

# **Innovation efficiency in heterogeneity context: A matter of inputs and outputs or innovation capabilities? The case of Catching-Up countries**

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## Abstract

The aim of the paper at hand is two-fold. Firstly, our work focuses on the introduction of innovation capabilities in an innovation efficiency heterogeneity context. Secondly, we identify innovative firms' heterogeneous firm clusters within the innovation frontier realized by including innovation capabilities and explore the characteristics that classify each firm into a specific cluster.

We develop the theoretical and methodological framework which allows the inclusion of the firm's innovation capabilities, in the form of non-continuous variables, in the DEA approach for estimating innovation efficiency in a benchmarking context. Regarding firms' innovation capabilities, we are focusing on the innovation property rights (IPR) case. The methodological contribution is closely related to the conceptual dimension of the firm's/country heterogeneity in the innovation process.

We introduce an approach to estimating the efficiency of innovation activities by incorporating non-continuous variables. In this vein, we provide solid theoretical arguments and develop a novel approach for innovation efficiency estimation. IPR serve as a mediator as they are considered inputs and outputs of the innovation process (Alnafrah, 2021; Choi & Zo, 2019). Therefore, "hard" innovation inputs exhibit direct and indirect effects.

The estimation of innovation efficiency is based on the employment and further development of the modified DEA model of Banker & Morey (1986), which allows the introduction of non-continuous data. The implementation of the modified DEA approach is used for the evaluation of the innovation efficiency of five Catching Up countries (Hollanders & Esser, 2007), namely, Greece, Portugal, Hungary, Croatia, and Lithuania, from the CIS 2012-2014 microdata wave.

With our work, we produce solid empirical evidence that firms' innovation capabilities, combined with innovation inputs and outputs, provide valuable insights on the innovation efficiency distribution. In particular, we reveal that latent heterogeneous firms' groups of innovation efficiency co-exist, and the investigation of innovation efficiency under a common frontier is not a proper one (Gkypali et al., 2019). One of the major contributions of the analysis introduced, is the finding that the identified latent heterogeneous groups are hierarchically structured. Therefore, the multiple meta-frontiers concept, clustering the partial identified technologies, is coming in the front and interesting potential learning flows between groups arise (Chatzistamoulou et al., 2022).

Through the development of a heuristic algorithm, the heterogeneous subgroups of the efficient frontiers and the corresponding hierarchy are identified. Lastly, the main drivers that determine innovation efficiency groups' hierarchy are explored using ordinal regression.

The factors determining the classification of each group of firms in each frontier rank for each country are obtained using ordered probit regression. All Catching-Up countries exhibit a considerable negative link between the efficiency classifications and public funding, whether from the government or the E.U. Furthermore, cooperation and absorptive capacity have a negative impact on the likelihood of a business being assigned to the high-efficiency classification in all countries except Lithuania for the cooperation variable and Croatia and Lithuania for the absorptive capacity variable. From the results, public funding and R&D cooperation appear to be the common negative determinant of the probability of a firm belonging to a high-efficiency cluster in Catching-Up countries.

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