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Can a low-carbon-energy transition be sustained in post-Fukushima Japan? Assessing the varying impacts of exogenous shocks[☆]

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HIGHLIGHTS

- Contributing to the literature on low carbon transitions.
- Comparing post-Fukushima electricity consumption across regions and user groups.
- Recommending reforms to sustain energy savings after an exogenous shock.

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ABSTRACT

In the aftermath of the Fukushima nuclear crisis, Japan began contemplating energy policy reforms that drew inspiration from low-carbon research. This article focuses on a question central to advancing low-carbon research in Japan and elsewhere: namely, how does an exogenous shock affect the onset, magnitude, and permanence of changes in electricity consumption? The article employs intervention analysis with an autoregressive moving average (ARMA) model to answer this question. The data analysis reveals that post-Fukushima electricity use underwent a sudden, significant, and sustained reduction across Japan. The shock not only affected the Tokyo Electric Power Company (TEPCO) coverage area but the more distant Kansai Electric Power Company (KEPCO) coverage area. Large electricity users responded with an immediate and significant reduction in electricity consumption that rebounded to below pre-crisis levels; households responded more gradually with no rebound. Two of the more interesting results from the data analysis – the persistence in reductions in the more distant KEPCO coverage area and the rebound among large users – are then explained with a review of survey data and policy trends. Overall the quantitative and qualitative evidence suggests that an exogenous shock may give rise to a reduction in electricity consumption but cannot sustain a low-carbon transition.

1. Introduction

In the aftermath of the Fukushima nuclear crisis, experts from Japan's Ministry of Economy Trade and Industry (METI) and the Ministry of the Environment (MoE) came together in a pioneering effort to draft an innovative energy and environment strategy. The strategy would combine planned cutbacks in nuclear power with a slate of energy savings initiatives, renewable energy targets, and liberalising reforms to regional electricity monopolies (CAO, 2012a, 2012b). Many of the more forward-looking provisions in the new strategy drew upon the same low-carbon models that informed Japan's mid-term greenhouse gas (GHG) emissions target in the lead up to the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2009.[3] Yet the degree to which the strategy's key

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[3] Before COP15, the Ministerial Committee on Global Warming was established to analyse and evaluate 'the reduction of greenhouse gases by 25% as compared to 1990 figures in 2020' from a scientific perspective. The task force consisted of

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provisions would induce and sustain changes would depend upon their performance not during the relative calm preceding COP 15 but after a potentially transformative crisis. The impacts of Japan's low-carbon research would hence hinge upon an exogenous shock. This article seeks to answer a question advancing low-carbon research in Japan and elsewhere: namely, how does an exogenous shock affect the onset, magnitude, and permanence of changes in key energy-related metrics such as electricity consumption?

The article employs intervention analysis with an autoregressive moving average (ARMA) model to answer this question. ARMA models can filter temporal and seasonal patterns from time-series data, thereby isolating the effects of shocks. The data analysis reveals that post-Fukushima electricity use underwent a sudden, significant, and sustained reduction across Japan. The shock not only affected the Tokyo Electric Power Company (TEPCO) coverage area but the more distant Kansai Electric Power Company (KEPCO) coverage area. Large energy users responded with an immediate and significant reduction in electricity consumption that rebounded to below pre-crisis levels; households responded more gradually with no rebound. A review of survey data and policy trends helps illuminate the channels through which the two more interesting results from the data analysis emerged. In the KEPCO area, an outpouring of nationwide anti-nuclear sentiment prompted decisions to extend temporary plant closures and prolong voluntary reduction quotas to fill regional supply shortfalls. Among large electricity users, many industries retained low-cost electricity savings measures but post-crisis activity levels and electricity consumption returned as supply chain disruptions eased. Overall the quantitative and qualitative evidence suggests that an exogenous shock like the Fukushima disaster may give rise to a reduction in electricity consumption but cannot sustain a low-carbon transition. Sustaining that transition may require governance reforms that can keep open and expand post-shock windows of opportunity.

The article is divided into five sections. First, the article reviews literature on the drivers of low-carbon transitions to arrive at hypotheses on the effects of post-shock electricity use. Second, the article provides a review of the varying energy policy reforms after Fukushima to put those hypotheses in context. Third, the article draws upon ARMA models with intervention analysis to estimate the onset, magnitude, and permanence of the effect of the Fukushima shock on Japan's electricity consumption across regions, user groups, and time. Fourth, the article draws upon survey data and a review of recent policy reforms to shed light on the reasons behind the more interesting results from the data analysis. Fifth, the paper discusses those results and presents conclusions.

