cagno (2010) and Trianni and Cagno (2012).

The remainder of the paper is structured as follows: Section 2 discusses the Materials and Methods used for the study; Sections 3 and 4, respectively, present and discuss the results. Concluding remarks and further research avenues are offered in Section 5.

2 Materials and Methods

2.1 Selection of performance indicators to be used in the exploratory investigation

The investigation was conducted having as a guideline a previously developed method for the evaluation of sustainability indicators in an industrial context. The purpose of adopting a guideline is twofold: on the one hand, to have a common reference for the categorization of the indicators collected; on the other, to spotlight possible issues that are not previously addressed by the literature.

A literature review was carried out to select indicators for the model of performance. For this crucial purpose, four criteria were deemed necessary – by using previous works as a guide (Chen et al., 2013; Searcy et al., 2005): first, the model should simultaneously address the TBL (Carter and

Rogers, 2008; Elkington, 1997); second, it should be as complete as possible, acknowledging previous literature; third, it should be suitable for industrial firms at a plant level, not focusing exclusively on production issues or addressing sustainability only at the corporate level, as recent research shows (Trianni et al., 2017); fourth, it should be sufficiently general to allow application in different contexts and benchmarking among firms characterized by different contextual factors such as sector, country, and size (Azapagic and Perdan, 2000; Christofi et al., 2012; Ghadimi et al., 2012).

The selection of the model relied on Ahmad and Wong, (2018), Chang and Cheng (2019), Du Plessis and Bam (2018), Hsu et al. (2017) and Sangwan et al. (2018), who recently provided an in-depth overview of the literature on sustainability indicators for industrial firms. Based on these, 95 contributions were retrieved and analysed, of which 51 were deemed relevant. The screening procedure led to the exclusion of contributions not providing indicators, rather than assessment methodology (Ness et al., 2007; Rödger et al., 2016) or a review of previous developments (Singh et al., 2012; Tanzil and Beloff, 2006). Contributions focusing on LCA were not examined (Egilmez et al., 2014; Kim et al., 2013), since LCA does not consider a long term perspective (Hallstedt et al., 2015) and in general mostly focused on the environment pillar (Del Borghi et al., 2014; Djekic et al., 2014). Given their applicability limits, other initiatives, such as the Global Reporting Initiatives, Sustainability Metrics of the Institution of Chemical Engineers, Dow Jones Sustainability Index, and Indicators of Sustainable Development of the Commission on Sustainable Development were excluded (Delai and Takahashi, 2011; Labuschagne et al., 2005).

Information		*Level on analysis and focus on specific contexts*				*Classification of indicators and number of indicators*				
Authors and years	**Source**	**Level**	**Sector**	**Country**	**Size**	**Eco**	**Env**	**Soc**	**Other classification**	**Number**
Afgan et al. (2000)	Energy Policy	System	Energy system	-	-	-	Y	Y	Resource efficiency	14
Veleva and Ellenbecker (2001)	Journal of Cleaner Production		Production	-	-	-	-	-	Sustainable Production aspects	22
Graedel and Allenby (2002)	Environmental Quality Management	Corporate	-	-	-	-	Y	-		10
Krajnc and Glavič (2003)	Clean Technologies and Environmental Policy	Firm	-	-	-	Y	Y	Y		83
Azapagic (2004)	Journal of Cleaner Production		Mining and Mineral	-	-	Y	Y	Y		129
Basu and Kumar (2004)	International Journal of Surface Mining	Corporate Global	Mining and Mineral	-	-	Y	Y	Y		N.A.
Labuschagne et al. (2005)	Journal of Cleaner Production	Firm	Manufacturing	South Africa	-	**Y**	Y	Y		N.A.
Searcy et al. (2005)	Measuring Business Excellence	Firm	Electricity	-	-	-	-	-	Stakeholders relationships Land use practices Governance	122
Nordheim and Barrasso (2007)	Journal of Cleaner Production	Firm	Aluminium	Europe	-	Y	Y	Y	-	34
Singh et al. (2007)	Ecological Indicators	-	Steel	-	-	Y	Y	Y	Organizational Governance Technical aspects	60
Jain and Kibira (2010)	Conference proceeding	Process	Manufacturing	-	-	Y	Y	Y	Manufacturing	48
Shao et al. (2010)	Conference proceeding	Process	Manufacturing	-	-	-	Y	-		8
Amrina and Yusof (2011)	Conference proceeding	Firm	Automotive	-	-	Y	Y	Y		41
Corbière-Nicollier et al. (2011)	Ecological Indicators	Supply Chain	Bioethanol	-	-	Y	Y	Y		18
Delai and Takahashi (2011)	Social Responsibility Journal	Corporate	-	-	-	Y	Y	Y		46
Erol et al. (2011)	Ecological Economics	Supply Chain	-	-	-	Y	Y	Y		37
Lu et al. (2011)	Conference proceeding	Product Process	-	-	-	Y	Y	Y		N.A.
Amindoust et al. (2012)	Applied Soft Computing	Firm	-	-	-	Y	Y	Y		29
Azadnia et al. (2013)	Procedia Social and Behavioural Science	Firm	-	-	-	Y	Y	Y		8
Ghadimi et al. (2012)	Journal of Cleaner Production	Product	Manufacturing	-	-	Y	Y	Y		21
Lee and Farzipoor Saen (2012)	International Journal of Production Economics	Corporate	-	-	-	Y	Y	Y		12
Büyüközkan and Cįfçi (2013)	Applied Soft Computing	Firm	-	-	-	Y	Y	Y		12
Hemdi et al. (2013)	International Journal of Sustainable Energy	Product Process				Y	Y	Y		28
Govindan et al. (2013)	Journal of Cleaner Production	Firm	-	-	-	Y	Y	Y		26
Joung et al. (2013)	Ecological Indicators	Product Process	-	-	-	Y	Y	Y	Technological Performance management	N.A.
Strezov et al. (2013)	Journal of Cleaner Production	Technology	Iron and Steel	-	-	-	Y	-		5
Tseng (2013)	Journal of Cleaner Production	Process		-	-	Y	Y	Y		21
Armstrong et al. (2014)	Conference proceeding	Product	Caddisfly jewellery	-	SMEs	Y	Y	Y		8
Chardine-Baumann and Botta-Genoulaz (2014)	Computers & Industrial Engineering	Supply Chain	-			Y	Y	Y		66
Chen et al. (2014)	CIRP Annals - Manufacturing Technology	Firm	Manufacturing	-	SMEs	Y	Y	Y		133
Garbie (2014)	International Journal of Production Research	Firm	Manufacturing	-	-	Y	Y	Y		83
Lodhia and Martin (2014)	Journal of Cleaner Production	Corporate	Mining and Minerals	Australia	-	-	.	-	Integrated (Environmental-Economic; Environmental-Social; Social-	26

									Economic)	
Mani et al. (2014)	International Journal of Production Research	Process		-	-	-	Y	-		7
Efroymson and Dale (2015)	Ecological Indicators	Process	Biofuels	-	-	-	Y	-		16
Harik et al. (2015)	International Journal of Production Research		Manufacturing	-	-	Y	Y	Y	Manufacturing	45
Marnika et al. (2015)	Journal of Cleaner Production		Mining and Minerals	Protected areas	-	Y	Y	Y		36
Rahdari and Anvary Rostamy (2015)	Journal of Cleaner Production	Corporate	-	-	-	-	Y	Y	Governance	70
Salvado et al. (2015)	Sustainability	Firm Supply chain	Automotive	-	-	Y	Y	Y		14
Sureeyatanapas et al. (2015)	Production Planning & Control	Corporate	Sugar	Thai	-	Y	Y	Y	Quality	30
Zhang and Haapala (2015)	Journal of Cleaner Production	Process	-	-	-	Y	Y	Y	-	N.A.
Amrina et al. (2016)	Procedia CIRP	Firm	Cement	-	-	Y	Y	Y		12
Fang et al. (2016)	Conference proceeding	Machine	-	-	-	Y	Y	Y	Technology	14
Jia et al. (2016)	Clean Technologies and Environmental Policies	Process	Chemical	-	-	Y	Y	Y		20
Kluczek (2016)	Management and Production Engineering Review	Process	Manufacturing	-	-	Y	Y	Y	Technical	14
Long et al. (2016)	Journal of Cleaner Production	-	Iron and Steel	China	-	Y	Y	Y		17
Singh et al. (2016)	Procedia CIRP	Firm	Manufacturing		SMEs	Y	Y	Y		49
Winroth et al. (2016)	Journal of Manufacturing Technology Management	Firm	Manufacturing	Sweden	SMEs	Y	Y	Y		52
Helleno et al. (2017)	Journal of Cleaner Production	Process	Manufacturing	Brazil		Y	Y	Y	Lean	61
Hsu et al. (2017)	Journal of Cleaner Production		Manufacturing	Taiwan	SMEs	Y	Y	Y	Performance (Finance; Customer; Internal Process; learning and growth)	28
Du Plessis and Bam (2018)	Sustainability	-	-	-	-	Y	Y	Y		18
Chang and Cheng (2019)	Journal of Cleaner Production	Firm	Manufacturing	Taiwan	SMEs	Y	Y	Y		31

Table 1 presents the analysis and classification of the selected contributions. Among these, the that by Garbie (2014) – reported in

Pillar	Category	Code	Indicator	Unit
Economic	**Globalisation and international issues**	1	Supply chain management	Number of stops caused by suppliers
		2	IT	Degree or percentage (%) of using internet and e-commerce
		3	Energy price	$/barrel
		4	Emerging markets	Number of markets around the world
		5	Business models	Number of new customers/year
	Contemporary and contingency issues	6	Process technology	Degree or percentage (%) of using new technology
		7	Government regulations	Degree or percentage (%) of following the regulations
		8	Growth of population	Number of populations increased per year per region
		9	Growth of economics	Degree or percentage (%) of profitability
		10	Consumption of resources	Percentage (%) of utilisation of resources
	Innovative designed products and research	11	Needs	Degree or percentage (%)
		12	Market opportunity	Degree or percentage (%)
		13	Product development cost	Percentage (%) of annual budget to R&D
		14	Product development time	Days, hours
		15	Development capability	Days, hours
		16	Regionalised products	Number of new regions related to total Number of regions
		17	Personalised products	Number of new products related to total Number of products
	Reconfigurable manufacturing enterprises	18	Enterprise size	Number of resources (e.g. machines)
		19	Enterprise functionality	Number of different operations (flexibility range)
		20	Material handling equipment	Number of material handling equipment

		21	Material handling storage	Space of storage (Cubic Metres)
		22	Identification system	Number of new identification systems related to existing
		23	Plant location	Number of locations of the plant around the world
		24	Functional layout*	Number of production departments
		25	Product layout*	Percentage (%) of modification in product layout
		26	Cellular layout*	Number of focused cells
	Manufacturing strategies	27	Complexity analysis	Degree or percentage (%) of complexity in the plan
		28	Lean production	Value added (e.g., employee productivity)
		29	Agile manufacturing	Degree or percentage (%) of agility
		30	Remanufacturing	Number of parts or component can be replaced again/product
		31	Recycling processes	Percentage (%) of total consumption of recycled parts
	Performance evaluation	32	Product costs	$/unit
		33	Response (lead time)	Days
		34	Enterprise productivity	Units/hour
		35	HR appraisal	Utilisation (%) of manual labour
		36	Resources status	Reliability, OEE (%)
		37	Product quality	Rate of customer complaints (units/unit time)
	Flexible organisation management	38	Strategic planning	Degree of clarity of strategic planning
		39	Organising work	Number of subordinates per supervisor
		40	Organisation structure	Number of organisation structure
		41	Leadership role	Degree or percentage (%) of leadership
		42	Staffing	Percentage (%) to access to skilled personnel
		43	Managing culture	Percentage of understanding foreign cultures
Social	**Work management**	44	Employment	Number of new employees per year
		45	Work conditions	Number of accidents due to working condition
		46	Social dialogue	Degree or percentage of talking between stakeholders
		47	Society security	Degree or percentage of social security
		48	HR development	Number of training hours/employee
	Human rights	49	Child labour	Degree or percentage of hiring children
		50	Freedom of association	Degree or percentage of creating association
		51	Discrimination	Degree or percentage of discrimination
	Societal commitment	52	Involvement in local community	Degree or percentage of involvement in local community
		53	Education	Average of education level per total employees
		54	Healthcare	Degree or percentage of health service level or Budget
		55	Job creation	Number of new jobs creation/local community
		56	Societal investment	Degree or percentage of annual budget to investment in society
		57	Culture and technological development	Degree or percentage of technology and culture regarding society
	Customers issues	58	Marketing and information	Degree or percentage
		59	Private life protection	Degree or percentage
		60	Access to essential services	Degree or percentage
	Business practices	61	Fight against corruption	Degree or percentage
		62	Fair trading	Degree or percentage
		63	Understanding foreign culture	Degree or percentage
Environment	**Environment management**	64	Environmental budget	Monetary units (cost for EHS compliance)
		65	Environmental certification	Degree or percentage follows the compliance ISO14001
		66	Environmental concerns and compliance	Degree or percentage of environmental impact assessment
		67	Workers implications	Number of environmental accidents per year
	Use of resources	68	Renewable energy	Degree or percentage of using renewable energy/total energy
		69	Recycled water	Degree or percentage of using recycled water/ total water consumption
		70	Recyclable wastes	Degree or percentage of using recycled wastes/total wastes
	Pollution	71	Air pollution	kg of gases (e.g. carbon dioxide emission in air)
		72	Water pollution	kg of particles
		73	Land pollution	kg and/or cubic metres of particles are needed to landfilled
	Dangerousness	74	Dangerous inputs	kg and/or cubic metres of dangerous materials
		75	Dangerous outputs	kg and/or cubic metres of dangerous materials
		76	Dangerous wastes	kg and/or cubic metres of dangerous materials
	Natural environmental	77	Eco-system services	Percentage of Level of carbon dioxide in the atmospheric
		78	Bio-diversity	Degree or percentage of health of ecosystems
		79	Land use	Squared metres of land used for the plant
		80	Development of rural areas	Percentage of annual budget to investment regarding rural areas

Table *2* - was chosen as the theoretical base for the present work.

Information		Level on analysis and focus on specific contexts				Classification of indicators and number of indicators				
Authors and years	**Source**	**Level**	**Sector**	**Country**	**Size**	**Eco**	**Env**	**Soc**	**Other classification**	**Number**
Afgan et al. (2000)	Energy Policy	System	Energy system	-	-	-	Y	Y	Resource efficiency	14
Veleva and Ellenbecker (2001)	Journal of Cleaner Production		Production	-	-	-	-	-	Sustainable Production aspects	22
Graedel and Allenby (2002)	Environmental Quality Management	Corporate	-	-	-	-	Y	-		10
Krajnc and Glavič (2003)	Clean Technologies and Environmental Policy	Firm	-	-	-	Y	Y	Y		83
Azapagic (2004)	Journal of Cleaner Production		Mining and Mineral	-	-	Y	Y	Y		129
Basu and Kumar (2004)	International Journal of Surface Mining	Corporate Global	Mining and Mineral	-	-	Y	Y	Y		N.A.
Labuschagne et al. (2005)	Journal of Cleaner Production	Firm	Manufacturing	South Africa	-	Y	Y	Y		N.A.
Searcy et al. (2005)	Measuring Business Excellence	Firm	Electricity	-	-	-	-	-	Stakeholders relationships Land use practices Governance	122
Nordheim and Barrasso (2007)	Journal of Cleaner Production	Firm	Aluminium	Europe	-	Y	Y	Y	-	34
Singh et al. (2007)	Ecological Indicators	-	Steel	-	-	Y	Y	Y	Organizational Governance Technical aspects	60
Jain and Kibira (2010)	Conference proceeding	Process	Manufacturing	-	-	Y	Y	Y	Manufacturing	48
Shao et al. (2010)	Conference proceeding	Process	Manufacturing	-	-	-	Y	-		8
Amrina and Yusof (2011)	Conference proceeding	Firm	Automotive	-	-	Y	Y	Y		41
Corbière-Nicollier et al. (2011)	Ecological Indicators	Supply Chain	Bioethanol	-	-	Y	Y	Y		18
Delai and Takahashi (2011)	Social Responsibility Journal	Corporate	-	-	-	Y	Y	Y		46
Erol et al. (2011)	Ecological Economics	Supply Chain	-	-	-	Y	Y	Y		37
Lu et al. (2011)	Conference proceeding	Product Process	-	-	-	Y	Y	Y		N.A.
Amindoust et al. (2012)	Applied Soft Computing	Firm	-	-	-	Y	Y	Y		29
Azadnia et al. (2013)	Procedia Social and Behavioural Science	Firm	-	-	-	Y	Y	Y		8
Ghadimi et al. (2012)	Journal of Cleaner Production	Product	Manufacturing	-	-	Y	Y	Y		21
Lee and Farzipoor Saen (2012)	International Journal of Production Economics	Corporate	-	-	-	Y	Y	Y		12
Büyüközkan and Cifçi (2013)	Applied Soft Computing	Firm	-	-	-	Y	Y	Y		12
Hemdi et al. (2013)	International Journal of Sustainable Energy	Product Process				Y	Y	Y		28
Govindan et al. (2013)	Journal of Cleaner Production	Firm	-	-	-	Y	Y	Y		26
Joung et al. (2013)	Ecological Indicators	Product Process	-	-	-	Y	Y	Y	Technological Performance management	N.A.
Strezov et al. (2013)	Journal of Cleaner Production	Technology	Iron and Steel	-	-	-	Y	-		5
Tseng (2013)	Journal of Cleaner Production	Process		-	-	Y	Y	Y		21
Armstrong et al. (2014)	Conference proceeding	Product	Caddisfly jewellery	-	SMEs	Y	Y	Y		8
Chardine-Baumann and Botta-Genoulaz (2014)	Computers & Industrial Engineering	Supply Chain	-			Y	Y	Y		66
Chen et al. (2014)	CIRP Annals - Manufacturing Technology	Firm	Manufacturing	-	SMEs	Y	Y	Y		133
Garbie (2014)	International Journal of Production Research	Firm	Manufacturing	-	-	Y	Y	Y		83
Lodhia and Martin (2014)	Journal of Cleaner Production	Corporate	Mining and Minerals	Australia	-	-	.	-	Integrated (Environmental-Economic; Environmental-Social; Social-Economic)	26
Mani et al. (2014)	International Journal of Production Research	Process		-	-	-	Y	-		7

Efroymson and Dale (2015)	Ecological Indicators	Process	Biofuels	-	-	-	Y	-		16
Harik et al. (2015)	International Journal of Production Research		Manufacturing	-	-	Y	Y	Y	Manufacturing	45
Marnika et al. (2015)	Journal of Cleaner Production		Mining and Minerals	Protected areas	-	Y	Y	Y		36
Rahdari and Anvary Rostamy (2015)	Journal of Cleaner Production	Corporate	-	-	-	-	Y	Y	Governance	70
Salvado et al. (2015)	Sustainability	Firm Supply chain	Automotive	-	-	Y	Y	Y		14
Sureeyatanapas et al. (2015)	Production Planning & Control	Corporate	Sugar	Thai	-	Y	Y	Y	Quality	30
Zhang and Haapala (2015)	Journal of Cleaner Production	Process	-	-	-	Y	Y	Y	-	N.A.
Amrina et al. (2016)	Procedia CIRP	Firm	Cement	-	-	Y	Y	Y		12
Fang et al. (2016)	Conference proceeding	Machine	-	-	-	Y	Y	Y	Technology	14
Jia et al. (2016)	Clean Technologies and Environmental Policies	Process	Chemical	-	-	Y	Y	Y		20
Kluczek (2016)	Management and Production Engineering Review	Process	Manufacturing	-	-	Y	Y	Y	Technical	14
Long et al. (2016)	Journal of Cleaner Production	-	Iron and Steel	China	-	Y	Y	Y		17
Singh et al. (2016)	Procedia CIRP	Firm	Manufacturing		SMEs	Y	Y	Y		49
Winroth et al. (2016)	Journal of Manufacturing Technology Management	Firm	Manufacturing	Sweden	SMEs	Y	Y	Y		52
Helleno et al. (2017)	Journal of Cleaner Production	Process	Manufacturing	Brazil		Y	Y	Y	Lean	61
Hsu et al. (2017)	Journal of Cleaner Production		Manufacturing	Taiwan	SMEs	Y	Y	Y	Performance (Finance; Customer; Internal Process; learning and growth)	28
Du Plessis and Bam (2018)	Sustainability	-	-	-	-	Y	Y	Y		18
Chang and Cheng (2019)	Journal of Cleaner Production	Firm	Manufacturing	Taiwan	SMEs	Y	Y	Y		31

Table 1. Analysis of the literature. The table reports the analysis of the contributions considered in the literature review. Contributions have been categorized according to: Information (Authors, Year, Source); Level of Analysis and Focus on Specific Contexts (Level, Sector, Country, Size); Classification of Indicators and Number of indicators (Environment, Economic, Social, Other classification, Number).

