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Energy and carbon intensity: A study on the cross-country industrial shift from China to India and SE Asia

Dimitrios Pappas[a,c], Konstantinos J. Chalvatzis[a,c,*], Dabo Guan[b,c], Alexis Ioannidis[a,c]

[a] Norwich Business School, University of East Anglia, Norwich NR4 7TJ, United Kingdom
[b] School of International Development, University of East Anglia, Norwich NR4 7TJ, United Kingdom
[c] Tyndall Centre for Climate Change Research, University of East Anglia, Norwich NR4 7TJ, United Kingdom

HIGHLIGHTS

- Emissions intensity higher in India and SE Asia countries compared to China.
- India's emissions intensity triple that of China in non-metallic minerals industry.
- India's emissions intensity double that of China in iron and steel industry.
- Indonesia's emissions intensity double that of China in non-metallic minerals sector.
- Paris Agreement INDC commitments to be challenged by industrial relocation.

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ABSTRACT

The potential relocation of various industrial sectors from China to India and countries of the SE Asian region presents low cost opportunities for manufacturers, but also risks rising for energy demand and CO_2 emissions. A cross-country shift of industrial output would present challenges for controlling emissions since India and SE Asian countries present higher industrial emissions intensity than China. We find that although there is a convergence in emissions intensity in the machinery manufacturing and paper and pulp industries, there are significant variations in all other industrial sectors. Indian emissions intensity is double that of China in the iron and steel and textile and leather industries and almost triple in the cement industry; Indonesian emissions intensity is almost double that of China in the non-metallic minerals and textile and leather industries and 50% higher in the chemical and petrochemical industry. We demonstrate that the expected higher emissions are driven by both a higher carbon fuel mix intensity in the recipient countries and higher energy intensity in their industrial activities. While industrial relocation could benefit certain countries financially, it would impose considerable threats to their energy supply security and capacity to comply with their Paris Agreement commitments.

1. Introduction

While China has been firmly established as the main locomotive of the global economy, it is also identified as a global industrial production hub. However, China shows evidence of slowing down with its economic growth rate being in decline, from 6.7% to 6.2% between 2016 and 2018 [1]. At the same time, Indonesia, the Philippines and Thailand are experiencing a 5.1%, 6.7% and 3.2% growth rate respectively for 2017 [1–4]. India's GDP growth stood at 6.7% in 2017 and is expected to accelerate to 7.4% and 7.8% in 2018 and 2019 respectively [5,6].

Overseas firms focus on India, among others, for establishing their production lines, with India surpassing China for greenfield FDI by $6.4 billion in 2015 [7,8] aided by initiatives such as the "Make in India" programme aimed in attracting foreign investors. In contrast to the anaemic growth of crisis hit countries in the EU [9] and other regions, SE Asia provides promising industrial hub destinations. Apart from India [10], Thailand, the Philippines and Indonesia are discussed as potential destinations by industries wanting to relocate from China [11,12]. In that context and in comparison to China, India, Indonesia, the Philippines and Thailand present young demographic characteristics which enhance their potential as destination for manufacturers [13,14]. However, they also present different energy and emission inventories [15]. From a manufacturer's point of view, industrial relocation from China to SE Asian countries can be preferable for a range of factors such as ageing population and the respective increased social

* Corresponding author at: Norwich Business School, University of East Anglia, Norwich NR4 7TJ, United Kingdom.
E-mail address: k.chalvatzis@uea.ac.uk (K.J. Chalvatzis).

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security costs [16], increased labour and production costs [17], higher environmental regulation standards [18], higher land value and less attractive tax policies [19,20].

Cross-country shift of industrial output presents different scales of production challenges that generate further impacts. The increase in production costs can be the result of increased energy input, defined by energy intensity; the ratio of energy consumption per economic output [21]. With the Chinese emissions taking the lead globally from 2005 onwards [22], carbon emissions are mainly driven by economic growth and energy consumption. Indeed, focusing on the case of China, India, Indonesia, the Philippines and Thailand, economic growth is strongly linked to increased energy consumption [23]. Empirical evidence shows that a unidirectional causality exists, running from economic growth to energy consumption [24]. This causality has also been found to be valid in the case of the Philippines and Thailand, from gross fixed capital formation to energy consumption [25].

Industrial production in the countries studied follows a growing trajectory with India's output rising by 60% from 2000 to 2012 [26]. Improving energy and carbon intensity acts as a basic element of sustainable development for mitigating the pressure posed by increased energy demand and environmental policies against climate change. Energy intensity improvements aid industrial sector competitiveness due to decreased energy costs and exposure to energy price volatility. On an economy-wide scale, effects on trade-balance can be observed not only in imported energy resources but on energy resources which are produced domestically. This is due to increased energy resources being available for export, with the potential of achieving high prices in international markets [27].

