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Assessing the relative importance of multiple channels for embodied and disembodied technological spillovers

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ABSTRACT

With ever increasing global integration, productivity improvements depend not only on in-house innovative efforts, but on those of international partners as well. This paper explores the impact of foreign R&D on productivity and technical efficiency of countries by considering three channels of embodied and disembodied spillovers, namely trade, foreign direct investment and patenting, and controlling for the direct licensing of foreign technologies. Furthermore, it contrasts these effects across 47 developed and transition countries between 1990 and 2009. Overall, I find that trade remains the dominant factor behind productivity and technical progress, while the effects of FDI- and patent-related spillovers are significantly smaller. The effect of foreign patenting is larger in developed nations while imports, inward FDI and foreign technology licensing are important sources of know-how for transition economies. The aggregate gains from spillovers appear larger for latter, confirming their significance in the process of development and catching-up.

1. Introduction

Over the past decades, globalization has accelerated both the rate of technological innovation and its diffusion worldwide [7]. The literature postulates research and development (R&D) efforts as the cornerstone of productivity and economic growth [38,71]. However, few can reap these benefits, since most R&D is carried out exclusively in a handful of industrialized nations, with few new players joining this club [42].[1] As a result, most countries depend on knowledge inflows from abroad to augment their productivity, and ultimately, economic competitiveness [49]. Thus, identifying the impact of these technology spillovers and the channels through which they operate, will help understanding the existing worldwide discrepancies in income per capita [41], and enunciate pertinent policy insights for developing and transition economies competing in global markets [34].

Technology transfer occurs between countries, sectors, firms or individuals and can take many forms. The literature investigates technological content that spills over via imported intermediates [27,55], equipment of multinationals [2,39,72] or skilled human capital [66,54]. Moreover, technical knowledge may diffuse in disembodied forms such as patents [8,77], licensing agreements [64,84], R&D contracting and outsourcing [21,70], and communication [75,83]. While patenting has been analyzed quite extensively [31,55], downstream revenues from it and other forms of intellectual property remain relatively unexplored, especially in large cross-sections [61]. Secondly, while theoretical arguments support multiple channels through which technical know-how migrates between firms, sectors and countries, empirical validations of these avenues remain rather scant [39,55]. Finally, a significant problem is the lack of reliable data for many developing and transition economies, exactly those for which theory predicts larger spillovers [65] with crucial implications for exports [5], growth and catch-up [32].

This paper proposes several contributions to the literature as follows. First, it quantifies both *embodied* and *disembodied* sources for spillovers of foreign R&D. To this purpose, it considers four alternative channels for exposure to foreign technological content, namely trade and FDI for embodied

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[1] Hall [42] shows that the concentration of R&D activities is decreasing slowly over time from 0.78 in 1999 to 0.75 in 2005, as opposed to an unchanged 0.69 in both years for GDP.

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knowledge, plus international patenting and licensing for disembodied one. With the exception of trade, the magnitude and effects of other channels of diffusion are still debated in the literature [10,35]. Moreover, while the effects of these channels have been explored in isolation by previous work, assessing their relative effectiveness in the diffusion of technology remains an open question [49]. Secondly, this work contrasts the effects of spillovers across a panel of both *developed* Western economies and *transition* countries from Eastern Europe (CEECs) and the Commonwealth of Independent States (CISs). The latter had mixed performance both in terms of R&D and growth rates, as a result of past dependence in terms of scientific and economic specialization to the socialist era [16,53]. Finally, this study deals with issues related to non-stationarity, cointegration and dynamic estimation to obtain robust results on the effect of embodied and disembodied spillovers on productivity and technical efficiency of countries.

