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SOCIAL LCA IN PROGRESS

Social sustainability in trade and development policy

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Abstract

Purpose Social sustainability may be assessed using a variety of methods and indicators, such as the social footprint, social impact assessment, or wellbeing indices. The UNEP guidelines on social life cycle assessment (sLCA) present key elements to consider for product-level, life cycle-based social sustainability assessment. This includes guidance for the goal and scope definition, inventory, impact assessment, and interpretation phases of S-LCA. Methods for and studies of the broader scale, life cycle social dimensions of production and consumption are largely unavailable to date. The current study assesses social risks associated with trade-based consumption in EU Member States using a life cycle-based compared to a non-life cycle-based approach in order to assess the value-added of life cycle thinking and assessment in this context.

Methods Social risk refers to the potential for one or more parties to be exposed to negative social conditions that, in turn, undermine social sustainability. In order to shed light on these risks, a macro-scale analysis of the social risk profile of trade-based consumption in the EU Member States has been conducted by combining intra- and extra-territorial import statistics with country- and sector-specific social risk indicator data derived from the Social Hotspots Database. These data cover 17 social risk indicators in five thematic areas, many of which are linked with the sustainable development goals set by the recent United Nations Agenda 2030. The apparent social risk profiles of EU imports have then been assessed based on consideration of country-of-origin social risk data (non-life cycle-based approach) as compared to a life cycle-based social risk assessment which also took into account the distribution of social risk along product supply chains. The intention was to better understand how and to what extent current trade-based consumption within the EU-27 may be associated with socially unsustainable conditions domestically and abroad, and the extent to which life cycle-based consideration of social risk is necessary.

Results and conclusions The analysis confirms the importance of a life cycle-based assessment of social risks in support of policies for socially sustainable production and consumption. Moreover, the methods presented herein offer a potentially powerful decision-support methodology for policy makers wishing to better understand the magnitude and distribution of social risks associated with EU production and consumption patterns, the mitigation of which will contribute to socially sustainable development.

Keywords Life cycle indicators · Policy support · Social Hotspots Database · Social LCA · Social risk · Trade policy

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1 Introduction

Due to the globalized nature of the supply chains that support much of contemporary production and consumption, understanding and managing for sustainability objectives present novel and unique challenges for consumers, businesses, and governance bodies tasked with advancing sustainability. This is because informed decision making and effective sustainability management require taking into consideration activities and stakeholders both within their immediate spheres of influence, as well as along global supply chains more broadly.

Sustainability is a guiding principle and objective for policy development in the European Union (EU) (EC 2001a). Indeed, the founding Treaty of the European Union (TEU) specifically includes the objective of "fostering sustainable economic, social and environmental development of developing countries, with the primary goal of eradicating poverty" (Article 21(2.d)). The Treaty on the Functioning of the European Union (TFEU) further specifies that the EU's external policies must respect the "principles of democracy, the rule of law, the universality and indivisibility of human rights and fundamental freedoms, respect for human dignity, the principles of equality and solidarity, and respect for the principles of the United Nations Charter and international law" (EC 2008). Toward this end, the EU Sustainable Development Strategy (SDS) requires an impact assessment of all major policy proposals vis-à-vis sustainability objectives (EC 2009).

With respect to trade policy specifically, all EU trade agreements must adhere to the core labor standards as defined in the International Labour Organization (ILO) Conventions in order to ensure the protection of human rights (EC 2001b). In a similar vein, the Commission's *Communication on* '*Corporate Social Responsibility: A Business Contribution to Sustainable Development*' also encourages the adoption of "codes of conduct, management standards, instruments for measuring performance, labels on products, and standards for Socially Responsible Investment (SRI)" (EC 2002).

In light of the strength of commitments in EU trade policy to furthering sustainability objectives, policy making and assessment require systemic perspectives and decision support tools of commensurate scope. In particular, such tools must enable the elucidation of the sustainability impacts of traded commodities, taking into account the globalized nature of production and consumption. They should, for example, enable assessing current production and consumption patterns in the EU in terms of positive or negative contributions to the sustainable development goals recently released by the United Nations (Transforming our World: The 2030 Agenda for Sustainable Development, UN 2015).

Life cycle thinking (LCT) refers to a management philosophy predicated on a holistic consideration of the impacts of management choices in order to understand potential trade-offs and to prevent unintentional burden shifting—whether between supply chain activities or issue areas (Pelletier et al. 2014). LCT and life cycle-based methodologies are central to robust sustainability science (Sala et al. 2013a, b). LCT is already operationalized in support of EU policy development and impact assessment to measure and manage the environmental dimensions of production and consumption (op. cit.).

In parallel to life cycle assessment (LCA) (ISO 14040 2006), social life cycle assessment (sLCA) focuses on issues related to social conditions and impacts (UNEP/SETAC 2009). Social LCA is comparatively new and considerably less developed than traditional LCA. It has not yet been used extensively to support policy development or policy impact assessment: indeed, more traditional non-life cycle-based indicators are usually employed (Murphy 2012).

