Bank of Japan Working Paper Series

Energy Efficiency in Japan: Developments in the Business and Household Sectors, and Implications for Carbon Neutrality

Kosuke Aoki*
kaoki@e.u-tokyo.ac.jp

Jouchi Nakajima**
nakajima-j@ier.hit-u.ac.jp

Masato Takahashi***
masato.takahashi@boj.or.jp

Tomoyuki Yagi****
tomoyuki.yagi@boj.or.jp

Kotone Yamada*****
kotone.yamada@boj.or.jp

No.23-E-10
May 2023

Bank of Japan
2-1-1 Nihonbashi-Hongokucho, Chuo-ku, Tokyo 103-0021, Japan

* University of Tokyo
** Research and Statistics Department (currently at Hitotsubashi University)
*** Research and Statistics Department (currently at the Personnel and Corporate Affairs Department)
**** Research and Statistics Department
***** Research and Statistics Department (currently at the Secretariat of the Policy Board)

Energy Efficiency in Japan: Developments in the Business and Household Sectors, and Implications for Carbon Neutrality*

Kosuke Aoki† Jouchi Nakajima§ Masato Takahashi‡

Tomoyuki Yagi** Kotone Yamada††

May 2023

Abstract

Recently the efforts toward decarbonization are spreading both in Japan and abroad. In this paper, we examine the developments in Japan's energy intensity, a measure of energy efficiency, and their background at the aggregate and sectoral levels. The main results are as follows. Energy efficiency in Japan improved considerably between the 1970s and the 1980s, mainly due to the progress in energy-saving technical changes in the business sector. Although the pace of improvement decelerated on the whole from the 1990s to the first half of the 2000s, Japan's energy efficiency has returned to a moderate improving trend, particularly in the household sector, in recent years. Our estimate using a simple model of the household sector shows that the recent improvement in aggregate energy efficiency may reflect households' purchases and utilization of energy-saving goods produced by the business sector. Further efforts are expected to be made in each sector to achieve carbon neutrality.

JEL classification: E21, E22, H23, Q54

Keywords: Climate Change, Carbon Neutrality, Energy Efficiency, Technical Change

---

* The authors thank Ryo Jinnai, Seisaku Kameda, and staff members of the Bank of Japan for their valuable comments. Any remaining errors are our own. The views expressed in this paper are those of the authors and do not reflect the official views of the Bank of Japan.

† University of Tokyo. E-mail: kaoki@e.u-tokyo.ac.jp

§ Research and Statistics Department, Bank of Japan (currently at Hitotsubashi University). E-mail: nakajima-j@ier.hit-u.ac.jp

‡ Research and Statistics Department (currently at the Personnel and Corporate Affairs Department), Bank of Japan. E-mail: masato.takahashi@boj.or.jp

** Research and Statistics Department, Bank of Japan. E-mail: tomoyuki.yagi@boj.or.jp

†† Research and Statistics Department (currently at the Secretariat of the Policy Board), Bank of Japan. E-mail: kotone.yamada@boj.or.jp

1. Introduction

Recently, there has been a growing interest in climate change globally. In Japan, efforts have been made to reduce greenhouse gasses, such as CO2 emissions, toward achieving carbon neutrality by 2050. Such efforts to address climate change may widely affect various economic agents in Japan and abroad for a long time, since energy consumption and the resultant greenhouse gas emissions are closely related to each entity's economic activity. Working toward decarbonization may also change the industrial structure considerably. Therefore, it is crucial to pay close attention to climate change in considering Japan's economic developments.

In discussing the progress of decarbonization thus far, Kaya (1990), the Intergovernmental Panel on Climate Change (IPCC, 2000), Kurachi *et al*. (2022), and others assess changes in the amount of CO2 emissions from the perspective of energy sources and energy saving. CO2 emissions per real GDP are measured by multiplying "CO2 emission intensity (carbon intensity)," *i.e.*, CO2 emissions per energy consumption, by "energy intensity (energy efficiency)," *i.e.*, energy consumption per real GDP. Therefore, it is necessary to lower carbon intensity or increase energy efficiency to reduce CO2 emissions. Carbon intensity may change due to shifts in the power source structure, such as a shift from thermal power generation to solar or wind power generation. On the other hand, energy efficiency is likely to change owing to various efforts by each economic entity. For example, in the business sector, firms can improve their energy efficiency of the production process at their factories or develop final products that operate efficiently with low energy inputs. If households use such energy-efficient final products, energy efficiency improves at the aggregate level. This consideration suggests that firms producing energy-using goods contribute to developments in energy efficiency at the aggregate level through two channels: the energy efficiency of the production process and that of the products themselves.

This paper reviews developments in Japan's energy efficiency and discusses their background. Most previous studies on energy efficiency focus on the business sector. For instance, Nomura (2021) measures Japan's energy efficiency over more than the last fifty years and indicates that it has improved in the manufacturing sector. Hamamoto (2006) and Norsworthy and Malmquist (1983) analyze the major industries in the manufacturing sector and argue that environmental regulations of the government promote research and development (R&D) in firms and, in turn, contribute to an improvement in productivity. Morikawa (2011) indicates that the higher the population density of the area, the higher the energy efficiency of the nonmanufacturing sector, and points out that enhancing infrastructure in urban areas contributes to reducing environmental burden and promoting

economic growth simultaneously.

