

# Moving towards an energy efficient future

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# Valorisation

In accordance with article 23.5 of the Regulation Governing the Attainment of Doctoral Degrees at Maastricht University, this addendum discusses the valorization opportunities presented by this Ph.D. thesis.

Sustainable development is a process that involves a wide range of dimensions and tailored strategies or policies are strongly needed, but there is a lack of data-driven and micro-founded studies of those detailed processes hidden in the aggregate dynamics. The focus of this thesis is on energy efficiency, one of the most important themes in sustainable development. The fundamental research questions in this dissertation are: (1) how do the aggregate energy consumption, aggregate energy efficiency and technologies related to energy efficiency evolve over time? (2) What are the driven factors that affect the growth of aggregate energy consumption and aggregate energy efficiency across sectors, regions and economies? How do countries perform in the technological fields related to energy efficiency? To explore the complex dynamics of energy efficiency across sectors, regions and economies, we developed several methodological frameworks based on well-documented economic literature from various fields such as input-output analysis, aggregate productivity, development economics and complex networks.

Unlike most prior studies on energy issues that use the aggregate data directly, in this work, we presented a series of statistical methods that rigorously construct the aggregate variable of interest using large datasets on (1) transactions between various sectors and economies across the world, (2) technological characteristics and behaviors of micro-agents (individual vehicles and their owners), and (3) patent related to energy efficiency in three fields (power station, ICT in buildings and vehicles). We showed how aggregate energy efficiency (sectoral, regional and economy levels) evolves: we precisely derived the influential factors affecting the growth of energy efficiency, discovered the crucial empirical patterns and investigated the long run trends. Also, we employed optimization technique for complex networks to identify the most important patents and their citation relations for energy efficiency technologies and assess countries' profiles in the technological fields under study.

The theories, methods and findings of this thesis offer some profound insights. First, this thesis has shown that the policy-oriented empirical research can greatly benefit from the development of large datasets and overcome some limitations of prior studies using sample data only and provide more precise results concerning crucial policy themes. By looking into the detailed processes of trade in production and consumption, life cycle of vehicles and technological development, this thesis provides a better understanding of the dynamics of energy efficiency at various levels, which is of great importance for policymakers and experts in relevant fields. Second, the strategies or policies concerning energy efficiency should better fit the evolution of energy efficiency. For instance, since industries perform differently in terms of energy consumption and

energy efficiency, the industrial policies in favor of technological change towards higher efficiency in medium/low-tech manufacturing would be preferable (Chapter 2). Third, this thesis links dynamics of aggregate energy efficiency to the technological characteristics of millions of individual vehicles and the collective behaviors of their owners (e.g., usage of vehicles, purchase of vehicles and migration, etc.). A smartly-designed policy package should take into account all of these aspects, for example, providing a range of policy instruments to stimulate the innovation and diffusion of new energy efficient products, the more efficient substitution of products with low energy efficiency and more effective usage of energy efficient products. Also, the policy scenario should match specific regional socio-economic characteristics. Fourth, the technological trajectory analysis in Chapter 4 provides a reasonable and clear guidance about which sub-technological fields are promising among lots of complex technological trends that both policymakers and entrepreneurs should focus on. In fact, globalization leads to an incredible expansion of technology and the cooperation of innovation, coupled with uncertainty, which significantly increased the difficulty of designing proper policies and strategies. The methods developed in this thesis are relevant beyond the study of energy efficiency. They can be applied to any other technological fields and commercially viable for business strategy and intelligence.

The target audiences of this dissertation include students, scholars, policymakers and experts in the fields of energy studies or studies related to sustainable development, business strategists, entrepreneurs, investors, innovators as well as everyone who is interested. The methods and findings of this dissertation have been disseminated with a wide range of audiences within and beyond academia during the course of this Ph.D. dissertation. Chapters 2, 3 and 4 have been presented to academic audiences and policy experts in various workshops and international conferences. Also, these three chapters have been included in the UNIDO Inclusive and Sustainable Industrial Development Working Paper Series. In particular, Chapter 2 has been a background paper for the UNIDO Industrial Development Report 2016.