To date, several applications of sLCA at the product level have been reported (Macombe et al. 2013; Feschet et al. 2013; Ekener-Petersen and Finnveden 2013; Arcese et al. 2012; Martínez-Blanco et al. 2014; Dong and Ng 2015). Conversely, few examples of application at meso- and macro-scale exist. (see, e.g., Rugani et al. 2014; Ekvall 2011). In order to assess the possible use of sLCA in policy contexts, case studies at scales from meso (regional) and macro (country/ global) scale are needed. Micro-, meso- and macro-scale analyses share some key challenges. These relate, for example, to process and product-specific data availability as well as cultural differences that affect the perception of specific kinds of social impacts.

The present study focuses on the application of sLCA at the macro-scale, with the purpose of assessing its potential relevance and utility in trade and development policy contexts. Toward this end, a case study has been carried out for 27 EU Member States (reference year 2010), considering the origin, magnitude, and distribution of social risk associated with traded commodities. The analysis employs two approaches in order to assess the added value of LCT and tools in this context. The first is a non-life cycle-based "country of origin" approach, where sector- and country-specific social risks for traded commodities imported into EU-27 Member States are considered. The second is a life cycle-based, cradle-to-country of consumption approach, where social risks along the supply chains that support production of these same imported commodities are taken into account.

2 Methodology

The primary objective of this study is to evaluate the social risks attributable to commodities imported into 27 EU Member States in 2010 from both intra- and extra-territorial trading partners using life cycle-based compared to non-life cycle-based methodologies. This was accomplished by combining Eurostat ComEx import data at the HS06 level (Eurostat 2013), mapped to Global Trade Analysis Project (GTAP 2013) sector codes, with the country/sector-specific social risk indicator data currently available in the Social Hotspots Database (SHDB) (Benoit et al. 2010).

2.1 Key elements characterizing the Social Hotspot Database

The SHDB is a social indicator data repository that provides sector- and country-specific indicator data in five overarching thematic areas. These thematic areas are Labour Rights and Decent Work (with indicator data for child labor; forced labor; excessive working time; wage assessment; poverty; migrant labor; freedom of association, right to strike, and collective bargaining rights); Health and Safety (with indicator data for injuries and fatalities; and toxics and hazards); Human Rights (with indicator data for indigenous rights; gender equity; and high conflicts); Governance (with indicator data for legal system and corruption); and Community Infrastructure (with indicator data for access to hospital beds; improved drinking water; and improved sanitation). The indicators are further divided and calculated based on 115 sub-indicators. A summary of the thematic areas and indicators can be found in Table S1 (Electronic Supplementary Material).

Grouping is a technique used to make information manageable. As long as the group assignments are transparent and users are free to form and use their own grouping, this does not present a problem. The SHDB grouping of the indicators is generally consistent with the grouping found in other indicator systems such as that employed by the Global Reporting Initiative. Obviously, some indicators could potentially fit in more than one category. For example, child labor could fit under the thematic areas of both Human Rights and Labor Rights and Decent Work. The choice was made to include it under Labor Rights and Decent Work in the SHDB default system. Users of the SHDB are free to group the indicators otherwise. In this study, it was decided to keep the default group assignments.

Because of resource constraints in developing the SHDB, it was not possible to develop and collect information for all desired indicators. The indicators to include in the database had to be prioritized. They were selected from among the UNEP Setac sLCA Guidelines impact subcategories, taking into account the suggestions made by the members of the SHDB advisory committee as well funder requirements. Data availability also informed indicator selection and development. Additional issues are being included in the database over time (Benoit Norris and Norris 2015).

The SHDB provides what is referred to as contextual information. Contextual data represent the typical social situation in a country and economic sector/industry. They can be used as "background data" or in "scoping assessments." However, the actual performance of a specific product supply chain can vary from the average, and so it is possible that the contextual data needs to be replaced by specific data according to the purpose and scope of a given study. For this reason, a company's specific supply chains cannot be attributed to social impacts in a concrete manner using contextual data alone. However, if an assessment signals that there is a high or very high risk that an issue is present in a certain country and economic sector of relevance to a company's supply chain, then the company may wish to investigate their specific supply chain activities in order to manage that risk.

The SHDB indicator data are derived from a variety of publicly available sources including the statistical agencies of the World Bank, the World Health Organization, and the International Labor Organization. In some instances, private audit databases are also consulted. In total, the SHDB references more than 200 data sources (Benoit Norris et al. 2012, 2013). Where single data sources are not sufficiently comprehensive across countries for specific issues, data are triangulated across multiple sources. Country- and sector-specific data are currently available for 113 specific countries and 57 sectors (as defined in the GTAP input-output economic general equilibrium model (GTAP 2013) for a total of 6441 country/sector-specific combinations.

The SHDB supports assessing the magnitude and distribution of social risk along product supply chains by using the life cycle attribute assessment approach (Norris 2006). This approach allows aggregation of social risks (attributes) that occur at different points along product supply chains in terms of a common activity variable (worker hours). Specifically, a Worker Hours Model that is derived by dividing total wages paid out by country and sector per dollar of output based on the GTAP input-output model, and country/sector-specific wage estimates are used to characterize worker hours per country, sector, and dollar of output. The distribution of potential social risks along product supply chains can then be calculated in an additive manner by multiplying the level of social risk in country-specific sectors by the worker hours per dollar of output in each sector. Since risk levels differ between sectors and countries, risk levels are weighted for each indicator in order to express instances of low risk, medium risk, high risk, and very high risk in terms of "medium risk hour-equivalent units" (mrh eq). As explained in detail in Benoit Norris and Norris 2015, a weighting that represents the relative probability of an adverse situation to occur was developed considering the risk characterizations contained across the entire database. This weighting will augment or lower the number of worker hours depending on the risk level. In doing so, it helps identify hotspots or country-specific sector where the risk is elevated, and the contribution to total worker hours is important.