Meanwhile, considering the recent increase in use of energy-efficient products such as eco-friendly automobiles and home appliances, it is essential to pay attention to developments in energy efficiency not only in the business sector (production sector)—in which such products are manufactured—but also in the household sector, in which these products are mainly used. To the best of our knowledge, few studies have focused on such efficiency in the household sector. Moreover, none of them are based on theoretical models.[1] This paper studies the changes in Japan's energy efficiency at the aggregate and sectoral levels and analyzes the recent developments in such efficiency in the business and household sectors using theoretical models and actual data. On the basis of this analysis, the paper discusses what kinds of efforts Japan needs to make to achieve a low-carbon society.

The remainder of this paper is organized as follows. Section 2 summarizes the developments in the energy efficiency in Japan and discusses their background. Sections 3 and 4 examine the energy efficiency of the business and household sectors, respectively, based on simple theoretical models and empirical analyses. Section 5 concludes.

2. Energy efficiency in Japan

Japan's energy intensity, a measure of energy efficiency, has followed a declining trend, indicating an improvement in efficiency in the long run, albeit with considerable fluctuations. Specifically, it improved substantially from the 1970s to the 1980s, but the pace of improvement decelerated significantly from the 1990s to the 2000s. It has recently improved again, although the pace has been moderate (Chart 1). Looking at it by sector, the improvement from the 1970s to the 1980s can be explained by the developments in the manufacturing sector. In contrast, the progress in recent years can be attributed to the household sector (Charts 2 and 3).[2]

---

[1] Nomura (2018), one of the few studies that refers to energy efficiency of the household sector, points to the widespread use of energy-saving products in this sector as a factor for the increase in Japan's energy efficiency, in addition to the improvement in such efficiency in the business sector.

[2] Energy efficiency at the aggregate level is often calculated by dividing the amount of energy supply or energy consumption by GDP. In decomposing the factors for changes in energy efficiency, we use the *General Energy Statistics* compiled by the Agency for Natural Resources and Energy for the amount of final energy consumption in the numerator. The household sector includes passenger vehicles for household use. As for the denominator, GDP for the household sector is based on the consumption of households in the expenditure side of gross domestic product, and GDP for the manufacturing and transport sectors are based on gross domestic product by economic activity (hereafter referred to as manufacturing sector GDP and transport sector GDP, respectively). Note that the former is on a fiscal year basis, while the latter is on a calendar year basis, due to statistical constraints. The intensity of "other

This section analyzes developments in energy efficiency and their background in detail by phase. In doing so, we decompose changes in Japan's overall energy efficiency into the contribution of each sector to changes in efficiency.

(Phase I: From the 1970s to the 1980s)

Japan's energy efficiency improved considerably from the 1970s to the 1980s, when the two Oil Shocks occurred (Phase I). There are three possible factors for improving energy efficiency in this phase.

First, changes in the industrial composition seem to have contributed to the improvement in energy efficiency at the aggregate level in Phase I (Chart 3). During this period, an increasing number of firms in the manufacturing sector shifted from a less energy-efficient material industry to a more energy-efficient processing industry (Chart 4). Moreover, as the economy matures, the share of the nonmanufacturing sector (services sector), of which the amount of energy consumption is relatively small, rose, and this also appears to have led to the improvement in energy efficiency at the aggregate level.

Second, an improvement in energy efficiency in the manufacturing sector appears to have brought about the progress in aggregate-level efficiency (Charts 2 and 3). In response to the severe pollution in Japan and abroad in the 1960s, regulations on emissions from factories and automobiles were introduced, and firms were required to comply with them. Hamamoto (2006) and Norsworthy and Malmquist (1983) point out that this response to environmental regulations promoted the energy-saving technical change in firms. In addition, the two Oil Shocks seem to have stimulated the development of energy-saving technology. Hassler *et al*. (2012) and Popp (2002) argue that the surge in energy prices during the Oil Shocks promoted energy-saving technical change and innovation.

As part of the process of regulating the automobile industry, amendments to the Clean Air Act (so-called Muskie Act) were enacted in 1970 in the United States. The amendments required automakers to reduce nitrogen oxide (NOx) emissions from automobiles significantly. In Japan, motor vehicle emission control (so-called the Japanese Muskie Act) was established in 1978. Ito and Urashima (2013) argue that, while opposition from major automobile companies prevented the Muskie Act from coming into force in the United States, Japanese automakers invented new engines that satisfied the new regulations, which in turn

---

sectors" is calculated as follows: energy consumption of all sectors excluding the manufacturing, transport, and household sectors / (GDP minus manufacturing sector GDP minus transport sector GDP minus consumption of households). It is worth noting that the denominator contains some overlap as we use GDP by economic activity and the expenditure side of GDP.