NBER WORKING PAPER SERIES

KNOWLEDGE SPILLOVERS, TRADE, AND FOREIGN DIRECT INVESTMENT

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Working Paper 28739
http://www.nber.org/papers/w28739

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2021

I have no financial relationships regarding this research to report. The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 28739
April 2021
JEL No. F1,F23,O3

ABSTRACT

I study knowledge spillovers, positive externalities that augment the information set of an economic agent, and reviews the evidence on such spillovers in the context of international economic transactions. Even though spillovers are by their very nature difficult to identify, over recent decades a number of advances-conceptual, empirical, as well as in form of new data–have produced robust evidence that both trade and foreign direct investment lead to sizable knowledge spillovers.

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1 Introduction

The surge in interest in the relationship between knowledge spillovers, trade, and FDI can be explained by two factors. First, the 1970s onwards witnessed increasing evidence that outward-oriented economies performed systematically better in a number of ways including productivity gains than inward-oriented economies.[1] Second, endogenous growth theory formalized the idea that through their impact on productivity, knowledge spillovers are central in generating long-run per-capita income growth.[2] Born was the idea that outward-oriented economies performed relatively well because opening up to foreign trade and investment generates additional knowledge spillovers because it means that domestic agents interact with foreign agents that have larger (or different) stocks of knowledge. This entry synthesizes the evidence by tracing out the literature from its beginning in the 1990s to current research by discussing a number of key papers.[3]

2 Knowledge Spillovers and Trade

2.1 Imports

Industry Studies Intermediate input imports is among the channels of international knowledge spillovers that empirical work started out with. Incorporating the gains from product variety of static models (Ethier 1982) into growth models in which R&D leads to an increase in intermediate inputs (Romer 1990), countries that begin to import these new inputs benefit from foreign R&D expenditures both because they amount to embodied technology and because reverse-engineering may lead to additional knowledge gains (Grossman and Helpman 1990, 1991, Rivera-Batiz and Romer 1991).[4] Thus, a country's import composition should matter. If imports are an important conduit of knowledge spillovers, then countries that import disproportionately from high-R&D countries should tend to have high productivity levels compared to countries that whose import

[1]Early work includes Bhagwati and Srinivasan (1975), Bhagwati (1978), and Krueger (1978).
[2]Romer (1990). A key feature of knowledge is that it is non-rival. See also Arrow (1969).
[3]For broader discussions, see also Keller (2010, 2004).
[4]Such inputs may also be shipped between multinational parent and affiliate, see Keller and Yeaple (2013).

patterns are more directed to low-R&D countries. In Coe and Helpman (1995), these considerations lead the authors to define the foreign knowledge stock S^f_{ct} of country c in year t as

$$S^f_{ct} = \sum_k m_{ck} S^d_{kt}, \tag{1}$$

where S^d_{kt} is country k's domestic knowledge stock in year t, measured as cumulative R&D spending subject to some rate of depreciation, and m_{ck} is country c's bilateral import share from country k.[5] Holding constant R&D spending, high values of the foreign knowledge stock indicate that a country's import pattern is skewed towards high-R&D countries, so a coefficient $\beta_1 > 0$ in the regression

$$lnTFP_{ct} = \alpha_c + \beta_1 lnS^f_{ct} + \beta_2 lnS^d_{ct} + \varepsilon_{ct}, \tag{2}$$

may be taken as evidence for knowledge spillovers through imports; TFP_{ct} is a measure of country productivity and α_c are country fixed effects. By estimating β_1 to be positive and significant in a sample of 22 OECD countries, Coe and Helpman (1995) concluded that indeed imports are a major channel of international knowledge spillovers. Subsequent work by Keller (1998) questioned this conclusion by showing that a placebo exercise yielded equally strong 'evidence' for import-related international knowledge spillovers. Specifically, Keller (1998) showed that replacing the actual bilateral import shares m_{ck} in equation (1) by randomly generated shares or simply by a constant yielded estimates of β_1 that are similar in sign and magnitude to the estimate obtained with the actual import shares.

