Product Lifetime, Energy Efficiency and The Environment: A Case Study of Air Conditioner in Japan

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Author: Daisuke NISHIJIMA
Co-Authors: Shigemi Kagawa

Based on residential sector electricity use in 2009, residential air conditioners are the fourth largest source of consumption, which also means that they are a major source of CO2 emissions. Moreover, future CO2 emissions caused by using air conditioners increases drastically because of global warming. Air conditioners will play a more important role in CO2 emissions in the future.

The energy efficiency of residential air conditioners has greatly improved in recent years as a result of the increased efficiency of compressors and heat exchangers. More recently, however, the energy efficiency of air conditioners has improved only marginally, as their technology approaches its limits.

Even as efforts to improve the energy efficiency of residential air conditioners face technological limitations, the reduction of CO2 emissions remains an urgent task. In addition, the environmental concerns of consumers continue to mount. In light of this, replacement purchases of new air conditioners do not promise any significant gain in energy efficiency, so from both economic and environmental viewpoints, consumers have an incentive to continue using their current air conditioners for a longer time. This results in fewer replacement purchases of new air conditioners and less quantity of CO2 emissions generated in the production phase of residential air conditioners. On the other hand, when old air conditioners are retained for a longer time, replacement purchases of new higher efficiency models are delayed, resulting in higher CO2 emissions in the use phase. Thus, in considering how a longer use of residential air conditioners affects CO2 emissions, there is a trade-off between CO2 emissions arising from the production phase and those arising from the use phase. Proceeding studies showed CO2 emissions induced by air conditioners with a variety of methods. However, they could not construct models for product lifetime and trend of energy efficiency of air conditioners and analyze the impact of those changes on life-cycle CO2 emissions simultaneously.

With this research motivation, this study proposes an integrated environmental input-output model that simultaneously considers both the lifetime of residential air conditioners and their energy efficiency (electricity consumption) for analyzing the influence of lifetime and energy efficiency on life-cycle CO2 emissions. The stock and flow of durable goods was modelled by the Weibull lifetime distributions and the trend in annual energy efficiency (i.e., annual electricity consumption) of an â€œaverageâ€• durable good was formulated as a reverse logistic curve including a technologically limit value (i.e., limit energy efficiency) with respect to time. Utilizing this model, we can examine the potential for reducing CO2 emissions not only by changing the average lifetime but also by improving the energy performance of air conditioners.

The results indicate that further reducing the electricity consumption of air conditioners is essential for continuing to cut the total CO2 emissions resulting from residential air conditioners. To promote such technological progress, it is important to adopt policies and initiatives that encourage the purchase of highly energy-efficient products, such as vehicle scrappage schemes introduced in various countries. Such measures serve not only to reduce the lifetimes of products but also to improve their energy efficiency.

One important question is how much the energy efficiency of new air conditioners needs to be

improved in order to offset the increase in production-phase emissions that occurs due to the additional new air conditioners resulting from a shorter average lifetime. Even at the reduced average lifetime by 1 year, if air conditioner energy efficiency can be improved by 3.6% from the current level, CO2 emissions can be reduced by approximately the same amount as when the average lifetime is extended by 1 year(at the current energy efficiency). If air conditioner energy efficiency is improved further to 5%, 10%, and 15% below the current level, it is possible to achieve CO2 emissions that are lower than those when the average lifetime is extended by 1 years.

The model proposed in this study not only estimates the CO2 emissions derived from residential air conditioners but also offers a target value for energy efficiency that indicates the degree to which energy-saving technology needs to be improved.