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Non-nuclear, low-carbon, or both? The case of Taiwan

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ABSTRACT

The Fukushima nuclear accident in Japan has renewed debates on the safety of nuclear power, possibly hurting the role of nuclear power in efforts to limit CO_2 emissions. I develop a dynamic economy-wide model of Taiwan with a detailed set of technology options in the power sector to examine the implications of adopting different carbon and nuclear power policies on CO_2 emissions and the economy. Without a carbon mitigation policy, limiting nuclear power has a small economic cost for Taiwan, but CO_2 emissions may increase by around 4.5% by 2050 when nuclear is replaced by fossil-based generation. With a low-carbon target of a 50% reduction from year 2000 levels by 2050, the costs of cutting CO_2 emissions are greatly reduced if both carbon sequestration and nuclear expansion were viable. This study finds that converting Taiwan's industrial structure into a less energy-intensive one is crucial to carry out the non-nuclear and low-carbon environment.

1. Introduction

Concern about global warming seems to make nuclear power an attractive option. The Fukushima nuclear accident in Japan, however, has renewed the debate on the safety of nuclear power, possibly hurting the role of nuclear power in efforts to limit CO_2 emissions. For instance, Japan has decided to increase its renewable energy supply and abandon the expansion of nuclear industry, and Germany will shut all nuclear reactors by 2022 (Fackler, 2011; Mcgroarty and Fuhrmans, 2011).

In Taiwan, the ongoing nuclear power project is intensely debated as well. Because of safety concerns and challenges in finding repository sites for nuclear waste, many people are urging the government to stop building the Longmen Nuclear Power Station. The concern persists, even after the government announced that Longmen will be Taiwan's fourth and last nuclear power project. On the other hand, others argue that the nuclear option should be kept since it is a viable approach to curb CO_2 emissions effectively without reducing electricity supply. This is especially important for Taiwan since, because of resource constraints, the role of renewable power sources may remain insignificant.

While more and more countries try to cut CO_2 emissions to reduce the threat of global warming, we still have limited understanding about the potential effects of pursuing low-carbon growth with or without the nuclear option. Thus, an economy-wide analysis that studies the role of nuclear power in pursuing a low-carbon economy is crucial, especially for a small economy such as Taiwan, which lacks natural resources and must import most of its energy supply.

Until now, existing studies have found that nuclear power is an effective tool to curb CO_2 emissions from the power sector, especially in the long run (Bensmann, 2010; Mori, 2000; Wang et al., 2011; Yang, 2011; Yun and Baker, 2009). They do not, however, analyze cases where nuclear power is no longer an option. One exception is Mori (2000), which found that limiting CO_2 emissions without nuclear power expansion requires a higher level of carbon sequestration implementation and would incur a greater negative impact on global GDP. Nevertheless, higher resolutions on regions and sectors are not presented in the research. A number of studies, on the other hand, examined energy and nuclear policies in Taiwan separately (Hsu et al., 1998; Huang, 2000; Ko et al., 2010; Liang, 2008; Liang and Kuo, 2003; Lin, 1997; Lin and Sue, 2008; Yang, 2009). None of the research, however, has presented a framework that can simultaneously assess the potential effects of pursuing a non-nuclear and low-carbon growth scenario. While other studies have explored CO_2 reduction impacts on different sectors or technologies (Bureau, 2011; Chen et al., 2011; Karplus et al., 2009; McFarland et al., 2009), the interaction between non-nuclear option and low-carbon policy is beyond their research scopes.

To fill this gap, this study takes Taiwan as an example and explores the policy implications of pursuing low-carbon growth with or without the nuclear option. With the low-carbon policy, Taiwan will eventually cut its CO_2 emissions to 50% of 2000 levels by 2050. Under the non-nuclear policy, while the existing three nuclear power plants of Taiwan will continue to operate until the end of their lives in 2020s, the coming nuclear power plant under construction will never be allowed to join the grid.

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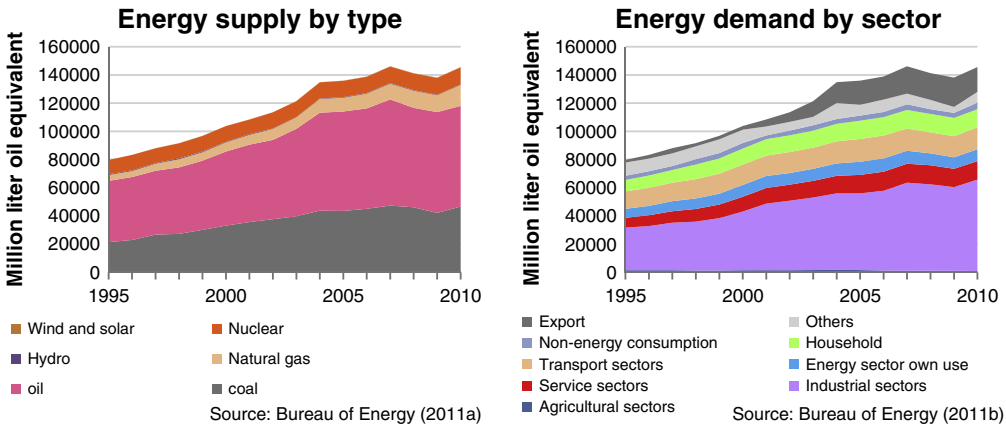

Fig. 1. Energy supply and demand in Taiwan.

