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Using the Framework for Integrated Sustainability Assessment (FISA) to expand the Multiregional Input–Output analysis to account for the three pillars of sustainability

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Abstract Decision makers interested in promoting sustainable development must simultaneously consider the environmental, economic and social implications of any action. This article proposes the Framework for Integrated Sustainability Assessment (FISA), a methodological framework for conducting a sustainability impact assessment of any investment project. Based on a Multiregional Input–Output (MRIO) framework, FISA links the extended MRIO results with social risk data from the Social Hotspots Database (SHDB) in order to integrate the social with the environmental and economic pillars. Resulting impacts are simultaneously considered and reported by means of FISA charts, making it possible to assess the different impacts within the three sustainability pillars across countries involved in the whole supply chain of investment projects. This methodological framework can be applied not only to compare the sustainability impacts of two alternative projects, but also to derive specific recommendations aimed at minimizing the harmful social, environmental and economic effects along the whole project supply chain.

Keywords Sustainability · Multiregional Input–Output · Social assessment · Supply chains · Decision-making support

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1 Introduction

Sustainability is an integrative concept which considers that responsible development requires a balanced consideration of environmental, social and economic aspects (World Commission on Environment and Development 1987; Kajikawa 2008; Schoolman et al. 2012). Striking this balance is far from easy as the three pillars involve different types of values that are not commensurable with each other. Also the controversial interests of different stakeholders frequently conflict within a single pillar of sustainability (Vucetich and Nelson 2010). While this challenge is universal, developing countries face important pressures to exploit their environmental resource base for profits. Their economies rely heavily on their natural resources, and they have laxer social and environmental protection laws (Lehman 1999). As a consequence, their rapid economic growth often comes at the expense of irreversible environmental and social damage. Furthermore, globalization and outsourcing have increased the complexity of supply chains and the amount of interaction between industrialized and developing countries. In a global market, products and services consumed in developed countries are likely to be based on factors of production in developing countries that might result in not only environmental impacts, but also social abuses due to weaker social protection measures, for example, low salaries (Oxfam 2013; Alsamawi et al. 2014). Besides, developing countries are often challenged by different priorities usually related to meeting their most basic needs (Oxfam 2013).

In this context, decision-making practices that emphasize solely economic and environmental impacts fail to capture many fundamental social issues in developing countries (e.g., need for equity, education and infrastructures). Practices such as corporate social responsibility were devised to address this issue by monitoring social and environmental conditions throughout the entire supply chains within companies (Elkington 1998). Even so, law enforcement is still insufficient in these countries, and most businesses do not meet their ethical responsibilities (Friedman 1970), although enforcement measures in supply chains are increasing through supply chain reporting (Spence and Bourlakis 2009). However, while field visits or auditing are useful ways to qualitatively explore the specific social conditions of businesses or factories—such as working conditions—they are of no use if a general overview of a whole industry or economic sector is required.

For the above reasons, it is of utmost importance for decision makers to have the right tools to measure and consider the three pillars of sustainability associated with any investment decision. In this respect, the research question to be addressed is, “Given the cost data of any investment project, is there a methodological framework which outputs simultaneously capture its economic, environmental and social impacts?”

The proposed Framework for Integrated Sustainability Assessment (FISA) is able to capture not only economic and environmental impacts, but also the associated social impacts by assessing the potential social risks from trade across economic sectors worldwide. Additionally, FISA results are reported simultaneously. The three sustainability pillars can be compared across all economic sectors and countries involved in the whole supply chain of projects.

2 State of the art

Methodologies aimed at assessing the three types of impacts have developed at different paces. While methodologies that assess the financial and economic dimensions of an investment project were developed many decades ago (e.g., project finance, life-cycle costing, activity-based costing, traditional input–output analysis), efforts to quantify, monetize and later internalize environmental and socioeconomic externalities are more recent. The early studies focused mainly on assessing greenhouse gases (GHG) and other local emissions (Hohmeyer 1988; Bernow and Marron 1990; Ottinger et al. 1990; Pearce et al. 1992; ETSU and METROECONOMICA 1995; NEEDS 2009), and job creation (Stone 1986; Ferroukhi et al. 2013; Duscha et al. 2014; Teske et al. 2014), for example. Besides, other social aspects (e.g., quality of employment, poverty, long working hours) have started to be accounted for (Senhbruch 2004; Dreyer et al. 2006; Cohen 2009; Hutchins and Sutherland 2009; Bezerr 2012; Casillas and Kammen 2012; Linke et al. 2013; Oxfam 2013).

