Energy Policy 98 (2016) 274–289

Contents lists available at ScienceDirect

Energy Policy

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

Baseline of the projection under a structural change in energy demand

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HIGHLIGHTS

- The structural change in energy demand was undertaken beginning in the late 2000s in Japan.
- We developed the energy demand model and project the future energy consumption considering the structural change.
- Our model forecasts a 12% reduction in the energy demand in 2030 compared to the reference case in the government's outlook.
- The demand reduction is equal to about 86.0% of the effect of the planned policy measures by the government.

ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form
26 July 2016
Accepted 27 August 2016

Keywords:
Structural change
Energy outlook
Energy policy
Energy demand model

ABSTRACT

This article investigates the long-term energy demand and energy policy measures when undergoing structural changes in energy demand. Initially, the statistical test shows the possibility of the structural change from the late 2000s. Therefore, we developed the energy demand model to forecast the energy demand by 2030 that considers the structural change. The results show that there may be a 12% reduction in the energy demand in 2030 compared to the reference case in the Japanese government's outlook, which is equal to about 86.0% of the effect of the planned policy measures by the government, but also that it is difficult to achieve energy-originated CO2 emissions in the national target. Our analysis suggests that mitigation policies are required, but those in the planned policy measures are not completely required to achieve the goal.

1. Introduction

The major nuclear accident at the Fukushima Daiichi power plant caused by the tsunami from the Great East Japan Earthquake (GEJE) is meaningful when energy and climate policy is considered. This nuclear reactor disaster was the first since the Kyoto Protocol came into effect and was the breaking point for decreasing reliance on nuclear power generation, at least in some countries. To this end, there are many studies that underline the importance of mitigation policies when nuclear power stations are phased out, but there have been very few attempts to incorporate a structural change in energy demand into the policy assessments. Consequently, most of the previous studies that assess the energy and climate policy focus on the proposed policy and measures and, in doing so, obfuscate a connection between the current and future economic situation to influence energy demand. In this paper, we address the possibility of having undertaken a structural change in energy demand since the late 2000s in Japan and analyze the policy measures under the structural change using an energy demand model.

Decreased reliance on nuclear power leads to uncertainty about national greenhouse gas (GHG) emissions' targets or pledges; a substitute renewable energy and decarbonized technology for nuclear power is required. This need can result in rising mitigation costs. Bauer et al. (2012) showed that the phase-out of nuclear power plants leads to an additional 1283 Mt-CO_2 of emissions without the policy and measures to mitigate CO_2 emissions, and its reduction costs will generate 2.1% per year of global GDP in 2050 under international carbon constraints. There is no negligible effect of decommissioning existing nuclear power stations and restricting investment on additional plants on the environment and

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http://dx.doi.org/10.1016/j.enpol.2016.08.035
0301-4215/

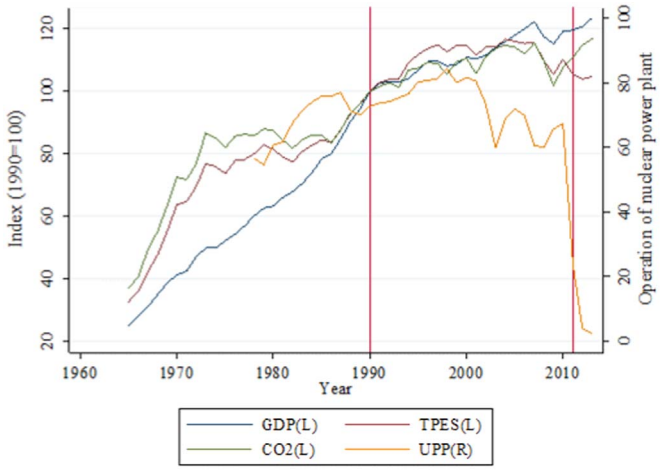

Fig. 1. Historical changes in energy-related data in Japan. Note: UPP is the ratio of operation in a nuclear power plant. The data are normalized to choose the base year as 1990 and make these indexes' values equal to 100. The vertical lines in the figure are drawn at 1990 and 2011. L and R in the legend denote the left axis and right axis, respectively.
Source: IEEJ (2015b).

economy; Japan, in particular, faces much higher reduction costs (Duscha et al., 2013).

