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Indigenous and Foreign Innovation Efforts and Drivers of Technological Upgrading: Evidence from China

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Summary. — This paper explores the role of indigenous and foreign innovation efforts in technological upgrading in developing countries, taking into account sectoral specificities in technical change. Using a Chinese firm-level panel dataset covering 2001–05, the paper decomposes productivity growth into technical change and efficiency improvement and examines the impact of indigenous and foreign innovation efforts on these changes. Indigenous firms are found to be the leading force on the technological frontier in the low- and medium-technology industries, while foreign-invested firms enjoy a clear lead in the high-technology sector. Collective indigenous R&D activities at the industry level are found to be the major driver of technology upgrading of indigenous firms that push out the technology frontier. While foreign investment appears to contribute to static industry capabilities, R&D activities of foreign-invested firms have exerted a significant negative effect on the technical change of local firms over the sample period.
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Key words — indigenous innovation, technology transfer, FDI, technology upgrading, China

1. INTRODUCTION

Technology upgrading is a key element of industrialization in developing countries. International technology transfer through foreign direct investment (FDI) has long been regarded as a major engine of technology upgrading in developing countries. Many developing countries combined competition for FDI with the expectation that advanced technological knowledge embedded in FDI can drive technological upgrading in their countries. On the other hand, in recent years more and more developing countries have started to question the effectiveness of such a FDI-led technology upgrading strategy and have called for greater emphasis on indigenous innovation as a driver of the development of indigenous technological capabilities. It is, therefore, timely to assess the following two questions: what are the major drivers of technological upgrading in developing countries and, secondly, can developing countries rely on foreign technology to catch up with industrialized countries? Furthermore, empirical evidence on the productivity gains from trade and FDI is mixed,[1] and the debate on the importance of foreign *versus* indigenous innovation efforts is inconclusive.

This paper attempts to explore the drivers of technology upgrading in middle-income developing countries, which often have sizeable domestic markets, considerable human capital, and a strong desire for economic independence. It assumes that developing countries, especially middle-income countries, are not only users but also creators of new technology in certain industrial sectors. It also takes into account the fact that the industry structure of these countries often consists of industries of a variety of technology intensities.[2]

The empirical analysis is carried out using a firm-level panel dataset of 56,125 Chinese firms over the 2001–05 period. China provides a good case for this study given its huge FDI inflows and its emphasis on indigenous innovation and industry upgrading. A nonparametric frontier technique is used to decompose the total factor productivity (TFP) growth of firms into technical change and efficiency improvement. The drivers of these changes are examined with special emphasis on the impact of indigenous and foreign research and development (R&D) efforts. Three types of R&D efforts are considered: R&D at the firm level, R&D in all foreign-invested firms within the same industry and region in China, and international R&D spillovers facilitated by FDI. To test the effect of the third type of foreign R&D effort, the international industry-specific R&D stock is linked to the Chinese firm-level data in the corresponding industry and adjusted by industry- and firm-level FDI-intensity.

This paper is organized as follows. Section 2 presents a theoretical framework for the understanding of the drivers of technological upgrading in a middle income developing country. Section 3 provides a brief overview of FDI and innovation in China. Section 4 discusses data, model, and methodologies. Section 5 presents the empirical results. Section 6 concludes with a discussion of policy implications.

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2. THEORETICAL FRAMEWORK

Innovation is costly, risky, and path-dependent. Innovation activities have, therefore, been largely concentrated among a few developed countries. If technologies are costless to diffuse and if the effectiveness of a technology is the same in different local contexts, developing countries can rely on foreign technology transfer and easily catch up with the world technology frontier without indigenous innovation. Foreign direct investment as a bundle of technological and managerial knowledge as well as financial capital has long been regarded as a major vehicle in the transfer of advanced foreign technology to developing countries (Dunning, 1993; Lall, 2003). A further reason to expect that FDI will lead to technology transfer derives from the fact that most of the world's R&D investment is concentrated among a few large multinational enterprises (MNEs).