Table 1 shows a compilation of early studies singling out the pillar of sustainability that they address. While the first set of studies considered only the economic dimension, the following group also accounted for (both or either) the environmental and social dimensions. Table 1 also highlights the associated limitations when considering a complete and simultaneous sustainability assessment.

As shown in Table 1, most methodologies conduct a partial sustainability assessment and do not cover all three pillars. The main methodological challenge is to expand and integrate social impact assessment with the other pillars, whose root is the specification of boundary definitions and the availability of data regarding some social concerns (Lehman 1999). Besides, most social impacts are based on qualitative results from surveys or field visits. They cannot be straightforwardly converted to quantifiable results and integrated with traditional economic or environmental methodologies. Also, qualitative data are often more subjective and more locally specific than quantitative values (UNEP et al. 2009). Additionally, according to some authors, data collection for most social databases is neither robust, consistent nor reliable (Ranis and Stewart 2010). Furthermore, most of the existing social indexes have significant calculation errors due to data uncertainty [e.g., the Human Development Index (Wolff et al. 2010)], data transformation [e.g., the Social Vulnerability Index (Tate 2012)] and the disparity of methods used (Smith et al. 2013; McBain and Alsamawi 2014). For example, some indexes employ an aggregation methodology based on subjective expert evaluations (Carraro et al. 2013). Finally, few methodologies take into account all the stages of the supply chains across various sectors and countries (Alsamawi et al. 2014).

In the light of the above challenges, the FISA methodological proposal presented in this paper broadens the existing body of literature and helps to fill the social gap by integrating this pillar into sustainability assessments. To do this, Multiregional Input–Output (MRIO) analysis is the selected overarching methodology, as it can account for a wide variety of socioeconomic and environmental impacts across countries and sectors based on project cost data. Next, the social pillar is integrated by combining MRIO results with the Social Hotspots Database social risk database. As a result, the economic sectors and countries most stimulated by the analyzed projects with high social risks are identified and named Project Social Hotspots (PSH). Through this methodological integration, the three types of impacts caused by investment projects are accounted for across economic sectors around the world.

The remainder of the paper is structured as follows. Sect. 3 presents the methodological steps of the proposed FISA. First, the Multiregional Input–Output (MRIO) methodology and the Social Hotspots Database social risk database are explained. Next, the methodological integration and FISA charts are described and the FISA results are simultaneously plotted. Finally, FISA's role in decision-making processes, future applications of the methodological framework and the main conclusions are presented.

Table 1 Literature review of methodologies assessing one or more pillars listing barriers to a complete and simultaneous sustainability assessment

Pillar covered	Studies	Methodology	Barriers to simultaneous sustainability assessment
Economic	Stanford University (2005)	Life-cycle costing	A focus on economic impacts
	Leontief (1936)	Input output (IO)	
	Shakya et al. (2005)	financial analysis	
	Caldés et al. (2006)	Activity-based costing	
Environmental with/without economic pillar	Hong et al. (2013)	Life-cycle assessment (LCA)	A focus on environmental impacts with/without economic issues
	Jala and Nandagiri (2015)	Travel cost method and contingent assessment	
	Munda (1996)	Cost–benefit analysis (CBA)	
	Esmaeili and Shahsavari (2011)	Hedonic price method	
Social pillar with/without economic or environmental pillars	Alsamawi et al. (2014) De la Rúa Lope (2009)	Extended MRIO LCA and IO	An exclusively employment-related social perspective
	Caldés et al. (2009)	Extended IO	A focus on exclusively economic and employment impacts
	Casillas and Kammen (2012)	Carbon abatement cost curve and equity metrics	Availability of carbon cost curves and social indicators of regions/countries. No simultaneous impact assessment
	Dreyer et al. (2006)	LCA	A focus on exclusively social impacts
	Hutchins and Sutherland (2009)	LCA, IO, indicators, modeling	No simultaneous impact assessment Availability of social indicators
	Cohen (2009)	Multidimensional Poverty Assessment Tool	A focus on exclusively social impacts Time and cost (based on interviews)
	Linke et al. (2013) Bezerr (2012)	Indicators	A focus on exclusively employment-related impacts Indicator availability (very specific processes)
	Weidema (2006)	LCA and CBA	A focus on social and economic aspects
	Senhbruch (2004)	Indicators	A focus on exclusively employment-related social concerns
	Mc Bain (2015)	Extended MRIO and indicators	No simultaneous sustainability impact assessment

3 Methodological integration: Framework for Integrated Sustainability Assessment (FISA)

Figure 1 illustrates the methodological steps of the proposed sustainability framework.

