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Waiting for the low-carbon transition: Expectations, asset stranding and investment decisions in the electricity sector

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Climate change and the required low-carbon transition will involve a fundamental revamp of the energy basis of our socioeconomic system. The transformation of physical capital is at the core of this transition. In particular, transitioning to a low-carbon economic system will require shifting electricity production to a new stock of low-emission physical capital operating on renewable sources of energy. Electricity is a primary input for production, and electrification of several productive sectors (e.g. transport) is widely regarded as a key element to climate mitigation.

Investment in low-carbon physical capital stocks is still lagging behind what would be needed to achieve a transition compatible with the respect of a 2°C threshold on global temperatures. This is due to a number of factors. While in some regions renewable energy technologies are almost at par with high-carbon alternatives in terms of their levelized costs (LCOE), most low-carbon technologies are still perceived as unattractive by firms, especially in lower-income countries rapidly developing. In addition, given that many large-scale utilities have a portfolio of plants with different technologies (i.e. low-carbon investments are often performed by firms that also own high-carbon plants), firms have an incentive in slowing and smoothing the transition, so not to suffer economic losses via asset stranding.

The issue of shifting to a new technological paradigm in the electricity sector has already been studied by energy and economic models. However, contributions of the topic have so far not investigated the role of expectations in detail. One can identify two main methodological approaches in the literature. Some models assume investments to be driven by a long-term intertemporal maximisation of a welfare function, with the aim of identifying optimal transition paths. Other models instead assume investments to be the result of a macro-econometric behavioural function based on adaptive expectations that only concern the following time period. In this paper, we aim at contributing to the literature by developing a more sophisticated representation of investment behaviour that could explain the inertia in investment by firms along the low-carbon transition process.

We develop a macroeconomic model of the low-carbon transition of the electricity sector in a closed economy in discrete time. The structure of the modelling framework is based on the representation of the physical and financial stocks/flows of heterogeneous macroeconomic sectors. Three goods exist in the economy: (i) a composite good used for both consumption and investment purposes; (ii) electricity; and (iii) fossil fuels. The price of the composite good is the numeraire of the system. Electricity can be produced using two distinct technologies: a high-carbon capital stock and a low-carbon capital stock. In addition to having different emission intensities, the two technologies are characterised by different productivities. These parameters indicate the amount of megawatt hours (MWh) that could be produced with an additional unit of capital expenditure on high- and low-carbon capital. Firms offer their product on a wholesale market with a merit order. We assume that electricity is offered on the market at its marginal production cost. For high-carbon firms, this is represented by the cost of purchasing the fossil fuels needed to run the plant. Low-carbon firms, on the other hand, do not have to purchase their primary energy input and thus have a marginal cost close to zero. Hence, low-carbon electricity is always sold first. The interaction between demand and supply determines the amount of electricity produced and sold by both technologies, as well as its price. Each capital stock offers certain profits, equal to the revenues obtained by selling electricity, less the costs incurred to produce it. Both sectors have to repay a proportion of their accumulated stock of loans. In addition, the high-carbon sector has to purchase the fossil fuels needed as production inputs.

Firms choose how to allocate their investments in two available technologies (high- and low-carbon) depending on two main factors. First, they have a preference for the technology that is likely to provide higher economic returns, as measured by the present value of the expected net profits obtainable by the two technologies over their lifetime. Second, they have a preference for having an energy mix aligned with the one prevalent in the economic system. In other words, they behave like passive investors, allocating their investments according to what they expect to be the relative proportions of the two types of capital stocks in the system. We assume market participants to develop transition expectations in the form of a logistic function with a moving higher asymptote, consistent with the trajectory of technology diffusion. Expectations are formed for the entire simulation period; however, only the values falling within firms' "planning horizon" are taken into consideration in determining investment. The length of the planning horizon is a measure of firms' short- or long-termism.

Our model main contribution is five-fold. First, it contributes to filling a gap regarding the role of expectations in transition processes. The neoclassical approach based on agents optimizing their intertemporal utility with nearly perfect foresight does not easily allow for endogenous and transition-related, but misinformed, expectations. The post-Keynesian approach based on adaptive expectations does not usually include the formation and update of expectations structurally different from past experience. Second, it allows for representing how long-term (policy-dominated) and short-term (market-dominated) expectations influence each other. Third, it can represent a wide set of transition scenarios, ranging from a decarbonisation causing wide assets stranding to a smooth decarbonisation. Fourth, it integrates a taxonomy of transition dynamics following different speeds through logistic and exponential trajectories in slow- and fast-growing economies. Finally, taking advantage of the stock-flow consistent methodology suitability to represent the financial sector, the model allows for simulating the effect of differentiated interest rates applied to high- and low-carbon technologies on the decarbonisation pathways.