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# International trade and R&D spillovers

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ABSTRACT

Departing from the usual tenets of proportionality between cross-border trade flows and knowledge spillovers, we investigate whether relatively intense trade relationships are associated with particularly large international R&D spillovers. A nonlinear specification nesting the hypothesis of global and trade-unrelated R&D spillovers is estimated on a sample of 24 advanced countries over 1971–2004. We find evidence that trade patterns positively affect the international transmission of knowledge, in particular when we consider bilateral trade flows that, thanks to the estimation of an auxiliary gravity model, are normalized for the size and the distance of the trading partners. Finally, we discuss the patterns of the bilateral relationships characterized by both relatively intense trade and large R&D spillovers.

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## 1. Introduction

Knowledge has positive effects on the productivity of the country in which it is produced and accumulated (see, for instance, Aghion and Howitt, 1992; Romer, 1990), but it may also affect foreign productivity to the extent that it is directly and indirectly transferred abroad, as shown in several theoretical contributions (e.g., Grossman and Helpman, 1991a,b; Rivera-Batiz and Romer, 1991; Keller, 2004). While this is received wisdom, the channels of the international transmission of knowledge are less clear.

Coe and Helpman (1995) are pioneers in developing an empirical approach to estimate the impact of domestic and foreign knowledge on domestic Total Factor Productivity (TFP). By focusing on a sample of 22 advanced countries over the period 1971–1990, they investigate the specific trade-related channel of international knowledge transmission. To account for this channel, they build import-weighted sums of trade partners' cumulative R&D expenditures as measures of foreign knowledge stocks. In their preferred specification, they also include an interaction term between the degree of trade openness (the country's import/GDP ratio) and the stock of trade-weighted foreign R&D stock.[1]

Keller (1998) questions the appropriateness of the weighting scheme used by Coe and Helpman (1995) in the construction of the foreign stocks of knowledge. According to his empirical findings, the unweighted sum of the foreign R&D stock does an equivalently good job of picking-up the knowledge diffusion process than the trade-weighted sum proposed by Coe and Helpman. Keller concludes that it remains unclear whether the knowledge diffusion process is global and trade-unrelated or not, in contrast with Coe and Helpman's suggestion that knowledge spillovers follow a local diffusion process affected by the size and structure of the trade flows.[2]

Keller (1998, 2004) points out that the empirical studies using trade-weighted foreign R&D stocks and trade-related interacting terms in the specification implicitly assume that the knowledge transferred across

[1] Several scholars have refined Coe and Helpman's (1995) seminal analysis along several directions, ranging from the econometric technique and the data to the level of disaggregation and the composition of the trade flows, while preserving their approach (e.g., Engelbrecht, 1997; Lichtenberg and van Pottelsberghe de la Potterie, 1998; Xu and Wang, 1999; Lumenga-Neso et al., 2005; Madsen, 2007; Coe et al., 2009; Bianco and Niang, 2012; Fracasso and Vittucci Marzetti, 2013). We refer to Keller (2004) for a review of the literature.

[2] At the theoretical level, the existence of global spillovers is consistent with a model of international technology diffusion without trade in intermediate goods, such as the model built by Keller (2004) on the basis of Eaton and Kortum (1999).

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countries is proportional to the size of the trade flows, in accordance with the idea that the exchanged goods embody the technological know-how of the exporting countries.[3] From the theoretical viewpoint, as discussed in Keller (2000, 2004) and recognized in passing by Coe et al. (2009, footnote 12), the exchange of technology embodied in the exchanged goods is only one of the various channels through which trade may influence knowledge transmission and thus productivity. Large trade relationships are certainly important for international knowledge transmission, but knowledge transfers and trade flows need not be proportional. As arm's length market transactions enhance communication between the partners, relatively intense trade partnerships can favor knowledge transmission even when small in absolute terms. Accordingly, the proportionality between trade and knowledge flows should not be arbitrarily imposed in the empirical specifications to estimate. This is all the more important because it has been shown that the specific trade-related weights used to aggregate foreign R&D stocks impact on the estimated coefficients and that the results vary considerably across the different adopted weights (see, for instance, Lichtenberg and van Pottelsberghe de la Potterie, 1998; Keller, 2000).

Our empirical strategy builds upon the straightforward observation that, if spillovers were global and trade-unrelated, all the countries could equally draw from the "global pool" of knowledge in the world (as in Keller, 1998). On the contrary, if spillovers were localized and trade-related, they should be relatively stronger (though not necessarily in a proportional way) where trade relations are relatively more intense. We investigate this hypothesis by relaxing the assumption about the existence of a proportional relationship between trade and knowledge flows. In so doing, we depart both from Keller (1998), as we account for the patterns of the international trade network, and from Coe and Helpman (1995), as we neither calculate a trade-weighted measure of foreign R&D stocks nor impose proportionality between trade and knowledge flows. Notably, while Coe and Helpman (1995) and Keller (1998) use non-nested specifications, that are not directly comparable, our estimated functional form nests the specification proposed by Keller (1998), thereby allowing to formally test his hypothesis of global and trade-unrelated R&D spillovers against that of trade-related (yet non-proportional) knowledge spillovers.[4]

The adoption of a nonlinear model and the use of an estimated critical value to identify the relatively intense flows of trade and knowledge raise some nuisance parameter problems in the estimation. We address these issues by building on the advances in the threshold regression literature, and in particular on Andrews and Ploberger (1994) and Hansen (1996, 1999).

