On the economics of real-time pricing in low-carbon electricity markets:

Efficiency and feasibility in the presence of policy-induced variable renewable energy supply

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Price responsive demand is increasingly considered as an integral part of low-carbon electricity markets, where accommodating the large share of variable renewable electricity generation from wind and solar power will be pivotal for efficiency and supply reliability. Exposing consumers to the variation in the marginal costs of electricity supply through real-time retail prices is to many economists the most intuitive solution to achieve this. The economic evaluation of implementing real-time pricing in low-carbon electricity markets requires a proper understanding of how climate policy instruments and variable renewable generation interact on the related welfare as well as distributional effects.

This thesis provides insights on this interaction, by identifying the major drivers and explaining the basic economic mechanisms underlying the effects of real-time retail pricing on transforming electricity markets. To this end, comparative static welfare analyses are conducted, by using a simple electricity market modeling framework to simulate long-run market equilibria and applying empirical market data.

In doing so, this thesis sheds light on crucial issues regarding the timing and feasibility of introducing real-time pricing, both of which are relevant to regulators and market actors. The optimal timing of rolling out real-time pricing is found to be complicated by a non-linear relationship between policy-induced variable renewable technology deployment and the gross welfare gains from real-time pricing. This result challenges existing rollout strategies, since it implies that real-time pricing does not necessarily become more beneficial in the presence than in the absence of large-scale variable renewable generation. Moreover, growing variable renewable deployment renders full-fledged real-time pricing virtually inevitable, as it allows for making efficient use of installed renewable capacity, and thus increasingly outperforms second-best pricing schemes, which are often considered less complex and therefore more feasible.

Besides the complexity of real-time pricing, its potentially adverse distributional effects are another important acceptance barrier, which this thesis addresses. Variable renewable electricity supply is shown to significantly attenuate these distributional effects, within and across consumer sectors, since reducing the influence of individual demand patterns on consumption costs. Most consumers might thus not have to expect significant consumption cost increases from real-time pricing in low-carbon electricity markets. Targeted rollouts of real-time pricing to large consumers, which are often considered efficient at low renewable supply shares, are, however, found to result in negative pecuniary externalities across consumer sectors, affecting particularly residential consumers. Such cross-sectoral distributional effects could foster already existing acceptance problems of dynamic pricing schemes. In addition to this, many consumers may make non-optimal tariff choices and decide not to switch to real-time pricing for a variety of reasons. This thesis shows that the resulting unrealized welfare gains could

be substantial and rapidly growing with variable renewable market penetration, particularly if mostly residential and commercial consumers do not adopt real-time pricing. It is therefore argued that the potential welfare losses from low adoption rates could justify corrective measures, if tariff choices are indeed non-optimal on average.

Furthermore, several findings in this thesis highlight the complementarity of real-time pricing and climate or renewable policies. This thesis particularly contributes to assessing the cost-effectiveness of renewable support instruments, by illustrating the circumstances under which renewable output subsidies can be more efficient than capacity subsidies in achieving a certain renewable supply target. Putting previous research on this topic into perspective, this seemingly counterintuitive result can obtain, if consumers are real-time priced and can thus react to the negative wholesale prices induced by output subsidies during periods of high variable renewable generation.

Addressing the potential influence of other technological factors on the effects of real-time pricing, this thesis analyzes the relevance of costs and price effects resulting from rapid changes in thermal-plant operation, caused by variable renewable generation. While these effects can decisively modify the evolution of efficiency gains from real-time pricing found in this thesis, it can be illustrated that they likely become negligible under reasonable assumptions about the dynamics in fuel prices, in the carbon price and the generation portfolio.

Concluding with a thorough discussion on future research avenues, this thesis argues that since knowledge about retail tariff choice is lacking, it remains fundamentally uncertain whether the efficiency potential of real-time pricing can actually be realized. Understanding and investigating the determinants of retail tariff choice hence appear to be the next important steps for advancing the economics of real-time pricing.