Introduction

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1 Conceptualising technology upgrading as a multi-dimensional process

As developing countries move from low-middle income to high-middle and high-income status, they have to upgrade technologically from imitative technology effort to technology diversification and technology frontier activities. However, increasing number of countries that get stuck in this process which has been depicted as ‘middle-income trap’ suggest that technological upgrading is a binding constraint for sustained growth (Lee and Kim, 2009; Lee, 2013). So, how emerging economies, which have reached middle-income status can further upgrade technologically has become significant academic and policy issue. Conventional models of technological development or upgrading based on either exogenous model of growth (Solow, 1957) or endogenous growth theory (Romer, 1990) do not capture critical features of technology upgrading of emerging economies. The Solow model treats technology as unexplained part of growth, which makes it of very limited relevance to our research question. In endogenous growth theory, research and development (R&D) is the primary source of innovation and growth, which is not the case in emerging economies where R&D operates primarily as a factor of absorptive capacity rather than a driver of the innovation process (Lin and Rosenblatt, 2012). More relevant for our purposes could be the neo-Schumpeterian perspective, which depicts different patterns of technology accumulation and innovation capabilities across countries as enabling factors for catching-up (see, for example, Verspagen, 1991; Nelson, 1995; Nelson and Pack, 1999; Lee, 2005; Fagerberg and Godinho, 2005; Mazzoleni and Nelson, 2007).

What evidence in this tradition suggests is that technological change and catch-up take different forms (Wang et al. 2014). Some researchers have argued in support of an incremental path from the importing of technology to the creation of original R&D (Kim, 1997; Hobday, 1995). Others have proposed a leapfrog method, either by utilising a window for technological development or by creating a new path (e.g., Perez and Soete, 1988; Lee and Lim, 2001). New structural economics makes an essential qualification to this. It indicates that the path to technology upgrading as based on ‘copying industries’ using latent comparative advantages is crucial in the transition from low to middle-income levels (Lin, 2012a, 2012b; Lin and Rosenblatt, 2012). On the other hand, the neo-Schumpeterian approach of Lee (2013) shows that paragons of successful catch up like Korea and Taiwan take ‘detours’ and establish their technological paths when moving to high-income levels.

Patterns of technology upgrading may also be changing due to the changing nature of new technologies coupled with the proliferation of global value chains (GVCs). GVCs lead to separation of production from innovation activities while new technologies like artificial intelligence and robotics may reduce advantages of this separation and lead to a slowdown in offshoring (De Backer et al., 2018). Also, innovation activities may lead to blurring the boundary between R&D and production activities, between manufacturing and services, which poses new challenges for technology upgrading of emerging economies about which we have limited in-depth knowledge. In short, there is need to understand better not only the scale but also scope of innovation activities in emerging economies.

Our conceptualisation of technology upgrading in emerging economies builds on this strand of neo-Schumpeterian contributions. Technology upgrading is a multi-dimensional process based on a broader understanding of innovation, which goes well beyond R&D. The concept suggests a multi-level process and at its core is a structural change in various dimensions: technological, industrial, organisational (Radosevic and Yoruk, 2016). It is also an outcome of global forces, embodied in international trade and investment flows, as well as local strategies pursued by host country firms and governments (Ernst, 2008; Fu et al., 2011; Lall, 1992; Giroud et al., 2012; Radosevic and Yoruk, 2014).

Given the multi-dimensional nature of technology upgrading this special issue builds on three dimensions of technology upgrading as explored in Radosevic and Yoruk (2018):

1 the intensity of technology upgrading as depicted by different types and levels of innovation

2 the breadth of technology upgrading in terms of changes to the structure of technological knowledge

3 the role of global interaction in terms of inflows of foreign technology and coupling with domestic technological efforts.

2 The intensity of technology upgrading

In principle, the intensity of technology upgrading is about the accumulation of different types and levels of capabilities. We distinguish between production, innovation and R&D capabilities (Bell and Pavitt, 1993, 1995; Bell, 2009). The first is concerned with firms' capabilities to use existing technologies in production; the latter is related to firms' capabilities to create new technology and change the technology they already use. R&D are capability on their own but also input into technological and production capabilities. The empirical firm-level literature on capabilities documented several successful cases of upgrading from production capability to innovation capability by latecomer firms (Hobday, 1995; Hobday et al., 2004; Ernst, 2013; Dutrenit, 2000; Radosevic and Yoruk, 2004). It is important to highlight, that production capabilities remain essential as economies technologically upgrade. Production, innovation and R&D activities continue to be present as economies upgrade technologically but play different roles depending on different strategies employed. Bernat and Karabag (this issue) show that R&D activities by firms in emerging economies support both the modification of current technologies as well as the generation of new ones. Their case studies suggest that through investment in training and learning-by-doing activities, R&D creates particular resources, skills and knowledge that are neither within the scope of regular educational institutions nor are derived from just using imported technologies. In turn, Busch et al. (this issue) focus upon frugal innovations in the Brazilian energy sector. They show that when firms pursue environmentally oriented frugal innovation, they pay stronger attention to overall technological effectiveness rather than technological efficiency. The focus on situational effectiveness rather than efficiency diverges from the traditional understanding of R&D. Frugal innovation represents broad-based innovation and a 'low-road strategy' (Fuchs, 2014) with narrow thresholds of adoption. Busch et al. (this issue) show that frugal innovation constitutes a form of indigenous innovation, which is required for technological upgrading and economic growth (Fu et al., 2011; Leliveld and Knorringa, 2017; Radosevic and Yoruk, 2016). In that respect, their research enlarges the scope of innovation activities specific to emerging economies.