Pillar	Category	Code	Indicator	Unit
Economic	**Globalisation and international issues**	1	Supply chain management	Number of stops caused by suppliers
		2	IT	Degree or percentage (%) of using internet and e-commerce
		3	Energy price	$/barrel
		4	Emerging markets	Number of markets around the world
		5	Business models	Number of new customers/year
	Contemporary and contingency issues	6	Process technology	Degree or percentage (%) of using new technology
		7	Government regulations	Degree or percentage (%) of following the regulations
		8	Growth of population	Number of populations increased per year per region
		9	Growth of economics	Degree or percentage (%) of profitability
		10	Consumption of resources	Percentage (%) of utilisation of resources
	Innovative designed products and research	11	Needs	Degree or percentage (%)
		12	Market opportunity	Degree or percentage (%)
		13	Product development cost	Percentage (%) of annual budget to R&D
		14	Product development time	Days, hours
		15	Development capability	Days, hours
		16	Regionalised products	Number of new regions related to total Number of regions
		17	Personalised products	Number of new products related to total Number of products
	Reconfigurable manufacturing enterprises	18	Enterprise size	Number of resources (e.g. machines)
		19	Enterprise functionality	Number of different operations (flexibility range)
		20	Material handling equipment	Number of material handling equipment
		21	Material handling storage	Space of storage (Cubic Metres)
		22	Identification system	Number of new identification systems related to existing
		23	Plant location	Number of locations of the plant around the world
		24	Functional layout*	Number of production departments
		25	Product layout*	Percentage (%) of modification in product layout
		26	Cellular layout*	Number of focused cells
	Manufacturing strategies	27	Complexity analysis	Degree or percentage (%) of complexity in the plan
		28	Lean production	Value added (e.g., employee productivity)
		29	Agile manufacturing	Degree or percentage (%) of agility
		30	Remanufacturing	Number of parts or component can be replaced again/product
		31	Recycling processes	Percentage (%) of total consumption of recycled parts
	Performance evaluation	32	Product costs	$/unit
		33	Response (lead time)	Days
		34	Enterprise productivity	Units/hour
		35	HR appraisal	Utilisation (%) of manual labour
		36	Resources status	Reliability, OEE (%)
		37	Product quality	Rate of customer complaints (units/unit time)
	Flexible organisation management	38	Strategic planning	Degree of clarity of strategic planning
		39	Organising work	Number of subordinates per supervisor
		40	Organisation structure	Number of organisation structure
		41	Leadership role	Degree or percentage (%) of leadership
		42	Staffing	Percentage (%) to access to skilled personnel
		43	Managing culture	Percentage of understanding foreign cultures
Social	**Work management**	44	Employment	Number of new employees per year
		45	Work conditions	Number of accidents due to working condition
		46	Social dialogue	Degree or percentage of talking between stakeholders
		47	Society security	Degree or percentage of social security
		48	HR development	Number of training hours/employee
	Human rights	49	Child labour	Degree or percentage of hiring children
		50	Freedom of association	Degree or percentage of creating association
		51	Discrimination	Degree or percentage of discrimination
	Societal commitment	52	Involvement in local community	Degree or percentage of involvement in local community
		53	Education	Average of education level per total employees
		54	Healthcare	Degree or percentage of health service level or Budget
		55	Job creation	Number of new jobs creation/local community
		56	Societal investment	Degree or percentage of annual budget to investment in society
		57	Culture and technological development	Degree or percentage of technology and culture regarding society
	Customers issues	58	Marketing and information	Degree or percentage
		59	Private life protection	Degree or percentage
		60	Access to essential services	Degree or percentage
	Business practices	61	Fight against corruption	Degree or percentage
		62	Fair trading	Degree or percentage
		63	Understanding foreign culture	Degree or percentage
Environment	**Environment management**	64	Environmental budget	Monetary units (cost for EHS compliance)
		65	Environmental certification	Degree or percentage follows the compliance ISO14001
		66	Environmental concerns and compliance	Degree or percentage of environmental impact assessment
		67	Workers implications	Number of environmental accidents per year

Use of resources	68	Renewable energy	Degree or percentage of using renewable energy/total energy
	69	Recycled water	Degree or percentage of using recycled water/ total water consumption
	70	Recyclable wastes	Degree or percentage of using recycled wastes/total wastes
Pollution	71	Air pollution	kg of gases (e.g. carbon dioxide emission in air)
	72	Water pollution	kg of particles
	73	Land pollution	kg and/or cubic metres of particles are needed to landfilled
Dangerousness	74	Dangerous inputs	kg and/or cubic metres of dangerous materials
	75	Dangerous outputs	kg and/or cubic metres of dangerous materials
	76	Dangerous wastes	kg and/or cubic metres of dangerous materials
Natural environmental	77	Eco-system services	Percentage of Level of carbon dioxide in the atmospheric
	78	Bio-diversity	Degree or percentage of health of ecosystems
	79	Land use	Squared metres of land used for the plant
	80	Development of rural areas	Percentage of annual budget to investment regarding rural areas

Table 2. The model for sustainability indicators proposed by Garbie (2014). For each pillar of sustainability, the categories identified are reported. For each category, indicators and related unit for measure are provided, as well as an identifier code for each indicator.
* Indicator slightly amended according to further considerations by the author (Garbie, 2016).

2.1.1 Garbie's model of sustainability indicators

Garbie (2014) modelled the TBL by identifying 80 indicators (43 economic, 20 social, 17 environmental), proposing a unit of analysis for each, as cited by previous literature (Du Plessis and Bam, 2018; Shibin et al., 2017a), different from the other contributions reviewed. In fact, other studies focused only on the environmental pillar (Efroymson and Dale, 2015; Mani et al., 2014), or environmental and social pillars (Afgan et al., 2000); others added performance areas not related to the TBL, such as technology (Fang et al., 2016; Kluczek, 2016) or governance (Rahdari and Anvary Rostamy, 2015; Singh et al., 2007), or based on a different categorization of indicators (Searcy et al., 2005; Veleva and Ellenbecker, 2001). Moreover, the selected model is based on a thorough literature review of extant contributions and appreciated by recent studies by offering the largest number and most complete set of indicators for manufacturing (Sangwan et al., 2018).

Furthermore, some literature also focused on the micro level, as defined by Ding et al. (2017), thus being applicable in industrial firms at a plant level. Among the other contributions reviewed, some are related to products (Armstrong et al., 2014; Ghadimi et al., 2012) or process levels (Helleno et al., 2017; Tseng, 2013; Zhang et al., 2015), to machines (Fang et al., 2016) and technology (Strezov et al., 2013), acknowledging that most works on sustainability assessment in manufacturing were conducted at a product level or at a specific process level, as also noted by recent studies (Saad et al., 2019). At the same time, other contributions reviewed address a strategic (corporate) viewpoint (Lee and Farzipoor Saen, 2012; Lodhia and Martin, 2014) or a system one, e.g., supply chain (Chardine-Baumann and Botta-Genoulaz, 2014; Erol et al., 2011).

Additionally, the selected model was generally applicable in manufacturing firms, different from others focused on specific contexts in terms of sectors, country, or firm size. By looking at sectors, several contributions were developed for specific applications, such as mining and minerals (Azapagic, 2004; Marnika et al., 2015), cement (Amrina et al., 2016), aluminium (Nordheim and Barrasso, 2007), steel (Singh et al., 2007; Strezov et al., 2013), and automotive (Amrina and Yusof, 2011; Salvado et al., 2015). Concerning countries, a considerable number of studies were conducted in specific geographical areas, such as South Africa (Labuschagne et al., 2005), China (Long et al., 2016), Taiwan (Hsu et al., 2017), or Sweden (Winroth et al., 2016). Focusing on size, few contributions were specifically developed for a specific size, and in particular for SMEs (Chang and Cheng, 2019; Singh et al., 2016).

Moreover, the selected model already contains the theoretical background for other contributions, for both theoretical development (Dubey et al., 2015; Latif et al., 2017) and empirical applications (Naderi et al., 2017).

2.2 Research Methods

2.2.1 Method and sample selection

The empirical investigation is based on case study research methodology, meeting the criteria for case study research identified by Voss et al. (2002) and Yin (2009), analysing a phenomenon with lack of detailed preliminary research, and advancing the conceptualization and operationalization of a theory (Dooley, 2002; Lynham, 2002).

The investigation was conducted through exploratory case studies with semi-structured interviews and secondary materials. Two units of analysis should be identified: the case to be studied and whom to interview within the case (Meredith, 1998).

The unit of analysis of the present study is the single firm (Dooley, 2002) and, according also to Lynham (2002), multiple cases are suitable to address the research issues identified. Case studies were carried out in 26 firms, addressing manufacturing SMEs in Italy and Germany, given the importance of the manufacturing sector in general for the European economy and in particular for these two countries (European Union, 2017b).

The investigation targeted the metalworking and chemical sectors. The first is relevant for all industrial countries in terms of added values and employment (Federmeccanica, 2018), with Germany and Italy placing, respectively, first and second in EU28 (CEFIC, 2018). This sector is characterized by solutions including automation and innovation, deemed to foster technology innovation among all the other sectors (Federmeccanica, 2018). The second sector has a major role in economic development and wealth in EU28, with Germany ranking as first in EU28 for revenues generated, followed by France and Italy (CEFIC, 2018). The industry is a heavy user of raw materials and energy (Verband der Chemischen Industrie, 2012), and firms themselves have the greatest interest in efficient production (Schmidt et al., 2019). Furthermore, recent research considers the chemical sector as a leader for both energy efficiency and safety in EU28 (Colombo, 2014).

Regarding the choice towards SMEs, in Germany the share of total employment among SMEs is of more than 60 %, exhibiting a higher economic performance than the European average (Söllner, 2014), and 90% of the metalworking firms are SMEs (Germany Trade & Invest, 2018); for the chemical sector, lower but still relevant figures are available (Vitali, 2012). In Italy, the share of total employment among SMEs is even greater – more than 80% – (Confcommercio, 2009), with Italian chemical SMEs playing a relevant role for innovation and competitiveness (Colombo, 2014), compensating for the decline of larger ones (Vitali, 2012).

The 26 firms composing the sample are equally distributed between countries, sectors and size, i.e. micro, small, and medium (European Union, 2003). The use of multiple case studies and the number of case studies allows replication logic rather than sampling one (Zainal, 2007): despite relying on some notions of statistical generalization (Dubois and Gadde, 2002), they proceed towards theoretical generalization, looking for similarities and differences across cases (Ketokivi and Choi, 2014), interpreting the results based on the specific context of interest (Denzin and Lincoln, 2011). However, given the sample size, a less qualitative description may be involved in the analysis and a more statistical measure of variables can be documented (Meredith, 1998).

The selected sample allows conducting collective case studies (Zainal, 2007). To further ensure proper data collection, aiming at theoretical replication (Voss et al., 2002), people involved in the decision-making process and knowledgeable for sustainability issues were selected as interviewees (details of sampled firms and persons interviewed are reported in

irm	Country	Sector	Employees	Size	Certification	Person interviewed
A	Germany	Metalwork	160	Medium	ISO 9001	Safety manager
B	Germany	Metalwork	35	Small	ISO 9001	Production manager
C	Germany	Metalwork	50	Medium	-	Human Resource manager
D	Germany	Metalwork	4	Micro	-	CEO
E	Germany	Metalwork	8	Micro	ISO 9001	Administrative employee
F	Germany	Metalwork	5	Micro	-	Sales manager
G	Germany	Metalwork	148	Medium	ISO 9001; ISO 14001	CEO
H	Germany	Chemical	50	Medium	ISO 9001	CEO
I	Germany	Chemical	50	Medium	ISO 9001	Production manager
J	Germany	Chemical	35	Small	ISO 9001; ISO 50001	Business Development manager
K	Germany	Chemical	240	Medium	ISO 9001	Product manager
L	Germany	Chemical	75	Medium	ISO 9001; ISO 14001; ISO 50001	CEO
M	Germany	Chemical	250	Medium	ISO 9001; ISO 14001; ISO 50001	Sales manager
N	Italy	Chemical	57	Medium	ISO 9001	Sales manager; safety manager
O	Italy	Chemical	4	Micro	ISO 9001; ISO 14001; OHSAS 18001	CEO; HSE manager
P	Italy	Chemical	60	Medium	ISO 9001; ISO 14001; OHSAS 18001	Technical director
Q	Italy	Chemical	250	Medium	ISO 9001; ISO 14001; OHSAS 18001	HSE manager
R	Italy	Chemical	49	Small	ISO 9001	CEO
S	Italy	Chemical	65	Medium	ISO 9001	CEO
T	Italy	Metalwork	3	Micro	-	CEO
U	Italy	Metalwork	9	Micro	ISO 9001	CEO
V	Italy	Metalwork	32	Small	-	CEO
W	Italy	Metalwork	55	Medium	ISO 9001; ISO 14001; OHSAS 18001	CEO
X	Italy	Metalwork	15	Small	-	CEO
Y	Italy	Metalwork	50	Medium	ISO 9001	CEO
Z	Italy	Metalwork	53	Medium	ISO 9001	CEO; Purchasing and logistics manager

Table *3*).

Firm	Country	Sector	Employees	Size	Certification	Person interviewed
A	Germany	Metalwork	160	Medium	ISO 9001	Safety manager
B	Germany	Metalwork	35	Small	ISO 9001	Production manager

C	Germany	Metalwork	50	Medium	-	Human Resource manager
D	Germany	Metalwork	4	Micro	-	CEO
E	Germany	Metalwork	8	Micro	ISO 9001	Administrative employee
F	Germany	Metalwork	5	Micro	-	Sales manager
G	Germany	Metalwork	148	Medium	ISO 9001; ISO 14001	CEO
H	Germany	Chemical	50	Medium	ISO 9001	CEO
I	Germany	Chemical	50	Medium	ISO 9001	Production manager
J	Germany	Chemical	35	Small	ISO 9001; ISO 50001	Business Development manager
K	Germany	Chemical	240	Medium	ISO 9001	Product manager
L	Germany	Chemical	75	Medium	ISO 9001; ISO 14001; ISO 50001	CEO
M	Germany	Chemical	250	Medium	ISO 9001; ISO 14001; ISO 50001	Sales manager
N	Italy	Chemical	57	Medium	ISO 9001	Sales manager; safety manager
O	Italy	Chemical	4	Micro	ISO 9001; ISO 14001; OHSAS 18001	CEO; HSE manager
P	Italy	Chemical	60	Medium	ISO 9001; ISO 14001; OHSAS 18001	Technical director
Q	Italy	Chemical	250	Medium	ISO 9001; ISO 14001; OHSAS 18001	HSE manager
R	Italy	Chemical	49	Small	ISO 9001	CEO
S	Italy	Chemical	65	Medium	ISO 9001	CEO
T	Italy	Metalwork	3	Micro	-	CEO
U	Italy	Metalwork	9	Micro	ISO 9001	CEO
V	Italy	Metalwork	32	Small	-	CEO
W	Italy	Metalwork	55	Medium	ISO 9001; ISO 14001; OHSAS 18001	CEO
X	Italy	Metalwork	15	Small	-	CEO
Y	Italy	Metalwork	50	Medium	ISO 9001	CEO
Z	Italy	Metalwork	53	Medium	ISO 9001	CEO; Purchasing and logistics manager

Table 3. Detail of the firms investigated. For each firm investigated, the following are specified: country, sector, number of employees, size, certifications held, and person interviewed.

2.2.2 Data collection

Data collection is organized into three parts. Firstly, the sample was selected starting from a database "ORBIS" (https://orbis.bvdinfo.com) containing relevant industrial information for European firms, using EU classification of SMEs (European Union, 2003), filtering for metalworking and chemical SMEs located in Italy and Germany. Firms were contacted by e-mail or phone call. After a preliminary contact via phone to invite companies to participate in the research, for those confirming their participation, secondary data were collected regarding firm structure, production processes, projects and initiatives towards increased industrial sustainability, including their sustainability report (if any). Secondary data were retrieved from the firm website, reports and, when applicable, newspapers.

Secondly, an investigation within the firm was performed by carried out using semi-structured interviews, with a questionnaire as a guide so to standardize the sequence of questions and minimize the impact of contextual effects (Patton, 1990). Additional questions emerging during the interview were asked and free comments collected (Dicicco-Bloom and Crabtree, 2006; Remler and

Van Ryzin, 2014). Interviewees were initially asked to introduce the firm – describing the main production processes, number of employees, firm turnover – and how sustainability is internally managed. A particular focus was given to the different roles in sustainability management and how sustainability is perceived. Following this, interviewees were asked to describe how sustainability was defined within the firm, how firm performance was affected, and how sustainability was measured, with an indication of the specific TBL pillars. During the investigation, which on average took about 1.5 hours per firm, researchers used field notes.

Third, interviews were transcribed and coded. The indicators mentioned were re-categorized according to Garbie (2014). The findings deriving from the different steps of the investigation were corroborated with secondary data and other material gathered during the interviews (e.g., field notes), in order to identify possible misalignments. In found, interviewers followed up with a second contact for further clarification.

2.2.3 Data analysis and methodological rigour

For data analysis an "emergent coding" technique was adopted, establishing categories based on preliminary data examination (Stemler, 2001). First, a structural code was applied - useful as a foundation for further detailed coding and suitable for semi-structured data-gathering protocols – followed by axil code, reassembling data split in the first coding (Saldaña, 2009; Voss et al., 2002).

