Alexander Burkhardt and Markus Blesl

THE ROLE OF MODEL FORESIGHT ON THE EFFECTIVENESS OF CARBON PRICING IN ENERGY SYSTEM MODELS – A CASE STUDY OF THE GERMAN BUILDING AND TRANSPORT SECTOR

Alexander Burkhardt: Institut für Energiewirtschaft und rationelle Energieanwendung (IER)
Universität Stuttgart, Heßbrühlstraße 49a, 70565 Stuttgart, Phone: +4971168587500,
Email: alexander.burkhardt@ier.uni-stuttgart.de

Markus Blesl: Institut für Energiewirtschaft und rationelle Energieanwendung (IER)
Universität Stuttgart, Heßbrühlstraße 49a, 70565 Stuttgart, Phone: +4971168587865,
Email: markus.blesl@ier.uni-stuttgart.de

Overview

Carbon pricing has gained a lot of traction in recent years, either in the form of national carbon prices or emission trading schemes [1]. Currently, the EU is developing the EU ETS 2, which will include the building and transport sector [2], while Germany has introduced its own carbon pricing scheme for these sectors in 2021 [3]. The level of carbon pricing to achieve the climate targets are a topic of ongoing discussions. Energy Systems Models can be used to assess the effect of different carbon price paths [4–6]. However, when assessing the effects of policy measures such as carbon pricing, the model architecture and the role of the foresight of the model should be taken into account [7]. Analysis of different CO_2-price paths under different levels of foresights show that perfect foresight models might overestimate the effect of CO_2-prices on the decarbonization of the energy system.

Method

To analyze the effectiveness of carbon prices, the TIMES PanEU energy systems model is used. TIMES PanEU is a technology rich, bottom-up, linear optimization model that includes all relevant energy sectors for the EU27, Switzerland, Norway and the UK [8]. The model solves milestone-years every 5 years until 2050. The model typically is solved under perfect foresight (PF), meaning the model knows all parameters in advance, but can be switched to a time-stepped or myopic solution, where the so-called myopic window determines the length of model foresight. CO_2 price-paths are implemented for all sectors, the global discount rate is set to 5% and the prices for fossil fuel inputs are chosen from the WEO 2022, APS Scenario [9]. The focus of this analysis is on the buildings and transport sector, as the majority of investment decisions in these sectors are made by private households, which might not have a lot of knowledge about energy policies or future carbon prices [10].

No additional policy measures are considered besides the CO_2-price. The results are analyzed as a case study of the building and transport sector in Germany. Three different price paths (low, medium, high) are implemented with either perfect foresight or myopia (_myo) with a myopic window of 10 years (Table 1). The results are compared to a reference scenario, which achieves carbon neutrality in Germany by 2045 (ref).

Table 1: Implemented scenarios and CO_2-price paths.

Scenario		€$_{2020}$/t CO_2						
		2020	2025	2030	2035	2040	2045	2050
low	low_myo	0	55	80	105	130	155	180
medium	medium_myo	0	55	105	155	205	255	305
high	high_myo	0	65	135	205	275	345	415

Results

When comparing the scenario results under myopia and perfect foresight, it becomes clear that under myopia, the intended effect of CO_2-prices (reducing CO_2-emissions) is smaller over the whole timeframe. Especially in the early period, the myopic scenarios delay investment in climate-neutral technologies, and fail to catch up once CO_2-prices rise. Under myopia, the model avoids long-term investments with high investment costs that will pay of later, and opts for technologies with lower investment, but higher operation costs. In the case of medium and especially high CO_2-prices in later periods, the model then tries to decarbonize as fast as possible, but has to rely on more expensive technologies like e-fuels to make up for the delayed investments. Thus, total system costs also increases under myopia. In addition, the cumulative CO_2-emissions over the whole timeframe increase by 6-17%.

Figure 1 shows the CO_2-emission pathways of the buildings sector in Germany for different scenarios. Under perfect foresight, the high CO_2-price path is almost able to reduce the CO_2-emissions to the levels that would be required if the reference scenario is seen as a relevant benchmark to reach the german climate targets in this sector. However, under myopia, emissions are significantly higher. The same effect can be observed with the medium and low CO_2-price path.