3 The breadth of technology upgrading

Technology upgrading entails not only increased intensity or scale of technological activity but also changes in the underlying structural features of technological capabilities. As countries upgrade technologically, Lee (2013) shows that technological diversification, rather than specialisation, is one of the significant factors in catching up to high-income levels. Successful middle-income countries may temporarily specialise in narrow areas with high technological opportunities, but the path of technology upgrading is characterised by increasing knowledge diversification (ibid). Also, technological diversification entails changes in the underlying organisational structure of technological upgrading, which increasingly depends on network linkages with other actors and infrastructure organisations as well as on time-consuming building of organisational capabilities. Against this background, Shubbak (this issue) shows how the impact of innovation capability on economic performance at the firm level is highly heterogeneous across different types of network linkages. Shubbak studies the technological upgrading of China in photovoltaics technology and shows a significant effect of the interaction between innovation-capability and network-embeddedness dimensions on the economic performance of organisations. This underlies the critical structural dimension of technology upgrading, which is not only about accumulation of technological capabilities but also about diversification and organisational networking of latecomer firms.

4 The global interaction of technology upgrading

Growth and technology upgrading are never entirely autonomous processes but linked to *global interaction*. However, global interaction does not equate with passive openness but instead entails active technology capability building. For example, Akamatsu (1962) describes technology upgrading as an interactive process between 'leaders' and 'followers'. Traditionally, inward foreign direct investment (FDI) has been associated with a centrally accumulated technological advantage originating in the home country, which is transferred to the host country where it diffuses to the domestic economy (Findlay, 1978). Research shows that technical innovations are most effectively copied when there is personal contact between those who already know the innovation and those who eventually adopt it (Nelson, 1968; Mansfield, 1961, 1968). Research showed also that such diffusion is conditional upon the technical and managerial competence of the foreign firms as well as the domestic firm's decision to invest in learning (Wang and Blomström, 1992; Marin and Bell, 2006; Castellani and Zanfei, 2006; Damijan et al., 2013; Jindra, 2011; Giroud et al., 2012). Contributing to this line of research, Obaya et al. (this issue) conclude that the decision to promote technological upgrading in foreign subsidiaries in emerging regions remains at the level of headquarters during the early stages of the learning process. Only when subsidiaries go beyond a capability threshold, they can gain autonomy to make autonomous learning initiatives. Furthermore, they demonstrate that a hierarchical structure of functionally integrated MNE networks leads to asymmetries in the learning process of different subsidiaries in the same MNE network. In this way, Obaya et al. (this issue) enrich our understanding of nonlinear nature of technology upgrading through MNE integration.

GVC participation is another vital element of upgrading at the level of the firm and industry. The corresponding GVC literature shows that upgrading takes place through various forms: efficiency gains by reorganising the production system or introducing superior technology; product upgrading, where a firm moves into more sophisticated product lines; functional upgrading, where a firm acquires new functions (or abandons existing ones) to increase the overall skill content of activities (Kaplinsky and Morris, 2001; Humphrey and Schmitz, 2002, 2004; Sturgeon and Gereffi, 2009; Gereffi and Fernandez-Stark, 2011). Therefore, in principle the entry of emerging market firms into GVCs creates opportunities for technological upgrading through learning and interaction. Kaplinsky and Morris (this issue) show how regulations and standards shape these interactions. They show that on the one hand there is ample evidence that certification to regulations and standards is an essential contributor to the upgrading of capabilities of producers in GVCs, enabling them to achieve sustainable income growth. On the other hand, standards compliance can also be exclusionary. As a consequence of conforming to regulations and standards, disadvantaged and marginal producers and workers can simultaneously be excluded from the fruits of development. These adverse outcomes arise because of not being able to meet entry requirements in chains or by being deliberately forced out of the chain.

Finally, if we conceptualise technology upgrading as a multi-dimensional process that includes intensity, structural change and global interaction, it is important to highlight that it cannot be exclusively measured by a narrowly defined single variable such as R&D or exogenously derived total factor productivity. Against this background, there has been a call for new metrics to understand how technology upgrading takes place – emphasising the challenges of middle-income countries (Radosevic and Yoruk, 2016). Kruss (in this issue) reflects conceptually on this challenge by using the case of South Africa, to propose a high-level framework, as a contribution to inform the adaptation of existing, and the creation of new complementary measures of innovation. She argues that this approach should be based on broader models of innovation that emphasise the systemic and dynamic nature of innovation, encompass multiple dimensions of technology upgrading; and focus on technological capability building, particularly at the local level. Importantly, she stresses that it should be oriented to not only firms and the formal sector, but also to other economic and social actors in informal settings.

In conclusion, we believe that the contributions collected in this thematic issue significantly advance our understanding of the technology upgrading in emerging economies in all its dimensions (intensity, structural change and global interaction) including policy dimension. We also hope to encourage future investigations that apply and extend the concept of technology upgrading, test corresponding propositions and develop new metrics more broadly across emerging economies.

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