2.2 Methodology for the calculation of the social risks attributable to commodities imported into EU Member States

The methodology for assessing social risks attributable to commodities imported into EU-27 countries builds upon a previous study, reported in Pelletier et al. (2013), and here further refined. In order to evaluate the social risks attributable to commodities imported into EU-27 Member States, a concordance table from the World Bank (2013) was used to map Eurostat HS06 trade data (7395 unique classifications) from ComEx to the GTAP sectors employed by the SHDB. Eurostat trade data does not include services; hence, the number of GTAP sectors actually considered in the analysis was 43 rather than 57. Where full, six-digit HS06 data were not available for specific trade flows for confidentiality or other reasons, these were excluded from the analysis. Such exclusions generally represented minor fractions of overall trade flows with only 2.5 % of import flows by value excluded from the analysis on this basis. Although EU-27 Member States actually traded with a total of 202 extra-territorial trading partners in 2010, data for a total of 78 extra-territorial trading partners, along with the (at the time of the study) 27 Member States of the EU, were considered only due to current limitations with respect to availability of country-specific social risk indicator data in the SHDB. However, this effectively encompassed 88.4 % of imports by value from extra-territorial trading partners, 95.5 % of imports by value from intra-territorial trading partners, and 92.8 % of overall imports by value into EU-27 Member States in 2010.

GTAP-mapped Eurostat ComEx trade data and SHDB social risk indicator data were subsequently combined and evaluated in two ways: (a) a country of origin approach and (b) a life cycle-based approach (Fig. 1). For the country of origin approach (Fig. 2), we undertook to assess the comparative social risks attributable to products imported into the EU-27 from extra-territorial trading partners compared to similar products produced and traded within the EU-27, taking into account the social risk scores for country- and sector-of-origin only (i.e., not using a life cycle approach). Here, we used Excel spreadsheets to multiply the social risk scores of imports for each country/sector combination by the percentage by value that imports from the country/sector combination contributed to total (intra- or extra-territorial) import values for that sector. The sum of results for each country/sector combination provided a value-weighted average indicator score per euro of imports for each sector and for each of the 117 sub-indicators. These scores were also multiplied by total trade value by sector to obtain overall risk scores for each sub-indicator.

The calculations were carried out as per Eq. (1). The social risk indicator score for a particular imported commodity "A" from either intra- or extra-territorial trading partner's equals the sum of the social risk indicator score for each i-th country in sector "A" multiplied by the import value of i-th country divided by total import value for A:

$$SR_{Ci,A} = \sum_{i=1}^{n} SR_{i,A} * \frac{V_{imp_{i},A}}{V_{imp_{A}}} \tag{1}$$

where
SR = social risk score
Ci = i-th country
A = economic sector A
V_{imp} = value of import of A

We applied the same set of sub-indicators and the same weighting scheme used in the life cycle-based social risk assessment approach in order to re-express the sub-indicator results per indicator (characterization) and thematic area (damage assessment) and as a single score. This allowed us to rank sectors in terms of apparent social risk per euro spent on imports from a sector as well as based on the total value of sectorial imports for both intra- and extra-territorial imports. We also computed "externalization ratios," which are intended to convey the ratio of risk associated with the production of traded products outside of territorial boundaries to that which occurs within the EU-27, per euro spent on traded goods in each sector.

For the life cycle-based approach (Fig. 3), we performed a life cycle-based evaluation of the social risk profile of EU-27 imports in 2010 using the version of the SHDB available in the SimaPro 8.0 software package. Here, we entered all GTAP-mapped trade data for imports by sector from intra- and extra-territorial trading partners into a SimaPro model and used the Social Life Cycle Impact Assessment Method Version 01.1 to assess the magnitude and distribution of social risks attributable to EU-27 trade by sector and in aggregate. Characterization results by social risk indicator, damage assessment results by thematic area, and aggregated, single score results for life cycle social risks were generated. As before, we also computed externalization ratios per euro spent on trade in each sector, following Eq. (2). The social risk indicator scores for a particular imported commodity A from either intra- or extra-territorial trading partners equals the sum of the social risk indicator score for each l-th sector providing an input to the sector producing commodity A in the country of origin. The metric for accounting for the contribution of different sectors is working hours in the l-th sector, which are multiplied by the social risk in that sector in the i-th country where the sector is located:

$$SR_{Ci,A} = \sum_{i=1}^{n} \sum_{l=1}^{m} SR_{i,l} * \frac{whl, i}{V_{output\ l,\ i}} \tag{2}$$

where
SR = social risk score
Ci = i-th country
A = economic sector A
V_{output} = value of output l-th sector providing input to A
wh_l = working hours in the different l-th sectors providing input to A