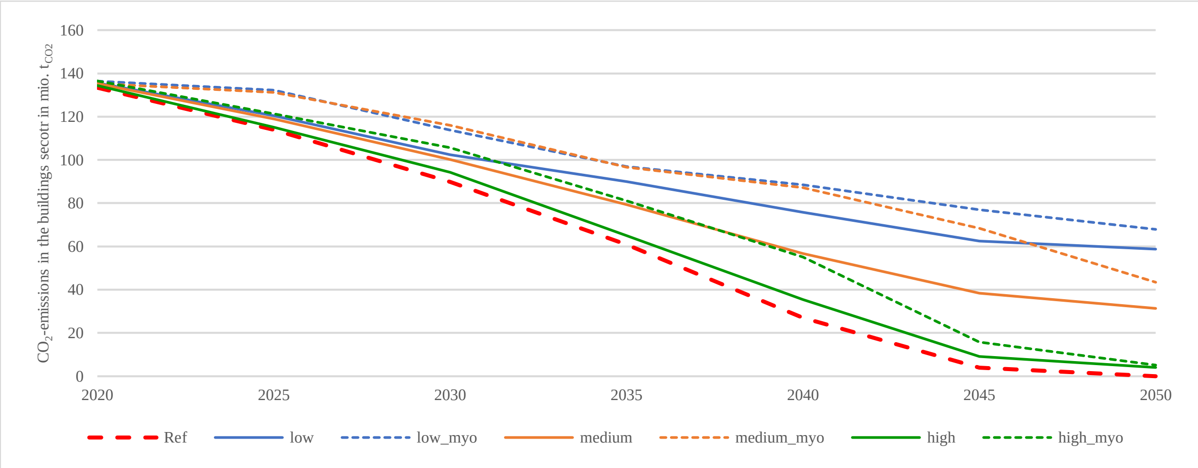

Figure 1: Development of CO_2-emissions in the german buildings sector for the different scenarios.

Similar effects can also be observed in the transport sector, where the failure to invest in fossil free propulsion technology in time (e.g. BEV or fuel-cell vehicles) requires the model to use e-Fuels in later periods, while overall CO_2-emissions under myopia are significantly higher. These effects also extend to the installment of renewable energies or electrolyzers, as well as a delay in investment in electricity, hydrogen or district heat grids under myopia.

Conclusions

The results of the scenario analysis shows that the effect of CO_2-prices on the decarbonization of the energy system are much higher under perfect foresight then under myopia. This hints at a possible overestimation of the usefulness of CO_2-pricing using models with perfect foresight. Therefore, effects such as myopia should ideally be taken into account when using energy systems models to determine the effectiveness of policy measures. Otherwise, implemented CO_2-prices could not yield the expected CO_2-emissions reductions. If myopia of decision makers is assumed, especially low CO_2-prices in the early periods (until 2030) cause a big delay in the ramp-up of technologies such as electric vehicles or heat pumps. This would hint at the practicality of rising CO_2-prices early on (in contrast to the proposed price mechanisms in the EU ETS 2) and of communicating the expected rise of CO_2-prices and its consequences to the public effectively and transparently, so that short-sighted (= myopic) investment decisions can be avoided. In this paper, only carbon pricing has been considered, however an effective policy mix would ideally combine regulations and taxation to generate better outcomes. Depending on the policy measure, myopia of decision makers might still represent a hurdle for the effectiveness of climate policy, and thus requires more thorough examination in energy system models.

References

[1] World Bank, *State and Trends of Carbon Pricing 2021*. Washington, DC: World Bank, 2021. [Online]. Available: http://hdl.handle.net/10986/35620

[2] Wissenschaftliche Dienste des Deutschen Bundestages, "Neuer EU-Emissionshandel für Gebäude und Straßenverkehr: Zum geplanten EU-ETS II und den Auswirkungen auf das um geplanten EU-ETS II und den Auswirkungen auf das nationale Enationale Emissionshande missionshandelssystem," WD 8 - 3000 - 001/23, 2023.

[3] S. Braungardt, V. Bürger, and B. Köhler, "Carbon Pricing and Complementary Policies—Consistency of the Policy Mix for Decarbonizing Buildings in Germany," *Energies*, vol. 14, no. 21, p. 7143, 2021, doi: 10.3390/en14217143.

[4] Y. Zhou, W. Fang, M. Li, and W. Liu, “Exploring the impacts of a low-carbon policy instrument: A case of carbon tax on transportation in China,” *Resources, Conservation and Recycling*, vol. 139, pp. 307–314, 2018, doi: 10.1016/j.resconrec.2018.08.015.
[5] A. Burkhardt and M. Blesl, “Erreichung der Klimaneutralität bis 2045 mittels CO2-Bepreisung in den Sektoren Verkehr und Gebäude,” Graz, 2022. Accessed: Mar. 22 2022. [Online]. Available: https://www.tugraz.at/fileadmin/user_upload/tugrazExternal/738639ca-39a0-4129-b0f0-38b384c12b57/files/lf/Session_A1/112_LF_Burkhardt.pdf
[6] O. Ruhnau *et al.,* “Why electricity market models yield different results: Carbon pricing in a model-comparison experiment,” *Renewable and Sustainable Energy Reviews*, vol. 153, p. 111701, 2022, doi: 10.1016/j.rser.2021.111701.
[7] F. Fuso Nerini, I. Keppo, and N. Strachan, “Myopic decision making in energy system decarbonisation pathways. A UK case study,” *Energy Strategy Reviews*, vol. 17, pp. 19–26, 2017, doi: 10.1016/j.esr.2017.06.001.
[8] F. Kattelmann, J. Siegle, R. Cunha Montenegro, V. Sehn, M. Blesl, and U. Fahl, “How to Reach the New Green Deal Targets: Analysing the Necessary Burden Sharing within the EU Using a Multi-Model Approach,” *Energies*, vol. 14, no. 23, p. 7971, 2021, doi: 10.3390/en14237971.
[9] IEA and International Energy Agency, “World Energy Outlook 2022,” 2022.
[10] S. Maerz, “Private Kleinvermieter - Ein vergessener Akteuer auf dem Weg zur Waermewende?!,” *Energiewirtschaftliche Tagesfragen*, vol. 68, no. 3, pp. 17–21, 2018.