The requirements for methodological rigor of explorative case study research (Baškarada, 2014; Beverland and Lindgreen, 2010; Yin, 2009) were addressed as follows. Construct validity was obtained with triangulation of multiple source of evidence and with the development of a chain of evidence: data obtained through the multiple sources of evidence was corroborated (Beverland and Lindgreen, 2010; Voss et al., 2002) and an electronic folder was created for each case containing all the data collected (Rowley, 2002). External validity was guaranteed by defining the domain to which study findings can be generalized and using multiple case studies (Beverland and Lindgreen, 2010; Meredith, 1998). Reliability was addressed using a case study protocol (Beverland and Lindgreen, 2010), conducting multiple case studies (Voss et al., 2002) and involving more than one interviewer in each investigation (Eisenhardt, 1989; Voss et al., 2002).

3 Results of the empirical investigation

In this section, the results of the exploratory investigation are reported and analysed. Full details of the sustainability indicators measured by the firms sampled can be found in the Annex (Table A1).

3.1 Analysis of the total sample

3.1.1 Analysis of the most measured indicators

On average[1], the sampled SMEs adopt about 18 indicators out of the 80 suggested by Garbie (2014) (

	Total (80 indicators)			***Economic (43 indicators)***			***Social (20 indicators)***			***Environment (17 indicators)***		
	Max	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*
Total Sample	40	5	18.5	23	3	10.1	7	1	3.7	12	0	4.7
Germany	27	5	18	14	3	9.4	7	2	4	8	0	4.6
Italy	40	5	18.9	23	3	10.8	7	1	3.4	12	0	4.8
Medium	33	14	21.5	19	5	11.4	7	2	4.3	8	2	5.8
Small	40	5	14.3	23	3	8.3	6	1	2.8	12	0	3.2
Chemical	40	14	22.33	23	5	11.3	7	2	4.8	12	3	6.3
Metal	33	5	15.1	19	3	9.1	6	1	2.8	8	0	3.3

Table 4). A strong variance in the number of indicators can be observed, from a minimum of 5 to a maximum of 40, aligned with Lääts et al. (2017).

Focusing on the TBL pillars, of the 18.5 indicators measured on average, 10 belong to the economic pillar, while only about 4 and 5, respectively, to the social and environmental ones. Interestingly, the range of variation is 3-23 indicators for the economic pillar, and 1−7 and 0−12 indicators for the social and environmental ones, respectively.

The results, in terms of the number of indicators measured, contribute to the open debate on how many indicators a firm can and should measure. The findings are in line with Krajnc and Glavič

[1] Average values have been rounded to the previous integer for decimal values lower or equal to 0.50, to the next integer for decimal values higher than 0.50.

(2003), who deemed that between 10 and 20 should be included, even if the number obtained is higher than the threshold of 9 identified by Collins et al. (2016) and lower than that of 30 proposed by previous studies (Nordheim and Barrasso, 2007). However, the result seems to suggest that firms lag behind the measurement of a set of sustainability indicators recognized as appropriate by the academic literature. The findings seem to underline a low maturity of firms towards a holistic encompassing of TBL, highlighting the main role still played by economic indicators, confirming Harik et al. (2015). All firms measure at least one social indicator (i.e. work conditions), but this is likely due to legislative obligations (i.e. Directive 89/391/EEC – OSH) (Pawłowska, 2015; Pütter, 2017), and firms still appear to be far from exploiting the benefits derived from holistic approaches to sustainability (Cagno et al., 2018).

	Total (80 indicators)			***Economic (43 indicators)***			***Social (20 indicators)***			***Environment (17 indicators)***		
	Max	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*
Total Sample	40	5	18.5	23	3	10.1	7	1	3.7	12	0	4.7
Germany	27	5	18	14	3	9.4	7	2	4	8	0	4.6
Italy	40	5	18.9	23	3	10.8	7	1	3.4	12	0	4.8
Medium	33	14	21.5	19	5	11.4	7	2	4.3	8	2	5.8
Small	40	5	14.3	23	3	8.3	6	1	2.8	12	0	3.2
Chemical	40	14	22.33	23	5	11.3	7	2	4.8	12	3	6.3
Metal	33	5	15.1	19	3	9.1	6	1	2.8	8	0	3.3

Table 4. Number of indicators measured. The table shows the detail of the maximum, minimum, and average number of indicators measured by the firms sampled considering the totality of indicators provided by Garbie (2014)'s model and the indicators related to each pillar. The analysis was conducted according to the different clusters of firms based on contextual factors, i.e. total sample, country, size, and sector.

Focusing on the most measured indicators[2] (

				Total sample	**Germany**	**Italy**	**Medium**	**Small**	**Chemical**	**Metalworking**
Economic	**Globalisation and international issues**	5	Business models	●●●	●●●	●●	●●●	●●	●●●	●●●
	Contemporary and contingency issues	9	Growth of economics			●●			●●	
		10	Consumption of resources	●●●	●●●	●●●	●●●	●●	●●●	●●
	Innovative designed products and research	13	Product development costs	●●	●●	●●	●●		●●●	
		14	Product development time		●●				●●	
		16	Regionalised products		●●					

[2] Indicators measured at least by 50% of the firms of the cluster, with further distinction on those measured by at least the 75% of the firms of the cluster.

		17	Personalised products	●●	●●	●●	●●		●●	●●
	Reconfigurable manufacturing enterprises	18	Enterprise size			●●				
	Manufacturing strategies	31	Recycling processes	●●	●●●		●●	●●	●●	●●
	Performance evaluation	32	Product costs	●●●	●●●	●●	●●●	●●●	●●	●●
		33	Response (lead time)	●●	●●		●●		●●	
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Social	Work management	44	Employment			●●				
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●		●●	●●		●●	
	Societal commitment	54	Healthcare	●●	●●●		●●	●●	●●●	●●
		56	Societal investment				●●		●●	
Environment	Environment management	67	Workers implications			●●				
	Use of resources	70	Recyclable wastes		●●					
	Pollution	71	Air pollution			●●	●●		●●●	
		72	Water pollution	●●	●●	●●	●●		●●●	
	Dangerousness	74	Dangerous inputs	●●	●●●		●●		●●●	
		75	Dangerous outputs	●●	●●		●●		●●●	
		76	Dangerous wastes	●●	●●		●●●		●●●	●●

Table 5), the majority are economic, as also observed by Singh et al. (2007). In particular, they are related to *product cost*, *business model*, *product quality*, and *consumption of resources*. The social indicator *working conditions* is among the most measured ones, confirming the role of legislative obligations as mentioned above. Furthermore, as can be inferred from Table 6 showing the three most measured indicators for each pillar (

				Total sample	Medium	Small	Germany	Italy	Chemical	Metalworking
Economic	Globalisation and international issues	5	Business models		●●●	●●	●●●	●●		●●●
	Contemporary and contingency issues	9	Growth of economics					●●		
		10	Consumption of resources	●●●	●●●	●●	●●●	●●●	●●●	●●
	Innovative designed products and research	13	Product development costs		●●				●●●	
		17	Personalised products		●●					
	Manufacturing strategies	31	Recycling processes				●●●			
	Performance evaluation	32	Product costs	●●●	●●●	●●●	●●●	●●	●●●	●●●
		33	Response (lead time)		●●					
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Social	Work management	44	Employment					●●		●
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●	●●	●		●●	●●●	
	Societal commitment	54	Healthcare	●●	●●	●●	●●●	●	●●●	●●
		56	Societal investment				●			
Environment	Environment management	64	Environmental budget					●		
		65	Environmental certification					●	●	
		67	Workers implications					●●	●	
	Use of resources	69	Recycled water						●	
		70	Recyclable wastes			●	●●		●	●
	Pollution	71	Air pollution			●		●●	●●●	
		72	Water pollution	●●	●●	●	●●	●●	●●●	●

		73	Land pollution			•		•	•	
	Dangerousness	74	Dangerous inputs	••	••	•	•••	•	•••	•
		75	Dangerous outputs	••	••	•	••	•	•••	•
		76	Dangerous wastes	••	•••	•	••	•	•••	••

Table *6*), in the social pillar, beyond *working conditions,* the monitoring of training hours and investments related to safety were relevant, while firms devote particular attention to the dangerousness of inputs and outputs, and the measurement of water pollution belonging to the environmental pillar.

				Total sample	Germany	Italy	Medium	Small	Chemical	Metalworking
Economic	Globalisation and international issues	5	Business models	•••	•••	••	•••	••	•••	•••
	Contemporary and contingency issues	9	Growth of economics			••			••	
		10	Consumption of resources	•••	•••	•••	•••	••	•••	••
	Innovative designed products and research	13	Product development costs	••	••	••	••		•••	
		14	Product development time		••				••	
		16	Regionalised products		••					
		17	Personalised products	••	••	••	••		••	••
	Reconfigurable manufacturing enterprises	18	Enterprise size			••				
	Manufacturing strategies	31	Recycling processes	••	•••		••	••	••	••
	Performance evaluation	32	Product costs	•••	•••	••	•••	•••	••	••
		33	Response (lead time)	••	••		••		••	
		37	Product quality	•••	•••	•••	•••	•••	•••	•••
Social	Work management	44	Employment			••				
		45	Work conditions	•••	•••	•••	•••	•••	•••	•••
		48	HR development	••		••	••		••	
	Societal commitment	54	Healthcare	••	•••		••	••	•••	••
		56	Societal investment				••		••	
Environment	Environment management	67	Workers implications			••				
	Use of resources	70	Recyclable wastes		••					
	Pollution	71	Air pollution			••	••		•••	
		72	Water pollution	••	••	••	••		•••	
	Dangerousness	74	Dangerous inputs	••	•••		••		•••	
		75	Dangerous outputs	••	••		••		•••	
		76	Dangerous wastes	••	••		•••		•••	••

Table 5. The most measured performance indicators. Details of the most measured indicators from the total set for each cluster of firms considered in the analysis. We considered as the most measured indicators those measured by at least the 50% of the firms in the cluster, with a further specific focus on indicators measured by at least the 75% of the firms in the cluster. These two types of indicators are indicated with •• and light blue boxes, and with ••• and dark blue boxes, respectively.

				Total sample	Medium	Small	Germany	Italy	Chemical	Metalworking
Economic	Globalisation and international issues	5	Business models		•••	••	•••	••		•••
	Contemporary and contingency issues	9	Growth of economics					••		
		10	Consumption of resources	•••	•••	••	•••	•••	•••	••
	Innovative designed products and research	13	Product development costs		••				•••	
		17	Personalised products		••					
	Manufacturing strategies	31	Recycling processes				•••			
	Performance evaluation	32	Product costs	•••	•••	•••	•••	••	•••	•••
		33	Response (lead		••					

			time)							
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●

Social	**Work management**	44	Employment					●●		●
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●	●●	●		●●	●●●	
	Societal commitment	54	Healthcare	●●	●●	●●	●●●	●	●●●	●●
		56	Societal investment				●			

Environment	**Environment management**	64	Environmental budget					●		
		65	Environmental certification					●	●	
		67	Workers implications					●●	●	
	Use of resources	69	Recycled water						●	
		70	Recyclable wastes			●	●●		●	●
	Pollution	71	Air pollution			●		●●	●●●	
		72	Water pollution	●●	●●	●	●●	●●	●●●	●
		73	Land pollution			●		●	●	
	Dangerousness	74	Dangerous inputs	●●	●●	●	●●●	●	●●●	●
		75	Dangerous outputs	●●	●●	●	●●	●	●●●	●
		76	Dangerous wastes	●●	●●●	●	●●	●	●●●	●●

Table 6. The first three measured indicators for each pillar. Details of the first three measured indicators from each pillar. For each of these indicators, we provide a detail of the percentage of firms in the cluster measuring it: ●●● and dark coloured box if the indicator was measured by more than the 75% of the firms in the cluster; ●● and medium coloured box if the indicator was measured by more than the 50% (but less than 75%) of the firms in the cluster; ● and light coloured box if the indicator was measured by less than the 50% of the firms of the cluster. We used a different colour for each pillar: grey for Economic, violet for Social; green for Environment.

3.1.2 Analysis of the least measured indicators

The evaluation of the least measured indicators (and related categories, as shown in

Table 7) can provide further insights about possible misalignments between theoretical models of indicators and empirical applications within companies. Notably, the category *customer issues* was considered only by Firm K, which is likely to be at least partially explained by the higher level of product customization shown by the company compared to the others sampled. When considering specific indicators, 14 of the 80 indicators were not considered by any firm, i.e. the 18% with same percentage by looking at economic and social pillars separately, while half that of the environmental one.

Among the least measured indicators, some are beyond the direct operation range of a firm and difficult to be measured, as they are ascribable to a single firm process, e.g., *growth of population, eco system* and *bio-diversity*, belonging to the economic and the environmental pillars. This aspect is quite controversial in the literature: it is rather ineffectual to think that firms can solve global problems, despite being recognized as the only actors in the economic system with sufficient strength and resources to accomplish this (Bauman, 2003; Elkington, 1997). These indicators are frequently reported in the literature, and this seems to spotlight a misalignment between what firms consider as relevant for sustainability assessment and what is proposed by academia or by external stakeholders, as underlined by Delai and Takahashi (2011). In particular, the result seems to slightly differ from previous research by Roca and Searcy (2012), who nevertheless analysed the indicators disclosed in sustainability reports. Other neglected indicators are related to the management of the production system, e.g., *identification systems, product layout, cellular layout, agile manufacturing*, belonging to the economic pillar. As several interviewees commented, these indicators are perceived to be more related to organisation of production, rather than to economic aspects, and therefore not acknowledging a relationship to sustainability performance. Moreover, a straightforward link between such indicators and economic aspects cannot be easily discerned: quite often, decisions over layout and production strategy are based on the type of production system rather than on economic reasons (Garbie, 2016). Among the least considered indicators, some related to compliance with specific regulations can be identified, e.g., *environmental concerns and compliance*, belonging to the environment pillar, and some that are not applicable in the two countries investigated, e.g., *child labour* - illegal as from International Labour Organization (1973) - belonging to the social pillar. Still, such indicators can be frequently found in models developed to measure sustainability performance of industrial firms, and showcasing these models is often inadequate for many firms (Delai and Takahashi, 2011), which have been developed from the perspective of external stakeholders (Nordheim and Barrasso, 2007).

Pillar	Category	Code	Indicator	Total sample	Medium	Small	Germany	Italy	Chemical	Metalworking
Economic	**Globalisation and international issues**	1	Supply chain management				(×)		(×)	
		2	IT	(×)	(×)	×	(×)	×	(×)	×
		3	Energy price							
		4	Emerging markets		(×)	(×)	×		(×)	(×)
		5	Business models							
	Contemporary and contingency issues	6	Process technology		(×)			×	(×)	
		7	Government regulations	(×)	(×)	×	(×)	×	×	(×)
		8	Growth of population	×	×	×	×	×	×	×
		9	Growth of economics							
		10	Consumption of resources							
	Innovative designed products and research	11	Needs	×	×	×	×	×	×	×
		12	Market opportunity	(×)	×	(×)	(×)	×	×	(×)
		13	Product development costs							
		14	Product development time							
		15	Development capability		(×)	(×)	(×)	(×)	(×)	(×)
		16	Regionalised products					(×)		
		17	Personalised products							
	Reconfigurable manufacturing enterprises	18	Enterprise size							
		19	Enterprise functionality							
		20	Material handling equipment	(×)	×	(×)	×	(×)	(×)	×
		21	Material handling storage			(×)	×			
		22	Identification system	×	×	×	×	×	×	×
		23	Plant location		(×)	(×)	×		(×)	(×)
		24	Functional layout			(×)				
		25	Product layout	×	×	×	×	×	×	×
		26	Cellular layout	×	×	×	×	×	×	×
	Manufacturing strategies	27	Complexity analysis	(×)	×	(×)	×	(×)	(×)	×
		28	Lean production			(×)	×			
		29	Agile manufacturing	×	×	×	×	×	×	×
		30	Remanufacturing	(×)	(×)	×	×	(×)	×	(×)
		31	Recycling processes							
	Performance evaluation	32	Product costs							
		33	Response (lead time)							
		34	Enterprise productivity							
		35	HR appraisal				(×)			(×)
		36	Resources status			(×)	×		(×)	
		37	Product quality							
	Flexible organisation management	38	Strategic planning	×	×	×	×	×	×	×
		39	Organising work			(×)	(×)			
		40	Organisation structure		(×)	(×)	(×)	(×)		×
		41	Leadership role	(×)	(×)	×	(×)	×	(×)	×
		42	Staffing	×	×	×	×	×	×	×
		43	Managing culture	(×)	(×)	×	×	(×)	×	(×)
Social	**Work management**	44	Employment				(×)			
		45	Work conditions							
		46	Social dialogue			×		×	(×)	(×)
		47	Society security	(×)	×	(×)	(×)	×	(×)	×
		48	HR development							

	Human rights	49	Child labour	×	×	×	×	×	×	×
		50	Freedom of association			(×)		(×)		×
		51	Discrimination	(×)	(×)	×	×	(×)	(×)	×
	Societal commitment	52	Involvement in local community			(×)				
		53	Education			×	(×)	(×)	×	
		54	Healthcare							
		55	Job creation	×	×	×	×	×	×	×
		56	Societal investment							
		57	Culture and technological development	(×)	(×)	×	(×)	×	(×)	×
	Customers issues	58	Marketing and information	(×)	(×)	×	(×)	×	(×)	×
		59	Private life protection	(×)	(×)	×	(×)	×	(×)	×
		60	Access to essential services	(×)	(×)	×	(×)	×	(×)	×
	Business practices	61	Fight against corruption		(×)	(×)	(×)	(×)	(×)	(×)
		62	Fair trading	×	×	×	×	×	×	×
		63	Understanding foreign culture	×	×	×	×	×	×	×
Environment	**Environment management**	64	Environmental budget			(×)	×			
		65	Environmental certification			(×)				
		66	Environmental concerns and compliance	×	×	×	×	×	×	×
		67	Workers implications				×			
	Use of resources	68	Renewable energy				(×)		(×)	
		69	Recycled water							(×)
		70	Recyclable wastes					×		
	Pollution	71	Air pollution							
		72	Water pollution							
		73	Land pollution							(×)
	Dangerousness	74	Dangerous inputs							
		75	Dangerous outputs							
		76	Dangerous wastes							
	Natural environmental	77	Eco-system services			×	(×)			(×)
		78	Bio-diversity	×	×	×	×	×	×	×
		79	Land use		(×)	(×)	×		(×)	(×)
		80	Development of rural areas	(×)	(×)	×	×	(×)	×	(×)

Total	**14** (18%)	**18** (23%)	**28** (35%)	**28** (35%)	**26** (33%)	**20** (25%)	**26** (33%)
Economic	**8** (19%)	**11** (26%)	**13** (30%)	**17** (40%)	**13** (30%)	**12** (28%)	**13** (30%)
Social	**4** (20%)	**5** (25%)	**11** (55%)	**5** (25%)	**10** (50%)	**5** (25%)	**11** (55%)
Environmental	**2** (12%)	**2** (12%)	**4** (24%)	**6** (35%)	**3** (18%)	**3** (18%)	**2** (12%)

Table 7. Details of indicators not measured by the analysed cluster. For each cluster, indicators not considered by any of the firms in the cluster are identified with an X, those considered only by one firm of the cluster are identified with an (X). At the bottom of the table, additional information is provided about the total number of indicators not measured and the corresponding percentage with respect to the total number of indicators (of the total set and of each single pillar).

