***The Economics of Nuclear Power Plant Lifetime Extensions – Conceptual Approach and Lessons from Electricity Sector Modeling in the US, France, and Germany***

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## Keywords

Nuclear power, lifetime extension, CO2 emissions, electricity sector model

## Overview

The potential role of nuclear power in the low-carbon energy transformation is discussed controversially. In a static modeling framework, extending the licenses of existing nuclear power plants leads to a reduction of CO2 emissions, mainly through displaced natural gas and coal; on the other hand, a dynamic analysis may lead to reduced CO2-emissions even without nuclear plant extensions, if the share of renewable energies is increased. In a recent NBER paper, Jarvis, et al. (2019) assess the decision of the German government to end the commercial use of nuclear power before the end of the technical lifetime of the reactors, and conclude that this policy has reduced private and collective welfare. In our paper, we provide an in-depth analysis of the nuclear power plant closures vs. lifetime extension currently debated in the United States, France, and Germany. The main focus of analysis is the potential contribution of lifetime extensions on CO2-emissions under various policy scenarios, e.g. “no policy”, carbon pricing, or renewable portfolio standards.

## Methods

This paper consists of a theoretical section, in which the change of emissions of an electricity system is decomposed into various elements, and a numerical section, in which results from electricity sector modeling are presented for the United States, France, and Germany. In the first part of the paper, we decompose changes in the CO2 intensity of a lifetime extension, compared with a business-as-usual and other scenarios: The change of total CO2 emissions depends on a scaling factor reflecting a changing electrictiy demand, and changes on the intensive margin (composition of electricity mix and technology) and the extensive margin (change of generating units). It is also shown that different policies impact the effect of nuclear lifetime extensions differently.

The second part of the paper includes the use of a detailed electricity sector model, called dyn-ELMOD, with a high temporal resolution (hourly), and a high level of technical detail .(Gerbaulet and Lorenz 2017; Kunz et al. 2018). We assess the effects of different scenarios on CO2-emissions, considering three countries with significant nuclear energy generation, i.e. the two largest producers world-wide, the United States and France, and the (historically unique) case of Germany. We analyze the effect of simple policy instruments, e.g. subsidized lifetime extensions of NPPs, and of more complex settings, e.g. carbon pricing and/or renewable standards, on CO2-emissions.

## (Preliminary) Results

At this point, the theoretical decomposition is developed, and the parameters for the numerical modeling are being defined; in addition, data for the three country case studies are collected, and an extensive survey of the literature on the energy transformation in the three countries is conducted, including our own work (Wealer et al. 2017; Hainsch et al. 2020, 2021). Preliminary model results indicate that - ceteris paribus – NPP lifetime extensions reduce CO2 emissions, but they are expensive and require direct support or a high CO2-price (three digit US-$/t of CO2). At the same time, a high CO2 price would favor the deployment of renewable energies, which have lower (sum of investment and operating) costs than NPPs. This holds even more as renewable portfolio standards are introduced: In the paper, we can identify a “critical” CO2 price that would render additional RPS unnecessary.

In the US, the situation is most complex, due to the large number of nuclear plants (about 90) and regional market specificities; concrete results will be available by May 2021. Preliminary results for France indicate that a lifetime extension of a part of the nuclear fleet (e.g. 20 of the total of 56 reactors) is possible, but the CO2-reduction targets could also be achieved through a mandatory renewables program. In Germany, the closure of the six remaining plants would lead to higher CO2-emissions unless the share of renewables is significantly increased.

## Conclusions

The paper provides insights into an important issue of industrial strategy and energy policy, i.e. the future role of nuclear power in the decarbonization process. By covering three large, but structurally different electricity systems (US, France, Germany), the model-based paper increases the understanding of the complex interaction between nuclear power and the low-carbon energy transformation.

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