Modeling Technological Change Under Increasing Returns and Uncertainty

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Abstract The aim of this paper is to analyze methodological challenges involved in modeling of endogenous technological changes with increasing returns and uncertainties by using stylized versions of models. Realistic versions of these models are analytically intractable making it difficult to comprehend the interplay of different assumptions on their outcomes. We demonstrate path-dependences of myopic evolutionary approaches, the infeasibility of straightforward "trial-and-error" processes, and the need for adequate long-term policy assistance. We also show why increasing returns and uncertainties radically offset the rationale for postponed investments in new technologies and how stochastic models cope with systemic risks implicitly induced by interdependencies among uncertainties, technologies, the structure of models, and decisions. The paper demonstrates possible misleading character of alternative models of uncertainties. It shows the need for proper modeling of long-term random horizons, corresponding discounting, security constraints and requirements of robustness by using systemic valuations and "distribution free" stochastic programming/optimization.

1 Introduction

The proper modeling of Technological Changes (TC) is decisive for the evaluation of the true socio-economic and environmental impacts of development policies. Traditional models assume that technological innovations are key factors of long-term economic growth and the prosperity of nations (Abramovitz 1993; Barnett

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and Morse 1967; Freeman 1994). However, on-going global changes, in particular, the pollution with potential catastrophic global climate changes, the increasing gap between the rich and poor, insecurity of food, water, energy, and countries, inspire great concerns about sustainable developments, equity and the welfare. Searching only for economic efficiency and growth produce adverse impacts of innovations which are impossible to evaluate by using traditional models.

The aim of this paper is to analyze methodological challenges involved in adequate modeling of TC by using simple versions of IIASA[1] path-breaking models (Arthur 1989; Arthur et al. 1987; Gritsevskyi and Ermoliev 1999; Gritsevskyi and Nakićenović 2002; Grübler and Gritsevskyi 2002). Realistic versions of these models are analytically intractable making it difficult to comprehend the interplay of different assumptions and their outcomes. The paper analyses the following basic issues.

In traditional economic models (see detailed analysis in (Cowan 1991; Gritsevskyi and Nakićenović 2002; Grübler and Gritsevskyi 2002; Nakićenović 1996; Ruttan 1997)) TC is represented by exogenous variables which improve performance of technologies through time independently of policies. As a consequence, such models strongly advocate to postpone investments in new technologies until they became cheap enough, i.e., "weight-and-see" policies. In reality, technological changes are (see discussion in (Grübler and Gritsevskyi 2002)) endogenous. They can be affected by deliberate policies related to urgent socio-economic, environmental and safety/security issues.

In other words, models with exogenous technological changes ignore the necessity to invest in new technology in order to make this technology cheaper and better with respect to desirable performance indicators. As technology becomes more widely adopted, the cheaper and better it becomes. This is so-called increasing returns phenomenon. Explicit modeling of increasing returns and uncertainties, as it was demonstrated in (Gritsevskyi and Ermoliev 1999; Gritsevskyi and Nakićenović 2002; Grübler and Gritsevskyi 2002), radically offsets the rational for postponed investments with crucial policy implications regarding timing of investments.

The modeling approaches with diminishing returns do not allow representation of these essential characteristics of technological developments. Despite this deficiency (see discussion e.g., in (Metcalfe 1987; Nakićenović 1996)), the diminishing returns dominate the standard models because such models are convex with simple concepts of global solutions and equilibriums. Contrary, increasing returns are associated with non-convexities, local solutions, disequilibriums, path dependencies and the concept of "lock-in" states of developments. This case requires significant remodeling of traditional approaches (Arrow 1962; Griliches 1996; Gritsevskyi and Ermoliev 1999; Grossman and Helpman 1991; Ruttan 1997). In particular, a new technology requires a vast variety of other technologies (Gritsevskyi and Nakićenović 2002; Grübler and Gritsevskyi 2002), including infrastructures. Nonetheless, these essential interdependencies (externalities) are represented in

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