Keller's (1998) result was an earlier warning that empirical work on international knowledge spillovers would be challenging. By definition, spillovers–as external effects–are not reflected in market transactions, and any evidence will therefore have to be of an indirect nature. Furthermore, measures related to technology such as R&D, patents, and (total factor) productivity are comparatively noisy, which makes econometric identification particularly hard. In the case of Coe and

[5] The approach of applying weights to external R&D has a long tradition in research on identifying domestic knowledge spillovers, see Terleckyj (1974), Griliches (1979), and Scherer (1984).

Helpman (1995), trending productivity and R&D variables at the country level created a strong spurious correlation-whether or not actual import shares are employed. Subsequent work in the same spirit but at the industry level, greatly increasing the amount of identifying variation, finds robust evidence for import-related international knowledge spillovers (Keller 2000, 2002).

Key to obtaining robust evidence on knowledge spillovers is to employ a variable capturing spillovers not related to imports in addition to a measure of the import channel of international knowledge spillovers. Acharya and Keller (2009) estimate the impact of import-related R&D spillovers from six large OECD economies in a sample of manufacturing industries of other high-income countries. Their regression specification is as follows:

$$TFP_{cit} = \beta_1 S_{cit} + \sum_{s \epsilon G6} \beta_{2s} S_{sit} + \sum_{s \epsilon G6} \beta_{3s} \left(m_{csit} \times S_{sit} \right) + X\kappa + \varepsilon_{cit}, \tag{3}$$

where TFP_{cit} is defined as log total factor productivity in country c's industry i and year t, s indexes the six large OECD countries whose imports are being considered, S_{sit} is the cumulative R&D stock of in country s's industry i in year t, and m_{csit} is country c's bilateral import share from country s in industry i and year t; the term X is a vector of control variables that includes import shares (m_{csit}) as well as country-by-industry and year fixed effects. Notice that the specification distinguishes import-related from general spillovers, with the former captured by β_{3s} and the latter by β_{2s}, respectively. Another advantage of this specification is that the non-symmetric specification–examining spillovers from one set of countries to another set of countries–reduces endogeneity concerns. Acharya and Keller (2009) find strong evidence of import-related R&D spillovers in the sense of $\beta_{3s} > 0$.

Firm- or Plant-level Studies A new wave of results was triggered by the availability of micro data on firms or plants for an increasing number of countries. Data at the level of firms (or, more typically, plants) also allows to examine whether changes in industry productivity, the left hand side in equation (3), are due to the reallocation of market shares between high- and low-productivity firms or due to changes in productivity firm by firm (between-firm and within-firm effects, respectively). In principle, productivity gains through the reallocation of market shares from low- to high-productivity domestic firms in response to a change in imports need not involve positive externalities (such as technological learning) – it is consistent with unchanged productivity in each of the domestic firms. However, if productivity changes within-firm as a consequence of an import change this provides evidence for trade-related spillovers.

Pavcnik (2002) examines the productivity impact of a trade liberalization in Chile, which reduced import tariffs to a uniform 10% rate by 1979 from rates of often above 100% in the year 1974. She finds that after the trade reform, plants in import-competing industries experience sizable –between 3 and 10 percent–productivity increases. These results are largely unchanged with the inclusion of plant fixed effects, indicating that these are within-plant effects in line with positive spillovers from the adoption of new technology or improvements in management techniques through new import competition. In addition to evidence on learning spillovers through import competition, Pavcnik (2002) also finds evidence for increases in industry productivity through market share reallocations, especially through the exit of low-productivity plants.

The imports considered in Pavcnik (2002) is trade in final goods, not intermediate goods as in the Coe and Helpman (1995) and Keller (1998) spillover regressions. Along these lines, Pavcnik's (2002) result is significant because the increase in final goods trade constitutes additional competition, which depending on the model may lower profits as well as the incentive to adopt new management techniques or technology. Amiti and Konings (2007) shift the focus back to intermediate goods trade by showing with manufacturing census data for Indonesia that it is primarily the liberalization of input tariffs, not output tariffs, that is behind the observed productivity gains. They argue that lower input tariffs may lead to gains due to variety, quality, embodied technology, and learning.

