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Long term impacts of international outsourcing of manufacturing on sustainability

Seyed Hamed MoosaviRad [a], Sami Kara (1)[a,*], Michael Zwicky Hauschild (1)[b]

[a] Sustainable Manufacturing and Life Cycle Engineering Research Group, School of Mechanical and Manufacturing Engineering, The University of New South Wales, Sydney, NSW 2052, Australia

[b] Quantitative Sustainability Assessment, Department of Management Engineering, Technical University of Denmark, Lyngby, Denmark

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ABSTRACT

International outsourcing seems to be a cost efficient way of production. However, there are serious concerns about its long term impacts on the environmental, social and economic sustainability. This paper aims to quantify these impacts by using input output analysis, linear programming and system dynamics in a case study including European electrical industry (outsourcer), Chinese electrical industry (outsourcee) and their main suppliers. Results depict the differences related to the total CO_2 emissions, the number of employees and the gross value added of these two regions between a 10% international outsourcing scenario and the baseline scenario due to their differences in production technologies.

1. Introduction

International outsourcing as a manufacturing strategy has been expanded worldwide particularly in OECD and EU countries [1]. This decision can occur at the industry level when manufacturers transfer the production of the products that they previously manufactured internally to an external party in another country [2–4]. Although international outsourcing seems to be a cost efficient way of production, there are serious concerns about its long term impacts on the environmental, social and economic sustainability of both outsourcer and outsourcee countries [5,6]. To support a globally sustainable development, it is essential for the governments and managers at the industry level to consider and quantify the long term environmental, social and economic impacts of their decisions influencing international outsourcing. It is the objective of this paper to develop and quantify indicators representing these impacts.

2. Literature review

Two different kinds of outsourcing are distinguished in literature. A *domestic* outsourcing occurs when the production section is supplied by an external firm within the country. Otherwise, when the external firm is outside of country's boundaries, it is called *international* outsourcing. Potentially, international outsourcing can affect the sustainability of nations. Therefore, it is essential for the governments and industrial managers at the macro level to assess the sustainability when making decisions about international outsourcing. Triple bottom line evaluation needs to be done in order to judge the impacts in terms of social, economic and environmental sustainability [7,8], and to effectively manage these impacts, their magnitudes need to be measured as well.

The social dimension of sustainability is commonly recognised as the 'weakest' pillar due to the lack of analytical and theoretical underpinnings [9,10]. Social impacts of international outsourcing concern the well-being of the individuals and the society which in this case can be seen in the labour market and represented by the number of employees as a direct impact [11]. For instance, Zhang [11] demonstrated that outsourcing need not generate unemployment, but also that in certain conditions outsourcing may lead to a net welfare loss [11].

Although questioned for some types of industrial activities [12], the environmental impact is frequently represented by "Greenhouse gas emissions" among which emissions of CO_2 is dominating [13]. In [14], it was shown how international outsourcing of Australian manufacturing industry will reduce not only the CO_2 emissions of that industry but also the CO_2 emissions of the other Australian domestic industries in a specific year. In contrast, this international outsourcing will increase the CO_2 emissions of the outsourcee China and the other associated supplier countries. The authors concluded that this international outsourcing will lead to a net growth of global CO_2 emissions [14]. Herrmann and Hauschild [13] investigated the carbon footprint of products when production is changed from UK or Denmark to China. They found that carbon footprint will increase considerably because of the differences between the production technologies and practices of European and Chinese manufacturing industries [13].

To represent the economic impact of international outsourcing at the industry level the Gross Value added (GVA) of industries is chosen due to its important contribution to the nations' GDP, which is the dominating indicator of economic prosperity. The static economic impacts of international outsourcing in Australian car manufacturing industry were quantified in [15]. They revealed

* Corresponding author.

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the hidden Australian GVA loss caused by the outsourcing by considering not only the GVA reduction of the Australian car manufacturing industry but also the GVA loss of other associated Australian industries. The study showed a negative relationship between international outsourcing ratios and the GVA of industries within the outsourcer country [16].

In spite of these studies there is lack of research investigating the static and dynamic impacts of international outsourcing on the proposed economic, environmental and social sustainability indicators – GVA, CO_2 emission and the number of employees.

3. Methodology

Potentially several analytical methods can be applied for the research objective such as input output analysis (IOA), computable general equilibrium (CGE), econometric analysis of historic data and system dynamics (SD). IOA is able to deal with the complexity of economic interactions among and within the many industries and other sectors, but it is by nature static, reflecting the past patterns of economic interactions. Combination of econometric analysis methods with SD method is deemed suitable for studying the dynamic impacts of international outsourcing over time. The following subsections present the research approach combining these methods.

3.1. Analysing static impacts

Four steps were developed for investigating the static impacts of international outsourcing on three sustainability indicators including GVA, CO_2 emission and the number of employees as follows:

1) Developing a baseline input–output table for the case study.
2) Formulating a set of constraints based on the developed table and the new assumption of an alternative international outsourcing scenario (see constraints of Table 1). In Table 1, Eqs. (1) and (2) respectively depict the reductions in the outsourcer sector's production (outputs) and inputs due to the international outsourcing by a fraction b. Eq. (3) shows that the new final demands of all sectors except outsourcer and outsourcee are equal to what it was before outsourcing. The technical coefficients of all sectors in the baseline scenario and the new international outsourcing scenario are presented in Eqs. (4) and (5) respectively. The fact that outsourcee sector can support the demands of outsourcer sector is illustrated in Eq. (6). The last constraint (Eq. (7)) represents the concept of IOA that the total production of each sector equals to the intermediate demands and the final demand of that sector.
3) Finding a feasible solution by maximising the nations' GVA, maximising the nations' number of employees and minimising the nations' CO_2 emissions (see Eq. (8)) as the assumptions of this research subject to the presented constraints. For solving this multi-objective linear programming problem, Lexicographic method was programmed in Matlab software.
4) Creating a new input–output table and computing GVA, number of employees and CO_2 emissions for the new international outsourcing scenario.