Based on investment and operations and maintenance (O and M) cost data as the specific project inputs, the Multiregional Input–Output (MRIO) methodology can assess the response of all economic sectors across several countries to an increase in the demand for goods and services using MRIO tables (MRIOT). An extension of the MRIO methodology accounts for the socioeconomic and environmental impacts by adding vectors related to CO_2 emissions, employment or working hours per dollar produced for each sector and country, for example. The social pillar is later incorporated into the FISA methodological framework by linking the MRIO results with social risk data from the Social Hotspots Database (SHDB) classified by countries and sectors according to the World Input–Output Database (WIOD). This analysis is capable of identifying Project Social Hotspots (PSH). PSHs represent the sectors that will be both highly stimulated by the analyzed project and associated with high social risks. The different effects caused by the analyzed projects are compared simultaneously using FISA charts. Such illustrations can provide decision makers with support when considering and comparing the impacts of alternative projects across the three sustainability pillars.

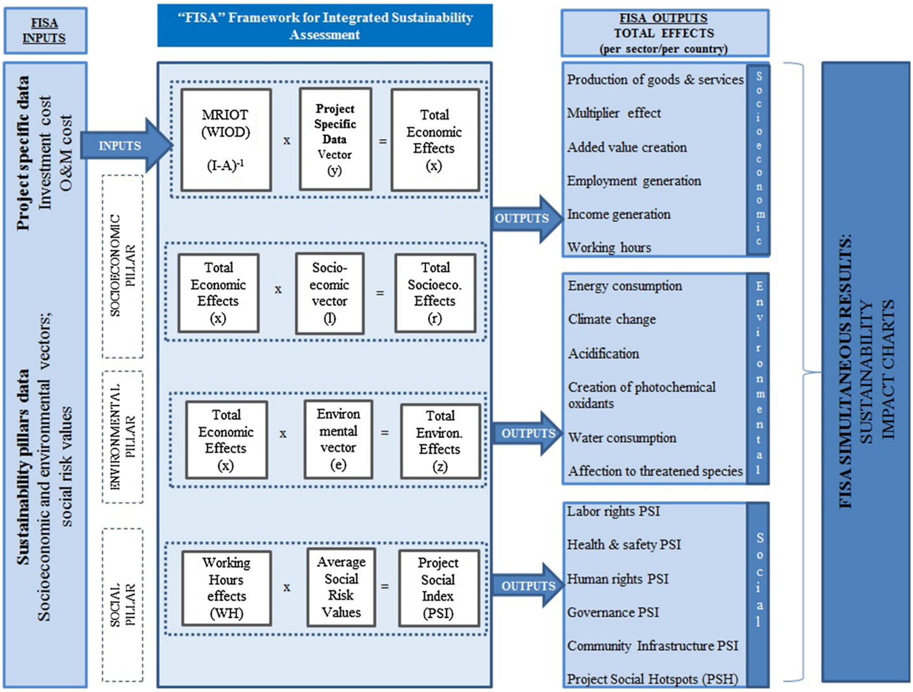

Fig. 1 Methodological integration through FISA

3.1 Multiregional Input–Output model (MRIO)

The Input–Output (IO) methodology analyzes the response of economic sectors in a region or country caused by a change in the demand for goods and services generated by a project (Ten Raa 2006). This methodology was first developed in 1936 by Wassily Leontief, who studied the relations between the US economic sectors between 1919 and 1929. His work was based on IO tables (IOT), which show the relation between consumption or inputs and production or outputs among the economic sectors of an economy. Technical coefficients can be calculated from the IOT. The technical coefficients indicate the intermediate consumption that one sector requires from another sector to produce one single monetary unit (Leontief 1936).

Leontief's traditional IO model was expanded to account for trade among different regions or countries through a Multiregional Input–Output (MRIO) analysis (Isard 1951). The first studies using MRIO assessment date from the 1950s, when MRIO is considered as an extension of the traditional IO model analyzing not only trade among economic sectors, but also among different regions using Multiregional Input–Output Tables (MRIOT) (Moses 1955). This geographical expansion is extremely relevant in the light of globalization, increasing competition in product manufacturing and growing trade flow among countries (Navarro 2012).