2.2 Exports

Research on knowledge spillovers through export activity starts typically from the premise that exporting might lead to access to new knowlege, such as learning about tastes or technologies in foreign markets, which in turn increases productivity. In this sense, exporting may be considered to be a technology sourcing activity, and research on spillovers in this context addresses the question whethere there is "learning-by-exporting".

A well-established finding at least since the late 1990s is that in a given given cross-section, firms that export tend to be more productive than firms that do not export (Clerides, Lach, and Tybout 1998, Bernard and Jensen 1999). This result is consistent both with the idea that more productive firms select into exporting and that there is learning-by-exporting. Based on US data, Bernard and Jensen (1999) find that conditional on plant survival, there is higher labor productivity growth among the set of exporting compared to non-exporting firms, though this difference becomes smaller and even insignificant for longer time horizons.[6] Moreover, exporters are also more likely to survive than non-exporters. Because low productivity growth is an important reason for exit of plants, Bernard and Jensen's (1999) estimate of the productivity growth differences between exporters and non-exporters is likely to be an underestimate.

The paper by Clerides, Lach, and Tybout (1998) provides evidence on learning externalities from exporting using micro data from Columbia, Morocco, and Mexico. By estimating simultaneously a dynamic discrete choice equation that determines export market participation, these authors take account that it is on average the already-productive firms that self-select into the export market. The authors estimate jointly an export market participation equation stipulating that a firm exports if there are profits to it given the firm's past cost, any fixed cost of entering the export market, and the exchange rate together with the autoregressive evolution of the firm's cost, which allows for learning-by-exporting because the firm's cost may depend on past export participation.

[6] Usually a measure of total factor productivity (TFP) would be preferred because it accounts for the contribution of all factors of production, not only labor. Bernard and Jensen (1999) however estimate TFP as the residual from an OLS regression, which suffers from a number of problems that have been addressed in future applications of control function approaches (e.g. Olley and Pakes 1996).

Clerides, Lach, and Tybout (1998) show results for the three countries separately, and also by major industry, using maximum likelihood and generalized method of moments estimation.

They also discuss results for each country separately, and also by major industry. In general, they tend to show no signicant effects from past exporting experience on current performance. In fact, to the extent that Clerides et al.'s estimates are significant, they go into the wrong direction (exporting raising costs). It would be surprising if indeed there would be negative learning effects, and the authors give a number of plausible reasons of why this finding may have to be discounted. Another interpretation of the generally insignificant estimates may be that the estimation framework is demanding too much of the data. However, Clerides et al.s descriptive plots of average cost before and after export market entry support their main result of no evidence for learning-by-exporting effects. Exporters are more productive, but that is because they self-select themselves into the export market.

Using similar methods as Clerides, Lach, and Tybout (1998), van Biesebroeck (2005) has revisited the issue by studying productivity dynamics of firms in nine African countries. In contrast to Clerides, Lach, and Tybout (1998), he estimates that starting to export boosts productivity by about 25% for the average firm in his sample. Van Biesebroeck (2005) also estimates that the higher productivity growth of exporters versus non-exporters is sustained. By employing instrumental-variable and semi-parametric techniques as alternative ways to deal with the selection issue, van Biesebroeck's analysis is more comprehensive than most. His analysis generally supports the notion that exporting leads to the transfer of technological knowledge.

In trying to reconcile his findings with some of the earlier results, van Biesebroeck shows that part of the difference in productivity growth between exporters and non-exporters appears to be due to unexploited scale economies for the latter. This suggests that at least in part his results are due to constraints imposed by demand, and not due to technology transfer in the sense of an outward shift of the production possibility frontier at all levels of production. Richer data is needed to make further progress on distinguishing these hypotheses.

De Loecker (2007) uses matched sampling techniques to analyze whether firms that start exporting become more productive, using micro data of Slovenian manufacturing firms. Controlling for self-selection into exporting, De Loecker finds that export entrants indeed become more productive once they start exporting, and that the productivity gap between exporters and their domestic counterparts increases further over time.