3.2 *Analysis by the Country*

3.2.1 *Analysis of the most measured indicators*

The average number of indicators measured both by the German and Italian firms sampled is aligned with the total sample. Similar considerations can be drawn for the minimum number. Regarding the maximum number, German firms present lower values than the total sample, particularly for the economic and the environmental pillars (

				Total sample	Germany	Italy	Medium	Small	Chemical	Metalworking
Economic	**Globalisation and international issues**	5	Business models	●●●	●●●	●●	●●●	●●	●●●	●●●
	Contemporary and contingency issues	9	Growth of economics			●●			●●	
		10	Consumption of resources	●●●	●●●	●●●	●●●	●●	●●●	●●
	Innovative designed products and research	13	Product development costs	●●	●●	●●	●●		●●●	
		14	Product development time		●●				●●	
		16	Regionalised products		●●					
		17	Personalised products	●●	●●	●●	●●		●●	●●
	Reconfigurable manufacturing enterprises	18	Enterprise size			●●				
	Manufacturing strategies	31	Recycling processes	●●	●●●		●●	●●	●●	●●
	Performance evaluation	32	Product costs	●●●	●●●	●●	●●●	●●●	●●	●●
		33	Response (lead time)	●●	●●		●●		●●	
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Social	**Work management**	44	Employment			●●				
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●		●●	●●		●●	
	Societal commitment	54	Healthcare	●●	●●●		●●	●●	●●●	●●
		56	Societal investment				●●		●●	
Environment	**Environment management**	67	Workers implications			●●				
	Use of resources	70	Recyclable wastes		●●					
	Pollution	71	Air pollution			●●	●●		●●●	
		72	Water pollution	●●	●●	●●	●●		●●●	
	Dangerousness	74	Dangerous inputs	●●	●●●		●●		●●●	
		75	Dangerous outputs	●●	●●		●●		●●●	
		76	Dangerous wastes	●●	●●		●●●		●●●	●●

Table 5). The most evaluated indicators in both countries are *consumption of resources, product quality*, and *work conditions* (

				Total sample	Germany	Italy	Medium	Small	Chemical	Metalworking
Economic	**Globalisation and international issues**	5	Business models	●●●	●●●	●●	●●●	●●	●●●	●●●
	Contemporary and contingency issues	9	Growth of economics			●●			●●	
		10	Consumption of resources	●●●	●●●	●●●	●●●	●●	●●●	●●
	Innovative designed products and research	13	Product development costs	●●	●●	●●	●●		●●●	
		14	Product development time		●●				●●	
		16	Regionalised products		●●					
		17	Personalised products	●●	●●	●●	●●		●●	●●
	Reconfigurable manufacturing enterprises	18	Enterprise size			●●				
	Manufacturing strategies	31	Recycling processes	●●	●●●		●●	●●	●●	●●
	Performance evaluation	32	Product costs	●●●	●●●	●●	●●●	●●●	●●	●●
		33	Response (lead time)	●●	●●		●●		●●	
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●

Social	**Work management**	44	Employment			●●				
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●		●●	●●		●●	
	Societal commitment	54	Healthcare	●●	●●●		●●	●●	●●●	●●
		56	Societal investment				●●		●●	
Environment	**Environment management**	67	Workers implications			●●				
	Use of resources	70	Recyclable wastes		●●					
	Pollution	71	Air pollution			●●	●●		●●●	
		72	Water pollution	●●	●●	●●	●●		●●●	
	Dangerousness	74	Dangerous inputs	●●	●●●		●●		●●●	
		75	Dangerous outputs	●●	●●		●●		●●●	
		76	Dangerous wastes	●●	●●		●●●		●●●	●●

Table 5) but interesting differences can be seen, as also pointed out by Winroth et al. (2016).

The German SMEs appear to be interested in measuring indicators related to R&D, budget devoted to safety, dangerous inputs, and recycling process. These findings are in line with previous reports (Germany Trade & Invest, 2018) referring to the high level of safety and R&D investment in Germany, and with Eurostat (2017b) for the high level of waste treated in the country, which may be also partially due to the strategies established by the federal government towards increased efficiency in utilization of resources (Schmidt et al., 2019). Regarding the Italian SMEs, *employment* and *workers implications* are among the most widely measured indicators. This may be justified by the different ways in which Occupational Health and Safety (OHS) issues are legislatively faced by the two countries, with Italy showing a more precautionary attitude (Fulton, 2018).

Looking at the social pillar (

				Total sample	**Medium**	**Small**	**Germany**	**Italy**	**Chemical**	**Metalworking**
Economic	**Globalisation and international issues**	5	Business models		●●●	●●	●●●	●●		●●●
	Contemporary and contingency issues	9	Growth of economics					●●		
		10	Consumption of resources	●●●	●●●	●●	●●●	●●●	●●●	●●
	Innovative designed products and research	13	Product development costs		●●				●●●	
		17	Personalised products		●●					
	Manufacturing strategies	31	Recycling processes				●●●			
	Performance evaluation	32	Product costs	●●●	●●●	●●●	●●●	●●	●●●	●●●
		33	Response (lead time)		●●					
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Social	**Work management**	44	Employment					●●		●
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●	●●	●		●●	●●●	
	Societal commitment	54	Healthcare	●●	●●	●●	●●●	●	●●●	●●
		56	Societal investment				●			

Environment	**Environment management**	64	Environmental budget					•		
		65	Environmental certification					•	•	
		67	Workers implications					••	•	
	Use of resources	69	Recycled water						•	
		70	Recyclable wastes			•	••		•	•
	Pollution	71	Air pollution			•		••	•••	
		72	Water pollution	••	••	•	••	••	•••	•
		73	Land pollution			•		•	•	
	Dangerousness	74	Dangerous inputs	••	••	•	•••	•	•••	•
		75	Dangerous outputs	••	••	•	••	•	•••	•
		76	Dangerous wastes	••	•••	•	••	•	•••	••

Table *6*), sampled German SMEs are more focused on safety investment, and Italian ones on the work management category. This difference might be explained by more deeply analyzing the characteristics of the sample. Indeed, German firms showed more involvement than Italian ones in social initiatives – such as being part of a program to aid refugees (Firm C), donations to an association chosen by employees (Firm G), distance child adoption (Firm H), or benefits for the well-being of employees, e.g. free public transport, course languages, and massages (Firm K). Italian firms seemed more focused on issues related to OHS. In the environment pillar, German SMEs mainly focused on the recycling process, while Italian ones consider *air pollution* and *workers implications* as more relevant. A greater focus on *air pollution* might be due to the more critical situation of air emissions in Italy than in Germany (European Environmental Agency, 2017), leading to stricter control on them; moreover, Italy has recently focused on improving performance in terms of sustainable production and consumption, aspects already met by Germany (Antanasijević et al., 2017). When considering *workers implications*, the greater focus could be related to a stricter system of regulatory sanctions in place in Italy (International Labour Organization, 2017).

3.2.2 Analysis of least measured indicators

Focusing on German SMEs, flexible organization and natural environment categories are considered by just one firm each (

Table 7), respectively Firm M and Firm K. The results can be corroborated with the characteristics of each firm: Firm M is part of a very structured group, while Firm K measures the emission of several types of pollutants rather than just CO_2, as requested by a specific sustainability declaration signed by the firm. Focusing on Italian SMEs, the human rights category is considered only by Firm P, who based its definition of sustainability on the COM(2016) 739 – thus relying on the sustainable development goals taking freedom of association and zero discrimination as targets.

Corroborating the results with previous literature, the country plays a relevant role in the measurement of performance indicators. In particular, economic indicators emerged as the most evaluated ones, confirming Long et al. (2016) but in contrast to Hsu et al. (2017) who investigated similar issues in Taiwan. This result can nevertheless be biased by the stronger efforts of the Republic of China towards an environmental-friendly transformation of Taiwan, confirming the important role of legislation (Winroth et al., 2016).

Regarding the most evaluated indicators, the importance of *consumption of resources* and *product quality* has been confirmed by Amrina et al. (2016), Chang and Cheng (2019), and Hsu et al. (2017). The Italian firms sampled seem to be in contrast with the investigation of Amrina et al. (2016) in Indonesia, regarding the importance of issues related to work management and *air pollution*, rather being aligned with Hsu et al. (2017) and Winroth et al. (2016) concerning the low relevance given to indicators on human rights.

Differences exist in the indicators measured by firms of the same size and sectors operating in different countries. The results appear to be related to differences in the industrial culture and specific national legislation. To conclude, although benchmarking in general terms has been recognized to be of fundamental importance, this nevertheless seems to clash with the specific needs of firms operating in the two countries.

3.3 *Analysis by the size of the firm*

3.3.1 *Analysis of the most measured indicators*

Concerning the average number of indicators measured, the cluster of micro- and small firms presents a lower number than the total sample, confirming previous studies (Garengo et al., 2005). In addition to indicators already mentioned for the total sample - *product cost*, *product quality*, and *work conditions*-, medium-size firms highlighted the relevance of *consumption of resources* (

				Total sample	Germany	Italy	Medium	Small	Chemical	Metalworking
Economic	**Globalisation and international issues**	5	Business models	•••	•••	••	•••	••	•••	•••
	Contemporary and contingency issues	9	Growth of economics			••			••	
		10	Consumption of resources	•••	•••	•••	•••	••	•••	••
	Innovative designed products and research	13	Product development costs	••	••	••	••		•••	
		14	Product development time		••				••	
		16	Regionalised products		••					
		17	Personalised products	••	••	••	••		••	••
	Reconfigurable manufacturing enterprises	18	Enterprise size			••				
	Manufacturing strategies	31	Recycling processes	••	•••		••	••	••	••
	Performance evaluation	32	Product costs	•••	•••	••	•••	•••	••	••
		33	Response (lead time)	••	••		••		••	
		37	Product quality	•••	•••	•••	•••	•••	•••	•••
Social	**Work management**	44	Employment			••				
		45	Work conditions	•••	•••	•••	•••	•••	•••	•••
		48	HR development	••		••	••		••	
	Societal commitment	54	Healthcare	••	•••		••	••	•••	••
		56	Societal investment				••		••	
Environment	**Environment management**	67	Workers implications			••				
	Use of resources	70	Recyclable wastes		••					
	Pollution	71	Air pollution			••	••		•••	
		72	Water pollution	••	••	••	••		•••	
	Dangerousness	74	Dangerous inputs	••	•••		••		•••	
		75	Dangerous outputs	••	••		••		•••	
		76	Dangerous wastes	••	••		•••		•••	••

Table 5): this finding may be related to a need for medium firms to develop deeper product analysis – given the high number of production resources normally in place – beyond the mere product cost measured by smaller firms. Moreover, medium-size firms also appear to have a greater measurement of *business model* and *dangerous wastes*.

Focusing on the economic pillar (

				Total sample	Medium	Small	Germany	Italy	Chemical	Metalworking
Economic	**Globalisation and international issues**	5	Business models		•••	••	•••	••		•••
	Contemporary and contingency issues	9	Growth of economics					••		
		10	Consumption of resources	•••	•••	••	•••	•••	•••	••
	Innovative designed	13	Product		••				•••	

	products and research		development costs							
		17	Personalised products		••					
	Manufacturing strategies	31	Recycling processes				•••			
	Performance evaluation	32	Product costs	•••	•••	•••	•••	••	•••	•••
		33	Response (lead time)		••					
		37	Product quality	•••	•••	•••	•••	•••	•••	•••
Social	**Work management**	44	Employment					••		•
		45	Work conditions	•••	•••	•••	•••	•••	•••	•••
		48	HR development	••	••	•		••	•••	
	Societal commitment	54	Healthcare	••	••	••	•••	•	•••	••
		56	Societal investment				•			
Environment	**Environment management**	64	Environmental budget					•		
		65	Environmental certification					•	•	
		67	Workers implications					••	•	
	Use of resources	69	Recycled water						•	
		70	Recyclable wastes			•	••		•	•
	Pollution	71	Air pollution			•		••	•••	
		72	Water pollution	••	••	•	••	••	•••	•
		73	Land pollution			•		•	•	
	Dangerousness	74	Dangerous inputs	••	••	•	•••	•	•••	•
		75	Dangerous outputs	••	••	•	••	•	•••	•
		76	Dangerous wastes	••	•••	•	••	•	•••	••

Table *6*), the medium-size firms sampled seemed to be interested in evaluating innovation and R&D aspects, confirming the previous findings by Choi and Lee (2017) who found that innovative advantages and heterogeneity of R&D activities augmented with increased size of the firm. Regarding the environmental pillar, medium-size firms place particular focus on dangerousness and water pollution, while the smaller ones did not present any clear pattern.

3.3.2 Analysis of the least measured indicators

Regarding smaller firms, human rights and business practice categories are considered only by Firm J, and environmental management and natural environment ones only by Firm O (

Table 7). In particular, Firm J affirms that sustainability is directly linked to employee wellbeing, constantly involving workers in the discussion, supporting dialogue, and associations; moreover, whereas the firm deems corruption to be a minor issue in Germany, it has measured such performance as it operates in other countries. For Firm O, the abovementioned stronger environmental proactivity helps to corroborate the results.

Focusing on medium-size firms, customer issues are considered only by Firm K, business practices by Firm W, and natural environment by Firm Z (

Table 7). The aforementioned high level of customization of Firm K can help to corroborate these findings. Firm W measures corruption as a mandatory part of the ethical codes signed in accordance with its customers, while Firm Z measures all air pollutant emissions in a very detailed way, but only as a service included in the contract by the external contractor measuring their air pollution.

Focusing on specific indicators, the cluster of medium-sized companies was quite aligned with the total sample, apart from *market opportunity, material handling*, and *complexity analysis*; for small firms, only a few measure *IT, leadership role, managing culture,* and *discrimination* as well as several indicators related to social commitment.

The findings can be discussed in light of previous literature about SMEs that, however, does not distinguish between small and medium-size firms. The relevance of *product cost* and *product quality* is aligned with Chang and Cheng (2019) and Hsu et al. (2017), and the importance of the environmental aspects evaluated in terms of consumption of resources, waste, and pollution is confirmed by Hsu et al. (2017) and Winroth et al. (2016). Regarding social issues, the main role of the work condition is underlined by Hsu et al. (2017), and the low attention given to aspects like discrimination and social commitment has been highlighted by Winroth et al. (2016). Investment in innovation and R&D are significant for Chang and Cheng (2019), while IT importance partially contrasts with Chang and Cheng (2019) and Hsu et al. (2017), not being pointed out by smaller firms.

The overall results are still aligned with Hsu et al. (2017) regarding the main role of environmental indicators. However, as discussed above, this result might be due to the countries investigated. Differences can be appreciated when clustering firms by size, with medium-size firms presenting a higher availability of economic and personnel resources for sustainability performance assessment and evaluation (Borga et al., 2009; Stubblefield Loucks et al., 2010; Veleva et al., 2003). Interestingly, despite the exploratory nature of the investigation, medium-size firms appear to measure a common base of indicators, further enriched with other specific indicators, differently from smaller firms, facing difficulties in understanding the most important indicators to be measured and effort needed for their measurement (Arena and Azzone, 2012; Cahan et al., 2016; Ocampo et al., 2015), thus further highlighting the challenges for effective benchmarking.

3.4 *Analysis by sector*

3.4.1 Analysis of the most measured indicators

Chemical firms presented higher average values of measured indicators than the total sample (

	Total (80 indicators)			***Economic (43 indicators)***			***Social (20 indicators)***			***Environment (17 indicators)***		
	Max	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*
Total Sample	40	5	18.5	23	3	10.1	7	1	3.7	12	0	4.7
Germany	27	5	18	14	3	9.4	7	2	4	8	0	4.6
Italy	40	5	18.9	23	3	10.8	7	1	3.4	12	0	4.8
Medium	33	14	21.5	19	5	11.4	7	2	4.3	8	2	5.8
Small	40	5	14.3	23	3	8.3	6	1	2.8	12	0	3.2
Chemical	40	14	22.33	23	5	11.3	7	2	4.8	12	3	6.3
Metal	33	5	15.1	19	3	9.1	6	1	2.8	8	0	3.3

Table 4), seeming overall to show greater involvement in sustainability performance than their metalworking counterparts. This result is particularly evident when considering indicators related to technology and manufacturing strategy, confirming the focus of the chemical sector on safety and R&D (Vitali, 2012).

Additionally (

				Total sample	**Germany**	**Italy**	**Medium**	**Small**	**Chemical**	**Metalworking**
Economic	**Globalisation and international issues**	5	Business models	●●●	●●●	●●	●●●	●●	●●●	●●●
	Contemporary and contingency issues	9	Growth of economics			●●			●●	
		10	Consumption of resources	●●●	●●●	●●●	●●●	●●	●●●	●●
	Innovative designed products and research	13	Product development costs	●●	●●	●●	●●		●●●	
		14	Product development time		●●				●●	
		16	Regionalised products		●●					
		17	Personalised products	●●	●●	●●	●●		●●	●●
	Reconfigurable manufacturing enterprises	18	Enterprise size			●●				
	Manufacturing strategies	31	Recycling processes	●●	●●●		●●	●●	●●	●●
	Performance evaluation	32	Product costs	●●●	●●●	●●	●●●	●●●	●●	●●
		33	Response (lead time)	●●	●●		●●		●●	
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Social	**Work management**	44	Employment			●●				
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●		●●	●●		●●	
	Societal commitment	54	Healthcare	●●	●●●		●●	●●	●●●	●●

Pillar	Category	#	Item	Total sample	Medium	Small	Germany	Italy	Chemical	Metalworking
		56	Societal investment				••		••	
Environment	Environment management	67	Workers implications			••				
	Use of resources	70	Recyclable wastes		••					
	Pollution	71	Air pollution			••	••		•••	
		72	Water pollution	••	••	••	••		•••	
	Dangerousness	74	Dangerous inputs	••	•••		••		•••	
		75	Dangerous outputs	••	••		••		•••	
		76	Dangerous wastes	••	••		•••		•••	••

Table 5), chemical firms present a larger focus on pollution and dangerousness categories, as recent studies also reveal (Van Schoubroeck et al., 2018). Chemical SMEs appear to be interested in the time needed for product development, as well as in investment in safety and society. Similar considerations can be drawn by looking at single pillars (

Pillar	Category	#	Item	Total sample	Medium	Small	Germany	Italy	Chemical	Metalworking
Economic	Globalisation and international issues	5	Business models		•••	••	•••	••		•••
	Contemporary and contingency issues	9	Growth of economics					••		
		10	Consumption of resources	•••	•••	••	•••	•••	•••	••
	Innovative designed products and research	13	Product development costs		••				•••	
		17	Personalised products		••					
	Manufacturing strategies	31	Recycling processes				•••			
	Performance evaluation	32	Product costs	•••	•••	•••	•••	••	•••	•••
		33	Response (lead time)		••					
		37	Product quality	•••	•••	•••	•••	•••	•••	•••
Social	Work management	44	Employment					••		•
		45	Work conditions	•••	•••	•••	•••	•••	•••	•••
		48	HR development	••	••	•		••	•••	
	Societal commitment	54	Healthcare	••	••	••	•••	•	•••	••
		56	Societal investment				•			
Environment	Environment management	64	Environmental budget					•		
		65	Environmental certification					•	•	
		67	Workers implications					••	•	
	Use of resources	69	Recycled water						•	
		70	Recyclable wastes			•	••		•	•
	Pollution	71	Air pollution			•		••	•••	
		72	Water pollution	••	••	•	••	••	•••	•
		73	Land pollution			•		•	•	
	Dangerousness	74	Dangerous inputs	••	••	•	•••	•	•••	•
		75	Dangerous outputs	••	••	•	••	•	•••	•
		76	Dangerous wastes	••	•••	•	••	•	•••	••

Table 6), with particular attention for *consumption of resources* and *product development cost* (not so relevant for the metalworking ones) for the economic pillar, categories related to work management and society for the social pillar, and pollution, dangerousness of inputs and outputs, recycling and workers implication for the environment one. These results have been reported in

Colombo (2014) and Verband der Chemischen Industrie (2012), and acknowledged by previous studies (European Commission, 2009).

