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# On the mechanism of international technology diffusion for energy technological progress

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ABSTRACT

As a needed methodological complement to the existing large-scale complex policy modelling for energy technology diffusion, this paper contributes to an analytical exposition of the fundamental mechanism of international technology diffusion (ITD) for energy technological progress. We offer two different and complementary perspectives to explore the dynamics of energy technology diffusion and progress. We first develop a Solow-type efficiency-improving model of energy technological progress which is described by improvements in primary energy-augmenting efficiency. We further provide a Romer-type variety-expanding model of energy technological progress which is represented by the expansion of differentiated varieties of primary energy technology blueprints. Analysis based on two different models reaches consistent results: there are potential forces in the world economy – working through ITD – that pull individual countries to advance energy technology, ensuring a cross-country convergence in the growth rates of energy technology in the balanced growth path. While ITD plays a role in a cross-country convergence in technological growth rates, cross-country differences in the efficiency of undertaking indigenous research and the capacity of absorbing foreign technology spillovers would lead to a cross-country divergence in the absolute levels of energy technology.


## 1. Introduction

There is wide consensus that the importance of cross-country technological interdependence and interactions should be explicitly considered in the process of formulating effective technology solutions to global energy and climate challenges (Gillingham et al., 2008; Popp et al., 2010a). On the one hand, the developed OECD countries have taken the lead in cross-country energy technology sharing and partnerships for building energy-efficient green economies. On the other hand, the developing world, particularly the emerging economies, direly calls for transfers of advanced energy-saving technologies to support their indigenous efforts of decoupling fossil energy uses from rapid economic growth in a cost-efficient way (World Bank, 2008; Popp, 2011). In such a context, issues related to international technology diffusion (ITD) have received much

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attention in current policy agenda of energy/climate governance, and the mission of accelerating energy technology diffusion has been institutionalized in some international frameworks including the Asia-Pacific Partnership on Clean Development and Climate, the IEA Implementing Agreements, and the Technology Mechanism under the United Nations Framework Convention on Climate Change (UNFCCC). With the issues of ITD placed high upon policy agenda, there is also a growing need in our research community to conduct rigorous investigations on the mechanism of ITD for energy technological progress and offer deeper insights into the implications of cross-country technological interaction for global energy and climate governance (Grubb et al., 2002; Philibert, 2004; Popp, 2006a).

Basically, the recent literature has progressed along two tracks. On the one side, econometricians adopt econometric methods to examine the empirical evidences of energy technology diffusion (e.g., Lanjouw and Mody, 1996; Popp, 2006b; Dechezleprêtre et al., 2008; Johnstone et al., 2010; Popp et al., 2010b; Lovely and Popp, 2011; Verdolini and Galeotti, 2011; Hall and Helmers, 2013). On the other side, policy modelers use large-scale modelling to quantitatively examine economic and environmental effects of ITD. In particular, with an economy-wide framework that enables a representation of various technology details, the large-scale economic modelling has become a fruitful avenue for studying issues related to ITD in the field of environmental and energy economics. For example, some energy/climate studies build on multi-region, multi-sector computable general equilibrium (CGE) models to examine the impact of ITD on energy technological progress (Gerlagh and Kuik, 2007; Hübler 2011; Leimbach and Baumstark, 2010; Leimbach and Edenhofer, 2007; Leimbach and Eisenack, 2009), while others choose an integrated assessment model (IAM) to investigate the implications of international knowledge spillovers for global energy/carbon savings (Buonanno et al., 2003; Bosetti et al., 2008, 2011; De Cian and Tavoni, 2012; Parrado and De Cian, 2014).

While the above-mentioned large-scale economic modelling has the merit of comprehensiveness to represent the real-world economy for various energy/climate policy analyses, a characteristic weakness is that inside the "black box" complex modelling structure, it is ambiguous to capture the underlying mechanism of ITD for energy technological progress and its impact on energy/carbon savings. There is thus a particular need for researchers to develop a methodological complement to the existing complex large-scale modelling by presenting an analytical exposition of the basic mechanism of ITD for energy technological progress.

Therefore, the value added of this paper is to provide analytical insights into the mechanism of ITD for energy technological progress. In particular, we offer two complementary perspectives to explore the mechanism of energy technological progress. We first develop a Solow-type efficiency-improving model of energy technological progress, which is specific to a context where energy technological progress is considered as improvements in the efficiency of converting primary energy inputs into secondary energy products. In parallel, we further provide a Romer-type variety-expanding model of energy technological progress, which is specific to a context where energy technological progress is viewed as the expansion of the varieties of differentiated primary energy technology blueprints, in the sense that R&D in energy sectors can innovate and create new technology blueprints producing secondary energy products using differentiated varieties of primary energy resources, i.e., in addition to traditional energy technology blueprints based on fossil fuels such as coal, oil, and gas, energy innovation also creates new varieties of renewable energy technologies based on solar, wind, wave, bioenergy etc.[1]

From the analysis of both Solow-type efficiency-improving and Romer-type variety-expanding models of energy technological progress, we aim to highlight the following consistent results. First, there are potential forces in the world economy – working through ITD – that pull individual countries to advance energy technology, ensuring a cross-country convergence in the growth rates of energy technology in the long-run balanced growth path (BGP). Second, albeit a cross-country convergence in the growth rate, cross-country differences in the efficiency of undertaking indigenous research and the capacity of absorbing foreign knowledge spillovers would lead to a cross-country divergence in the absolute levels of energy technology in terms of either primary energy-augmenting efficiency or primary energy technology blueprint variety. This prediction basically coincides with the empirical evidences provided in IEA's *World Energy Outlook 2012* (IEA, 2012): differences in cross-country growth rates of energy technology may be present during transitional dynamic periods, but there are only small differences in growth rates in the long-run BGP when cross-country technology diffusion is present at the world level. With this specific emphasis, the models presented in this paper will be useful to unveil the basic mechanism of ITD in the energy context and rationalize the importance of ITD for energy technological progress.

The rest of this paper is organized as follows. Section 2 presents a Solow-type efficiency-improving model of energy technological progress. Section 3 develops a Romer-type variety-expanding model of energy technological progress. Section 4 presents some concluding remarks.

[1] In addition to the specific application to the energy context, we think the basic framework presented in this paper has the applicability to the analysis of more general issues related to cross-country technology interdependence and interactions through the channel of international technology diffusion within an extended Solow or Romer model, because the main contribution of our work is incorporating into the standard Solow and Romer models the feature of multi-country interactions that explicitly considers the dual drivers of technological progress – indigenous innovation and international technology diffusion.