The previous discussion has highlighted the importance of distinguishing differences in firm productivity that exist before entry into the export market, versus increases in productivity as the result of exporting. Since the late 1990s, the literature has increasingly relied on control function approaches such as Olley and Pakes (1996) to model the productivity process because it addresses selection and simultaneity issues in the estimation by including a proxy, ω_{it}, for time-varying firm specific productivity

$$\begin{aligned} y_{it} &= \beta_0 + \beta_1 x_{it} + \beta_2 k_{it} + e_{it} \\ e_{it} &= \omega_{it} + u_{it} \end{aligned} \tag{4}$$

where y_{it}, x_{it}, and k_{it} are outout, intermediate inputs (e.g. labor and materials), and capital of firm i at time t, while u_{it} is a well-behaved error term. Olley and Pakes (1996) show that under reasonable conditions the unobserved term ω_{it} can be modeled by inverting investment, ι_{it}, of the firm at time t

$$\omega_{it} = \iota_{it}^{-1}(\iota_{it}, k_{it}) = \theta_{it}(\iota_{it}, k_{it}). \tag{5}$$

Substituting equation (5) into equation (4), Olley and Pakes (1996) show that the production function parameters β_1 and β_2, and therefore total factor productivity, can be consistently estimated.[7] Early work in this framework tended to assume that the time-varying firm-specific productivity evolves as an exogenous first-order Marov process

$$\omega_{it+1} = g_1(\omega_{it}) + \xi_{it+1}, \tag{6}$$

[7] Given that the function $\theta_{it}(.)$ is unknown it is in practice typically approximated by a higher-order polynomial in investment and capital.

where productivity at time t+1, ω_{it+1}, consists of expected productivity given firm i's information set at time t, $g_1(\omega_{it})$, and a productivity shock, ξ_{it+1}. Work on the importance of international knowledge spillovers has developed the econometric toolkit by noting that the assumption of an exogenous process of productivity is restrictive because in the case of the learning-by-exporting hypothesis, for example, the key question is whether the productivity process changes as the result of export market entry. Thus, the productivity process should depend on the firm's export status (De Loecker 2013):

$$\omega_{it+1} = g_2\left(\omega_{it}, E_{it}\right) + \xi_{it+1}, \tag{7}$$

where E_{it} is a measure of firm i's export activity at time t. Furthermore, De Loecker (2013) shows that accounting for export activity in the productivity process is not only appropriate conceptually but that it also strengthens the evidence in favor of learning-by-exporting relative to earlier work that had not done so.

Examining the evolution of output-based productivity to detect learning-by-exporting–see equation (4)– the focus of the literature has so far been on what is referred to as revenue total factor productivity (TFPR). TFPR depends on the output price of the firm, and firms' output prices might well fall upon the liberalization of trade–such as Chile's liberalization from 1974-79–that includes substantial cuts in tariffs. Lower output tariffs increase competition by changing the residual demand that firms face. To the extent that firm markups–price over marginal cost–are largely constant as firms enter the export market, a decline in the firm's output price implies a decrease in its marginal cost. Based on De Loecker and Warzynski's (2012) approach to estimating mark-ups and product-level output prices for a sample of Chilean plants 1996-2007, Garcia-Marin and Voigtlaender (2019) show that upon export entry productivity increased by between 15-25%.[8]

Overall, there is by now solid evidence for spillovers through learning-by-exporting that increase firm productivity. Where we know still relatively little is what mechanisms are most important for the spillovers to materialize. The relative contribution of learning about new products or inputs,

[8] Their analysis of multi-product plants follows De Loecker, Goldberg, Khandelwal, and Pavcnik (2016).

management techniques, information about new process technologies, or simply demonstration effects is still largely undetermined.