FDI may contribute to technological upgrading in the host economy in several ways. Technology spillovers from foreign-invested firms may contribute to technical change in indigenous firms. Knowledge spillovers may take place from foreign to local firms in the same industry and region through the movement of trained labor, demonstration effects, and competition effects when the competitive pressure caused by the foreign presence forces local firms to improve their production technology and management (Buckley, Clegg, & Wang, 2002; Caves, 1974; Fosfuri, Motta, & Ronde, 2001). There may also be significant knowledge transfer within the supply chain *via* forward and backward linkages (Javorcik, 2004). Moreover, advanced technologies embedded in imported machinery and equipment in foreign-invested enterprises (FIEs) may raise the average technology level of the host economy. Multinational enterprises may also bring in advanced innovation management practices and thus improve the innovation efficiency of the local innovation system (Fu, 2008). On the other hand, the introduction of FDI may make competing domestic firms worse off (Aitken & Harrison, 1999) and reduce the R&D efforts of local firms (OECD, 2002). This could occur if foreign firms exploit their superior technology and marketing power to force local competitors to reduce their outputs or if they attract the most talented researchers, something which in particular might threaten local SMEs (Aitken & Harrison, 1999; Hu & Jefferson, 2002; UNCTAD, 2005).

Moreover, there are several pre-conditions for local firms to benefit in an effective manner from FDI spillovers. Firstly, technology transfer *via* the supply chain requires effective linkages between foreign firms and their local suppliers and customers (Fu, 2004; Javorcik, 2004). Secondly, significant spillovers from foreign to local firms require sufficient absorptive capacity in the local firms (Cohen & Levinthal, 1989; Fu, 2008). A threshold level of human capital has been found to be necessary (Eaton & Kortum, 1996; Xu, 2000). R&D activities are also found to be important as a means of learning and accumulating absorptive capacity (Aghion & Howitt, 1992; Griffith, Redding, & Van Reenen, 2003). Thirdly, different types of FDI have markedly different productivity spillover effects (Driffield & Love, 2003). Given these preconditions, it is not surprising that despite the possible benefits from international technology transfer, empirical evidence in this field is mixed.

Moreover, the need for foreign technology to be appropriate to the specific socio-economic and technical context of a developing country implies that developing countries cannot rely on foreign technology for technological upgrading and that indigenous innovation is of crucial importance. Different technologies are specific to particular combinations of inputs (Basu & Weil, 1998). For a particular country, an appropriate technology is "a technology tailored to fit the psychosocial and biophysical context prevailing in a particular location and period" (Stewart, 1983; Willoughby, 1990). Therefore, technological progress can be seen as "localized learning by doing" (Atkinson & Stiglitz, 1969).

Acemoglu (2002) suggests that technologies are designed to make optimal use of the conditions and factor supplies in the country where the technology is developed. Most new technologies are invented and developed in industrial countries, for example, OECD countries, which are abundant in skilled labor. Therefore, these new technologies often make intensive use of skilled labor, for example, engineers, managers, and other professionals, and are usually capital augmenting or skilled-labor augmenting. Such advanced technologies might be inappropriate for conditions in developing countries and hence less productive given the different factor endowments that the developing countries have (Acemoglu, 2002; Acemoglu & Zilibotti, 2001). The extent of directed technical change and the difference in factor endowment between creator and user economies will determine how inappropriate a technology is with respect to the needs of the importing country.

As endowments in developing countries differ between countries, and the demand for skilled labor varies across industries, the degree of appropriateness of foreign technology for productivity growth in a developing country depends on the characteristics of the country and the industry under study. Since the demand for unskilled and semi-skilled labor is higher in labor-intensive industries, adoption of unskilled-labor augmenting technology will generate greater returns than the use of skilled-labor augmenting technology. In other words, firms using unskilled-labor augmenting technology will be more efficient than firms using skilled-labor augmenting technology in low-technology industries. For similar reasons, skilled-labor augmenting technology will be more efficient in high-technology industries. Indigenous technology created in a labor-abundant developing country will be unskilled labor-augmenting, as suggested by the Directed Technical Change theory. Therefore, in such populous developing countries, indigenous technology might be more efficient than foreign technology in labor-intensive industries. By contrast, foreign technology created in developed economies will be more efficient than indigenous technology in technology-intensive industries. In sum, technical change and the appropriateness of a technology are sector-specific. This sectoral extension of the analysis is important because in reality, countries often produce a diverse mixture of goods rather than simply specializing in either labor or capital-intensive production.

Middle-income countries have accumulated a pool of knowledge and skills which distinguish their factor endowments from those of the least developed countries as well as those of the industrialized countries. Therefore, middle-income economies are more likely to generate "intermediate" innovations with medium-level technology intensity. These middle-income countries can reap the gains from investment in such technologies through the sale of patents, payment of royalties, or South–South direct foreign investment in other developing countries. Moreover, for the same relative factor prices, the gain from introducing new techniques is higher the larger the volume of demand. This also implies that countries such as China, Brazil, and India are more likely to generate "intermediate" technology than smaller economies with the same degree of capital scarcity (Findlay, 1978).

In sum, while there are potential gains from international technology transfer, the extent of benefits might be limited

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