Applied Energy 223 (2018) 124–133

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Untangling the drivers of energy reduction in the UK productive sectors: Efficiency or offshoring?

Lukas Hardt[a,b,*], Anne Owen[a,b,c], Paul Brockway[a,b], Matthew K. Heun[d], John Barrett[a,b,c], Peter G. Taylor[a,b,e,f], Timothy J. Foxon[g]

[a] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK
[b] UK Energy Research Centre, 58 Princess Gate, London, SW7 2PG, UK
[c] Centre for Industrial Energy, Materials and Products, School of Earth and Environment, University of Leeds, LS2 9JT, UK
[d] Engineering Department, Calvin College, Grand Rapids, MI 49546, USA
[e] Low Carbon Energy Research Group, School of Chemical and Process Engineering, University of Leeds, Leeds LS2 9JT, UK
[f] Centre for Integrated Energy Resarch, University of Leeds, Leeds LS2 9JT, UK
[g] SPRU (Science Policy Research Unit), University of Sussex, Falmer, Brighton BN1 9SL, UK

HIGHLIGHTS

- Novel decomposition using results using exergy analysis and input-output model.
- Thermodynamic efficiency is not the main driver of energy intensity improvements.
- Majority of energy savings from structural change are due to offshoring.
- Significant slow-down in energy savings from all factors after 2009.

ARTICLE INFO

Keywords:
Energy consumption
Decomposition
UK
Exergy
Multiregional input-output databases
Offshoring

ABSTRACT

The UK has been one of the few countries that has successfully decoupled final energy consumption from economic growth over the past 15 years. This study investigates the drivers of final energy consumption in the UK productive sectors between 1997 and 2013 using a decomposition analysis that incorporates two novel features. Firstly, it investigates to what extent changes in thermodynamic efficiency have contributed to overall changes in sectoral energy intensities. Secondly, it analyses how much of the structural change in the UK economy is driven by the offshoring of energy-intensive production overseas. The results show that energy intensity reductions are the strongest factor reducing energy consumption. However, only a third of the energy savings from energy intensity reductions can be attributed to reductions in thermodynamic efficiency with reductions in the exergy intensity of production making up the reminder. In addition the majority of energy savings from structural change are a result of offshoring, which constitutes the second biggest factor reducing energy consumption. In recent years the contributions of all decomposition factors have been declining with very little change in energy consumption after 2009. This suggests that a return to the strong reductions in energy consumption observed between 2001 and 2009 in the UK productive sectors should not be taken for granted. Given that further reductions in UK final energy consumption are needed to achieve global targets for climate change mitigation, additional policy interventions are needed. Such policies should adopt a holistic approach, taking into account all sectors in the UK economy as well as the relationship between the structural change in the UK and in the global supply chains delivering the goods and service for consumption and investment in the UK.

1. Introduction

Most of the IPCC scenarios aiming to limit global warming to 2 °C result in a stabilisation of energy consumption at the global level [1]. This requirement for stabilisation should be considered as an optimistic requirement as most of the scenarios also rely on large quantities of unproven negative emission technologies [2,3]. If such technologies do not materialise at sufficient scale, stabilisation of global energy

* Corresponding author at: Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK.
E-mail address: e14l2b@leeds.ac.uk (L. Hardt).

https://doi.org/10.1016/j.apenergy.2018.03.127
Received 13 December 2017; Received in revised form 1 March 2018; Accepted 27 March 2018
Available online 25 April 2018

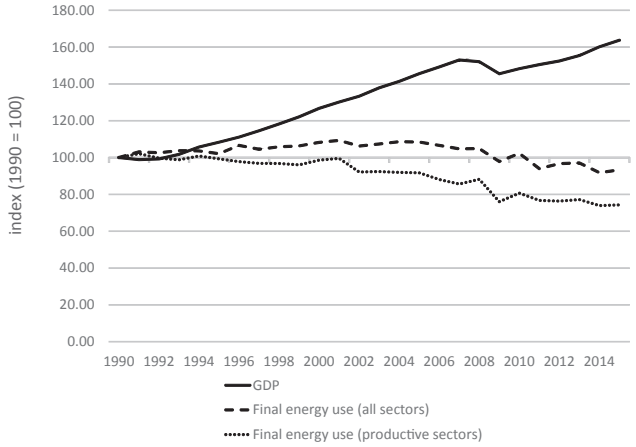

Fig. 1. UK GDP and final energy consumption (exluding non-energy use) between 1990 and 2015. Values are indexed with 1990 = 100. Productive sectors include the industry and non-industrial sectors but excludes energy consumption for domestic and transport purposes. GDP and energy data were obtained from the UK Office for National Statistics [7] and the Energy Consumption in the UK data collection [8] respectively.