On the other hand, even if general metalworking SMEs measure fewer indicators, *product quality* and *product cost* were relevant for the economic pillar, *work conditions* for the social one, and dangerous wastes for the environment one (

				Total sample	Germany	Italy	Medium	Small	Chemical	Metalworking
Economic	**Globalisation and international issues**	5	Business models	●●●	●●●	●●	●●●	●●	●●●	●●●
	Contemporary and contingency issues	9	Growth of economics			●●			●●	
		10	Consumption of resources	●●●	●●●	●●●	●●●	●●	●●●	●●
	Innovative designed products and research	13	Product development costs	●●	●●	●●	●●		●●●	
		14	Product development time		●●				●●	
		16	Regionalised products		●●					
		17	Personalised products	●●	●●	●●	●●		●●	●●
	Reconfigurable manufacturing enterprises	18	Enterprise size			●●				
	Manufacturing strategies	31	Recycling processes	●●	●●●		●●	●●	●●	●●
	Performance evaluation	32	Product costs	●●●	●●●	●●	●●●	●●●	●●	●●
		33	Response (lead time)	●●	●●		●●		●●	
		37	Product quality	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Social	**Work management**	44	Employment			●●				
		45	Work conditions	●●●	●●●	●●●	●●●	●●●	●●●	●●●
		48	HR development	●●		●●	●●		●●	
	Societal commitment	54	Healthcare	●●	●●●		●●	●●	●●●	●●
		56	Societal investment				●●		●●	
Environment	**Environment management**	67	Workers implications			●●				
	Use of resources	70	Recyclable wastes		●●					
	Pollution	71	Air pollution			●●	●●		●●●	
		72	Water pollution	●●	●●	●●	●●		●●●	
	Dangerousness	74	Dangerous inputs	●●	●●●		●●		●●●	
		75	Dangerous outputs	●●	●●		●●		●●●	
		76	Dangerous wastes	●●	●●		●●●		●●●	●●

Table *5*), in line with previous research, given that the metalworking sector generates more hazardous wastes than the chemical one (European Commission, 2009).

3.4.2 Analysis of the least measured indicators

Considering the least measured indicators in the chemical sector (

Table *7*), business practices are measured only by one firm (J). In the metalworking sector, human rights and customer issues categories are not considered by any firm, and business practices and natural environment are considered only by Firm W and Firm Z, respectively, perhaps due to the specific aforementioned characteristics of the firms (as detailed in Section 3.3).

The relevance of the economic indicator is in line with the findings of studies in other sectors, such as automotive (Salvado et al., 2015) and steel (Long et al., 2016; Singh et al., 2007). The importance of environment protection, such as pollution and dangerousness of material and waste, is in line with Long et al. (2016), but in contrast with Amrina et al. (2016) for the cement industry. Another contrast with Amrina et al. (2016) can be observed by referring to the importance given by firms to issues related to work management and working conditions. The results are, however, confirmed by Salvado et al. (2015), regarding the low relevance of human rights issues.

From these results, firms do have different needs and may focus on the measurement of specific indicators. In particular, similar to the findings for the country and size, the sector also plays a relevant role when selecting the indicators adopted, further highlighting the difficulties in combining the need for benchmarking with the specific needs of firms characterised by different contextual factors.

3.5 Analysis of indicators by multiple contextual factors

The results were also analysed by clustering firms according to multiple contextual factors such as country, size, and sector (Figure 1).

Italian and German SMEs measure almost the same number of indicators for the total set and for each pillar, with reference to all the clusters considered. However, a slight difference can be observed, since both small and medium-size Italian firms measure indicators more than the corresponding German ones. Furthermore, for all the clusters considered, the largest share of measured indicators is economic, followed by environmental and social ones.

Regarding the least measured indicators (Figure 2), the analysis allowed identification of commonalities and differences between the clusters. Italian SMEs presented almost the same tendency in all the different clusters, both for the total set of indicators and for single pillars, while smaller German firms and metalworking ones appeared to measure fewer indicators than German medium-size and chemical firms. This finding may be partially related to the considerable number of indicators that were not measured, either social and environmental (by smaller firms) or economic (by metalworking ones). Firms appear to have the same trend in the two countries when analysed according to size (small vs medium firms) and sector (metalworking vs chemical).

Figure 1. Measured indicators. Number (average) of indicators measured according to a combination of the different contextual factors, i.e. country with size and sector.

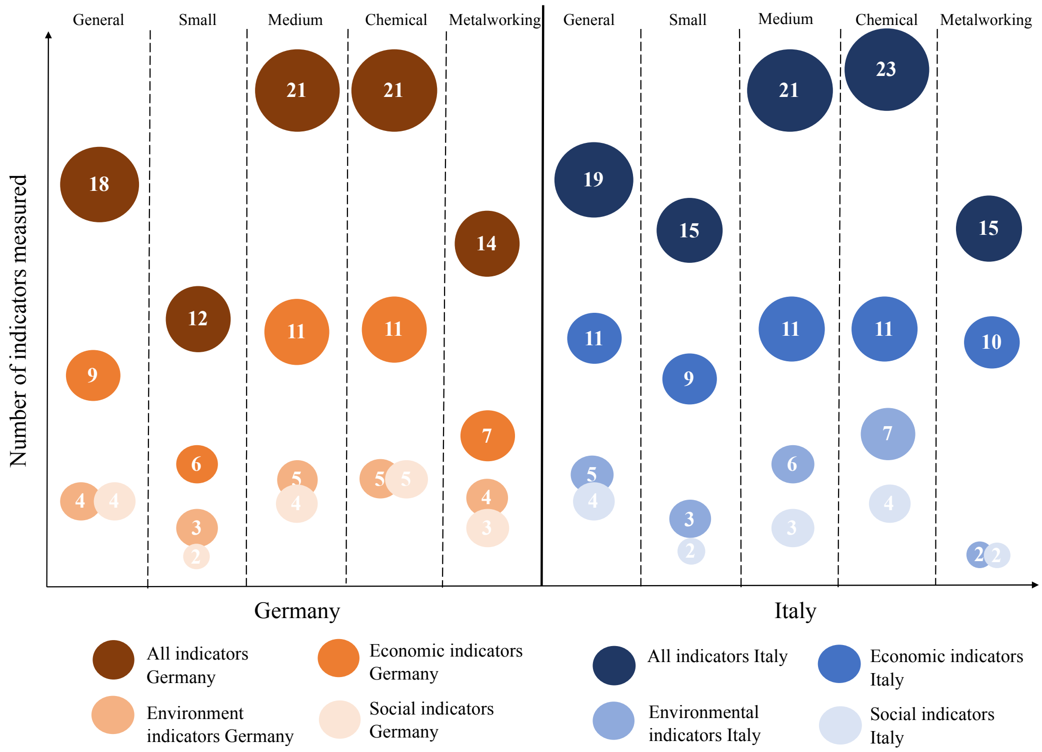
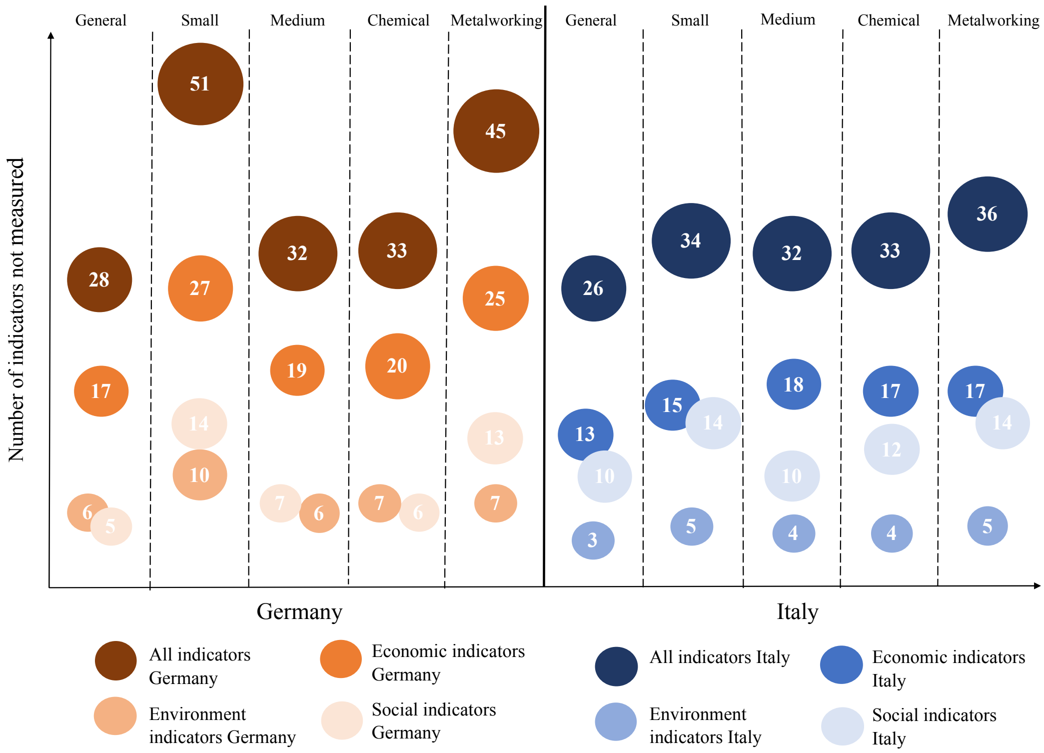


Figure 2. Indicators not measured. Number (average) of indicators not measured according to a combination of the different contextual factors, i.e. country with size and sector.



3.6 Additional considerations about firm's perspective on sustainability and presence of certifications

Additional analyses were conducted trying to understand whether the perception and management of sustainability by firms – based on interviewees' judgment over sustainability definition and performance affected – can impact measurement of sustainability indicators (

irm	***Person responsible***	***Definition provided***	***Pillars considered*** *Eco*	*Soc*	*Env*	***Impact of sustainability on firm performance***
A	Management, technical director, suggestions from employees	As environmental sustainability and creation of value	•		•	Any
B	Quality manager	Mainly related to energy and gas consumption; it has not properly faced social aspects yet.			•	Positive effect on environment and employees' wellbeing
C	No responsible. Management and individual employees	Mainly related to waste, recycling and energy consumption. Social pillar seen as training and help to community.		•	•	Any
D	Management	Related to reduction, separation of waste, increase in recycling.			•	No direct impact on value creation
E	Management	Environmental aspects only in terms of compliance with regulation, reduction of resources' consumption implemented only for economic reason. Social aspects related to improve working condition and avoid use of dangerous materials.	•	•	•	Positive effect on employees' wellbeing
F	Management	Important but not a priority because of orders fluctuation.			•	Any
G	No specific manager, more than one person involved	Importance of all the three pillars; necessary for building a long -term relationship with customers and suppliers, employees' wellbeing, social commitment, reduction of resource consumption.	•	•	•	Positive effect on overall firm performance
H	Management	Important for optimize machines' consumption, remove hazardous material (good for employees and environment), and evaluate possible methods for reusing materials.	•	•	•	Positive effect on economic and safety performance

I	No specific manager, all employees involved	Impact on production in terms of material that can be used, and on safety in terms of training and standards.		●	●	Any
J	Management	Long-term perspective.	●	●	●	Positive effect on workers' wellbeing
K	R&D manager, management	Declaration with environmental and social purposes.		●	●	It leads to technical disadvantages and ethical advantages. Not sure of positive effects on final customers
L	No specific manager, all employees involved	Social commitment in the long term.	●	●	●	Positive impact on employees' wellbeing
M	Management (plus a manager for each certification)	Difficult to be integrated into production; mainly related to customers' satisfaction and avoid the use of dangerous materials.		●	●	Any
N	No manager	Mainly seen as elimination of dangerous substances and not sustainable material (e.g. palm oil). Economic sustainability related to relationship with customers, social one focused on employees' wellbeing. Sustainability not considered in the decision-making process.	●	●	●	Sustainability as a philosophical concept. No economic advantages, but disadvantages
O	Safety manager, environment manager, ecology manager	Firm considers itself as really green oriented. Efforts directed towards reducing air and water pollution, waste, noise.	●	●	●	No advantages but the potentiality of advantage
P	Technical director, collaborators	Mainly focused on sustainability, in particular on goals related to sustainable development goals number 9 and 15.	●	●	●	Positive effect on overall firm performance
Q	Health safety and environment manager	Aligned with the triple bottom line's definition.	●	●	●	Positive effect on overall firm performance
R	Safety manager, external safety consultant, external energy consultant	Production process that must consider external factors (environment and people), and be able to balance production and emissions (pollution, waste).	●	●	●	Advantages since world is moving towards sustainability. Positive effect on firm's image
S	No specific manager. There is a safety manager	Relative concept to be contextualized in the single project undertaken.	●	●	●	Environmental issues and concerns as marketing instruments or related to economic reasons
T	CEO	Reduction of raw material use, and certified products and suppliers. However, firm only considers sustainability in terms of safety due to legislation.		●	●	Positive effect on overall firm performance
U	Safety manager, quality manager	Related to profit and firm activity's maintenance. Sustainability within firm mainly related to safety.	●	●	●	Positive effect on overall firm performance
V	External energy manager	Safety and environment considered as distinct aspects. Proactive firm, above all regarding environment issues: external energy manager is seen as an opportunity, not a cost.	●	●	●	Positive internal (employees' safety) and external (market) effect
W	CEO, Health safety and environment manager	Firm's ability to confirm its results in the long term.	●	●	●	Positive effect on overall firm performance
X	CEO	Running the business respecting the environment, but firm mainly focused on economic aspects.	●		●	Any
Y	Safety manager, quality manager	Reduction in resources' use and pollution emission, protection of human rights.		●	●	Awareness of sustainability as possible advantages on overall firm performance, but not always considered in decision making process
Z	Management	Ability to continuously adapt to changes.	●	●	●	Economic internal benefits and community external benefits

Table 8).

All firms include the environmental pillar in their definition of sustainability, while 15 of 26 (mainly Italian and chemical) considered all three pillars. Those firms appear to be aligned with the total sample in terms of number of indicators evaluated, but firms considering only the environmental pillar seem to measure more indicators regarding the environmental area – as expected - but also the economic ones. However, for all the clusters evaluated, the economic indicators are always considered the most important ones, far above social aspects (even when included), as previously noted by Charmondusit et al. (2014), Neri et al. (2017) and Van Schoubroeck et al. (2018), who related this to the subjective character of social indicators.

Lastly, considerations regarding the presence of a specific figure in the firm responsible for sustainability issues were encompassed. Only a few firms (5) have a specific person in charge – four Italian firms and four chemical firms - but the vast majority (15) do not have a specific person responsible, with sustainability mainly overseen by top management. From this preliminary analysis, the presence of a sustainability manager does not seem to clearly lead to a higher number of indicators measured. Nevertheless, further research is needed to explore this factor in-depth, as previous analyses deemed noted that the characteristics of managers are strictly related to the way performance is evaluated, being influenced by individual choices, motives, and values (Fuente et al., 2017).

Considering the presence of certifications (

irm	Country	Sector	Employees	Size	Certification	Person interviewed
A	Germany	Metalwork	160	Medium	ISO 9001	Safety manager
B	Germany	Metalwork	35	Small	ISO 9001	Production manager
C	Germany	Metalwork	50	Medium	-	Human Resource manager
D	Germany	Metalwork	4	Micro	-	CEO
E	Germany	Metalwork	8	Micro	ISO 9001	Administrative employee
F	Germany	Metalwork	5	Micro	-	Sales manager
G	Germany	Metalwork	148	Medium	ISO 9001; ISO 14001	CEO
H	Germany	Chemical	50	Medium	ISO 9001	CEO
I	Germany	Chemical	50	Medium	ISO 9001	Production manager
J	Germany	Chemical	35	Small	ISO 9001; ISO 50001	Business Development manager
K	Germany	Chemical	240	Medium	ISO 9001	Product manager
L	Germany	Chemical	75	Medium	ISO 9001; ISO 14001; ISO 50001	CEO
M	Germany	Chemical	250	Medium	ISO 9001; ISO 14001; ISO 50001	Sales manager
N	Italy	Chemical	57	Medium	ISO 9001	Sales manager; safety manager
O	Italy	Chemical	4	Micro	ISO 9001; ISO 14001; OHSAS 18001	CEO; HSE manager
P	Italy	Chemical	60	Medium	ISO 9001; ISO 14001; OHSAS 18001	Technical director
Q	Italy	Chemical	250	Medium	ISO 9001; ISO 14001; OHSAS 18001	HSE manager
R	Italy	Chemical	49	Small	ISO 9001	CEO
S	Italy	Chemical	65	Medium	ISO 9001	CEO
T	Italy	Metalwork	3	Micro	-	CEO
U	Italy	Metalwork	9	Micro	ISO 9001	CEO
V	Italy	Metalwork	32	Small	-	CEO
W	Italy	Metalwork	55	Medium	ISO 9001; ISO 14001; OHSAS 18001	CEO
X	Italy	Metalwork	15	Small	-	CEO
Y	Italy	Metalwork	50	Medium	ISO 9001	CEO
Z	Italy	Metalwork	53	Medium	ISO 9001	CEO; Purchasing and logistics manager

Table *3*), possibly affecting the number of sustainability indicators adopted, 6 of 26 firms hold at least three certifications, but 20 firms hold at least one (

irm	Country	Sector	Employees	Size	Certification	Person interviewed
A	Germany	Metalwork	160	Medium	ISO 9001	Safety manager

B	Germany	Metalwork	35	Small	ISO 9001	Production manager
C	Germany	Metalwork	50	Medium	-	Human Resource manager
D	Germany	Metalwork	4	Micro	-	CEO
E	Germany	Metalwork	8	Micro	ISO 9001	Administrative employee
F	Germany	Metalwork	5	Micro	-	Sales manager
G	Germany	Metalwork	148	Medium	ISO 9001; ISO 14001	CEO
H	Germany	Chemical	50	Medium	ISO 9001	CEO
I	Germany	Chemical	50	Medium	ISO 9001	Production manager
J	Germany	Chemical	35	Small	ISO 9001; ISO 50001	Business Development manager
K	Germany	Chemical	240	Medium	ISO 9001	Product manager
L	Germany	Chemical	75	Medium	ISO 9001; ISO 14001; ISO 50001	CEO
M	Germany	Chemical	250	Medium	ISO 9001; ISO 14001; ISO 50001	Sales manager
N	Italy	Chemical	57	Medium	ISO 9001	Sales manager; safety manager
O	Italy	Chemical	4	Micro	ISO 9001; ISO 14001; OHSAS 18001	CEO; HSE manager
P	Italy	Chemical	60	Medium	ISO 9001; ISO 14001; OHSAS 18001	Technical director
Q	Italy	Chemical	250	Medium	ISO 9001; ISO 14001; OHSAS 18001	HSE manager
R	Italy	Chemical	49	Small	ISO 9001	CEO
S	Italy	Chemical	65	Medium	ISO 9001	CEO
T	Italy	Metalwork	3	Micro	-	CEO
U	Italy	Metalwork	9	Micro	ISO 9001	CEO
V	Italy	Metalwork	32	Small	-	CEO
W	Italy	Metalwork	55	Medium	ISO 9001; ISO 14001; OHSAS 18001	CEO
X	Italy	Metalwork	15	Small	-	CEO
Y	Italy	Metalwork	50	Medium	ISO 9001	CEO
Z	Italy	Metalwork	53	Medium	ISO 9001	CEO; Purchasing and logistics manager

Table *3*). Interestingly, ISO9001 and ISO14001 certified firms are equally distributed between the two countries, although all four firms certified ISO50001 are located in Germany, and the four certified OHSAS180001 are all located in Italy, suggesting that each country may push for a certain type of certification. Regarding the sector, chemical firms hold more certifications than metalworking ones, also for historical reasons - e.g. in Italy the 1976 chemical plant accident in Seveso had a large impact (Colombo, 2014). These findings seem to be sound and can be confirmed by International Organization for Standardization (2017). The same can be also noted for size, with medium-size firms holding more certifications than small ones, in line with Hillary (2004), Jamieson et al. (2012), and Martín-Peña et al., 2014). From this preliminary analysis, firms holding more certifications seem to adopt more indicators, confirming previous research (Marshall and Brown, 2003) but, given the exploratory nature and the small sample, further research is necessary.