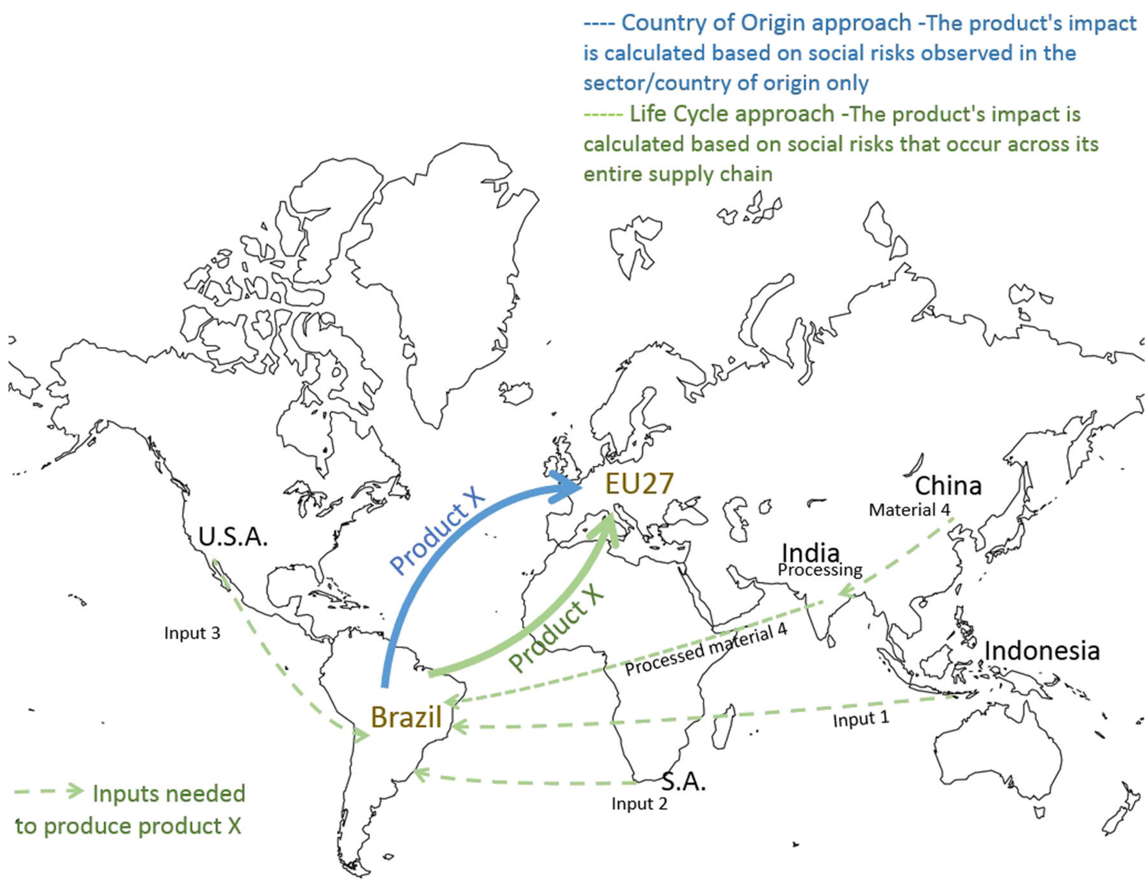


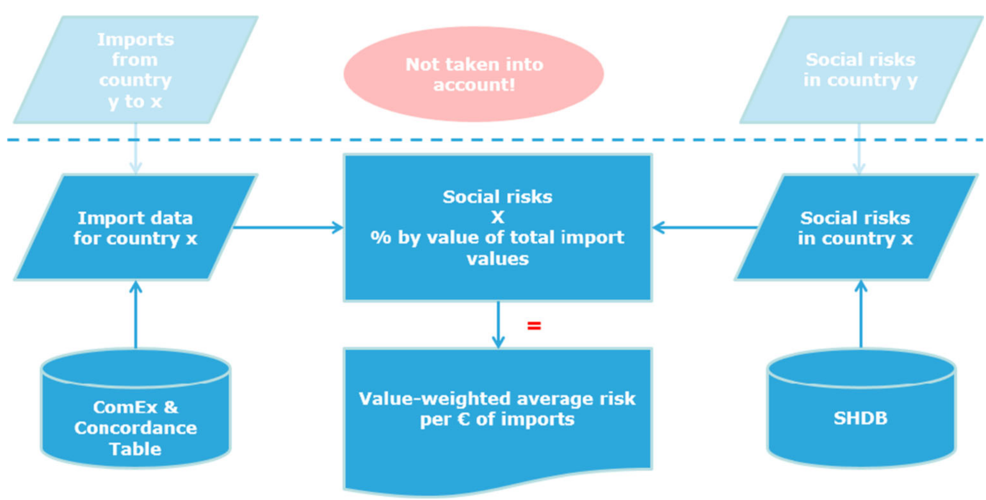
Fig. 1 Map representation of the country of origin and the life cycle approaches for considering social risks of an imported product into the EU27

In order to directly compare the country-of-origin versus life cycle-based social risk assessments, we transformed the results from both analyses into percentage of contributions to total risk for each measure. We subsequently compared results between the country-of-origin and life cycle-based assessments in order to determine if these two approaches provide different "signals" as to the magnitude and distribution of social risk and to evaluate the relevance of a life cycle approach to understanding and managing social risk.