The aim of our empirical exercise is to establish whether it is possible to identify relatively intense bilateral trade flows associated with relatively large knowledge flows without over-imposing any proportionality between the two. From an operational viewpoint, the method estimates the minimum value of bilateral trade (i.e., a threshold) which maximizes the ability of the specification to account for the actual patterns of international R&D spillovers by identifying a subset of bilateral relationships that exhibit both relatively intense trade and systematically different (expectedly larger, but possibly lower) R&D spillovers. For the sake of brevity, in what follows the bilateral flows which satisfy the joint condition of relatively intense trade and relatively large R&D spillovers will be synthetically called "strong flows": a "strong flow" is therefore a bilateral trade flow overcoming a certain estimated threshold and associated with a relatively large knowledge spillover. As our empirical specification nests both the hypotheses of trade-related and trade-unrelated R&D spillovers, we can discriminate between the two without imposing any implicit restriction on the estimated functional form. Indeed, were R&D spillovers trade-unrelated, no "strong flows" would be detected.

We estimate the specification on a sample of 24 advanced countries over the period 1971–2004, recently studied by Coe et al. (2009).

To anticipate our main findings, we reject the null hypothesis of a "global pool" of knowledge and identify some relatively intense trade flows associated with larger R&D spillovers. Our findings suggest that the international diffusion of knowledge is systematically related to cross-border trade relationships and, therefore, knowledge spillovers are localized. We show that the relaxation of the proportionality between trade and knowledge flows does not prevent from detecting that relatively intense bilateral trade relationships are statistically associated with larger spillovers. We explore various ways to identify relatively intense flows by adopting alternative measures of bilateral trade. Although all the estimates are consistent with the main findings mentioned above, we find that knowledge spillovers are particularly large when bilateral trade flows exceed what is expected on the basis of the partners' size and distance.

This work contributes to the literature in three respects. First, by developing a model that nests both trade-related and trade-unrelated knowledge spillovers, it helps discriminate between the two hypotheses, which are equally plausible from a theoretical perspective. In so doing, this work follows what done by Keller (2000) and addresses Keller (2004) claim that "the extent to which R&D spillovers are related to the patterns of international trade must be estimated in a model which allows simultaneously for trade-unrelated international technology diffusion" (2004 p.1480).[5] Second, this work addresses the econometric problems due to the presence of nuisance parameters, thereby tackling various issues associated with hypothesis testing in nonlinear specifications. Finally, this paper explores various ways to identify the relatively intense trade flows associated with large R&D spillovers without weighting the R&D stocks for the size of trade, thereby showing that trade matters in international knowledge transmission even relaxing the assumption of proportionality between trade size and knowledge spillovers.

The paper proceeds as follows. In Section 2, we frame the research question in the light of the empirical literature on international knowledge spillovers. Section 3 illustrates the empirical strategy we put forward to assess whether knowledge spillovers are trade-related or not. The results of the estimations using three alternative measures of trade intensity are discussed in Section 4, where we also map and discuss the subsets of "strong flows". In Section 5, we present an alternative analytical strategy that helps appreciate the value added of our threshold-based strategy. Section 6 concludes. The data are discussed in Appendix A, while Appendix B illustrates the details of the method adopted to deal with the nuisance parameter issue affecting statistical inference.

## 2. Trade flows, R&D stocks and international knowledge transmission

In their seminal paper, Coe and Helpman (1995) estimate an intuitive specification to capture the effect of foreign R&D on domestic TFP:

$$logF_{it} = \alpha_i + \beta^d logS^d_{it} + \beta^f logS^f_{it} + \epsilon_{it} \quad (1)$$

[3] More precisely, Keller (1998) argues that Coe and Helpman's (1995) empirical specification implicitly builds on three demanding assumptions: i) output and productivity positively depend on the number of differentiated intermediate inputs used in the production of final products; ii) the number of varieties produced in a country depends on the domestic R&D stock; and iii) the larger the aggregate trade flows, the greater the number of imported varieties of intermediate inputs. This setting is consistent with those models where traded goods are used as productive inputs and differentiated goods embody technological know-how (e.g., Grossman and Helpman, 1991b; Rivera-Batiz and Romer, 1991; Eaton and Kortum, 2002).

[4] See also Keller (1997, 2000), who is the first to include trade-related and trade-unrelated R&D spillovers in the same econometric model.

[5] Although Keller (2000) estimates trade-related and trade-unrelated R&D spillovers in the same model, his specification does not nest Coe and Helpman (1995) and Keller (1998), and imposes the assumption of proportionality between trade flows and knowledge spillovers.

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