Firm	***Person responsible***	***Definition provided***	***Pillars considered***			***Impact of sustainability on firm performance***
			Eco	***Soc***	***Env***	
A	Management, technical director, suggestions from employees	As environmental sustainability and creation of value	●		●	Any
B	Quality manager	Mainly related to energy and gas consumption; it has not properly faced social aspects yet.			●	Positive effect on environment and employees' wellbeing
C	No responsible. Management and individual employees	Mainly related to waste, recycling and energy consumption. Social pillar seen as training and help to community.		●	●	Any
D	Management	Related to reduction, separation of waste, increase in recycling.			●	No direct impact on value creation
E	Management	Environmental aspects only in terms of compliance with regulation, reduction of resources' consumption implemented	●	●	●	Positive effect on employees' wellbeing

		only for economic reason. Social aspects related to improve working condition and avoid use of dangerous materials.				
F	Management	Important but not a priority because of orders fluctuation.			•	Any
G	No specific manager, more than one person involved	Importance of all the three pillars; necessary for building a long -term relationship with customers and suppliers, employees' wellbeing, social commitment, reduction of resource consumption.	•	•	•	Positive effect on overall firm performance
H	Management	Important for optimize machines' consumption, remove hazardous material (good for employees and environment), and evaluate possible methods for reusing materials.	•	•	•	Positive effect on economic and safety performance
I	No specific manager, all employees involved	Impact on production in terms of material that can be used, and on safety in terms of training and standards.		•	•	Any
J	Management	Long-term perspective.	•	•	•	Positive effect on workers' wellbeing
K	R&D manager, management	Declaration with environmental and social purposes.		•	•	It leads to technical disadvantages and ethical advantages. Not sure of positive effects on final customers
L	No specific manager, all employees involved	Social commitment in the long term.	•	•	•	Positive impact on employees' wellbeing
M	Management (plus a manager for each certification)	Difficult to be integrated into production; mainly related to customers' satisfaction and avoid the use of dangerous materials.		•	•	Any
N	No manager	Mainly seen as elimination of dangerous substances and not sustainable material (e.g. palm oil). Economic sustainability related to relationship with customers, social one focused on employees' wellbeing. Sustainability not considered in the decision-making process.	•	•	•	Sustainability as a philosophical concept. No economic advantages, but disadvantages
O	Safety manager, environment manager, ecology manager	Firm considers itself as really green oriented. Efforts directed towards reducing air and water pollution, waste, noise.	•	•	•	No advantages but the potentiality of advantage
P	Technical director, collaborators	Mainly focused on sustainability, in particular on goals related to sustainable development goals number 9 and 15.	•	•	•	Positive effect on overall firm performance
Q	Health safety and environment manager	Aligned with the triple bottom line's definition.	•	•	•	Positive effect on overall firm performance
R	Safety manager, external safety consultant, external energy consultant	Production process that must consider external factors (environment and people), and be able to balance production and emissions (pollution, waste).	•	•	•	Advantages since world is moving towards sustainability. Positive effect on firm's image
S	No specific manager. There is a safety manager	Relative concept to be contextualized in the single project undertaken.	•	•	•	Environmental issues and concerns as marketing instruments or related to economic reasons
T	CEO	Reduction of raw material use, and certified products and suppliers. However, firm only considers sustainability in terms of safety due to legislation.		•	•	Positive effect on overall firm performance
U	Safety manager, quality manager	Related to profit and firm activity's maintenance. Sustainability within firm mainly related to safety.	•	•	•	Positive effect on overall firm performance
V	External energy manager	Safety and environment considered as distinct aspects. Proactive firm, above all regarding environment issues: external energy manager is seen as an opportunity, not a cost.	•	•	•	Positive internal (employees' safety) and external (market) effect
W	CEO, Health safety and environment manager	Firm's ability to confirm its results in the long term.	•	•	•	Positive effect on overall firm performance
X	CEO	Running the business respecting the environment, but firm mainly focused on economic aspects.	•		•	Any
Y	Safety manager, quality manager	Reduction in resources' use and pollution emission, protection of human rights.		•	•	Awareness of sustainability as possible advantages on overall firm performance, but not always considered in decision making process
Z	Management	Ability to continuously adapt to changes.	•	•	•	Economic internal benefits and community external benefits

Table 8. Firms' perspectives on sustainability. For each firm, the following are reported: person(s) responsible of sustainability, definition of sustainability provided, re-categorization of the definitions according to TBL's pillars, and perceived impact of sustainability on the firm's performance.

4 Discussion

This exploratory investigation examined how sustainability is measured in industrial firms and identified several important open issues.

First, the need for *context-tailored models* for evaluation of sustainability performance, in contrast with the need for a common and standardized model that would allow and foster benchmarking activities. As revealed from our exploratory investigation, and also confirmed by recent literature (Winroth et al., 2016), firms characterized by different contextual factors focus on different indicators. These differences seem to call for further research about the development of a unique framework for measurement of sustainability indicators. This framework would allow a proper comparison among different contexts - thus beyond the characteristics of each model (Azapagic and Perdan, 2000; Christofi et al., 2012) – still considering the specific needs of different firms, in terms of types, level of detail, and number of indicators.

Second, the *number of indicators* that should be included in a model. From our investigation, a considerable variance between the number of indicators measured by firms with different characteristics emerged empirically. Moreover, none of the sampled SMEs measured more than 40 indicators: therefore, it seems reasonable to think that, regardless the exploratory nature of the findings, the number of indicators proposed by Garbie (2014) should be revised.

Third, the *level of detail* of indicators. It can be perceived that a greater level of detail than that proposed is sometimes perceived as necessary by the firms sampled. A few examples from the investigation could offer suggestions for further research:

- Consumption of resources: some firms clearly distinguished between consumption of energy, material, raw material, water, natural gas, etc.;
- Air pollution: some firms distinguished among different pollutants, e.g., COD or nitrogen;
- Work conditions: some of the firms collect additional details for this indicator, specifically pointing out the need to measure days of illness, absenteeism, and employee involvement.

The need for a greater level of detail seems to be driven by the characteristics of the individual firm. Interestingly, chemical firms were consistently asking for more detailed indicators – in particular, regarding consumption of resources, as recently shown (Schmidt et al., 2019; Van Schoubroeck et al., 2018). This result seems to corroborate that different sectors need specific indicators to cover specific aspects, as noted by previous models of indicators specifically developed for the mining sector (Azapagic, 2004), palm oil production (Lim and Biswas, 2015), and sugar production (Sureeyatanapas et al., 2015).

Fourth, *categorization of indicators* into the different sustainability pillars. When interviewees were asked to mention indicators measured with reference to the three sustainability pillars, in some cases their attribution was different from that of Garbie (2014). A few examples from the exploratory investigation could offer valuable suggestions for further research:

- Consumption of resources: a large set of literature attributes this indicator to the eco-efficiency area (Alves and Dumke De Medeiros, 2015; Côté et al., 2006; Gimenez and Tachizawa, 2012). Interestingly, some firms were ascribing this indicator to the economic or environmental pillar;
- Customer-related aspects: firms equally related these to the economic and social pillars. Nevertheless, some authors consider them under the economic pillar (Krajnc and Glavič, 2003; Winroth et al., 2016), and others under the social pillar (Engida et al., 2018; Jiang et al., 2018), underlying the need to include them in a socio-economic area, which has received less attention from scholars to date.

Additionally, firms were particularly interested in evaluating more detailed aspects related to employees and productivity (e.g., productivity of the single employee), underlining the importance of linking these two concepts, as previously discussed by Das et al. (2008) and Pagell et al. (2014).

Fifth, *modelling of the multiple intersections* of sustainability pillars, as highlighted by Sikdar (2003). Contributions still tend to address sustainability through compartmentalisation, with separation of the three sustainability pillars (Lozano and Huisingh, 2011), although it has been recognized that understanding if and how the different indicators are interrelated can help firms in achieving sustainability (Amrina et al., 2016; Helleno et al., 2017; Searcy et al., 2005). Some contributions (Azapagic, 2004) tried to model the intersections between two different pillars along with single pillars or just within the intersections (Lodhia and Martin, 2014), but are referred to a specific industry (i.e. mining). Therefore, they neither appear to be scalable to an important contextual factor as firm size nor, above all, address the intersection of the three pillars.

Sixth, *how to balance measured indicators within the TBL*. The exploratory investigation revealed the primary role played by evaluation of the economic pillar over the other two, whereas the social pillar is considering mainly in terms of compliance with legislation, and the environmental one for a focus on the resource used – thus reflecting economic aspects. In this regard, further efforts should be paid towards policy-making at the European level, increasing awareness towards sustainability issues by understanding the crucial role of the environmental and social pillars in light of the goals of the UN on sustainable development. However, this primary role attributed by the firms could also be biased by the predominant presence of economic indicators in the theoretical model for evaluation of sustainability performance, as noted by recent studies (Van Schoubroeck et al., 2018).

5 Concluding remarks and suggestions for further research

This research, based on firms operating in two major European manufacturing economies, offers interesting empirical insights and a valuable contribution to the discussion about measuring and promoting sustainability in industrial activities at the theoretical, empirical, and managerial levels. The findings provide further confirmation that some aspects of measuring sustainability are missing still in the EU manufacturing sector (Johnson and Schaltegger, 2016) and SMEs, in particular, face difficulties in properly gauging sustainability performance (Arena and Azzone, 2012). Some limitations in the research method can be underlined, offering the opportunity to enhance the present efforts. The interviewees in the different firms were not in exactly the same leadership position and the results obtained from explorative research do not provide an analytical generalizability of the results. Further research should enlarge the sample, allowing statistical generalizability and more thoroughly investigating common patterns related to different features - more sectors and countries, and others like energy intensity, types of processes, and organizational structure. Further investigations in larger samples are also necessary to draw statistically relevant considerations on the relationship between the number and type of indicators measured and the way sustainability is perceived and managed by firms, which is out of the scope of the present study.

From a theoretical perspective, the study provides interesting information to further stimulate debate in the academic literature. In fact, despite highlighting the need for a generic model of sustainability indicators, easily integrated with specific indicators (Harik et al., 2015), further efforts should be given since such a model has not yet been developed (Medini et al., 2015). Further research should focus on the development of a new framework for holistic evaluation of sustainability performance in industrial firms, stemming from the results of the present study. A framework focusing on indicators of real interest for firms (Delai and Takahashi, 2011) is needed, allowing benchmarking but simultaneously being ascribable to different contexts in terms of contextual factors and different degrees to which a firm wants or can commit to sustainability – as related to different levels of resource availability and different competencies toward sustainability. These aspects are in turn related to the level of detail according to the firms' needs, and to the identification of a compromise with a reasonable number of indicators that can be handled by a single firm. Indeed, suggestions from previous authors (Krajnc and Glavič, 2005; Nordheim and Barrasso, 2007) should be followed, considering that a relevant number of indicators may be difficult to manage by a firm with limited resources, like SMEs (Borga et al., 2009; Stubblefield Loucks et al., 2010; Veleva et al., 2003), and may, in general, distract from pursuing a focused strategy (Epstein and Widener, 2010), negatively affecting the decision-making process (Medini et al., 2015). The selection of the most adequate indicators is thus quite challenging (Chee Tahir and Darton, 2010), and the literature to date is based only on the perspective of external stakeholders (Basu and Kumar, 2004; Naderi et al., 2017) or scholars (Feil et al., 2015).

Going beyond the firm's boundaries (Salvado et al., 2015; Seuring and Müller, 2008), the present work may also be a valuable basis for the development of a set of industrial sustainability indicators for the supply chain, considering that competitiveness is increasingly played at a system level

(Massaroni et al., 2015; Shibin et al., 2017b). The simultaneous application of the two models of performance indicators in a supply chain would help to more clearly understand the impact of adoption of an industrial sustainability measure (Trianni et al., 2017) at the single firm and supply chain levels.

Broadening the scope of the research, it would be interesting to evaluate and understand the problems faced by persons living near the investigated firms with reference to sustainability, thus perfectly inserting the firm within the context in which it operates.

From a practical perspective, the study provides additional knowledge about the critical areas of sustainability that have neither been measured nor addressed by companies. The research also offers a valuable contribution to policymakers for the development of proper actions aimed at increased awareness about this crucial issue. In particular, an application in a specific sector and geographical context can help in better understanding the problems faced by SMEs and the role of government and regulation. This is even more urgent when considering UN sustainability development goals that give equal focus to both environmental and social issues (United Nations, 2015), and therefore the need for companies to have in place a set of sustainability indicators that adequately cover the three sustainability pillars.

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References

Afgan, N.H., Carvalho, M.G., Hovanov, N. V., 2000. Energy system assessment with sustainability indicators. Energy Policy 28, 603–612. https://doi.org/10.1080/14640749308401071

Ahmad, S., Wong, K.Y., 2018. Sustainability assessment in the manufacturing industry: a review of recent studies. Benchmarking An Int. J. 25, 3162–3179. https://doi.org/https://doi.org/10.1108/BIJ-08-2017-0214

Alves, J.L.S., Dumke De Medeiros, D., 2015. Eco-efficiency in micro-enterprises and small firms: a case study in the automotive services sector. J. Clean. Prod. 108, 595–602. https://doi.org/10.1016/j.jclepro.2015.07.063

Amindoust, A., Ahmed, S., Saghafinia, A., Bahreininejad, A., 2012. Sustainable supplier selection:

a ranking model based on fuzzy inference system. Appl. Soft Comput. J. 12, 1668–1677. https://doi.org/10.1016/j.asoc.2012.01.023
Amrina, E., Ramadhani, C., Vilsi, A.L., 2016. A fuzzy multi criteria approach for sustainable manufacturing evaluation in cement Industry. Procedia CIRP 40, 620–625. https://doi.org/10.1016/j.procir.2016.01.144
Amrina, E., Yusof, S.M.M., 2011. Key performance indicators for sustainable manufacturing evaluation in automotive companies, in: IEEE International Conference on Industrial Engineering and Engineering Management. pp. 1093–1097. https://doi.org/10.1109/IEEM.2011.6118084
Antanasijević, D., Pocajt, V., Ristić, M., Perić-Grujić, A., 2017. A differential multi-criteria analysis for the assessment of sustainability performance of European countries: beyond country ranking. J. Clean. Prod. 165, 213–220. https://doi.org/10.1016/j.jclepro.2017.07.131
Apaydin, M., Bayraktar, E., Hossary, M., 2018. Achieving economic and social sustainability through hyperconnectivity: a cross- country comparison. Benchmarking An Int. J. 25. https://doi.org/https://doi.org/10.1108/BIJ-07-2017-0205
Arena, M., Azzone, G., 2012. A process-based operational framework for sustainability reporting in SMEs. J. Small Bus. Enterp. Dev. 19, 669–686. https://doi.org/10.1108/14626001211277460
Armstrong, J.L., Garretson, I.C., Haapala, K.R., 2014. Gate-to-gate sustainability assessment for small-scal manufacturing businesses: caddisfly jewelry production, in: International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. ASME. https://doi.org/doi:10.1115/DETC2014-34559
Azadnia, A.H., Saman, M.Z.M., Wong, K.Y., Ghadimi, P., Zakuan, N., 2013. Sustainable suppliers selection based on self-organizing map neural network and multi criteria decision making approaches. Procedia - Soc. Behav. Sci. 65, 879–884. https://doi.org/10.1016/j.sbspro.2012.11.214
Azapagic, A., 2004. Developing a framework for sustainable development indicators for the mining and minerals industry. J. Clean. Prod. 12, 639–662. https://doi.org/10.1016/S0959-6526(03)00075-1
Azapagic, A., Perdan, S., 2000. Indicators of sustainable development for industry: a general framework. Trans IChemE 78, 243–261. https://doi.org/10.1205/095758200530763
Baškarada, S., 2014. Qualitative case study guidelines. Qual. Rep. 19, 1–25. https://doi.org/10.7748/nr2013.05.20.5.28.e327
Basu, A.J., Kumar, U., 2004. Innovation and technology driven sustainability performance management framework (ITSPM) for the mining and minerals sector. Int. J. Surf. Mining, Reclam. Environ. 18, 135–149. https://doi.org/10.1080/13895260412331295394
Bauman, Z., 2003. Liquid love: on the fragilty of human bonds. Polity, Cambridge, UK.
Beverland, M., Lindgreen, A., 2010. What makes a good case study? A positivist review of qualitative case research published in Industrial Marketing Management, 1971-2006. Ind. Mark. Manag. 39, 56–63. https://doi.org/10.1016/j.indmarman.2008.09.005
Borga, F., Citterio, A., Noci, G., Pizzurno, E., 2009. Sustainability report in small enterprises: case studies in Italian furniture companies. Bus. Strateg. Environ. 18, 162–176. https://doi.org/10.1002/bse.561
Büyüközkan, G., Cįfçi, G., 2013. An integrated QFD framework with multiple formatted and incomplete preferences: a sustainable supply chain application. Appl. Soft Comput. J. 13, 3931–3941. https://doi.org/10.1016/j.asoc.2013.03.014
Cagno, E., Neri, A., Trianni, A., 2018. Broadening to sustainability the perspective of industrial decision-makers on the energy efficiency measures adoption: some empirical evidence. Energy Effic. 11, 1193–1210. https://doi.org/10.1007/s12053-018-9621-0
Cahan, S.F., De Villiers, C., Jeter, D.C., Naiker, V., Van Staden, C.J., 2016. Are CSR disclosures value relevant? Cross-country evidence. Eur. Account. Rev. 25, 579–611. https://doi.org/10.1080/09638180.2015.1064009