3 Results: social risk profiles of EU-27 trade—country-of-origin versus life cycle-based assessments

Although the results are computed for all 115 sub-indicators considered, for the sake of comparability between the country-of-origin and the life cycle-based assessments of social risk attributable to EU-27 imports in 2010, results are presented per indicator and thematic area and as single scores based on

Fig. 2 Schematic representation of country of origin approach



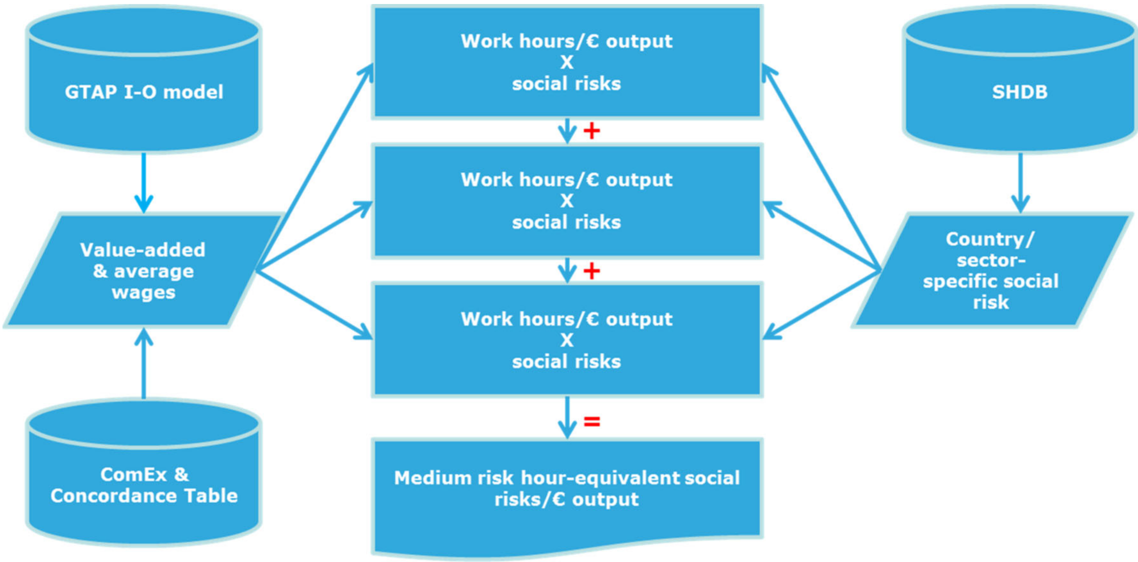


Fig. 3 Schematic representation of life cycle-based approach

the subset of sub-indicators and weights applied in the software version of the life cycle-based method only. Figure S1 (Electronic Supplementary Material) presents the weighted distribution of social risks (%) across the 17 social risk indicators considered for total EU-27 trade (by value) in 2010 originating from either extra- or intra-territorial trading partners. In this and subsequent Figs. S2, S3, S4, and S5 (see Electronic Supplementary Material), panel A presents the results of the country-of-origin analysis, whereas panel B presents the results of the life cycle-based analysis.

The "injuries and fatalities" indicator makes a disproportionately large contribution to the single score, overall measure of social risk—largely because of the high weighting for risk of fatalities relative to the weightings for the other social risks considered in the first release of the SHDB (a "very high risk" of fatalities has a weighing factor of 500 medium risk hour-equivalents compared to weightings of 10 for "very high risks" in most other indicator categories). This high weighting for risk of fatalities was assigned based on a review of disability weights (GBD 2010) for a range of injuries relevant in working contexts (e.g., back injuries, impaired hearing, loss of a finger, etc.). It was determined that weights tended to cluster around values of approximately 0.02. For this reason, a rough ratio of 50:1 for mortality vis-a-vis work-related morbidity was adopted. It was decided to keep the original weighting in this study, although a more recent version of the SHDB allows users to develop their own weighting schemes according to the specific objectives of their analysis. Clearly, different weighting schemes will provide for different relative risk assignments.

Also of note in both analyses is the much larger share of social risk associated with extra-territorial imports compared to intra-territorial imports (almost 100 % for the country-of-origin analysis and 83 % for the life cycle-based analysis). This observation is particularly striking in light of the fact that the overall value of EU-27 imports in 2010 from extra-territorial trading partners (1354.1 billion euros) contributes only 36.5 % of the total 2010 import flows (4001.8 billion euros) considered. Figure S2 (see Electronic Supplementary Material) presents the shares of social risk attributable to extra- versus intra-territorial trade for each indicator and in each analysis.

Beyond these two general similarities, the analyses provide otherwise quite different results. The Injuries and Fatalities risk indicator is more important relative to the other risk indicators in the country-of-origin analysis (90 % compared to 72 % in the life cycle-based analysis). Estimated risk, although much smaller than for Injuries and Fatalities, is nonetheless proportionately larger across all other indicators in the life cycle-based analysis. This is because risks are additive along supply chains in the life cycle-based analysis, and many of the social risks (for example, risks of child labor, forced labor, gender inequality, etc.) are often higher among non-EU trading partner countries. Considering individual indicators, contributions from intra-territorial trading partners are negligible across indicators in the country-of-origin analysis for overall trade. For the life cycle-based analysis, in contrast, these contributions range from 9 % for risk of Child Labor to 20 % for risk of Injuries and Fatalities. Again, this is because the social conditions associated with production of products within EU-27 Member States may be quite good (hence the minimal contribution of intra-territorial imports to estimated risk in the country-of-origin analysis), but these products may be produced using inputs from extra-territorial trading partners/sectors having much higher levels of social risk. These risks are only visible when a life cycle approach to quantifying risk is employed.