3 Spillovers through Foreign Direct Investment

3.1 Spillovers through Inward Foreign Direct Investment

Spillovers from FDI in the same Industry A sizable literature has studied the evidence for positive externalities in form of technological learning through foreign direct investment (FDI). Spawning hundreds of papers, it is typically referred to as the FDI spillovers literature. Aitken and Harrison (1999), one of the early papers employing firm-level longitudinal data, asks whether the special treatment of foreign-owned firms—e.g., lower income tax rates, tax holidays, or subsidies for infrastructure– to attract FDI can be justified through the positive externalities these firms generate in form of technology transfer in a sample of about 4,000 Venezuelan plants between 1976 to 1989. Aitken and Harrison (1999) note that inward FDI might also affect short-run productivity of domestic plants negatively by reducing their demand and forcing them up the average cost curve, an effect that one might refer to as a business-stealing effect (e.g., Aitken and Harrison 1999, p.606).

The measure of inward FDI in Aitken and Harrison (1999) is the share of foreign employment in total sector employment (Emp):

$$FS_{jt} = \frac{\sum_i FS_{ijt} \times Emp_{ijt}}{\sum_i Emp_{ijt}}, \tag{8}$$

where FS_{ijt}, $0 < FS_{ijt} \leq 1$, is firm i's foreign ownership share in sector j at time t. The hypothesis is that a higher value of sector-level FDI increases the chance that information on new products or processes introduced by foreign firms diffuses to domestic firms. This could be simply by observing foreign firms, or diffusion might occur from labor turnover as domestic employees move from foreign to domestic firms.

Regressing changes in log output on changes in log materials, skilled, and unskilled workers, year fixed effects and the sector-level measure of FDI in equation (8), Aitken and Harrison (1999) find that the coefficient on sector-level FDI is significantly negative (Table 1, columns 5 to 8). In terms of magnitude, the coefficient is about -0.27, suggesting that an increase in the share of FDI from 0 to 10 percent leads to a decline in domestic productivity by almost 3 percent. Based on this and a range of additional results Aitken and Harrison (1999) conclude that there are large, negative spillovers from foreign investment to domestic firms, and no evidence for the existence of knowledge spillovers to domestic firms from inward FDI. If indeed there are no significant positive externalities from inward FDI, there would be no case for using public funds to attract such FDI.

However, there are reasons to be more optimistic about using public funds to attract FDI. The first set of reasons for that lies in the fact that Aitken and Harrison (1999) does not address a number of key issues that have been shown to greatly matter in the time since they presented their pioneering work back in the late 1990s. First, we now know from the recent emphasis on control function approaches that a regression of output on labor, materials, and capital is unlikely to yield a consistent estimate of plant productivity (see, e.g., Olley and Pakes 1996).

Second, if one believes that the entry of foreign-owned firms into the domestic economy may lead to business stealing, or product market rivalry, it will be important to account for such effects in the empirical specification. As noted by Lucking, Bloom, and van Reenen (2020), econometric estimates of technology spillovers in the literature may be severely contaminated by product market rivalry effects.

Studying domestic knowledge spillovers Bloom, Schankerman, and van Reenen (2013) account for product market rivalry by employing the Compustat Segment Dataset, which gives each firm's total sales broken down across four-digit industries (597 of them). The product market closeness between any two firms i and j, SIC_{ij},is calculated as the uncentered correlation between the firms market shares across all four-digit industries:

$$SIC_{ij} = \frac{(S_i S_j')}{(S_i S_i')^{1/2}(S_j S_j')^{1/2}}, \tag{9}$$

where S_i is the vector of market shares across 597 four-digit industries by firm i. The authors then define the pool of product market R&D for firm i in year t, $RIVAL_{it}$, as

$$RIVAL_{it} = \sum_{j \neq i} SIC_{ij} S_{it}, \tag{10}$$

where S_{it} is the R&D stock of firm i at time t. Notice that the variable $RIVAL_{it}$ will be high if firm i shares the same product space with many other firms, and conditional on product space it will be high if other firms spend substantial amounts of R&D in order to protect or enlarge their markets. Bloom, Schankerman, and van Reenen (2013) tend to find negative coefficients on $RIVAL_{it}$ in their productivity estimation, consistent with a negative effect of R&D by neighbors in product space on the firms' own business. [9]