Carter, C.R., Rogers, D.S., 2008. A framework of sustainable supply chain management: moving toward new theory. Int. J. Phys. Distrib. Logist. Manag. 38, 360–387. https://doi.org/10.1108/09600030810882816
CEFIC, 2018. Landscape of the European Chemical Industry 2018 [WWW Document]. URL https://www.chemlandscape.cefic.org/ (accessed 5.6.19).
Chang, A.Y., Cheng, Y.T., 2019. Analysis model of the sustainability development of manufacturing small and medium- sized enterprises in Taiwan. J. Clean. Prod. 207, 458–473. https://doi.org/10.1016/j.jclepro.2018.10.025
Chardine-Baumann, E., Botta-Genoulaz, V., 2014. A framework for sustainable performance assessment of supply chain management practices. Comput. Ind. Eng. 76, 138–147. https://doi.org/10.1016/j.cie.2014.07.029
Charmondusit, K., Phatarachaisakul, S., Prasertpong, P., 2014. The quantitative eco-efficiency measurement for small and medium enterprise: a case study of wooden toy industry. Clean Technol. Environ. Policy 16, 935–945. https://doi.org/10.1007/s10098-013-0693-4
Chee Tahir, A., Darton, R.C., 2010. The Process Analysis Method of selecting indicators to quantify the sustainability performance of a business operation. J. Clean. Prod. 18, 1598–1607. https://doi.org/10.1016/j.jclepro.2010.07.012
Chen, D., Schudeleit, T., Posselt, G., Thiede, S., 2013. A state-of-the-art review and evaluation of tools for factory sustainability assessment. Procedia CIRP 9, 85–90. https://doi.org/10.1016/j.procir.2013.06.173
Chen, D., Thiede, S., Schudeleit, T., Herrmann, C., 2014. A holistic and rapid sustainability assessment tool for manufacturing SMEs. CIRP Ann. - Manuf. Technol. 63, 437–440. https://doi.org/10.1016/j.cirp.2014.03.113
Choi, J., Lee, J., 2017. Firm size and compositions of R&D expenditures: evidence from a panel of R&D performing manufacturing firms. Ind. Innov. 2716, 1–23. https://doi.org/10.1080/13662716.2017.1297222
Christofi, A., Christofi, P., Sisaye, S., 2012. Corporate sustainability: historical development and reporting practices. Manag. Res. Rev. 35, 157–172. https://doi.org/10.1108/01409171211195170
Clarke-sather, A.R., Hutchins, M.J., Zhang, Q., Gershenson, J.K., Sutherland, J.W., 2011. Development of social, environmental, and economic indicators for a small/medium enterprise. Int. J. Account. Inf. Manag. 19, 247–266. https://doi.org/https://doi.org/10.1108/18347641111169250
Collins, A.J., Hester, P., Ezell, B., Horst, J., 2016. An improvement selection methodology for key performance indicators. Environ. Syst. Decis. 36, 196–208. https://doi.org/10.1007/s10669-016-9591-8
Colombo, S., 2014. Innovation and Italy's chemicals industries. CEP Megazine April, 54–59. https://www.aiche.org/resources/publications/cep/2014/april
Confcommercio, 2009. Le piccole e medie imprese in Italia [WWW Document]. URL https://www.confcommercio.it/-/le-piccole-e-medie-imprese-in-italia (accessed 12.1.18).
Corbière-Nicollier, T., Blanc, I., Erkman, S., 2011. Towards a global criteria based framework for the sustainability assessment of bioethanol supply chains. Ecol. Indic. 11, 1447–1458. https://doi.org/10.1016/j.ecolind.2011.03.018
Côté, R., Booth, A., Louis, B., 2006. Eco-efficiency and SMEs in Nova Scotia, Canada. J. Clean. Prod. 14, 542–550. https://doi.org/10.1016/j.jclepro.2005.07.004
Das, A., Pagell, M., Behm, M., Veltri, A., 2008. Toward a theory of the linkages between safety and quality. J. Oper. Manag. 26, 521–535. https://doi.org/10.1016/j.jom.2007.06.005
De Villiers, C., Rouse, P., Kerr, J., 2016. A new conceptual model of influences driving sustainability based on case evidence of the integration of corporate sustainability management control and reporting. J. Clean. Prod. 136, 78–85. https://doi.org/10.1016/j.jclepro.2016.01.107
Del Borghi, A., Gallo, M., Strazza, C., Del Borghi, M., 2014. An evaluation of environmental

sustainability in the food industry through Life Cycle Assessment: the case study of tomato products supply chain. J. Clean. Prod. 78, 121–130. https://doi.org/10.1016/j.jclepro.2014.04.083
Delai, I., Takahashi, S., 2011. Sustainability measurement system: a reference model proposal. Soc. Responsib. J. 7, 438–471. https://doi.org/https://doi.org/10.1108/17471111111154563
Denzin, N.K., Lincoln, Y.S., 2011. Introduction the discipline and practice of qualitative research, in: Denzin, N.K., Lincoln, Y.S. (Eds.), The Sage Handbook of Qualitative Research. SAGE, Thousand Oaks, CA, pp. 1–19.
Dicicco-Bloom, B., Crabtree, B.F., 2006. The qualitative research interview. Med. Educ. 40, 314–21. https://doi.org/10.1111/j.1365-2929.2006.02418.x
Ding, K., Jiang, P., Zheng, M., 2017. Environmental and economic sustainability-aware resource service scheduling for industrial product service systems. J. Intell. Manuf. 28, 1303–1316. https://doi.org/10.1007/s10845-015-1051-7
Djekic, I., Miocinovic, J., Tomasevic, I., Smigic, N., Tomic, N., 2014. Environmental life-cycle assessment of various dairy products. J. Clean. Prod. 68, 64–72. https://doi.org/10.1016/j.jclepro.2013.12.054
Dooley, L.M., 2002. Case study research and theory building. Adv. Dev. Hum. Resour. 4, 335–354. https://doi.org/10.1177/1523422302043004
Du Plessis, J., Bam, W., 2018. Comparing the sustainable development potential of industries: a role for sustainability disclosures? Sustain. 10. https://doi.org/10.3390/su10030878
Dubey, R., Gunasekaran, A., Chakrabarty, A., 2015. World-class sustainable manufacturing: framework and a performance measurement system. Int. J. Prod. Res. 53, 5207–5223. https://doi.org/10.1080/00207543.2015.1012603
Dubois, A., Gadde, L.E., 2002. Systematic combining: an abductive approach to case research. J. Bus. Res. 55, 553–560. https://doi.org/10.1016/S0148-2963(00)00195-8
Efroymson, R.A., Dale, V.H., 2015. Environmental indicators for sustainable production of algal biofuels. Ecol. Indic. 49, 1–13. https://doi.org/10.1016/j.ecolind.2014.09.028
Egilmez, G., Kucukvar, M., Tatari, O., Bhutta, M.K.S., 2014. Supply chain sustainability assessment of the U.S. food manufacturing sectors: a life cycle-based frontier approach. Resour. Conserv. Recycl. 82, 8–20. https://doi.org/10.1016/j.resconrec.2013.10.008
Eisenhardt, K.M.E., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550. https://doi.org/10.5465/AMR.1989.4308385
Elkington, J., 1997. Cannibals with forks : the triple bottom line of 21st century business. Capstone, Oxford.
Engida, T.G., Rao, X., Berentsen, P.B.M., Oude Lansink, A.G.J.M., 2018. Measuring corporate sustainability performance– the case of European food and beverage companies. J. Clean. Prod. 195, 734–743. https://doi.org/10.1016/j.jclepro.2018.05.095
Epstein, M.J., Widener, S.K., 2010. Identification and use of sustainability performance measures in decision-making. J. Corp. Citizsh. 40, 43–73. https://doi.org/10.9774/GLEAF.4700.2010.wi.00006
Erol, I., Sencer, S., Sari, R., 2011. A new fuzzy multi-criteria framework for measuring sustainability performance of a supply chain. Ecol. Econ. 70, 1088–1100. https://doi.org/10.1016/j.ecolecon.2011.01.001
European Commission, 2009. FWC sector competitiveness studies - Competitiveness of the EU metalworking and metal articles industries. https://www.sectorcompetitiveness.com/studies-and-projects/sector-competitiveness-studies/
European Environmental Agency, 2017. Air quality in Europe - 2017 report. https://doi.org/10.2800/22775
European Union, 2017a. Communication from the Commission — Guidelines on non-financial reporting (methodology for reporting non-financial information) C/2017/4234. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017XC0705(01)

European Union, 2017b. The future of industry in Europe. https://doi.org/10.2863/709269
European Union, 2003. Commission Recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises. http://data.europa.eu/eli/reco/2003/361/oj
Eurostat, 2017. Waste statistics [WWW Document]. URL http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics (accessed 12.5.18).
Eurostat, 2013. Manufacturing statistics - NACE Rev. 2 [WWW Document]. URL http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Manufacturing_statistics_-_NACE_Rev._2 (accessed 12.5.18).
Fang, F., Cheng, K., Ding, H., Chen, S., Zhao, L., 2016. Sustainable design and analysis of CNC machine tools: sustainable design index based approach and its application perspectives, in: ASME 2016 International Manufacturing Science and Engineering Conference. https://doi.org/10.1115/msec2016-8730
Federmeccanica, 2018. L'industria metalmeccanica [WWW Document]. URL https://www.federmeccanica.it/centro-studi/industria-metalmeccanica.html (accessed 12.1.18).
Feil, A.A., De Quevedo, D.M., Schreiber, D., 2017. An analysis of the sustainability index of micro- and small-sized furniture industries. Clean Technol. Environ. Policy 19, 1883–1896. https://doi.org/10.1007/s10098-017-1372-7
Feil, A.A., De Quevedo, D.M., Schreiber, D., 2015. Selection and identification of the indicators for quickly measuring sustainability in micro and small furniture industries. Sustain. Prod. Consum. 3, 34–44. https://doi.org/10.1016/j.spc.2015.08.006
Ferrari, A.M., Volpi, L., Pini, M., Cristina, S., García-Muiña, F.E., Settembre-Blundo, D., 2019. Building a sustainability benchmarking framework of ceramic tiles based on Life Cycle Sustainability Assessment (LCSA). Resources 8, 1–30. https://doi.org/https://doi.org/10.3390/resources8010011
Fuente, J.A., García-Sánchez, I.M., Lozano, M.B., 2017. The role of the board of directors in the adoption of GRI guidelines for the disclosure of CSR information. J. Clean. Prod. 141, 737–750. https://doi.org/10.1016/j.jclepro.2016.09.155
Fulton, L., 2018. Health and safety representation in Europe, Labour Research Department and ETUI. http://www.worker-participation.eu/National-Industrial-Relations/Across-Europe/Health-and-Safety2
Garbie, I.H., 2016. Sustainability in manufacturing enterprises. concepts, analyses and assessments for Industry 4.0, First. ed. Springer International Publishing. https://doi.org/10.1007/978-3-319-29306-6
Garbie, I.H., 2014. An analytical technique to model and assess sustainable development index in manufacturing enterprises. Int. J. Prod. Res. 52, 4876–4915. https://doi.org/10.1080/00207543.2014.893066
Garengo, P., Biazzo, S., Bititci, U.S., 2005. Performance measurement systems in SMEs: a review for a research agenda. Int. J. Manag. Rev. 7, 25–47. https://doi.org/10.1111/j.1468-2370.2005.00105.x
Germany Trade & Invest, 2018. Industry overview - The machinery & equipment industry in Germany. https://www.gtai.de/GTAI/Navigation/EN/Invest/Service/Publications/industry-specific-information,t=the-machinery-and-equipment-industry-in-germany-,did=372458.html
Ghadimi, P., Azadnia, A.H., Mohd Yusof, N., Mat Saman, M.Z., 2012. A weighted fuzzy approach for product sustainability assessment: a case study in automotive industry. J. Clean. Prod. 33, 10–21. https://doi.org/10.1016/j.jclepro.2012.05.010
Gimenez, C., Tachizawa, E.M., 2012. Extending sustainability to suppliers: a systematic literature review. Supply Chain Manag. 17, 531–543. https://doi.org/10.1108/13598541211258591
Globerson, S., 1985. Issues in developing a performance criteria system for an organization. Int. J. Prod. Res. 23, 639–646. https://doi.org/10.1080/00207548508904734
Govindan, K., Khodaverdi, R., Jafarian, A., 2013. A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. J. Clean. Prod.

47, 345–354. https://doi.org/10.1016/j.jclepro.2012.04.014
Graedel, T.E., Allenby, B.R., 2002. Hierarchical metrics for sustainability. Environ. Qual. Manag. 12, 21–30. https://doi.org/10.1002/tqem.10060
Hallstedt, S.I., Bertoni, M., Isaksson, O., 2015. Assessing sustainability and value of manufacturing processes: a case in the aerospace industry. J. Clean. Prod. 108, 169–182. https://doi.org/10.1016/j.jclepro.2015.06.017
Harik, R., El Hachem, W., Medini, K., Bernard, A., 2015. Towards a holistic sustainability index for measuring sustainability of manufacturing companies. Int. J. Prod. Res. 53, 4117–4139. https://doi.org/10.1080/00207543.2014.993773
Helleno, A.L., De Moraes, A.J.I., Simon, A.T., Helleno, A.L., 2017. Integrating sustainability indicators and Lean Manufacturing to assess manufacturing processes: application case studies in Brazilian industry. J. Clean. Prod. 153, 405–416. https://doi.org/10.1016/j.jclepro.2016.12.072
Hemdi, A.R., Saman, M.Z.M., Sharif, S., 2013. Sustainability evaluation using fuzzy inference methods. Int. J. Sustain. Energy 32, 169–185. https://doi.org/10.1080/14786451.2011.605947
Hillary, R., 2004. Environmental management systems and the smaller enterprise. J. Clean. Prod. 12, 561–569. https://doi.org/10.1016/j.jclepro.2003.08.006
Hsu, C.H., Chang, A.Y., Luo, W., 2017. Identifying key performance factors for sustainability development of SMEs – integrating QFD and fuzzy MADM methods. J. Clean. Prod. 161, 629–645. https://doi.org/10.1016/j.jclepro.2017.05.063
Huang, A., Badurdeen, F., 2018. Metrics-based approach to evaluate sustainable manufacturing performance at the production line and plant levels. J. Clean. Prod. 192, 462–476. https://doi.org/10.1016/j.jclepro.2018.04.234
International Labour Organization, 2017. Occupational safety and health in Europe and Central Asia [WWW Document]. URL https://www.ilo.org/safework/countries/europe/lang--en/index.htm (accessed 5.6.19).
International Labour Organization, 1973. Convention concerning Minimum Age for Admission to Employment. http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C138
International Organization for Standardization, 2017. ISO Survey [WWW Document]. URL https://www.iso.org/the-iso-survey.html (accessed 5.6.19).
Jain, S., Kibira, D., 2010. A framework for multi-resolution modeling of sustainable manufacturing, in: Winter Simulation Conference. pp. 3423–3434. https://doi.org/10.1109/WSC.2010.5679032
Jamieson, D., Fettiplace, S., York, C., Lambourne, E., Braidford, P., Stone, I., 2012. Large businesses and SMEs: exploring how SMEs interact with large businesses. ORC International Department of Business, Innovation and Skills. https://www.gov.uk/government/publications/large-businesses-and-smes-exploring-how-smes-interact-with-large-businesses
Jia, X., Li, Z., Wang, F., Qian, Y., 2016. Integrated sustainability assessment for chemical processes. Clean Technol. Environ. Policy 18, 1295–1306. https://doi.org/10.1007/s10098-015-1075-x
Jiang, Q., Liu, Z., Liu, W., Li, T., Cong, W., Zhang, H., Shi, J., 2018. A principal component analysis based three-dimensional sustainability assessment model to evaluate corporate sustainable performance. J. Clean. Prod. 187, 625–637. https://doi.org/10.1016/j.jclepro.2018.03.255
Johnson, M.P., Schaltegger, S., 2016. Two decades of sustainability management tools for SMEs: how far have we come? J. Small Bus. Manag. 54, 481–505. https://doi.org/10.1111/jsbm.12154
Joung, C.B., Carrell, J., Sarkar, P., Feng, S.C., 2013. Categorization of indicators for sustainable manufacturing. Ecol. Indic. 24, 148–157. https://doi.org/10.1016/j.ecolind.2012.05.030

Ketokivi, M., Choi, T., 2014. Renaissance of case research as a scientific method. J. Oper. Manag. 32, 232–240. https://doi.org/10.1016/j.jom.2014.03.004
Kim, D., Thoma, G., Nutter, D., Milani, F., Ulrich, R., Norris, G., 2013. Life cycle assessment of cheese and whey production in the USA. Int. J. Life Cycle Assess. 18, 1019–1035. https://doi.org/10.1007/s11367-013-0553-9
Kluczek, A., 2016. Application of multi-criteria approach for sustainability assessment of manufacturing processes. Manag. Prod. Eng. Rev. 7, 62–78. https://doi.org/10.1515/mper-2016-0026
Krajnc, D., Glavič, P., 2005. A model for integrated assessment of sustainable development. Resour. Conserv. Recycl. 43, 189–208. https://doi.org/10.1016/j.resconrec.2004.06.002
Krajnc, D., Glavič, P., 2003. Indicators of sustainable production. Clean Technol. Environ. Policy 5, 279–288. https://doi.org/10.1007/s10098-003-0221-z
Lääts, K., Gross, M., Haldma, T., 2017. Sustainability reporting in central and Eastern European companies, in: Horváth, P., Pütter, J.M. (Eds.), Sustainability Reporting in Central and Eastern European Companies. Springer International Publishing, pp. 63–76. https://doi.org/10.1007/978-3-319-52578-5
Labuschagne, C., Brent, A.C., Van Erck, R.P.G.G., 2005. Assessing the sustainability performances of industries. J. Clean. Prod. 13, 373–385. https://doi.org/10.1016/j.jclepro.2003.10.007
Latif, H.H., Gopalakrishnan, B., Nimbarte, A., Currie, K., 2017. Sustainability index development for manufacturing industry. Sustain. Energy Technol. Assessments. https://doi.org/10.1016/j.seta.2017.01.010
Laurinkevičiute, A., Stasiškiene, Ž., 2011. SMS for decision making of SMEs. Clean Technol. Environ. Policy 13, 797–807. https://doi.org/10.1007/s10098-011-0349-1
Lee, J.Y., Lee, Y.T., 2014. A framework for a research inventory of sustainability assessment in manufacturing. J. Clean. Prod. 79, 207–218. https://doi.org/10.1016/j.jclepro.2014.05.004
Lee, K.H., Farzipoor Saen, R., 2012. Measuring corporate sustainability management: a data envelopment analysis approach. Int. J. Prod. Econ. 140, 219–226. https://doi.org/10.1016/j.ijpe.2011.08.024
Lim, C.I., Biswas, W., 2015. An evaluation of holistic sustainability assessment framework for palm oil production in Malaysia. Sustain. 7, 16561–16587. https://doi.org/10.3390/su71215833
Lodhia, S., Martin, N., 2014. Corporate sustainability indicators: an australian mining case study. J. Clean. Prod. 84, 107–115. https://doi.org/10.1016/j.jclepro.2014.05.050
Long, Y., Pan, J., Farooq, S., Boer, H., 2016. A sustainability assessment system for Chinese iron and steel firms. J. Clean. Prod. 125, 133–144. https://doi.org/10.1016/j.jclepro.2016.03.030
Lozano, R., Huisingh, D., 2011. Inter-linking issues and dimensions in sustainability reporting. J. Clean. Prod. 19, 99–107. https://doi.org/10.1016/j.jclepro.2010.01.004
Lu, T., Gupta, A., Jayal, A.D., Badurdeen, F., Feng, S.C., Dillon, O.W., Jawahir, I.S., 2011. Advances in sustainable manufacturing. Adv. Sustain. Manuf. https://doi.org/10.1007/978-3-642-20183-7
Lynham, S.A., 2002. The general method of theory-building research in applied disciplines. Adv. Dev. Hum. Resour. 4, 221–241. https://doi.org/10.1177/1523422302043002
Mani, M., Madan, J., Lee, J.H., Lyons, K.W., Gupta, S.K., 2014. Sustainability characterisation for manufacturing processes. Int. J. Prod. Res. 52, 5895–5912. https://doi.org/10.1080/00207543.2014.886788
Marnika, E., Christodoulou, E., Xenidis, A., 2015. Sustainable development indicators for mining sites in protected areas: tool development, ranking and scoring of potential environmental impacts and assessment of management scenarios. J. Clean. Prod. 101, 1–12. https://doi.org/10.1016/j.jclepro.2015.03.098
Marshall, R.S., Brown, D., 2003. Environmental reporting: what's in a metric ? Bus. Strateg. Environ. 12, 87–106. https://doi.org/10.1002/bse.354
Martín-Peña, M.L., Díaz-Garrido, E., Sánchez-López, J.M., 2014. Analysis of benefits and

