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Technology upgrading of middle income economies: A new approach and results

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ABSTRACT

We explore issues of measurement for technology upgrading of the economies moving from middle to high-income status. In exploring this issue, we apply theoretically relevant and empirically grounded middle level conceptual and statistical framework based on three dimensions: (i) Intensity (ii) breadth of technological upgrading, and (iii) technology and knowledge exchange. As an outcome, we construct a three-pronged composite indicator of technology upgrading based on 35 indicators which reflect different drivers and patterns of technology upgrading of countries at different income levels. We show that technology upgrading of middle-income economies is distinctively different from that of low and high-income economies. Our results suggest the existence of middle-income trap in technology upgrading – i.e. countries' technology upgrading activities are not reflected in their income levels. Based on the simple statistical analysis we show that the middle-income trap is present in all three aspects of technology upgrading, but their importance varies across different aspects. A trap seems to be higher for 'breadth' of technology upgrading than for 'intensity' of technology upgrading and is by far the highest for the dimension of knowledge and technology interaction with the global economy. Finally, our research shows that technology upgrading is a multidimensional process and that it would be methodologically wrong to aim for an aggregate index.

1. Introduction

Technology upgrading is a multidimensional process and the existing indicators, which are overly R&D oriented, do not capture this multidimensionality. In particular, the existing indicators do not reflect specificities of technology upgrading of middle-income economies. They are either atheoretical or not rooted in stylised facts of technology upgrading and thus not relevant for low/middle-income economies. Radosevic and Yoruk (2016a) have developed empirically grounded middle-level conceptual framework which could illuminate type of challenges that are pertinent to a significant number of middle income and 'lower' high-income economies (from $1000–$30,000 GNI pc) in their path out of the broadly defined middle-income trap. In this paper, we apply this new framework and explore its robustness and validity to a sample of 42 economies of different income levels.

There is a variety of proposed composite indicators that measure countries' performance in growth, competitiveness and innovation. Examples are: the Global Competitiveness Index (GCR, 2015), the Knowledge Economy Index of the World Bank (Chen and Dahlman, 2004; Chen and Dahlman, 2005), the World Competitiveness Report Index (WCY, 2016), index of technological capabilities (ArCo) (Archibugi et al., 2009; Archibugi and Coco, 2004, 2005), the UNIDO Industrial Performance Scoreboard (Lall and Albaladejo, 2002; UNIDO, 2002), Global Innovation Index,[1] European Innovation Scoreboard,[2] the Technological Achievement Index of the UNDP (Desai et al., 2002), and the S&T Capacity Index (STCI) proposed by the RAND Corporation,[3] the High-Tech Indicators (HTI) developed at the Georgia Tech Technology Policy and Assessment Center.[4]

However, this diversity of indexes has not led to a diversity of measurement outcomes. The similarity in ranking across different indexes are striking (Nasierowski and Arcelus, 2000). They all point to the importance of innovation to economic development, but differences in their conceptual perspectives do not change significantly ranking among countries. On the other hand, Archibugi et al. (2009) show that

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[1] https://www.globalinnovationindex.org/
[2] http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en
[3] http://www.rand.org/content/dam/rand/pubs/monograph_reports/2005/MR1357.0.pdf
[4] https://tpac.gatech.edu/sites/default/files/projectfiles/HTI_S_2008report_Jun10.pdf

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single indicator like R&D can not substitute differences in ranking. So, despite similarities in rankings, the conceptual differences do matter. Based on these insights, we do not see the primary value of our contribution in a new ranking but in pointing to differentiated drivers of growth and technology upgrading at different income levels. This Schumpeterian approach is in intention similar to the WEF *Global Competitiveness Index*, which takes a differentiated view on the role of technology across development path assuming that the closer countries are towards technology frontier, the more rest their growth and competitiveness on knowledge and technological activities. Our aim is not to focus on rankings per se but different drivers of technology upgrading. The learning effect should be in showing the diversity of drivers and compare countries regarding their upgrading paths. The ranking makes sense when comparing countries that are driven by similar drivers of technology upgrading or are at very similar stages of technology upgrading process.

We approach technology upgrading as a multidimensional conceptual framework which goes beyond R&D in explaining the building of technology capabilities, which accompanies long-term growth. This concept is open to sensitivities of different levels of development and is empirically informed but also has some theoretical relevance. We consider it as an appreciative theorising framework, which aims to overcome a frequent weakness of composite indicators which is that they represent "measurement without theory" (Koopmans, 1947).