India's energy intensity of various industrial sectors; including cement, iron & steel, paper pulp & print, has been evaluated for the period of 1973–1994 [28] using a "base-year" methodology. Voigt et al. [29] used the World Input Output Database (WIOD) to analyse energy intensity trends of 40 major economies, including China, India and Indonesia for 1995–2007. They attributed China's energy intensity reduction to efficiency improvements. India was classified as the only country of the sample that initially presented high energy intensity and slow energy intensity reduction. This study highlighted a shift of the global economy gross output from countries with low energy intensity; eg. US, Japan, to countries with higher energy intensity such as China and to India in a lesser extent during that timeframe. Sadorsky [30] used a compiled model of heterogeneous panel regression techniques to measure the effect of industrialization and urbanization on energy intensity in developing countries such as China, India, the Philippines, Thailand and Indonesia and concluded that policies aimed at speeding up industrialization will increase energy intensity, only to be countered by income growth offsetting the impact of the former.

Energy intensity measures energy consumption per economic output and the examined countries have progressed differently in developing the examined industrial sectors [31]. This should lead to use of different technologies, with different attributes in relation to energy consumption to produce the specific industrial goods [32]. We therefore, hypothesize that even when looking at the same industrial sector, countries will have different energy intensity per economic output (H1). Energy intensity relies largely on the technologies used and gradually cross-country knowledge transfer progresses by either governmental schemes or multinationals active in several countries [33]. Therefore, we hypothesize that different countries' energy intensity for the same industrial sectors will converge over time (H2).

When estimating carbon intensity, the specific fuel mix of every industrial sector is important as every fuel has significantly different emission factors [34]. This impact is different when carbon intensity is estimated per energy used and per economic output [35,36]. As a result, we hypothesize that different countries will present significantly different carbon intensity patterns, even for the same industry, when carbon intensity is estimated as a function of energy used and economic output (H3). Moreover, while technological convergence can be expected, fuel mix convergence might be significantly more difficult to achieve as countries prioritise their indigenous fuel reserves. Therefore, we hypothesize that different countries' carbon intensity per energy used will not converge in a short time (H4).

The IEA has directly linked lower energy intensity to emission reduction; in extension to carbon intensity, and increased energy security [37,38]. However, countries differ from one another in energy and carbon intensity levels, presenting research interest for evaluating their performance, enabling further appraisal of their potential for intensity levels reduction. Calculating sectoral energy and carbon intensity is a first necessary step in locating the country needs not only for technological progress but also output structure, technical efficiency, capital and labour energy ratio as these factors act as energy intensity drivers [39]. The relocation's impact on industrial CO_2 emissions is complex to estimate and depends on the specific country shifts, their relative energy intensity and their relative emissions intensity.

While the extent and trajectory of industrial relocation between the aforementioned countries is an issue for debate in the literature [40,41], in this manuscript, we compare the energy and emissions intensity of China, India and selected SE Asian countries to better understand the required energy for producing the same industrial output and the CO_2 impacts of a potential industrial relocation. We look into a range of industrial sectors to capture their intricacies in the examined countries. Therefore, this work provides a methodological contribution in reconciling energy, emissions and financial output datasets from the IEA and UNIDO. Furthermore, our results improve the understanding of the impact that potential relocations of industries have in terms of emissions, and more significantly to identify which sectors might be best and worst placed to accommodate relocation activities in the near future. Therefore, we advance the existing research by clarifying the methods and providing the results for country and industrial sector specific hierarchies in energy and carbon intensity.

After this brief introduction, this manuscript continues with an extensive explanation of the methodological approach and the use of specific datasets in Section 2. In Section 3, we present the results for all the examined countries and industrial sectors. Discussion of the results continues in Section 4 and we provide concluding remarks in Section 5.

2. Method and data

2.1. Data

According to the United Nations Sustainable Development Division (UNSDD), energy intensity is defined as the ratio of energy use to GDP [42] and as the final energy consumption divided by the Gross Value Added (GVA) at constant prices [43]. While Eurostat defines the unit of economic output as the GVA, the UNSDD argues that a standardized methodology for calculating energy intensity does not exist [42]. This claim is evidently supported by the US Office of Energy Efficiency & Renewable Energy, which plainly expresses the energy intensity as energy per unit of output [44]. For the purposes of this research, the industrial output that will be extracted from the appropriate database is expressed as the total output in current million US dollars. The IEA database is used for extracting energy consumption data per fuel product and industrial flows [45] and presents a wide range of flows and time series data [46]. IEA data has been used extensively for research on China [47,48], Indonesia [49,50], the Philippines and Thailand [51]. For comparison, regional data provided by Indian authorities (MOSPI) is characterized by limited length of time-series, generic fuel products and inconsistent data provision [52].

Focusing on the breakdown of products and flows found in Table 1, the labels are explained as following according to the IEA standards: "Chemical" refers to the chemical and petrochemical; "I&S" is the iron and steel; "N.M.M." stands for non-metallic minerals; "N-S" as non-specified; "PPP" as the paper pulp and print; and finally, "T&L" as the textile and leather industries. The physical quantities of products [54]