Based on traditional input–output tables, MRIOT combine endogenously domestic technical coefficient matrices with import–export matrices from multiple countries or regions, capturing world trade supply chains between all economic sectors of all trading partners (Álvarez 2014).

Table 2 shows the typical structure of a Multiregional Input–Output Table.

The intermediate consumption section refers to the trade among countries and sectors. The diagonal contains the domestic matrices (A_{nn}), which show the trade among sectors within the same country. Outside of the diagonal, the matrices cover the trade among sectors of the different countries (A_{nm}).

Traditional IO tables contain the domestic matrix of a country. The domestic matrix includes the national technical coefficients, which has R × R dimensions depending on

Table 2 Typical structure of a MRIOT

Country	Sector	Country intermediate consumption							Country final demand			Total output
		1			…	n			1	…	n	
		S_1	…	S_n	…	S_1	…	S_n				
1	Sector (S_1) …. Sector (S_n)	A_{11}			…	A_{1n}			Y_{11}	…	Y_{1n}	X_1
…	…	…			…	…			…	….		…
n	Sector 1 (S_1) …. Sector n (S_n)	A_{n1}			…	A_{nn}			Y_{n1}	Y_{nn}		X_n
Total inter. consumption		IC_1			…	ICn						
Value added		VA_1			…	VA_n						
Total output		X_1			…	X_n						

the number of domestic economic sectors within the analyzed country. These technical coefficients indicate the intermediate consumption that one sector requires from another sector to produce one single unit monetary unit within a country (Eq. 1) (De la Rúa 2009).

$$a_{ij} = X_{ij}/X_j \tag{1}$$

where X_{ij} is the amount of product that the economic sector j requires from the economic sector i to generate its final production X_j, and a_{ij} is the amount of product that the economic sector j requires from the economic sector i to produce one unit of product j.

In MRIO tables, domestic and import matrices within countries are combined endogenously, and their technical coefficients integrate relations between their sectors (Eq. 2) (Álvarez 2014).

$$a_{ij}^{mn} = X_{ij}^{mn}/X_j^n \tag{2}$$

where x_{ij}^{mn} is the amount of product that the economic sector j of the country n requires from the economic sector i of the country m to generate its final production X_j^n, and a_{ij}^{mn} is the amount of product that the economic sector j of the country n requires from the economic sector i of the country m to produce one unit of product jn.

With all technical coefficients included in the MRIO tables, the initial domestic matrix *R* x *R* becomes an *Rr* x *Rr* matrix, which accounts for the trade among sectors and different countries. Finally, a country's total output includes the relations between the intermediate consumption of sectors and countries and the demand from households, governments and nonprofit organizations (Eq. 3).

$$X = AX + Y \tag{3}$$

where *X* is a country's production, A is the MRIO technical coefficient matrix, and *Y* is the household, government and nonprofit organization demand vector. This equation takes into account the intra- and interregional relations between sectors in the different countries (Miller and Blair 2009).

Equation (3) can be also formulated as the Leontief equation (Eq. (4)).

$$X = (I - A)^{-1} \times Y \tag{4}$$

where $(I - A)^{-1}$ is the Leontief inverse matrix, which quantifies the total economic effects *X* of the investment project *Y*.

While *X* depicts the total (direct and indirect) increase in the demand for goods and services generated by an investment project *Y*, it is also possible to estimate the increase in added value by considering *X* and the corresponding share of added value per sector. Additionally, due to the interdependency among economic sectors, the development of any project involves a general stimulation of economic sectors. This is the so-called multiplier effect and indicates by how much the economic activity of a country increases for every monetary unit invested in a project. The multiplier effect is the ratio between total effects (direct and indirect effects) and direct effects (*X*/*Y*), where direct effects (*Y*) are effects related to the principal demands for the project and indirect effects are the inputs necessary to satisfy direct demand (*X*–*Y*) (Holland and Cooke 1992).