Table 1
The constraints and objectives of the static model.

Constraints	$X_{1\text{new}} = (1-b)X_1$	(1)
	$\begin{bmatrix} X_{11\text{new}} \\ X_{21\text{new}} \\ \vdots \\ X_{n1\text{new}} \end{bmatrix} = (1-b)\begin{bmatrix} X_{11} \\ X_{21} \\ \vdots \\ X_{n1} \end{bmatrix}$	(2)
	$\begin{bmatrix} Y_{1\text{new}} \\ Y_{2\text{new}} \\ \vdots \\ Y_{n-1\text{new}} \\ Y_{n\text{new}} \end{bmatrix} = \begin{bmatrix} Y_{1\text{new}} \\ Y_2 \\ \vdots \\ Y_{n-1} \\ Y_{n\text{new}} \end{bmatrix}$	(3)
	$a_{ij} = \frac{x_{ij}}{X_j}$ (4)	
	$a_{ij\text{new}} = a_{ij}$ if $i \neq 1, n$ otherwise $a_{ij\text{new}} = \frac{x_{ij\text{new}}}{X_{j\text{new}}}$	(5)
	$\begin{bmatrix} a_{12\text{new}} + a_{n2\text{new}} \\ a_{13\text{new}} + a_{n3\text{new}} \\ \vdots \\ a_{1n\text{new}} + a_{nn\text{new}} \end{bmatrix} = \begin{bmatrix} a_{12} + a_{n2} \\ a_{13} + a_{n3} \\ \vdots \\ a_{1n} + a_{nn} \end{bmatrix}$	(6)
	$X_{i\text{new}} = \sum_{j=1}^{n} x_{ij\text{new}} + Y_{i\text{new}}$	(7)
Objectives	$\text{Min} \quad Z_1 = \sum_{i=1}^{n} (CO_{2_i} \times X_{i\text{new}})$	
	$\text{Max} \quad Z_2 = \sum_{i=1}^{n} X_{i\text{new}} - \sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij\text{new}}$	(8)
	$\text{Max} \quad Z_3 = \sum_{i=1}^{n} (\text{em}_i \times X_{i\text{new}})$	

Parameter definitions.
X_j is the physical output of sector j. x_{ij} is the amount of products of sector i absorbed – as its inputs-by sector j. a_{ij} is the input coefficient of the product of sector i into sector j as a technical coefficient. b is the outsourcing ratio of sector 1 while sector 1 is the outsourcer industry and sector n is the outsourcee industry. Y_i is the final demands of the products of sector i that absorbed by households, government, and other final users. CO_{2i} is the CO_2 emissions coefficient of sector i which means the direct emitted CO_2 for one product unit of sector i. em_i is the employment coefficient of sector i which means the requirement of employees for producing one product unit of sector i. New subscripts are the values of parameters after international outsourcing.

3.2. Analysing dynamic impacts

The static results obtained with IOA are representative for the current year. However, based on historical data, four important groups of parameters are considered as dynamic in this research and their influence should be studied over time. These parameters are: industries' final demands, industries' technical coefficients within the input–output tables, industries' CO_2 emission coefficients and industries' employment coefficients. The best fitted models for forecasting the trends of each of these parameters were selected analysing historical data with the use of econometric methods involving linear regression, exponential growth, quadratic regression, S-curve, moving average, single exponential smoothing, double exponential smoothing, etc. in Minitab. Then, the SD model was developed in Simulink for studying the behaviour and trends of sustainability indicators over time. The SD model included IOA feedbacks (see Fig. 1) in which the forecasted values of parameters and the sustainability indicators were considered as the model's inputs and outputs respectively.

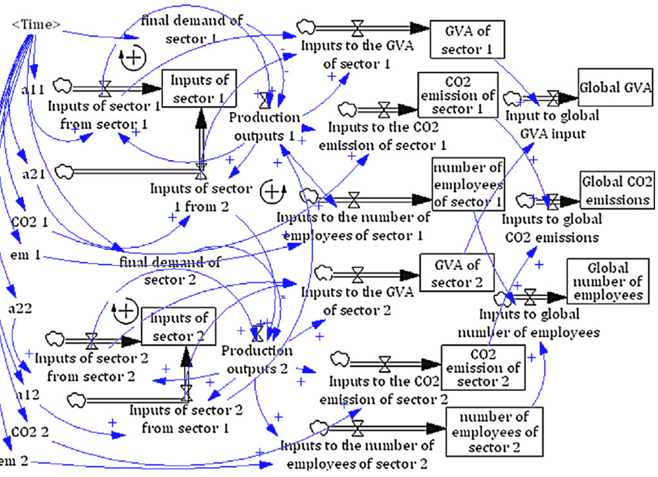

Fig. 1. Stock and flow diagram of SD model.

4. Case study

The case study includes nine sectors: (1) Electrical and Optical Equipment (EOE) industry in EU as an outsourcer industry, (2) its main supplier in EU "Basic Metals and Fabricated Metal (BMFM) industry", (3) the main CO_2 emitting supplier in EU "Electricity, Gas