For single score results at the sectoral level, the difference in results for the country-of-origin versus life cycle-based evaluations of social risks are more striking still (Fig. S3, Electronic Supplementary Material). The distribution of risks between sectors as well as the importance of extra- compared to intra-territorial imports vary considerably. Estimated single score social risk is greatest, for example, for the motor vehicles and parts sector in the country-of-origin analysis. Here, most of the risk is attributable to intra-territorial imports because they account for 86 % of total imports in this sector. The most important contributor in the life cycle-based evaluation, by a large margin, is the oil sector due to high levels of social risk in the oil sectors of some extra-territorial trading partners. In the wood products sector, intra-territorial imports contribute 70 % of estimated social risk in the country-of-origin analysis, but only 23 % in the life cycle-based evaluation (Fig. S4, Electronic Supplementary Material). Conversely, intra-territorial imports contribute 40 % of estimated social risk for the paddy rice sector in the country-of-origin analysis, but only 1 % in the life cycle-based evaluation (Fig. 4).

The top ten sectors for social risks associated with total EU-27 trade for the country-of-origin analysis are different (only seven of ten are common) from those indicated by the life cycle-based analysis (Table 1). They are also differently ordered and have different apparent contributions from extra- and intra-territorial imports. Of note here is that the overall percentage of contribution of these top ten sectors to total estimated single-score social risks is quite similar for the two analyses. This is likely strongly influenced by two factors. First is the percentage by value that the ten sectors contribute to overall trade (71 % for the country-of-origin analysis and 61 % for the life cycle-based analysis). Second is the relative importance of Injuries and Fatalities risks in these sectors.

The percentage of single-score risk per euro spent on trade in each sector presents even more divergent results between the two analyses because the results are not weighted by the magnitude of trade flows (Fig. S4, Electronic Supplementary Material). Here, the apparent contribution of intra-territorial imports per euro spent is generally greater for the country-of-origin analysis compared to the life cycle analysis. For the country-of-origin analysis, instances of similar scores for intra- and extra-territorial sectors were also observed (for example, the paddy rice sector was attributed to 1.8 % of social risk for each), whereas the life cycle-based analysis suggested a very different attribution of risk (for example, almost 0 % of social risk for intra-territorial paddy rice imports compared to 18 % for extra-territorial imports). In general, the life cycle-based analysis suggested high levels of social risks for imports from extra-territorial agricultural sectors (sugar 6 %; crops nec 9 %; plant-based fibers 9 %; processed rice 13 %; paddy rice 18 %).

The top ten sectors for social risks per euro spent in each sector are different in the country-of-origin analysis (only six of ten are common) compared to the life cycle-based analysis (Table 2). They are also ordered differently and have different apparent contributions from extra- and intra-territorial imports. The much wider distribution in apparent social risk attributable to the highest risk sectors in the life cycle-based compared to the country-of-origin analysis is notable.

4 Discussion and conclusion

Our analysis underscores the importance of a life cycle-based approach to understanding and managing social risk in support of policies for socially sustainable development. Both approaches that we evaluated provide the same high-level insights that (1) the majority of social risks associated with imports to EU-27 countries are attributable to extra-territorial rather than intra-territorial imports, and (2) the risks of Injuries and Fatalities make the largest proportionate contribution to an overall, single-score measure of risk. However, these two approaches provide otherwise dissimilar "signals" as to the magnitude and distribution of social risk associated with trade-based consumption in the EU. The country-of-origin (i.e., non life cycle-based) approach would invariably prioritize interventions targeting only those direct trading partners known to have high levels of social risk in the sectors providing exports to EU-27 Member States. In contrast, the life cycle-based approach provides insight as to the distribution of risk along supply chains, which may be low in the sector of a given country exporting products to Europe, but high overall for those products due to the social risks associated with the supply chain activities that support production in that sector. Although we observe that the majority of social risk associated with total trade flows is attributable to extra-territorial imports, this consideration is nonetheless also very relevant for intra-territorial trade. If considering only country/sector-of-origin social risk, intra-territorial imports may appear to have low associated social risk. Consideration of the distribution of social risk along upstream supply chains, however, may provide a very different picture if inputs to production within specific sectors in EU-27 Member States come from extra-territorial trading partners with higher social risk profiles. Hence, targeted policy initiatives to mitigate social risk in the interest of leveraging improved social sustainability based on either of these approaches would prioritize different countries and sectors. We believe that a life cycle approach is clearly essential to furthering social sustainability objectives via trade and development policy initiatives.