3.2 Extended MRIO: environmental and socioeconomic pillars

Once the total economic impacts (e.g., total gross domestic/import demand, added value, multiplier effect) associated with an investment project have been estimated, the methodology can be expanded to account for other noneconomic effects by considering socioeconomic and environmental vectors (Z_i). These vectors are constructed from environmental or socioeconomic data (CO_2 emissions, employment, etc.) per unit of economic output for each economic sector in each country. The associated impacts are estimated by multiplying the above vectors by the total economic effect generated by the project (Eq. 5) (Caldés and Lechón 2010).

$$Z_t = Z_i \times (I - A)^{-1} \times \Delta Y \quad (5)$$

where Z_t is the total (direct and indirect) socioeconomic or environmental impact analyzed (employment,…) and Z_i is the environmental or socioeconomic vector, which indicates the employment, emissions, energy consumption, etc., per unit of production for each economic sector.

The first studies that estimated socioeconomic impacts using an IO methodology dated from the 1960s (Stone 1966). Recently, the International Energy Agency–Renewable Energy Technology Deployment (IEA-RETD) project referred to the IO methodology as one of the most robust tools for assessing job creation and the cost and benefits of alternative scenarios or different energy technologies (Breitschopf et al. 2012). With regard to environmental concerns, the first analysis performed using MRIO focused on the inventory of emissions of a huge range of sectors and countries, e.g., OECD countries (Wyckoff and Roop 1994), Japan (Kondo et al. 1998) or Australia (Lenzen 1998), from a consumer point of view. The increasing interest in the environmental effects of trade has led to an increase in this type of methodological approaches like MRIO applied to environmental impacts (Lenzen 1998; Andrew et al. 2009; Hertwich and Peters 2009; Wiedmann et al. 2010; Feng et al. 2011; Zafrilla et al. 2014). Finally, other social effects are starting to be accounted for (Alsamawi et al. 2014; Mc Bain 2015).

One of the MRIO's methodological advantages is that it accounts for a wide range of supply chains of products and services across all involved countries (Alsamawi et al. 2014). However, the MRIO methodology is not without certain limitations. Some are that it assumes unlimited production capacity, it does not account for the possibility of storage, it does not account for all informal transactions in the economy, and the IOT are only published every few years (Holland and Cooke 1992). Additionally, the sectorial aggregation involves identical impacts assumed for all activities included in each economic sector (Corona et al. 2016). Despite these limitations, this framework has been widely used to predict future impacts (Barrett et al. 2013) and support decision-making processes (Baumol and Wolff 1994), as well as for identifying key economic sectors (Archer and Fletcher 1996) (Kofoworola and Gheewala 2008).

Of particular relevance for this research is the World Input–Output Database (WIOD).[1] This multiregional database provides Multiregional Input–Output Tables of forty countries, as well as socioeconomic and environmental accounts like employment, GHG emissions, and energy and water consumption. The World Input–Output Database (WIOD) is a European Commission project developed by a consortium of eleven European research institutions (Arto et al. 2014). It covers 35 economic sectors within 40 countries plus a rest

[1] http://www.wiod.org/new_site/home.htm.

of world (RoW) region from the period 1995 to 2011. Although there are other databases, like the Global Trade Analysis Project (GTAP) (Gehlhar 1996), one of the advantages of the World Input–Output Database (WIOD) is that its world input–output tables are based on supply and use tables (SUTs) from national accounts statistics based on sector level supply and demand data. They are later integrated with bilateral trade statistics, leading to fewer discrepancies between sectorial GDP data in their IOTs and national statistics (Jones et al. 2014). By using SUTs from national accounts, data can be harmonized over time series (Erumban et al. 2012). Multiregional IOTs from GTAP are not based on SUTs from national account statistics, but are constructed from country IOTs usually provided voluntarily by researchers. They are later adjusted with trade statistics and macroeconomic data from several sources (World Bank, International Trade Center's MAcMap system, etc.) (Huff et al. 2000; Harslett 2013). Because GTAP is not benchmarked on national accounts statistics, discrepancies between GTAP-computed GDPs and national statistics have been reported to be around 5–10 %, while WIOD results in 1 % (Jones et al. 2014). Additionally, the different versions of GTAP databases are inconsistent, which is an obstacle to the use of data for historical comparisons. Other differences between databases are the availability of Multiregional IOTs (GTAP multiregional IOTs are available every three years, and WIOD MRIOTs are available every year). Additionally, the WIOD database is publicly accessible. However, WIOD has fewer sectorial disaggregations (35 sectors for WIOD vs. 57 sectors for GTAP). This could play an important role in environmental impact assessments, mainly with respect to agricultural or energy sector disaggregation. Besides, WIOD contains fewer countries, predominating mostly European countries, and the RoW aggregation is a limitation if a specific impact assessment of a country, primarily developing countries, is required (Tukker and Dietzenbacher 2013).