The other reason for being more optimistic than Aitken and Harrison (1999) about using public funds to help generating FDI spillovers to domestic firms is that Aitken and Harrison (1999) apply the term "spillovers" indiscriminately to both externalities and non-externalities. Finding a negative correlation between FDI and domestic productivity can have many reasons, including that upon an inflow of FDI domestic firms lose market shares and have to move up their average cost curves. No matter the reason for the negative correlation, however, we know that these are not FDI spillovers since by definition such externalities would have to be positive. While in terms of positive economics such so-called "negative spillovers" might be of interest, they do not play a role for the key policy question of this research, namely are there positive externalities from FDI sufficient in size so as to warrant the public incentives that are expended to attract foreign-owned firms? The issue particularly important because many papers in the large literature on FDI spillovers have followed Aitken and Harrison's (1999) approach of not making a clear distinction between externalities and non-externalities.

[9] Instead of R&D one could employ a measure of firm size such as employment. Bloom, Schankerman, and van Reenen (2013) prefer R&D because then the market rivalry measure is analogous to their technology spillover measure, $SPILLTECH_{it}$, which is defined as $SPILLTECH_{it} = \sum_{j \neq i} TECH_{ij} S_{it}$, where $TECH_{ij}$, following Jaffe (1986) is defined as the correlation between firm i's and j's patent portfolios. Notice that as in the analysis of import-related spillovers of Acharya and Keller (2009) above, Bloom, Schankerman, and van Reenen (2013) improve identification by making sure that the spillover measure $SPILLTECH_{it}$ is not the only measure of other (firm or industry) R&D in the regression (see equation (3)).

In their analysis of the United Kingdom between 1973 and 1992, Haskel, Pereira, and Slaughter (2007) have also asked whether the size of FDI spillovers justifies the UK government's outlays to attract these foreign-owned firms. In contrast to the work by Aitken and Harrison (1999), these authors account for business stealing effects by including several variables that control for changes in the degree of competition. Haskel, Pereira, and Slaughter (2007) estimate positive sector-level FDI spillovers using one-year differences OLS though the corresponding instrumental-variables (IV) specification to address the endogeneity of FDI produces no significant results. More generally, the size of the spillover point estimates is small, leading Haskel, Pereira, and Slaughter (2007) to conclude that positive externalities through inward FDI are too small to justify the outlays of the UK government to attract foreign-owned firms.

A paper that estimates large FDI spillovers at the sector level is Keller and Yeaple (2009). These authors study spillovers from inward FDI in the US between 1996 and 2007 using the Compustat database. Their approach is similar to earlier work in that revenue-based total factor productivity growth is related to inward FDI in the sector in which the domestic firm operates. Keller and Yeaple (2009) estimate that FDI spillovers account for as much as 19% of US manufacturing productivity growth during 1996 to 2007.

Since finding economically large sector-level FDI spillovers is not a common finding in the literature, it is important to ask what drives Keller and Yeaple's (2009) result. One possibility is that it follows from the choice of country, the US. The typical firm in the US is likely to be more productive than in, say, Venezuela, and moreover, Compustat firms tend to larger and more productive than other US firms. To the extent that the technology gap between foreign-owned and domestic firms is too large, the latter might not have the absorptive capacity (Keller 1996) to benefit from positive externalities provided by foreign-owned firms.

While this is at some level plausible, there are also reasons to believe it does not drive Keller and Yeaple's (2009) findings. Not only is the technology gap between typical domestic firm and foreign-owned firms in Keller and Yeaple's (2009) sample sizable, given that only the most productive firms become multinationals, but Keller and Yeaple (2009) also show that FDI spillovers in their analysis are larger for firms with a relatively large technology gap (smaller, less productive firms). This is inconsistent with country-level technology gap being the main reason for their large FDI spillover estimates.

Other elements of their estimation strategy such as the control function approach to productivity estimation, controls for changes in market competition, and accounting for the possible endogeneity of FDI help to improve the estimation results but they are not central to the size of Keller and Yeaple's (2009) estimates. Rather, it is that they have a relatively precise measure of foreign ownership in the US economy at the sector level. Typically, researchers classify a foreign-owned firm or plant based on the industry in which the majority of its sales occurs ("main line of business").