The case study also highlighted the need for further consideration of several methodological issues. First, as the methodology for calculating the single score measure of social risk reported here requires a weighting scheme, this weighting should be transparently communicated in order to ensure an unbiased interpretation of the results. For the sake of brevity, only single-score social risks were discussed in this manuscript. For a detailed explication of evaluated social risks for the analysis at the characterization and damage assessment

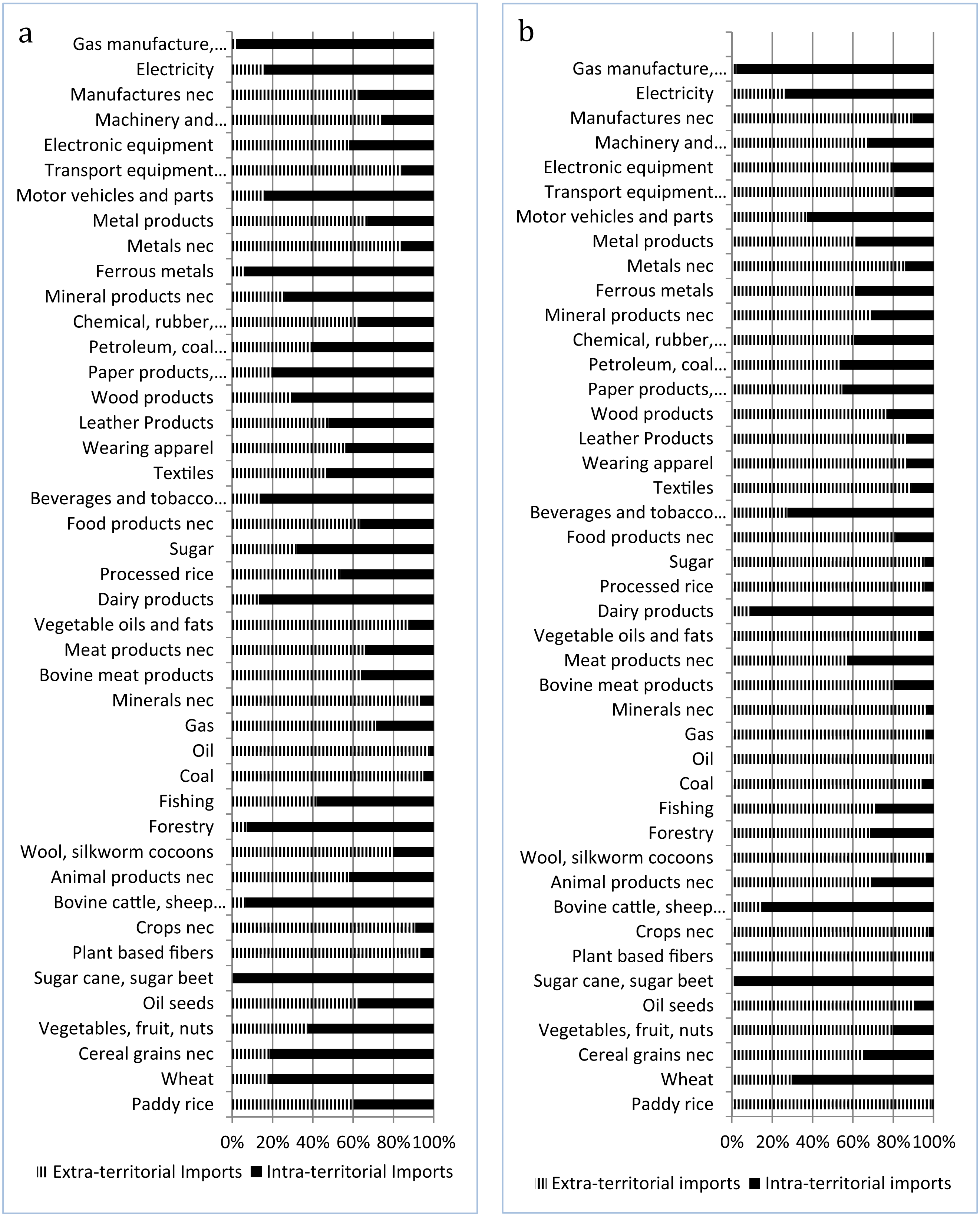


Fig. 4 Distribution (%) of single score social risks for total EU-27 intra- and extra-territorial imports for each sector in 2010 based on **a** country-of-origin or **b** cradle-to-producer gate life cycle social risks scores

Table 1 Top ten sectors for single-score social risk (by % contribution to overall social risk) attributable to EU-27 imports in 2010 from extra- and intra-territorial trading partners considering (A) country-of-origin or (B) cradle-to-producer gate life cycle social risk scores

A. Country-of-origin approach			
	Extra-	Intra-	Total
Motor vehicles and parts	2 %	12 %	15 %
Machinery and equipment n.e.c.	8 %	3 %	11 %
Chemical, rubber, plastic products	7 %	4 %	11 %
Oil	9 %	0 %	9 %
Ferrous metals	0 %	4 %	5 %
Textiles	2 %	2 %	4 %
Wearing apparel	2 %	2 %	4 %
Paper products, publishing	1 %	3 %	4 %
Metals n.e.c.	3 %	1 %	4 %
Electronic equipment	2 %	1 %	3 %
SUM	36 %	33 %	69 %
B. Life cycle-based approach			
	Extra-	Intra-	Total
Oil	17 %	0 %	17 %
Crops n.e.c.	8 %	0 %	8 %
Machinery and equipment n.e.c.	5 %	2 %	7 %
Metals n.e.c.	6 %	1 %	7 %
Chemical, rubber, plastic products	4 %	2 %	6 %
Textiles	5 %	1 %	6 %
Electronic equipment	4 %	1 %	5 %
Wearing apparel	4 %	1 %	4 %
Food products n.e.c.	3 %	1 %	4 %
Minerals n.e.c.	3 %	0 %	3 %
SUM	58 %	9 %	67 %