3.3 Expanding the social pillar: linking MRIO results with the Social Hotspots Database

When assessing the social effects of any economic activity, there is a need to explore beyond socioeconomic variables like the numbers of jobs created (UNEP et al. 2009). One way to do this is by linking the total effects estimated by the MRIO assessment with the Social Hotspots Database (SHDB). The SHDB quantifies social risks for every country-specific sector (CCS).

The first version of the SHDB was created in 2011 by New Earth[2] and was later improved in 2013. It contains a wide variety of social indicators mainly based on public data from institutions such as the International Labor Organization (ILO), World Bank (WB) and other organizations that periodically gather large volumes of social data (Franze 2013). The indicators are classified into 22 social themes based on the United Nations Environment Programme (UNEP) guideline and five impact categories (UNEP et al. 2009), as shown in Table 3.

The selection of indicators within social themes is based on the comprehensiveness of the indicator—data availability in the economic sectors and countries—data source legitimacy, data collection reliability, the possibility of quantifying the indicators and relevance with respect to the investigated theme. There are a great many different types and forms of social indicators, ranging from human rights to gender equality, and from qualitative to quantitative or semiquantitative indicators (Franze 2013).

[2] http://socialhotspot.org/.

Table 3 SHDB impact categories and social themes

Impact categories				
Labor rights and decent work	Health and safety	Human rights	Governance	Community infrastructure
Social themes				
Child labor	Injuries and fatalities	Indigenous rights	Legal system	Hospitals
Forced labor				
Excessive working time		High conflicts		Drinking water
Wage assessment				
Poverty	Toxics and hazards	Gender equality	Corruption	Sanitation
Migrant labor				
Freedom of association				Children out of school
Unemployment		Human health issues		
Labor laws				Smallholders versus commercial farm

According to the SHDB methodology, the identification of social hotspots across sectors within one country is based on the analysis and conversion of social indicators to social risk values (Benoît et al. 2012). Social risk values are figures that represent the existence and degree of different social threats occurring in economic sectors. There are four levels of social risk values, represented on a quantitative scale: low risk (1), medium risk (2), high risk (3) or very high risk (4). These social risk values are obtained by means of a process of characterizing and normalizing the different social indicators, based mainly on the data distribution (e.g.,. quartiles). Depending on the type and form of the social indicator (quantitative, semiquantitative, qualitative, etc.), other approaches are also used (e.g., expert consultation) (Franze 2013). More information about the processes of transformation and types of social risk is available from New Earth (2013). Thus, a wide variety of social issues are quantified and categorized on the same risk scale. It is therefore possible to compare and identify the highest social risks within economic sectors and countries across supply chains (GreenDelta 2013). However, this methodology also has some limitations. They include missing data for some CSS, the use of obsolete data or error accumulation throughout social risk quantification (data collection errors, uncertainty in databases, conversion into quantitative data, etc.) (Franze 2013), or the use of qualitative data, which may be biased by some degree of subjectivity (UNEP et al. 2009). Additionally, it also suffers from the same constraints as most social databases, as mentioned by Ranis & Stewart (2010) and Wolff et al. (2010).

Until now, social risk values have only been available for the GTAP classification[3] of countries and sectors (see, for example, Benoît et al. (2012)). Thus, one of the contributions of this paper is the use of social risk values for WIOD sectors and countries, and their direct linkage with a MRIO assessment of a specific project through FISA. FISA is capable of identifying Project Social Hotspots (PSH), namely the sectors with the highest social risk values in the economic sectors most stimulated by a specific project. These PSHs are identified by calculating the Project Social Index (PSI). The PSI is computed by multiplying the extended MRIO working hours results (WH) by the average social risk values in

[3] https://www.gtap.agecon.purdue.edu/.

each CSS per impact category. Of all the possible socioeconomic variables, we selected working hours as the indicator for calculating the PSI, as it reflects labor stimulation and gives a better overview of the sectors that are more vulnerable to particular social risks. In this respect, the economic sectors with the highest PSI values correspond to the PSHs. These are, at the same time, (i) the sectors most stimulated by the project in terms of WH and (ii) the economic sectors with the highest social risk values.

