Risk aversion in an agent-based model for the transition to a low-carbon electricity system

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Overview

The transition to a low-carbon electricity system needs large amounts of investments in low-carbon technologies. However, when making investment decisions, investors face many uncertain factors, such as future climate policy, electricity prices, and demand, fuel costs, competitors' investment decisions, etc. These uncertainties bring investment risk. Risk-averse investors may abstain from investments in low-carbon technologies and this may thus slow the speed of the transition. To ensure a transition in line with the intention of the stated policy goals, it is important to understand how investors' risk aversion impacts their investment decisions and find possible ways to avoid the transition being delayed due to policy uncertainty and risk aversion. In this study, we apply an agent-based model with a dynamic portfolio approach and analyze how different levels of risk aversion affect investors' investment decisions, and in turn, affect the speed of the transition to a low-carbon electricity system. We focus on the risk aversion caused by uncertainties in future carbon prices. We find that policy uncertainty and risk aversion slow down the transition and this slowdown crucially depends on the level of uncertainty and risk aversion.

Methods

The model is built on Jonson et al. (2020) and Yang et al. (2022). Agents in this model are power companies who produce electricity in an ideal electricity market and also invest in new capacity. There are five types of technologies in which an agent can choose to invest: coal-fired, gas-fired, nuclear, wind, and solar PV power.

The agents face uncertainty about future carbon prices. A growing carbon price scenario is used as the 'real' carbon price that will be materialized in the simulation. However, the agent only knows the carbon price in the past and needs to infer future prices. Here we use a set of different values to present the company's expectations of possible future price levels. The company calculates future prices as follows:

$$\left[\bar{p}^{CO2}_{future}\right] = \bar{p}^{CO2}_{past} \times \left[\omega - 3\Delta_{CO_2}, \omega - 2\Delta_{CO_2}, \omega - \Delta_{CO_2}, \omega, \omega + \Delta_{CO_2}, \omega + 2\Delta_{CO_2}, \omega - 3\Delta_{CO_2}\right] \qquad (1)$$

- $\bar{p}^{CO2}_{future}$ = a set of possible future carbon prices that the company expects. Each value stands for a future price level on average, not for a particular year.
- $\bar{p}^{CO2}_{past}$ = the years' average price.
- ω = the median value of the set.
- Δ_{CO_2} = the step spread in the CO_2 price.

When evaluating an investment option, the company takes into account the CO_2 price uncertainty and calculates the expected profits upon investing in a particular technology T per Euro of investment. If the company is risk-neutral, it will choose the technology with the highest expected positive profits to invest in. However, if the company is risk averse, then the selection criteria will be adjusted by the risk aversion measure. In the base case, the agent is averse to losses, i.e., the probability of an investment that may turn out to be unprofitable must be smaller than a threshold set by the agent.

We run the model for 100 years. Each year, plants that reach the end of their lifetime are removed one by one, while agents evaluate investment options and make investment decisions. The model starts with a fossil system.

Results

Along with the growing carbon price, the system gradually transits to a low-carbon system. However, we observe that when agents are risk-averse, there are delays in the expansion of low-carbon technologies such as wind, solar and nuclear (Figure 1). The more risk-averse the agent is (higher λ value), the larger the delay is. Furthermore, due to the delayed investments in low-carbon technologies, the CO_2 reduction is also slower when agents are more risk-averse. This also results in higher average electricity prices when agents are more risk averse.

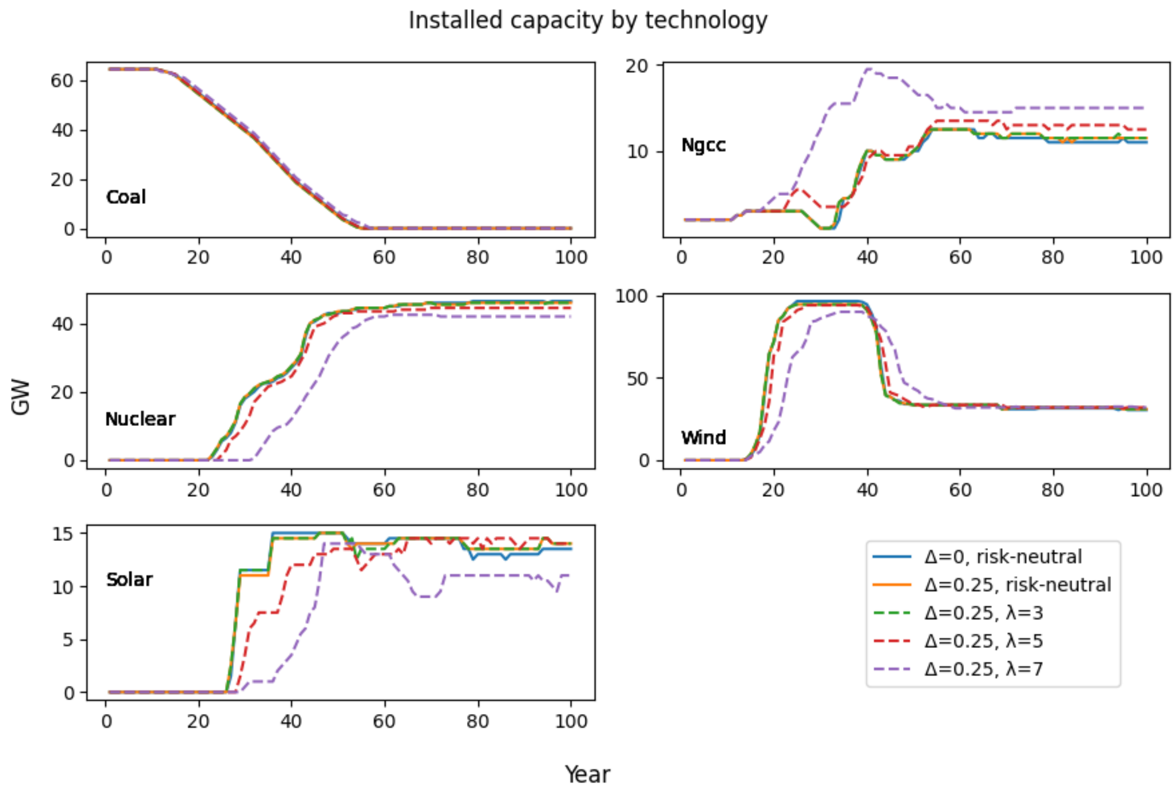

Figure 1. The system installed capacity in risk-neutral and risk averse cases. Δ is the uncertainty level of the carbon price and λ is the risk averse level of the investor. It shows that when the investor is more risk-averse, there is a delay in investments in low-carbon technologies. (Note that the scale is different for each panel).

Conclusions

In this study, we apply an agent-based model approach to simulate agents' investment decisions in new generation technologies. We have in particular analyzed how the agents' level of risk-aversion affects their investment decisions and in turn, the speed of transition to a low-carbon electricity system given there is uncertainty about how the future CO2 price will develop.

Our results show that uncertainty and risk aversion slow down the transition. The more risk-averse agents are, the longer the delay. This implies that to ensure a speedy transition, it is essential to lower the policy-related risks for investors who invest in low-carbon technology, e.g. through Contracts for Difference, or lower the uncertainty levels through clear policy commitments.

Reference

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