Table 2 Top ten sectors for single-score social risk per euro spent in each sector (by % contribution to the sum of social risk for 1 euro spent in each sector) attributable to EU-27 imports in 2010 from extra- and intra-territorial trading partners considering (A) country-of-origin or (B) cradle-to-producer gate life cycle social risk scores

A. Country-of-origin			
	Extra-	Intra-	Total
Processed rice	4 %	2 %	6 %
Meat products n.e.c	4 %	0 %	4 %
Paddy rice	2 %	2 %	3 %
Cereal grains n.e.c	2 %	2 %	3 %
Vegetables, fruit, nuts	2 %	2 %	3 %
Oil seeds	2 %	1 %	3 %
Sugar	2 %	1 %	3 %
Wheat	2 %	1 %	3 %
Bovine cattle, sheep and goats, horses	2 %	2 %	3 %
Leather Products	2 %	2 %	3 %
SUM	24 %	15 %	34 %
B. Life cycle-based			
	Extra-	Intra-	Total
Paddy rice	18 %	0 %	18 %
Processed rice	13 %	0 %	14 %
Crops n.e.c	9 %	0 %	10 %
Plant-based fibers	9 %	0 %	9 %
Sugar	6 %	0 %	6 %
Forestry	3 %	0 %	3 %
Vegetables, fruit, nuts	3 %	0 %	3 %
Cereal grains n.e.c	2 %	0 %	3 %
Vegetable oils and fats	2 %	0 %	2 %
Oil seeds	2 %	0 %	2 %
SUM	67 %	0 %	70 %

levels, we invite the reader to refer to Pelletier et al. 2013. We note that presenting results per indicator at the characterization level (i.e., as opposed to aggregated risk measures) obviates potential concerns regarding weighting schemes.

In general, weighting has been a contested issue in life cycle assessment, largely because assigned weights are inevitably (to a greater or lesser degree) subjective in nature. However, weighting schemes developed based on expert input and authoritative sources are obviously preferable to arbitrarily assigned weights. For this reason, we did not elect to alter the weights provided in the SHDB impact assessment method that we employed, nor did we see value in providing a sensitivity analysis using an arbitrary, alternative weighting scheme. We trust that the reader is able to appreciate that different weighting schemes will provide for different results, without devoting page space to an illustrative example. It should be noted that a more recent version of the SHDB impact assessment method provides equal weighting between indicators as the default, but allows users to define their own weighting schemes. We caution that calculating a single-score measure of social risk assuming equivalency between all risk indicators, regardless of the nature of the risks considered, should not be mistaken as avoiding weighting. Rather, this is perhaps the most arbitrary weighting of all. We also underscore, however, that weighting of different social risks will often be best defined relative to the stakeholder context. Deliberative democratic processes may hence be appropriate for use by stakeholder groups in the goal and scoping phase of an sLCA study. With respect to the current analysis, future work might fruitfully focus on defining a social risk weighting scheme that best reflects the established social sustainability priorities of the EU, as communicated in existing European Commission policy and regulatory documents.

Beyond the issue of weighting schemes, we are also cognizant that data quality is perennially a critical issue in life cycle assessment, including the specific kind of "macro-scale" sLCA implemented in this study. While the SHDB does use triangulated data in areas where single data sources are considered too weak, on-going efforts will nonetheless be essential to continuously improve upon existing data as well as to ensure data currency. Changing social and political conditions may quickly render current data obsolete.

We are confident that the country/sector scale of assessment is appropriate to the nature of the analysis we present. That said, it should be recognized that substantial variability may exist even within single country/sector combinations, depending on region, social conditions, prevalent technologies, etc. We hence reiterate that assessments such as the one we present may be appropriate for prioritizing foci for more detailed investigation of supply chain social risks, but that they are not suitable for company/product-specific assessments.

We also note that some authors have questioned the appropriateness of human labor (i.e., worker hours) as an activity variable for social life cycle risk assessment (e.g., Iribarren and Vázquez-Rowe 2013; Rugani et al. 2012). This variable could potentially be subject to a sensitivity analysis, although we are not certain what other activity variables might be considered more appropriate.

Finally, even if our analysis did incorporate the majority of EU-27 trade by value, more comprehensive analyses should be undertaken once country/sector-specific SHDB data are available for all EU-27 trading partners. Current data unavailability for certain trading partners that contribute minor shares to overall trade may nonetheless result in underestimation of risk as well as misallocation of proportional risk if the country/sector combinations of concern, along with the supply chains that support them, are home to high levels of specific kinds of social risk. These elements contribute to the broader discussion on challenges and limitations of social life cycle impact assessment both at micro- (product) and meso/macro-scales, as reported in several recent studies (Smith and Barling 2014; Wu et al. 2014, 2015; Chhipi-Shrestha et al. 2015; Martínez-Blanco et al. 2015). We anticipate that contributions of comparable macro-scale sLCA studies by other authors will bring further clarity and nuance to the preliminary perspectives that our work has afforded.

Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

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