Compared to previous analyses using the SHDB (Benoît et al. 2012), this paper is the first to use social risk values for WIOD economic sectors and countries. Besides, the resulting PSHs round out the traditional extended MRIO assessment by expanding the social impacts to other aspects beyond employment, income and working hours. From this assessment, it is then possible to identify, for any given investment project, which sectors require special attention (PHSs) either because they are calculated by the PSI to have the heaviest burden in terms of working hours or prominent social risks. Figure 2 shows the proposed SHDB–MRIO linkage.

A possible example of PSH identification would be a project stimulating the "Renting of machinery and equipment and other business activities" WIOD sector through machinery hire, architecture or engineering services, among other activities. According to the MRIO assessment, this sector accounts for a large percentage of the total working hours across the whole project, that is, in both the investment and operational phases. Additionally, the "Construction" sector is also highly stimulated in terms of working hours, but accounts for a smaller proportion because the construction phase is shorter. Moreover, both sectors have a high average social risk value within all five impact categories, although the figure for the "Construction" sector is higher. After multiplying the respective WH and averaged social risk values in both sectors, the final PSI of both sectors is similar. This means that both sectors account for a large proportion of WH and also have high social risk values, and both are therefore PSHs. Then, it is possible to explore the highest risk values within the PSHs in order to find out which specific social issues require more attention.

Once the three types of impacts have been assessed, FISA charts consider all impacts simultaneously. The three impacts types are integrated together into the same FISA charts by comparing the specific effects of each type of impact over its effects. FISA charts could help decision makers to easily take into account that, for example, environmental and social impacts could differ widely even if alternative projects have similar figures for

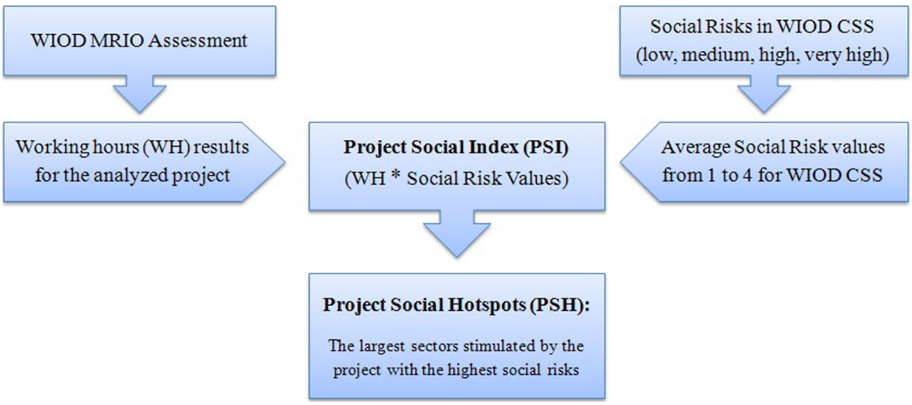

Fig. 2 SHDB–MRIO linkage with WIOD countries and sectors

economic stimulation. In this case, it is possible to explore which project phases, types of effects or countries are responsible for the largest share of impacts. This could steer decision-making processes toward the selection of the best project from a sustainability point of view, as well helping with the identification of harmful effects. Figure 3 shows the combined impacts through FISA charts.

Figure 3 is an example of a possible chart plotting FISA results. This chart shows the economic, environmental and social impacts of two hypothetical investment projects. It illustrates the proportion of direct and indirect effects over the total effects on each impact within the three sustainability pillars associated with the different projects. Other possible charts may single out the effects across countries or project phases. An immediate future line of research in this paper is the application of this methodological framework to specified case studies.

In a nutshell, FISA's strength is that it provides the possibility of integrating economic, environmental and social impacts which can be reported simultaneously by means of FISA charts. In this manner, different effects among the sustainability pillars can be compared along the whole supply chain of specific investment projects. This is possible thanks to the use of an extended MRIO analysis, whereby socioeconomic and environmental impacts can be estimated based on project cost data inputs. Additionally, these impacts are also estimated within the social pillar by linking MRIO working hour results with social risk values from the SHDB to identify PHSs. They pinpoint the riskiest economic sectors most stimulated by the development of the project. Accordingly, a wide range of output effects can be singled out: direct, indirect or induced effects across the investment or operational phases of the projects; impacts occurring on a national or international scale caused by domestic or imported components, as well as related impacts from trade relationships between countries.