The Japanese government carefully revised its energy plan after the accident and developed guidelines for the dependency on nuclear power. The government insists that the dependency has been reduced, but nuclear power currently plays the same role that it played before the earthquake (ANRE, 2014a, 2014b). Reduced reliance on nuclear power generation, which reduces the dependency to the range of 21–22%, was initiated by ANRE (2015) with the publication of the outlook on long-term energy demand and supply. According to the outlook, reduced reliance is achieved by significant conservation of the final energy demand and the introduction of renewable energy in the electricity sector, while economic growth is expected to increase energy demand.

However, the data on energy consumption and GDP seem to show another relationship in which energy demand may be conserved in spite of economic growth. Both the total primary energy supply (TPES) and the GDP maintained an upward trend by the second half of 2000, but TPES became inverse to the GDP beginning in 2011 (Fig. 1), which offers the possibility that a structural change in energy demand and supply occurs from that year. The structural change may diminish the causal effect of energy consumption on the GDP in Japan, which Soytas and Sari (2003) found. When the energy and climate policy is evaluated out of consideration of the structural change, it is possible to overestimate the impact of the policy. We develop the energy demand model and analyze the long-term energy demand considering the recent relationship of the economy and energy at the aggregated level after we assess the structural change in energy demand and supply in Japan.

Energy policy plays an important role in attaining CO_2 emissions reduction targets and securing the domestic energy supply in major countries; therefore, some studies have analyzed a future reduction of CO_2 emissions considering energy demand. Roelfsema et al. (2014) showed that it is difficult to restrict the increase of the temperature by two degrees Celsius using the model to evaluate the energy and climate policy. Unfortunately, their analysis on Japan did not provide an assessment of whether Japan will meet its pledge to reduce greenhouse gas emissions because of the lack of sufficiently available information on future energy plans. More studies on energy policy in the EU states exist due to demands by the energy efficiency directive (Directive 2012/27/EU) implemented in 2012. The residential sector has a gap between actual energy consumption and policy targets in France and Spain (Charlier and Risch, 2012; Yearwood Travezan et al., 2013, respectively). Thollander et al. (2012) show that it is difficult to attain EU energy efficiency improvement goals by 2020 in the Swedish industry and building sectors that accounted for Swedish-specified energy demand and supply structures in EU member states.

The effect of energy and climate policy is analytically measured by the magnitude of energy consumption and GHG emissions if the proposed policy is implemented. The structure for future energy consumption is regarded as an extension of a current relationship between energy demand and related factors, and the relationship is described by parameters to be determined a priori from previous studies or calibration in models. Consequently, when the structure of energy demand and supply is changed, it is difficult to consider the impact of the change on the energy consumption and CO_2 emissions from the previous literature.

We find that there is an option to change the structure of energy demand from the late 2000s in Japan using aggregated data and an empirical model. This option drives us to question the degree to which the structural change only affects energy demand and CO_2 emissions. We develop the energy demand model and analyze the outlook on energy consumption by 2030 to find the answer. Our model is estimated using an econometric model, which consists of energy intensities and activities via multiple sectors and energy sources. Structural equations in the econometrics model are estimated during a period from 1990 to 2013, including the structural change of energy demand, which is the focus of this analysis, and we construct the dummy for the structural change from 2008 as far as the estimation result is statistically directed. Our analysis showed that energy-related CO_2 emissions are reduced by 15.8% by 2030 from 2013 levels; this reduction does not meet the most recent governmental reduction targets aside from energy. The results imply that there may be a 13% reduction in the energy demand in 2030 compared to the reference case in the Japanese government's outlook, which is equal to 95% of the effect of the planned policy measures by the government.

The remainder of this article is organized as follows. First, we statistically test the possibility of structural changes in energy demand in Section 2. Section 3 reviews the most recent energy policy measures that the Japanese government proposed in 2015. Section 4 explains the data and energy demand model. Section 5 provides the simulation results, and Section 6 discusses the effect of the planned energy policies by the government with the structural change. Finally, we finalize with conclusions in Section 7.

2. Current energy demand and future energy policy

2.1. Overview of energy and the economy after the great east japan earthquake

Fig. 1 illustrates the historical change in the GDP and energy-related statistics in Japan. The GEJE had an influence on the energy supply, and the magnitude of its impact on electricity generation was huge. The operational rate of nuclear power plants was 84.2% in 1998, and the rate fell to 67.3% the year before the earthquake. The GEJE caused all nuclear power plants to stop operating in mid-September 2011, and consequently, the operational rate sharply declined to 2.3% in 2013. The outages at the nuclear power reactors accelerated the substitution of coal for nuclear power for electricity generation. The shift to carbon-intensive energy consequently increased CO_2 emissions rapidly after the GEJE.