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Global pattern of wind and solar power adoption and mechanisms of energy transitions

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Climate change mitigation requires the global deployment of low-carbon energy technologies, including renewable electricity. What drives the difference in national uptake of renewable technologies and explains the global pattern of adoption? Why do some countries adopt renewable energy technologies earlier or later? No consistent or robust answers to these questions have emerged from past studies, primarily due to the lack of an effective interdisciplinary framework to research clean energy deployment at the national or global scale. On the one hand, long-term climate-energy scenarios developed through Integrated Assessment Models (IAMs) rarely differentiate between countries and regions other than in terms of energy demand growth or availability of natural resources. On the other hand, most of studies attempting cross-national comparisons are rooted in political science and assume that the use of renewables is primarily a direct effect of renewable energy policies, thus underestimating both non-policy mechanisms such as technology diffusion and learning, and the two-way interaction between the deployment of renewables and their support policies.

To address this research gap, we develop an explanatory model for renewable electricity deployment that supplements national-level insights from political science with theories of technology diffusion. We use this model to compare the years when the combined share of wind and solar power in national electricity supply first reaches 1%, the takeoff year. The takeoff year marks the transition from the formative phase of technology deployment with unstable growth to the sustained growth phase that follows roughly an exponential pattern. This framing allows us to apply event history (survival) analysis to identify factors leading to sooner or later renewable energy adoption. We are able to explain a surprisingly large amount of cross-national variation in solar and wind power generation using our conceptual model and simple variables such as size of the economy, GDP/capita, and fossil resource exports.

Using event history analysis, we show that within high-income OECD countries, EU membership and federal structure of state are associated with faster adoption of renewables, thus defining the core of global diffusion. We also show that outside of high-income countries it is not the wealth of a country (GDP per capita) but its economy size (GDP) that leads to earlier adoption of wind and solar power. Moreover, major fossil-fuel exporters and countries that deploy large amounts of nuclear power lag behind comparable countries in introducing renewable energy. We also find no evidence that the level of democracy, a government's ideological orientation, carbon intensity, or reliance on imported fuels significantly affect the introduction of wind and solar power either in high or middle- and low-income countries.

One application which we anticipate for this work to inform energy models on the global spread and growth of renewable energy technologies. In particular, our work could help parameterize national factors which influence the geographic diffusion of renewable energy technologies based on easily-observable variables. Additionally, the conceptual model can be applied to other clean energy technologies such as distributed generation systems.