In contrast, Keller and Yeaple (2009) compute their sector-level FDI measure summing over all employment in the US based not only on the majority-of-sales industry but the eight largest industries in which each of the foreign-owned firms is active. This information at the sub-firm level is comparable to the "business segment" data available in some data sets, and it yields a more precise characterization of changes in industry foreign ownership from year to year.[10]

To corroborate this simple point, Keller and Yeaple (2009) compare their FDI spillover coefficients with the alternative based on the standard "main line of business" definition. The results from this exercise reveal that the FDI spillover estimate using the measurement-error prone main line of business variable is an order of magnitude smaller than using the business segment definition to create the FDI variable, and the typically available main line of business FDI variables tends to be not significantly different from zero.[11]

Overall, the analysis of Keller and Yeaple (2009) shows that issues of measurement can greatly affect the findings on FDI spillovers, and that once key issues are addressed there is evidence of substantial positive externalities from inward FDI in the same sector.

[10] Compounding this, the measure of sector FDI in many studies tends to be at a relatively aggregate level, such as two-digit industries.

[11] For example, Keller and Yeaple (2009) estimate a FDI spillover coefficient of 0.379 (robust s.e. of 0.196) using "business segment" information, compared to 0.035 (s.e. of 0.095) using "main line of business" data, see Table 7.

Spillovers from FDI in Other Industries The relative lack of evidence in the early literature on spillovers to domestic firms in the same industry has led researchers to look for spillovers from FDI in other industries, especially in industries that buy inputs from domestic firms (so-called backward spillovers). One way of thinking about this strategy is that it is a simple way of addressing competition effects that are present through FDI in the same industry. While one consequence of foreign-owned firms in the same industry is typically that they steal some of the business of domestic firms in the same industry, a multinational that buys from domestic input suppliers does not compete with them, in fact FDI spillovers may be particularly likely because the multinational may want to transfer technology to its supplier. An influential paper is Javorcik (2004) who finds evidence for FDI spillovers through backward linkages, a result that has been replicated in other papers.

There are some reasons to be careful in interpreting these results. For one, while multinational buyers have an incentive to transfer technology to their suppliers, they will also internalize the incentive that suppliers may start selling their improved input to other buyers that compete with the multinational. Moreover, the multinational buyer will typically demand something in return for any technology transfer (such as lower-priced inputs, see Javorcik, Keller, and Tybout 2008), which poses a challenge for quantifying the size of the externality.[12] Furthermore, because of unavailability of data work on backward FDI spillovers typically models the multinational buyer-domestic seller relationship by using the economy's input-output matrix for some particular year. However, input-output linkages are bound to be a very imperfect measure of linkages between multinationals and their domestic suppliers. Alfaro-Urena, Manelici, and Vasquez (2020) show that sector-level backward linkages predict less than 1% of the actual firm-level linkages between multinationals and their suppliers. Given the importance of measurement in the analysis of same-sector FDI spillovers (see above) existing results on FDI spillovers through backward (or forward) linkages are unlikely to be the last word (see also section 4).

[12] For additional discussion on these issues, see Keller (2010).

3.2 Outward FDI Spillovers

In analogy to the import and export side of trade, research has not only considered spillovers from inward FDI but also positive externalities from outward FDI. An important hypothesis in this context is that outward FDI provides a way to source new technologies in foreign countries (FDI as a 'listening post'). While the literature on outward FDI spillovers is smaller than that on inward FDI spillovers, some research provides evidence that technology sourcing through outward FDI is important.

Employing data on British outward FDI in the United States, Griffith, Harrison, and van Reenen (2005) show that controlling for a host of other factors, the productivity growth of UK firms is higher for those firms that have foreign affiliates in regions of the US with the highest R&D spending (think Silicon Valley). As the measure for technological presence, the authors compute for each UK firm the fraction of its US patent applications for which the lead inventor is located in the United States. The evidence is consistent with the idea that outward FDI helps to bring foreign technology into a country.