The empirical results confirm the paramount role of trade in the diffusion of new technologies, consistent with previous findings [25,55,82]. FDI is particularly important for transition economies, as multinationals (MNEs) boost significantly host countries productivity and GDP levels [34]. The spillover effects from foreign patents are prevalent in developed economies that utilize this channel efficiently to tap new knowledge produced by MNEs active in these markets [81]. Oppositely, emerging markets lack the capacity and the intellectual property enforcement tools to attract MNEs to patent domestically or set-up local R&D facilities. Finally, direct acquisition of foreign technologies through licensing agreements translates into greater total factor productivity and technical efficiency gains for transition economies that are further from the global technological frontier. In today's global economy densely interlinked through trade, investment and knowledge exchanges, developing countries benefit significantly from foreign spillovers to accelerate their development and “catch”-up with the industrialized world. These results shed light on the relative importance and effectiveness of these channels and provide concrete pointers for policy-makers in these countries. Trade, FDI and bilateral patenting with developed and R&D intensive countries all bear positive effects on productivity levels [19,50]. However, effects vary across countries based on their portfolio of trade, FDI and innovating partners and their relative R&D intensity.[2] These indirect sways are stimulated by good institutions [18,26,75], highly skilled human capital [9,63] and incentives for foreign firms to develop local high-tech capabilities, such as local R&D units [33,43,76]. Unlike embodied spillovers, imports of technologies contribute directly to total productivity via domestic firms that make these purchases. This represents a more expensive, yet faster, alternative for developing countries to move closer to the world's technological frontier, and recent history provides us with several examples of countries (e.g. Japan, Taiwan, South Korea and China) that have been successful utilizing this strategy to boost their economic performance.[3]

The rest of the paper is organized as follows. Next section provides a discussion of the literature on the international R&D spillovers. Section 3 details the empirical framework used, starting with the background model, data and variables employed, econometric investigation and subsequent checks for robustness. Finally, Section 4 concludes and discusses policy implications stemming from this work.

2. Theoretical background

2.1. Embodied versus disembodied spillovers

R&D investments spur new knowledge about materials and processes, ways of recombining them to produce new goods and services. However, in practice, such benefits are impossible to be fully internalized. Thus, it is interesting to quantify the effects of these “spillovers” throughout a sector or economy, and secondly seek ways to maximize them. Endogenous growth models see R&D spillovers as a significant source of growth, and starting with the work of Coe and Helpman [27] a large body of literature has brought numerous empirical evidences to support this conventional wisdom [72].

However, the type of underlying R&D process plays an important role in identifying and classifying spillovers. Los and Verspagen [58] classify R&D efforts as “process-oriented” (aiming at lowering production costs) and “product-oriented” (focusing on developing new products or improving quality of the existing ones). This classification has a particular influence on the type of spillovers analyzed, since process R&D is usually protected using *secrecy*, while product R&D is exposed in produced goods. Furthermore, in a famous contribution, Griliches [37] distinguishes two types of R&D externalities, namely the *knowledge spillovers (disembodied)* and *rent spillovers (embodied)*. The latter implies that the price of imported intermediate goods does not fully reflect the amount of innovative efforts undertaken to develop them, mainly due to competitive pressures in oligopolistic markets [24]. In contrast, *spillovers from knowledge* arise because due to imperfect appropriability without involving any economic transaction.[4] While disembodied spillovers are difficult to quantify due to their immaterial nature, common empirical strategies involve adopting various proxies, such as technological proximity measures [14,55,66]. Moreover, both types are highly correlated across countries and time posing additional econometric problems.

2.2. Multiple channels for technological spillovers and learning

2.2.1. Imports

Starting with Coe and Helpman [27] and Coe et al. [28], the literature has documented in great detail the role of *trade* (particularly, imports) in facilitating the exchange of technological information between firms, industries and countries [25,53,55]. Studies employing sectoral data for OECD countries confirm that the foreign R&D spillovers greatly influence

[2] By having extensive networks in all these areas, a country has more chances of drawing upon multiple sources of spillovers: imports, inward FDI and inward patents.

[3] During 2001 to 2006, China has imported technology worth more than 90 billion US$, mostly from EU, Japan and the USA.

[4] By definition, knowledge is a quasi public good with non-rival and non-excludability characteristics. For example, it would be extremely hard to prevent one from using knowledge (e.g. using the Pythagorean theorem to find the length of a triangle's side) and moreover this usage will not diminish the quantity or quality of this knowledge left for others to use.