difficulties associated with firms' Environmental Management Systems: the case of the Spanish automotive industry. J. Clean. Prod. 70, 220–230. https://doi.org/10.1016/j.jclepro.2014.01.085
Massaroni, E., Cozzolino, A., Wankowicz, E., 2015. Sustainability in supply chain management - a literature review. Sinergie 33, 331–355. https://doi.org/10.7433/1115
Medini, K., Da Cunha, C., Bernard, A., 2015. Tailoring performance evaluation to specific industrial contexts - application to sustainable mass customisation enterprises. Int. J. Prod. Res. 53, 2439–2456. https://doi.org/10.1080/00207543.2014.974844
Meredith, J., 1998. Building operations management theory through case and field research. J. Oper. Manag. 16, 441–454. https://doi.org/10.1108/01443579310048182
Micheli, G.J.L., Cagno, E., 2010. Dealing with SMEs as a whole in OHS issues: Warnings from empirical evidence. Saf. Sci. 48, 729–733. https://doi.org/10.1016/j.ssci.2010.02.010
Naderi, M., Ares, E., Peláez, G., Prieto, D., Fernández, A., Pinto Ferreira, L., 2017. The sustainable evaluation of manufacturing systems based on simulation using an economic index function: a case study. Procedia Manuf. 13, 1043–1050. https://doi.org/10.1016/J.PROMFG.2017.09.128
Neri, A., Cagno, E., Di Sebastiano, G., Trianni, A., 2018. Industrial sustainability: modelling drivers and mechanisms with barriers. J. Clean. Prod. 194, 452–472. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.05.140
Neri, A., Melià, P., Cagno, E., Trianni, A., 2017. A review of industrial sustainability indicators for Life Cycle Sustainability Assessment, in: Atti Del XI Convegno Dell'Associazione Rete Italiana LCA Resource Efficiency e Sustainable Development Goals: Il Ruolo Del Life Cycle Thinking. ENEA, pp. 414–422.
Ness, B., Urbel-Piirsalu, E., Anderberg, S., Olsson, L., 2007. Categorising tools for sustainability assessment. Ecol. Econ. 60, 498–508. https://doi.org/10.1016/j.ecolecon.2006.07.023
Nordheim, E., Barrasso, G., 2007. Sustainable development indicators of the European aluminium industry. J. Clean. Prod. 15, 275–279. https://doi.org/10.1016/j.jclepro.2006.02.004
Ocampo, L., Vergara, V.G., Impas, C., Tordillo, J.A., Pastoril, J., 2015. Identifying critical indicators in sustainable manufacturing using Analytic Hierarchy Process (AHP). Manuf. Ind. Eng. 14, 1–8. https://doi.org/10.12776/mie.v14i3-4.444
Pagell, M., Johnston, D., Veltri, A., Klassen, R., Biehl, M., 2014. Is safe production an oxymoron? Prod. Oper. Manag. 23, 1161–1175. https://doi.org/10.1111/poms.12100
Paju, M., Heilala, J., Hentula, M., Heikkilä, A., Johansson, B., Leong, S., Lyons, K., 2010. Framework and indicators for a sustainable manufacturing mapping methodology, in: Winter Simulation Conference. pp. 3411–3422. https://doi.org/10.1109/WSC.2010.5679031
Patton, M.Q., 1990. Qualitative evaluation and research methods, 2nd ed. SAGE, Newbury Park, California.
Pawłowska, Z., 2015. Using lagging and leading indicators for the evaluation of occupational safety and health performance in industry. Int. J. Occup. Saf. Ergon. 21, 284–290. https://doi.org/10.1080/10803548.2015.1081769
Pütter, Judith M, 2017. Corporate Sustainability Reporting: summary and conclusions, in: Horváth, P., Pütter, Judith Maja (Eds.), Sustainability Reporting in Central and Eastern European Companies. Springer International Publishing, pp. 215–222. https://doi.org/10.1007/978-3-319-52578-5
Rahdari, A.H., Anvary Rostamy, A.A., 2015. Designing a general set of sustainability indicators at the corporate level. J. Clean. Prod. 108, 757–771. https://doi.org/10.1016/j.jclepro.2015.05.108
Remler, D.K., Van Ryzin, G.G., 2014. Research methods in practice: strategies for description and causation, Second. ed. SAGE.
Roca, C.L., Searcy, C., 2012. An analysis of indicators disclosed in corporate sustainability reports. J. Clean. Prod. 20, 103–118. https://doi.org/10.1016/j.jclepro.2011.08.002
Rödger, J.M., Bey, N., Alting, L., 2016. The Sustainability Cone – A holistic framework to integrate sustainability thinking into manufacturing. CIRP Ann. - Manuf. Technol. 65, 1–4.

https://doi.org/10.1016/j.cirp.2016.04.033
Rowley, J., 2002. Using case studies in research. Manag. Res. News 25, 16–27. https://doi.org/10.1108/01409170210782990
Saad, M.H., Nazzal, M.A., Darras, B.M., 2019. A general framework for sustainability assessment of manufacturing processes. Ecol. Indic. 97, 211–224. https://doi.org/10.1016/j.ecolind.2018.09.062
Saldaña, J., 2009. The coding manual for qualitative researchers. SAGE.
Salvado, M.F., Azevedo, S.G., Matias, J.C.O., Ferreira, L.M., 2015. Proposal of a sustainability index for the automotive industry. Sustain. 7, 2113–2144. https://doi.org/10.3390/su7022113
Sangwan, K.S., Bhakar, V., Digalwar, A.K., 2018. Sustainability assessment in manufacturing organizations: development of assessment models. Benchmarking An Int. J. 24, 994–1027. https://doi.org/http://dx.doi.org/10.1108/MRR-09-2015-0216
Schmidt, M., Spieth, H., Haubach, C., Kühne, C., 2019. 100 pioneers in efficient resource management. Springer Spektrum. https://doi.org/10.1007/978-3-662-56745-6
Searcy, C., Karapetrovic, S., Mccartney, D., 2005. Designing sustainable development indicators : analysis for a case utility. Meas. Bus. Excell. 9, 33–41. https://doi.org/10.1108/13683040510602867
Seuring, S., Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16, 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020
Shao, G., Kibira, D., Lyons, K., 2010. A virtual machining model for sustaianbility analysis, in: International Design Engineering Technical Conference & Computers and Information in Engineering Conference. ASME.
Shibin, K.T., Gunasekaran, A., Dubey, R., 2017a. Flexible sustainable manufacturing via decision support simulation: a case study approach. Sustain. Prod. Consum. 12, 206–220. https://doi.org/10.1016/j.spc.2017.08.001
Shibin, K.T., Gunasekaran, A., Dubey, R., 2017b. Explaining sustainable supply chain performance using a total interpretive structural modeling approach. Sustain. Prod. Consum. 12, 104–118. https://doi.org/10.1016/j.spc.2017.06.003
Siebert, A., O'Keeffe, S., Bezama, A., Zeug, W., Thrän, D., 2018. How not to compare apples and oranges: generate context-specific performance reference points for a social life cycle assessment model. J. Clean. Prod. 198, 587–600. https://doi.org/10.1016/j.jclepro.2018.06.298
Sikdar, S.K., 2003. Sustainable development and sustainability metrics. AIChE J. 49, 1928–1932. https://doi.org/10.1002/aic.690490802
Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2012. An overview of sustainability assessment methodologies. Ecol. Indic. 15, 281–299. https://doi.org/10.1016/j.ecolind.2011.01.007
Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2007. Development of composite sustainability performance index for steel industry. Ecol. Indic. 7, 565–588. https://doi.org/10.1016/j.ecolind.2006.06.004
Singh, S., Olugu, E.U., Musa, S.N., 2016. Development of sustainable manufacturing performance evaluation expert system for small and medium enterprises. Procedia CIRP 40, 609–614. https://doi.org/10.1016/j.procir.2016.01.142
Söllner, R., 2014. The economic importance of small and medium-sized enterprises in Germany. Wirtschaft und Statistik.1, 40-51
Stacchezzini, R., Melloni, G., Lai, A., 2016. Sustainability management and reporting: the role of integrated reporting for communicating corporate sustainability management. J. Clean. Prod. 136, 102–110. https://doi.org/10.1016/j.jclepro.2016.01.109
Staniškis, J.K., Arbačiauskas, V., 2009. Sustainability performance indicators for industrial enterprise management. Environ. Res. Eng. Manag. 2, 42–50. https://doi.org/10.5755/j01.erem.48.2.13

Stemler, S., 2001. An overview of content analysis. Pract. Assessment, Res. Eval. 7. http://pareonline.net/getvn.asp?v=7&n=17
Strezov, V., Evans, A., Evans, T., 2013. Defining sustainability indicators of iron and steel production. J. Clean. Prod. 51, 66–70. https://doi.org/10.1016/j.jclepro.2013.01.016
Stubblefield Loucks, E., Martens, M.L., Cho, C.H., 2010. Engaging small- and medium-sized businesses in sustainability. Sustain. Accounting, Manag. Policy J. 1, 178–200. https://doi.org/10.1108/20408021011089239
Sureeyatanapas, P., Yang, J.B., Bamford, D., 2015. The sweet spot in sustainability: a framework for corporate assessment in sugar manufacturing. Prod. Plan. Control 26, 1128–1144. https://doi.org/10.1080/09537287.2015.1015470
Székely, N., Vom Brockem, J., 2017. What can we learn from corporate sustainability reporting? Deriving propositions for research and practice from over 9,500 corporate sustainability reports. PLoS One 12, 1–27. https://doi.org/https://doi.org/10.1371/journal. pone.0174807
Tanzil, D., Beloff, B.R., 2006. Assessing impacts: overview on sustainability indicators and metrics. Environ. Qual. Manag. 15, 41–56. https://doi.org/10.1002/tqem.20101
Tremblay, A., Badri, A., 2018. A novel tool for evaluating occupational health and safety performance in small and medium-sized enterprises: the case of the Quebec forestry/pulp and paper industry. Saf. Sci. 101, 282–294. https://doi.org/10.1016/j.ssci.2017.09.017
Trianni, A., Cagno, E., 2012. Dealing with barriers to energy efficiency and SMEs: some empirical evidences. Energy 37, 494–504. https://doi.org/10.1016/j.energy.2011.11.005
Trianni, A., Cagno, E., Neri, A., 2017. Modelling barriers to the adoption of industrial sustainability measures. J. Clean. Prod. 168, 1482–1504. https://doi.org/10.1016/j.jclepro.2017.07.244
Tseng, M.L., 2013. Modeling sustainable production indicators with linguistic preferences. J. Clean. Prod. 40, 46–56. https://doi.org/10.1016/j.jclepro.2010.11.019
United Nations, 2015. Transforming our World: The 2030 Agenda for Sustainable Development. https://sustainabledevelopment.un.org/post2015/transformingourworld
Van Schoubroeck, S., Van Dael, M., Van Passel, S., Malina, R., 2018. A review of sustainability indicators for biobased chemicals. Renew. Sustain. Energy Rev. 94, 115–126. https://doi.org/10.1016/j.rser.2018.06.007
Veleva, V., Ellenbecker, M., 2001. Indicators of sustainable production: framework and methodology. J. Clean. Prod. 9, 519–549. https://doi.org/https://doi.org/10.1016/S0959-6526(01)00010-5
Veleva, V., Hart, M., Greiner, T., Crumbley, C., 2003. Indicators for measuring environmental sustainability. Benchmarking An Int. J. 10, 107–119. https://doi.org/https://doi.org/10.1016/S0959-6526(01)00010-5
Verband der Chemischen Industrie, 2012. The German Chemical Industry in 2030. https://www.vci.de/vci-online/services/publikationen/broschueren-faltblaetter/vci-prognos-study-the-german-chemical-industry-2030-update-2015-2016.jsp
Vitali, G., 2012. The chemical sector in Italy: Industrial structure and competitive advantage, ERIEP. http://revel.unice.fr/eriep/index.html?id=3396
Voss, C., Tsikriktsis, N., Frohlich, M., 2002. Case research in operations management. Int. J. Oper. Prod. Manag. 22, 195–219. https://doi.org/10.1108/01443570210414329
Winroth, M., Almström, P., Andersson, C., 2016. Sustainable production indicators at factory level. J. Manuf. Technol. Manag. 27, 1–16. https://doi.org/10.1108/JMTM-04-2016-0054
Yin, R.K., 2009. Case Study Research Design and Methods, 4th ed. SAGE, Thousand Oaks.
Zainal, Z., 2007. Case study as a research method. J. Kemanus. 9.
Zhang, H., Haapala, K.R., 2015. Integrating sustainable manufacturing assessment into decision making for a production work cell. J. Clean. Prod. 105, 52–63. https://doi.org/10.1016/j.jclepro.2014.01.038
Zhang, Y., Zheng, H., Fath, B.D., 2015. Ecological network analysis of an industrial symbiosis system: a case study of the Shandong Lubei eco-industrial park. Ecol. Modell. 306, 174–184.

https://doi.org/10.1016/j.ecolmodel.2014.05.005

Annex

Pillar	Category	Code	Indicator	Firm A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	Total
Economic	Globalisation and international issues	1	Supply chain management							●								●								●	●	●		5
		2	IT												●															1
		3	Energy price							●				●				●	●								●		●	6
		4	Emerging markets															●											●	2
		5	Business models	●	●	●		●	●	●	●	●	●	●	●	●		●	●			●		●	●	●	●	●	●	21
	Contemporary and contingency issues	6	Process technology		●				●	●			●																	4
		7	Government regulations			●																								1
		8	Growth of population																											0
		9	Growth of economics										●	●			●		●	●	●	●		●	●	●		●		11
		10	Consumption of resources	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●	●	●	23
	Innovative designed products and research	11	Needs																											0
		12	Market opportunity		●																									1
		13	Product development costs							●	●	●	●	●	●	●		●	●		●	●			●	●			●	14
		14	Product development time							●	●	●	●	●	●	●		●	●					●						10
		15	Development capability												●									●						2
		16	Regionalised products	●	●	●				●	●			●	●	●		●												9
		17	Personalised products	●	●	●				●	●	●			●		●	●	●			●	●	●			●		●	15
	Reconfigurable manufacturing enterprises	18	Enterprise size	●				●			●				●			●	●			●			●	●	●		●	11
		19	Enterprise functionality	●											●			●	●		●	●				●			●	8
		20	Material handling equipment															●												1
		21	Material handling storage														●		●			●				●	●		●	6
		22	Identification system																											0
		23	Plant location															●								●				2
		24	Functional layout*	●												●		●								●			●	5
		25	Product layout*																											0
		26	Cellular layout*																											0
	Manufacturing strategies	27	Complexity analysis																		●									1
		28	Lean production															●	●							●		●	●	5
		29	Agile manufacturing																											0
		30	Remanufacturing																									●		1
		31	Recycling processes	●	●	●			●		●	●	●	●	●	●								●	●	●	●			14
	Performance evaluation	32	Product costs	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●			●	22
		33	Response (lead time)	●			●			●	●		●	●	●			●	●			●				●		●	●	13
		34	Enterprise productivity										●	●				●	●	●						●		●	●	8
		35	HR appraisal										●					●		●									●	4
		36	Resources status															●								●		●		3
		37	Product quality	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	25
	Flexible organisation management	38	Strategic planning																											0
		39	Organising work													●		●								●			●	4
		40	Organisation structure													●		●												2
		41	Leadership role													●														1
		42	Staffing																											0
		43	Managing culture																							●				1
Social	Work management	44	Employment													●		●		●		●			●	●	●	●	●	9
		45	Work conditions	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	26
		46	Social dialogue			●										●														2
		47	Society security										●																	1

		48	HR development	●						●	●	●	●				●	●	●	●	●	●	●			●				**13**
	Human rights	49	Child labour																											**0**
		50	Freedom of association										●			●			●											**3**
		51	Discrimination																●											**1**
	Societal commitment	52	Involvement in local community			●				●				●	●				●		●									**6**
		53	Education							●																●				**2**
		54	Healthcare		●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●					●				**17**
		55	Job creation																											**0**
		56	Societal investment	●		●				●	●			●	●			●	●	●	●									**10**
		57	Culture and technological development												●															**1**
	Customers issues	58	Marketing and information											●																**1**
		59	Private life protection											●																**1**
		60	Access to essential services											●																**1**
	Business practices	61	Fight against corruption										●													●				**2**
		62	Fair trading																											**0**
		63	Understanding foreign culture																											**0**
Environment	**Environment management**	64	Environmental budget															●	●							●		●		**4**
		65	Environmental certification							●					●	●		●	●	●						●				**7**
		66	Environmental concerns and compliance																											**0**
		67	Workers implications														●	●	●	●		●				●	●			**7**
	Use of resources	68	Renewable energy							●								●						●					●	**4**
		69	Recycled water			●						●		●	●			●			●									**6**
		70	Recyclable wastes	●	●	●		●	●			●		●	●	●														**9**
	Pollution	71	Air pollution		●					●				●	●	●	●	●	●	●	●	●				●				**12**
		72	Water pollution	●	●				●	●				●	●	●	●	●	●	●	●	●				●				**14**
		73	Land pollution		●									●			●	●			●	●								**6**
	Dangerousness	74	Dangerous inputs	●	●	●			●	●	●	●	●	●		●		●	●	●		●				●				**15**
		75	Dangerous outputs		●	●			●	●	●	●	●	●		●		●	●	●		●			●	●				**15**
		76	Dangerous wastes	●	●	●			●	●	●	●	●			●	●	●	●	●		●				●		●		**16**
	Natural environmental	77	Eco-system services											●			●			●									●	**4**
		78	Bio-diversity																											**0**
		79	Land use															●											●	**2**
		80	Development of rural areas																										●	**1**
			Total	**18**	**18**	**18**	**5**	**8**	**12**	**25**	**18**	**16**	**21**	**27**	**24**	**24**	**14**	**40**	**30**	**18**	**15**	**21**	**5**	**11**	**10**	**33**	**12**	**14**	**23**	

Table A1. Detail of indicators measured by each firm. The indicators measured are reported for each firm investigated (indicated with a ●).