2. Low-carbon transitions and exogenous shocks

In the early 2000s, the realisation that “warming of the climate system is unequivocal” and “very likely due to…increase[s] in anthropogenic greenhouse gas concentrations” brought public attention to a growing body of low-carbon research (IPCC, 2007). This research addressed two fundamental questions (Skea and Nishioka, 2008; Strachan et al., 2008a, 2008b; NIES, 2008a, 2008b; Hughes et al., 2013): first, what visions (scenarios) could lead to a low-carbon future? Second, what policy and technical options were consistent with those visions? These dual concerns were central to work that the National Institute for Environmental Studies (NIES, 2008a, 2008b) conducted to demonstrate the technical and economic feasibility of a 70% CO_2 emission reduction below 1990 levels by 2050 in Japan. The NIES studies were based on two scenarios – a technology-driven and nature-oriented scenario – that involved options that changed activity levels, reduced service demand, improved energy intensity, or improved carbon intensity. The NIES research further illustrated that while about 17–33% of the 2050 reductions could be achieved with shifts to low-carbon energy sources or installations of carbon capture technologies on the supply-side, about 83–67% of the reductions would come from changes to the industrial, residential/commercial and transportation sectors on the demand-side (NIES, 2008a, 2008b).

But while this research yielded revealing insights into the *long-term* feasibility of a low-carbon future, the *short-term* difficulties of a low-carbon transition were not explored with comparable analytical rigour. These difficulties warranted attention because moving onto low-carbon development paths often involved overcoming inertia in technological systems that favoured less efficient technologies and production processes (Unruh, 2000). Yet another set of difficulties stemmed from well-established political–economic interests that stood to lose from introducing new technologies and production processes. A related set of challenges emanated from existing political–economic institutions that could privilege well-established over emerging interests (Hourcade and Crassous, 2008). The combination of these technological and institutional forces could create “techno-institutional lock-in, a persistent state that creates systemic market and policy barriers to technological alternatives” (Konnola et al., 2006, 239). In contrast to the predictions of much of the low-carbon modelling research, the combined resistance of existing technologies and institutions could undermine a low-carbon transition. Rather than selecting low-carbon development paths, the techno-institutional lock-in often meant policymakers favoured staying the course (Konnola et al., 2006; Carrillo, 2004).

Although there is a tendency to maintain the status quo, there is also a possibility of breaking lock-ins. Two sets of forces could help in this regard: social movements could agitate for policy change, or exogenous shocks could fundamentally alter technological and policy choices. The former possibility – a social movement – underlines that emerging interests can increase public awareness as well as persuade policymakers and businesses of the merits of a low-carbon policy (Kemp et al., 2007). Such a movement could gather momentum as a critical mass of people adapt to a new technological system (Witt, 1992; Safarzynska and van den Bergh, 2010; Geels and Schot, 2007). The latter possibility – an exogenous shock – highlights the potential of unanticipated triggering events or environmental jolts from outside of the techno-institutional complex to break down interests and institutions preventing reforms within the system (Cowan and Hultén, 1996; March and Olsen, 1989; Hughes, 1987; Biggs et al., 2011; Biggs et al., 2009; Sine and Robert, 2003; Kinzig et al., 2006). To be sure, both the social movement and exogenous shock explanations were not mutually exclusive. The two could complement each other; mounting public concerns could extend the reach or deepen a shock's impacts.

This possibility suggests that whether an exogenous shock enables and then sustains a low-carbon transition can hinge on several conditioning factors. Three possible channels through which those impacts are transmitted can help to illuminate those factors. First, the *macroeconomy channel* involves the immediate effect of a shock on infrastructure that can reverberate throughout the economy by, for example, disrupting supply chains, changing production levels, and altering energy use patterns (see the grey curved arrow in Fig. 1). Second, the *public awareness* channel involves the immediate effect on public perceptions that can also ripple through the economy by, for instance, inducing lifestyle changes, modifying consumption decisions, and altering energy use patterns (see the striped curved arrow in Fig. 1). Third, the *policy channel* involves policy reforms that target direct responses

(*footnote continued*)
experts from institutions with energy modelling expertise and a Vice Ministerial level review team.