Our results show the relevance of three-pronged approach to technology upgrading as the process driven by the intensity and breadth of technology upgrading, which are complemented by the degree and differences in modes of technology and knowledge exchange with the global economy. Although statistically, it is possible to unite three dimensions of technology upgrading into a single index we remain sceptical regarding policy usefulness of such exercise. We show the positive relationship between three dimensions of technology upgrading and levels of income, but also the non-linear relationship between levels of individual indexes (dimensions) and levels of income. We identify middle-income trap in technology upgrading and through simple OLS, we quantify its weight across different dimensions of technology upgrading.

First, we explain in Section 2 the relationship between technology upgrading and technology gap literature. In Section 3 we explain the conceptual framework that lies behind the concept of technology upgrading. In Section 4, we describe individual indicators as well as applied method for constructing a three-pronged composite indicator of technology upgrading. In Section 5 we explore key stylised facts that emerge from the use of dataset that falls within our conceptual framework. In Section 6, we discuss the relevance of results and conclude.

2. The relationship between technology upgrading and technology gap literature[5]

Similar to the literature on 'technology gap' our paper addresses the issue of accumulation of technological capabilities. For example in similar fashion to Fagerberg (1987), we show that there is a close relationship between a country's economic and technological levels of development. However, we are primarily concerned with the accumulation of technology itself and we do not aim to explore determinants of growth but we recognise that the nature of technology accumulation changes as countries grow. Similar to very recent work in 'technology gap' literature (Castellacci, 2011) we show that the interaction among different dimensions of technology is a crucial factor in technology upgrading.

Technology gap literature assumes linear or log-linear relationship between technology variables and growth and postulates relationship across all income levels without exploring inflection points or threshold or middle trap levels (Fagerberg and Verspagen, 2002). However, we show that this relationship is not linear as we demonstrate the existence of middle income trap and show how that trap varies across three dimensions of technology upgrading. We show that three drivers of technology upgrading are qualitatively different.

Technology gap literature's ambition to explain determinants of growth has its price in several stark simplifications. First, innovation is highly varied at different income levels. In some specifications (Castellacci, 2011) innovation is equated solely with patents and scientific papers which we consider quite problematic, since this has implications for use in developing countries that we study. Second, the potential for diffusion (a possible source of convergence, proxied by the level of productivity or GDP per capita) is not directly measured but is proxied by the outcome variable – i.e. levels of productivity. This assumption implies automatic convergence which is quite different from the idea of middle-income trap. Third, in these models interaction with the global economy is ignored or is proxied through openness which in itself is highly problematic variable and endogenous to growth. Technology gap literature uses the notion of absorptive capacity which is vague and is reduced on human capital and infrastructure.

On the other hand, the drawback of our approach is that we are not yet able to run regression models as we do not yet have enough long run series for meaningful testing of dynamics of relationships between growth and technology upgrading factors.

3. A framework for measuring technology upgrading: a conceptual approach

We conceptualise technology upgrading as a three-dimensional process which consists of:

(i) Technology upgrading as depicted by ***intensity*** of production, R&D and technology generation activities,
(ii) ***Breadth*** of technology upgrading, which is about diversity of technological knowledge, types of supporting infrastructure and organisational capabilities of firms which are the main carriers of technology upgrading, and
(iii) ***Knowledge inflows and outflows*** in and out of the economy through a variety of forms such as trade, FDI and disembodied knowledge flows.

All of the three dimensions have a strong grounding in the respective literature on firm-level technology upgrading, on structural change and growth, and on the integration of the global economy (see Radosevic and Yoruk, 2016a for overview and argument).

Technology upgrading is an outcome of the interaction between intensification of different types of technology activities (dimension I), structural factors and changes in this process (dimension II) which are mediated by the way economy interacts in this process with the global economy (dimension III). Given its three-dimensional nature the aggregate indicator of technology upgrading can be calculated statistically but as we show later on it is not justified conceptually and policy-wise. Especially, a third dimension (interaction with global economy) is a complementary dimension, i.e. it amplifies or reduces effects of technology upgrading depending on modes of integration or interaction with the global economy.

3.1. Intensity of technology upgrading by types (scale)

This dimension of upgrading is about acquiring different kinds of technology capabilities, which are also a reflection of the various technological levels of economies. Economies that operate behind technology frontier are more likely to grow based on production

[5] We are thankful to the anonymous reviewer for drawing our attention to the intricate links among the concepts of technology gap, technological capabilities and technology upgrading.