4 New Directions

This overview has shown that research on knowledge spillovers through international trade and FDI has made some major progress. While quantifying the size of positive externalities will always be challenging, not least because data on technological knowledge and innovation –such as it is– imposes significant constraints, a lot has been learned over the last three decades. In addition to the breakthrough in terms of theory, our understanding has been improved through a combination of advances in econometric methodology, new sources of data, and appropriate empirical work.

But the work is far from done, and it is reasonable to expect that some of the same factors will play a key role in the future. In terms of new sources of data, in particular, the increasing availability of data sets such as that in Alfaro-Urena, Manelici, and Vasquez (2020) on Costa Rica that record actual firm-to-firm level trade–instead of input-output matrix approximations–will likely lead to a re-writing of the literature on FDI spillovers through backward and forward linkages.

Other parts of the research on international knowledge spillovers will also be affected by the availability of new data sources. They will increasingly shed light on the precise way through which international transactions generate positive externalities. Anecdotally, face-to-face interactions are important to transmit knowledge, for example, and there is evidence consistent with the hypothesis that business travel helps to diffuse knowledge internationally (Hovhannisyan and Keller 2015). At the same time, cell phone location data, as in Atkin, Chen, and Popov (2020), may be a great way of substantiating these accounts by quantifying the returns to face-to-face interactions in international business transactions.

Another fruitful area for more research is empirical strategy. Much existing research seeks to estimate the impact of international trade or FDI on spillovers by appealing to a general increase in the level of globalization, perhaps combined with an instrumental-variables strategy. Some recent research has considered specific policy changes that yield a substantial period for analysis both before and after the policy change. This would generally seem to be a promising line of research. In one of these papers, Lu, Tao, and Zhu (2017) study the spillover effect of China's FDI liberalization as the country entered the World Trade Organization in 2002.

Lu, Tao, and Zhu (2017) find that an increase in industry FDI significantly lowers the level of productivity of domestic firms, at the same time when it increases their productivity growth rate. These results may be in part due, as the authors discuss, to the way FDI spillovers develop over time. Another possibility is that the abolishment of the joint venture requirement with China's WTO entry–foreign firms had to pair up with a Chinese firm to do FDI–led to an inflow of marginal wholly-foreign-owned FDI in China. Consistent with that, a recent study studying both joint ventures and wholly foreign-owned FDI as China entered the WTO finds stronger spillovers post-2002 from the former than from the latter (Jiang, Keller, Qiu and Ridley 2020). A structural shift from one to another form of FDI might play a similar role for the spillover estimation as lower output prices due to tariff reductions, for example.

Recent work by Alfaro-Urena, Manelici, and Vasquez (2020) employs an event-study design to examine various impacts on domestic firms that become first-time suppliers to multinational firms in Costa Rica between the years 2010 and 2015. Importantly, despite the unusual level of information, the sample is with about 450 multinationals and around 3,700 first-time suppliers sizable. Consistent with learning externalities from FDI, the authors find that after a couple of years first-time multinational suppliers not only have grown in size and started selling to other new buyers but they also experience an increase in total factor productivity of between 4 to 9 percent.

Complementary survey evidence from Costa Rica provides some general clues on how to think about these knowledge spillovers.[13] First-time multinational suppliers had to improve their quality management system, change their sourcing of inputs, and hire more high-skilled workers. This suggests that spillovers come partly in form of process technology improvements, perhaps also product innovation, to the extent that higher quality products require more skilled workers. These are costly investments for the supplier that will take time to pay off. Furthermore, many first-time multinational suppliers also had existing employees work harder. Working existing workers harder

[13]See Alfaro-Urena, Manelici, and Vasquez (2020). Similar results are found in the relationship of large retailers versus its suppliers, see Javorcik, Keller, and Tybout (2008), Iacovone, Javorcik, Keller, and Tybout (2015).

may raise measured productivity, but it is not a Pareto-improving positive externality.

Overall, the view of knowledge spillovers associated with international trade and FDI that emerges is that the latter activities increase the probability that an agent can access new, business-relevant knowledge. To implement this knowledge, additional investment and effort is typically required, and any measured gains in terms of innovation, productivity, or sales are the result of positive knowledge externality minus costs of investment and effort.

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