Despite the advantages of this approach, it has some limitations related to sector aggregation. In this respect, the assumption of unique social risk values within each economic sector does not necessarily match up with all activities or industries aggregated in the respective sector. Additionally, this assumption does not account for the possibility of companies having different social responsibility practices within the same sector.

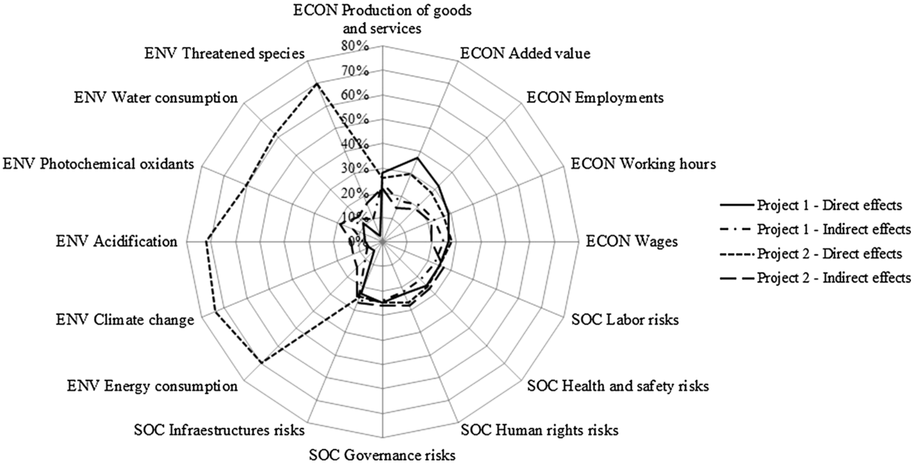

Fig. 3 Combined impacts through FISA chart

Given the globalized market, the application of the proposed methodological framework FISA to specified investment projects is expected to generate relevant results for decision makers as many projects import goods and services (either directly or indirectly) from developing countries, which often have laxer environmental and social protection legislations. The FISA results are able to account for such trade relationships and track the potential positive and most important harmful effects throughout the whole supply chain. As such, the use of this framework could make decision makers aware of the possible sustainability effects of their actions, both nationally and globally, in order to take the necessary measures to minimize the negative effects while fostering the positive impacts.

Another future line of research will focus on accounting for key stakeholder opinions and preferences in the results derived from FISA. According to Graymore (2014), stakeholders should be included in the development of sustainability methods, as they should bear in mind the priorities of counties and societies (Graymore 2014). In this way, the significance of the results produced by FISA will be assessed by key stakeholders (e.g., policy makers) through a preference questionnaire. Additionally, this exercise will compare the raw FISA results with the FISA results weighted to account for stakeholder preferences stated in the questionnaire. However, the limitations of this approach, such as possible lack of transparency or the potential subjectivity of expert evaluations and weighting processes, must also be considered (Carraro et al. 2013).

4 Conclusions

Sustainability is no longer a stranger to decision-maker agendas, and most stakeholders recognize the need to account for the economic, environmental and social implications of the decisions that they make in a globalized world. Consequently, any comprehensive sustainability assessment should account for the impacts of any project across the three sustainability pillars along supply chains linking producers with final consumers. One consideration of such assessments is the evaluation of the environmental and social impacts embodied in the traded commodities.

In this context, MRIO models are good at assessing the socioeconomic and environmental impacts of global trade. They should, however, integrate the social pillar, and this poses a methodological challenge.

In this respect, the research reported here contributes to expanding the existing body of literature by proposing the integration of MRIO analysis with social risks from the SHDB through the Framework for Integrated Sustainability Assessment (FISA). Based on the cost figures of the analyzed project, FISA estimates more than fifteen types of impacts within the three sustainability pillars, singling out direct and indirect effects, project phases and countries where the respective effects are felt. The results generated by the proposed framework also help to improve the understanding and communication of the complex relations between the three sustainability pillars. Additionally, it is useful for comparing the impacts of two alternative projects. In particular, it can identify the key impacts within the three sustainability pillars, while taking into account the whole supply chain and existing global trade. In this way, FISA aims to provide decision makers with support for choosing the best alternative taking into consideration the three sustainability pillars along the whole supply chain.

Future research lines will focus on the validation of the proposed framework through its application to alternative projects and an expert evaluation of its use in decision-making processes.

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