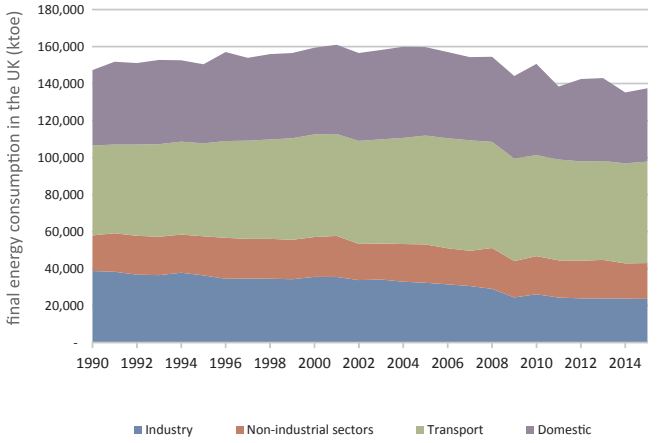

Fig. 2. Final energy consumption in the UK by sector. This article only investigates energy use in the productive sectors which represent the industry and non-industrial sectors shown here. Energy data were obtained from the Energy Consumption in the UK data collection [8].

consumption might not be sufficient and absolute reductions might be needed to avoid dangerous climate change. At the same time global population is predicted to increase over the period to 2050 by about 30% compared to current levels in the UN's medium variant [4] and many less-developed countries will need to increase their energy consumption to reduce poverty and social hardships, especially given that 16% of the global population currently do not have access to energy [5]. Increasing energy consumption in developing countries combined with a need to stabilise (let alone reduce) global energy use therefore implies the need for absolute reductions in energy consumption in developed countries, potentially exceeding 50% for per capita energy-use.

However, only very few developed countries have so far achieved an absolute decoupling of final energy consumption and economic growth over extended periods of time [6]. One of the few examples where this has happened is the UK. Despite a 19% growth in real GDP, final energy consumption (excluding non-energy use) declined by 11% between 2001 and 2013 (Fig. 1). However, to meet climate change targets energy consumption will most probably need to be reduced even further. To assess the need for further policy interventions and to see whether lessons from the UK can be applied in other countries, it is important to understand what has been driving the reduction in energy consumption in the UK and whether the trends are likely to continue into the future.

This study will contribute to this understanding by providing an analysis of the final energy consumption in the UK 'productive' sectors between 1997 and 2013, meaning the industrial and non-industrial sectors producing economic output. While final energy consumption in the productive sectors only accounted for 31% of all final energy consumption in the UK in 2013 (Fig. 2), the reductions in final energy consumption in these sectors accounts for about two thirds of the overall reductions in UK final energy consumption since 2001. To investigate the drivers of energy consumption in the productive sectors this study employs an index decomposition analysis with two novel features. Firstly, it draws on energy conversion chain (ECC) analysis that allows the estimation of the conversion efficiencies from final energy to useful exergy [9]. In this way energy intensity reductions can be broken down into a component representing thermodynamic conversion efficiency and a component representing the changing monetary output per unit of useful exergy. Secondly, it employs data from a multi-regional input-output (MRIO) model to investigate how much of the energy savings resulting from structural change can be attributed to offshoring. The results of this decomposition analysis are also compared to the results of a conventional approach featuring only energy intensity and structural change factors.

Index decomposition analysis is a widely-used tool to identify the drivers of change in energy use and carbon emissions [10,11]. It has been applied to study aggregate energy consumption in countries [12,13], as well as energy consumption in particular sectors, such as the residential [14,15] and transport sectors [16,17]. Index decomposition analysis of economic sectors commonly decomposes energy use according to three factors, namely energy intensity, structural change and output [18]. In such an approach energy intensity describes the energy used per unit of monetary output in each sector, structural change describes the sectoral composition of the economy and economic output describes the change in the aggregate output of the economy. Such decomposition analyses for the UK generally conclude that energy intensity reductions have been the major driver of reductions in UK final energy consumption over the last two decades, even though structural change has also been important [13,18–24]. However, most of these studies only pay brief attention to the UK as part of a multi-country study and there has not been a comprehensive analysis of the drivers of final energy consumption in the UK productive sectors in the past two decades. Hammond & Norman [21] decompose trends in energy and CO_2 emissions in the UK, but focus exclusively on the manufacturing sectors between 1990 and 2006. Reports from the ODYSEE-MURE project present detailed analyses of the ODEX efficiency indicator, but pay less attention to structural change [25].

The conventional decomposition approach focusing on energy intensity, structure and output provides important insights, but it leaves important questions unanswered about the underlying drivers of changes in energy intensity and economic structure. Firstly, the measure of energy intensity does not answer the question of whether changes have been driven by increasing thermodynamic efficiency of energy conversion processes or by other effects influencing monetary output. Secondly, looking at structural change within a country does not indicate whether this structural change is a reflection of offshoring, (i.e. a shift of energy-intensive production to other countries) or whether it is due to changed economic needs and the production structure that satisfies them. Whether structural change is due to offshoring is important, because it determines in how far energy savings from structural change have contributed to global climate change mitigation efforts. There are studies that have used input-output models to investigate changes in the energy-footprint of countries, including the UK [26,27]. However, these studies do not link the changes in the footprint to the changes in domestic structure to assess in how far domestic structural change has been a result of offshoring. Other studies specifically study the economic impacts of environmental improvements