

Moving towards an energy efficient future

Citation for published version (APA):

Zhong, S. (2017). *Moving towards an energy efficient future: essays on energy efficiency, technology and development*. [Doctoral Thesis, Maastricht University]. Datawyse / Universitaire Pers Maastricht. <https://doi.org/10.26481/dis.20170614sz>

Document status and date:

Published: 01/01/2017

DOI:

[10.26481/dis.20170614sz](https://doi.org/10.26481/dis.20170614sz)

Document Version:

Publisher's PDF, also known as Version of record

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy

If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.

Summary

As an influential development paradigm, sustainable development has gained broad support from various governments and organizations at regional, national and global levels. It is a process involving many important dimensions and its study requires efforts from researchers from all the disciplines of natural and social sciences. In this thesis, we focus on energy efficiency, a key element in the pursuit of sustainable development. The dynamics of energy efficiency is an evolutionary process that involves industries, technologies and institutions. Therefore, it requires a wide range of policies, aimed at both macro and micro levels. It is of primary importance to have a careful economic study of all the detailed processes that are involved in the policy-relevant areas. Numerous programs, funds, facilities related to energy efficiency have been implemented so far and are still ongoing. In the study of energy efficiency, many policy-relevant areas that require numerous research and financial inputs and careful empirical analysis are involved. Due to data availability and the feasibility of this study to be effectively conducted, as an early step, we narrow down our research at micro and macro levels to the following aspects: energy consumption and energy efficiency at sectoral and country levels, aggregate vehicle energy efficiency (regional level) and the technologies related to energy efficiency in the fields of power station, ICT in buildings and vehicles. We hope that our results can shed light on the relevant policies and studies in the future.

Using large datasets, this dissertation provides a comprehensive narrative of how energy efficiency and the technologies related to energy efficiency evolve over time. We develop a new analytical framework and several measures for crucial factors affecting energy consumption and energy efficiency in trade at sectoral and country levels. Based on big data of individual vehicles and their owners, we design an empirical statistical approach to estimate regional aggregate vehicle energy efficiency that is formed by the technological characteristics and collective behaviors of micro-agents (e.g., purchase and usage of vehicles and migration), and describe the life cycle and restructuring of the vehicle population. Also, we identify the technological trajectories of technologies related to energy efficiency, and develop some measures for whether a country can be classified as an incumbent country or a latecomer country, and for how much a country contributes to technological development. The approaches used in this dissertation that build aggregate or macro measures on the basis of detailed and micro large datasets are of great value for the study of economic, industrial and scientific evolution. The

optimal path method in this dissertation based on the patent citation networks may inspire studies in any other technological fields, and enable policymakers as well as investors to monitor technological development and discover business opportunities. The precise empirical evidence provided by this dissertation can assist policymakers in finding tailored solutions to the real world problems.

In Chapter 2 we review the decomposition techniques commonly used in energy and environmental economics, and propose a new decomposition method in the input-output framework to identify crucial factors affecting the growth of energy consumption and energy efficiency. We take into account trade relations and intermediate inputs in production that are mostly neglected by traditional methods. Unlike prior studies, we develop two perspectives: energy directly used for production or household consumption purposes, and energy embodied in the products consumed by economies and households. We also apply the analysis to all the major economies and sectors in the world. The results show that energy consumption increases caused by economic development can be roughly offset by reducing the energy intensity and lowering energy intensity is the overwhelming factor behind the decline in aggregate energy intensity in most economies, while trade in intermediate inputs has a small effect in changing energy consumption. We also find that the gaps of energy intensity between economies tend to narrow down and the relationship between energy intensity and GDP per capita is strictly decreasing.

The methods used in Chapter 3 are developed based on firm productivity literature and convergence analysis in development economics. We particularly focus on vehicles, a typical durable product consuming energy. By tracking every vehicle, we estimate regional aggregate vehicle energy efficiency based on the usage and energy efficiency of every individual vehicle. By doing so, we do not have the issues of heterogeneity and representative agent. We also estimate the entry effect of new vehicles, the reallocation of energy efficiency vehicles and the Ergodic distribution of aggregate vehicle energy efficiency. Additionally we check the socio-economic factors affecting the distribution of vehicles over locations and vehicle exit event. The availability of the big data makes this paper one of first few papers estimating regional energy efficiency for vehicles. Our results confirm the importance of structural change in the vehicle population, the convergence of aggregate vehicle energy efficiency between municipalities and the crucial role of socio-economic factors in shaping vehicle distribution.

In Chapter 4, using up-to-date bibliographical and citation information of patents from the European Patent Office, we study the technological evolution of three fields on energy efficiency classified by the OECD ENV-TECH list: power station, ICT in buildings and vehicles. We construct patent citation datasets for these fields, and identify the optimal technological paths by maximizing total search pair count (SPC) weights in the citation networks. We also develop new measures to evaluate countries' role (incum-

bent or latecomer) and contribution in these fields. The results show that latecomer countries tend to contribute less to the main technological trajectories in the fields of energy efficiency, while those countries with large bested interests in the dominant technological trajectories are also the ones that contribute more. This paper is an early attempt of quantifying technological development of the OECD ENV-TECH list. The methods used in this chapter can be applied to any other fields.