In addition, under the low-carbon policy, a counterfactual scenario that allows further expansion of nuclear power beyond the government's plan will also be discussed.

This study will answer the following questions: (1) what will be the economic implications of carrying out the low-carbon policy with or without the nuclear option; and (2) what will be the roles of various generation technologies under different policy scenarios? To conduct the analysis, a multi-sector recursive dynamic general equilibrium model is built. The model takes into account the optimized behaviors of distinct producers and a representative household, and their interactions through various market transactions. This study also disaggregates the electricity sector into six sub-sectors to account for the diversified carbon footprints of various generation technologies, and to represent the cost of CO_2 reduction, it considers a hypothetical carbon tax that covers all combustion CO_2 emissions, which constitute about 96% and 88% of Taiwan's national CO_2 emissions and GHG emissions as of 2008, respectively (EPA, 2009).[1] Further, this study presents a new approach that improves the modeling for the relationship between dispatchable generation (gas and hydro power for instance) and non-dispatchable generation (wind power in particular).

The rest of this study is organized as follows: Section 2 provides the energy and policy background of Taiwan; Section 3 describes model settings and the strategy of modeling dispatchable and non-dispatchable electricity generation; Section 4 presents the economic, demographic, technological, and emissions data used in this study; Section 5 explores the economy-wide effects of various policies; and Section 6 provides conclusions, which summarize contributions of this study and discuss future research directions.

2. Energy and policy background of Taiwan

Taiwan currently imports 99% of its energy supply. As Fig. 1 shows, in recent years over 90% of the supply comes from fossil fuels (Bureau of Energy, 2011a). Fig. 1 also reveals that in 2010, industrial sectors accounted for almost half of the energy demand (44.5%), following by exports of refined oil products (12.1%), transportation use (10.7%), service sectors (9.1%), household (8.9%), etc. (Bureau of Energy, 2011b). For decades, while the development of petroleum, chemical, iron, cement and non-metallic industries has played crucial roles in Taiwan's economy, they are relatively energy-intensive compared to other sectors.

Table 1
Electricity generation mix for selected countries in 2008.

	World	Taiwan	US	Japan	Germany	France	China	Brazil
Coal	40.8%	52.5%	48.8%	26.6%	45.6%	4.7%	79.1%	2.7%
Gas	21.2%	19.4%	20.8%	26.2%	13.8%	3.8%	0.9%	6.3%
Oil	5.5%	6.0%	1.3%	12.9%	1.5%	1.0%	0.7%	3.8%
Nuclear	13.5%	17.1%	19.2%	23.9%	23.3%	76.4%	2.0%	3.0%
Hydro	16.2%	3.3%	6.5%	7.7%	4.2%	11.9%	16.9%	79.8%
Other	2.8%	1.7%	3.4%	2.8%	11.6%	2.1%	0.5%	4.5%

Source: IEA (2011).

For Taiwan, since the domestic energy consumption highly relies on fossil fuels, to diversify that consumption, the government has tried to promote the use of various types of energy, including nuclear power and renewables. Table 1 shows that, as of 2008, coal-fired, gas-fired, oil-fired, nuclear, and hydro-powered generation accounted for roughly 52.5%, 19.4%, 6.0%, 17.1%, and 3.3% of Taiwan's national electricity supply, respectively. Currently, the government is expanding the country's nuclear power capacity by building the Longmen Nuclear Power Station, now in the last construction phase (Bureau of Energy, 2011c; The Nuclear Association of Taiwan, 2011). With a capacity of 2750 MWe, the plant would need only 80 t of uranium feedstock in a year to generate the same amount of electricity as 515 million t of coal or 143 million t of natural gas (The New Taipei City Government, 2011).[2]

The government also set a target of reducing national CO_2 emissions to the 2005 and 2000 levels by 2020, and 2025, respectively, and finally cutting emissions to the half of 2000 levels by 2050 (Environmental Protection Administration, 2012). Nuclear power proponents assert that nuclear power is a feasible way to curb CO_2 emissions in Taiwan, which have more than doubled in the last two decades and have made Taiwan become one of the highest per capita CO_2 emissions countries in Asia, as shown in Table 2. Taking the power sector for instance, Taiwan has the world's largest coal-fired power plant, and the three largest coal-fired power plants of Taiwan account for around 30% of its national CO_2 emissions, as shown in Fig. 2 (Carbon Monitoring for Action (CARMA), 2013). Proponents of nuclear power argue that without the nuclear option, achieving the emission reduction target would be next to impossible.

Opponents of nuclear power, on the other hand, emphasize that for Taiwan, the current risk of a devastating earthquake such as the one that occurred in Japan poses serious safety concerns for the existing and

[1] The hypothetical carbon tax requires individuals to internalize the cost of emissions imposed on others and on future generation (Metcalf and Weisbach, 2009). In particular, the larger tax base ensures a less distortionary impact on resource allocation and thus avoids overestimating the economic burden of cutting emissions.

[2] As a result, even at the highest historical uranium price level at $136 per pound in 2007 (Scott, 2011), the fuel cost of a nuclear power plant still constitutes a minor part of its production cost compared to fossil-based power plants.