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The Transfer of Knowledge across Countries

Wolfgang Keller*

How does knowledge flow between firms in different countries? Without any doubt there are firms with vastly different capabilities, or knowledge, operating in the world today. These firm-level differences lead to aggregate effects in terms of production, trade, and income across countries. Knowledge does not seem to have an automatic tendency to flow from one country to another, quickly leading to equalization across locations. Can firms actually facilitate, or prevent, international knowledge transfers? While some knowledge transfers are between business partners, others are not, and such unintended knowledge transfers to other firms are externalities (called spillovers). One well-known fact is that knowledge is geographically localized.¹ Localization, it turns out, is a natural outcome when knowledge is difficult to describe in a self-contained way. In this setting, knowledge transfers require the movement of people, and localization arises simply because there are costs of moving people in geographic space.

More generally, in recent research with several coauthors I examine the idea that knowledge transfers can be linked to the economic engagement of firms and people across countries. I analyze the relationship between knowledge flows and international business travel, the role of both multinational firms and trade, and a theoretical framework that focuses on the different ways in which knowledge flows.

Innovation and International Business Travel

When does the need for in-person contacts arise? There are several possibili-

ties. Take the corporate downsizer played by George Clooney in the 2009 movie “Up in the Air”; his job is it to fire people in person. Or, take the common belief among corporate executives that in-person contacts are far more effective than anything else for closing business deals.² These in-person contacts are cost-effective because they have an element of non-codifiability (that is, they cannot be subject to programmed rules), be it to show appreciation for past work, or to establish trust, that cannot simply be had from a letter or phone call.

Non-codifiabilities may play a particularly important role in the transfer of new knowledge, the kind of knowledge that is needed to engage in innovation, and in that case, it may be best to demonstrate and explain the knowledge face-to-face.³ In work with Nune Hovhannisyan, I evaluate the idea that international business travel may affect the rate of innovation across countries.⁴

Empirical research on international service trade is still relatively rare, not only because services are often highly differentiated (so difficult to aggregate) but also because there is not yet much comparable information across countries. Specifically, in the case of air travel there is typically no information on whether the purpose of travel is business or non-business; much of the information, in fact, is collected by national tourism agencies. Data employed in our study is both unusually rich and consistent. We have information on more than 100,000 trips between the years 1993 and 2003, including whether the purpose of travel was business or not. All trips are from the United States to 36 other countries, both rich and poor. We do not know the identity of the traveler, or his knowledge level, but there is information on the state in the United States where the trip originated so that we can distinguish high-innovation (California)

from low-innovation (Wyoming) states.

We ask whether business travel from the United States has an impact on innovation rates across countries, which are measured by patenting rates computed from the NBER patent database. In order not to simply pick up positive shocks that increase innovation and business travel from the United States, we include, essentially, the ratio of business to family trips in the regression. Because family trips are not affected by changes in a country’s business climate, this helps to filter out spurious effects.

Our finding is that inward business travel raises a country’s rate of patenting. The increase is modest, but statistically significant. In two ways, these results point to the importance of the knowledge carried by each individual traveler. First, the impact on patenting is higher if the traveler came from a high-innovation rather than a low-innovation U.S. state. Second, U.S. business travel has a stronger impact on innovation for patents that have U.S. co-inventors, consistent with the idea that the traveler was associated with this patent application. In that case, of course, the knowledge transfer would cease to be a pure spillover.

Knowledge Spillovers through Multinational Activity

Governments all over the world spend large amounts of resources in order to attract multinational firms to their country, based on the assumption that such firms generate positive externalities, or foreign direct investment (FDI) spillovers, to domestic firms.⁵ At the same time, the evidence on substantial FDI spillovers is thin.⁶ In earlier work with Stephen R. Yeaple, I consider spillovers to U.S. firms from U.S.-based affiliates owned by foreign multinationals.⁷

Our choice of a country as highly

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developed as the United States might seem strange, but foreign-owned affiliates located in the United States are considerably more productive than the average U.S. firm, so that the scope for knowledge transfers from foreign firms is definitely there.⁸ Moreover, employment in foreign-owned affiliates in the United States has increased by 50 percent between 1987 and 1996 (from about 8 percent to 12 percent). We analyze knowledge transfers in terms of changes in firms' productivity and ask whether U.S.-owned firms in industries where foreign-owned firms are relatively prevalent have become more productive.

In a sample of about 1,300 U.S. manufacturing firms, the estimated FDI spillovers account for about 14 percent of U.S. manufacturing productivity growth between the years 1987 and 1996. We find that FDI spillovers materialize relatively quickly, within two years, and they benefit disproportionately relatively small U.S. firms.

These FDI spillovers are large enough to make it worthwhile asking whether there may be a role for FDI subsidies. Why are the estimates larger than those in earlier studies? First, we show that FDI spillovers do not exist sector-wide but are largely concentrated in high-tech, R and D-intensive sectors. Second, the U.S. FDI data tracks foreign affiliate activity better than in other countries.⁹ Knowing more precisely in which sectors foreign firms operate improves the signal-to-noise ratio in the empirical analysis and leads to higher FDI spillover estimates.

Technology Transfer through Imports

In the typical model of international trade, there are no knowledge flows between firms. One way of looking at it is that such knowledge flows are unnecessary because by importing from abroad, domestic consumers have in fact gained access to foreign production knowledge. Estimates of the gains from trade are typically quite small, however, and research has moved to explore the role of trade in transferring production knowledge

between firms when this generates economies of scale.

In a project with Ram C. Acharya, I trace out international knowledge flows by relating foreign R and D to domestic productivity via bilateral imports in a large sample of manufacturing industries for three decades (1973 to 2002).¹⁰ A good reason for studying relationships at the industry level is that R and D provides an explicit measure of knowledge; at the micro level across many countries, there is no consistent data on a broad knowledge measure such as R and D.

One question is whether productivity is affected only by domestic R and D or also by foreign R and D and imports. We find that the R and D of six major countries close to the world's technology frontier typically increases their productivity by about three times as much as does domestic R and D. This finding suggests that for most countries in the world, foreign sources of knowledge are more important than domestic sources, underlining the importance of spillovers. We also show that foreign R and D spillovers from Germany, France, and the United Kingdom are more strongly related to imports from these countries, while spillovers from the United States are less tied to imports from the United States. The magnitude of knowledge transfers also varies strongly across bilateral country-pairs. For example, Ireland benefits much more, by a factor of seven, from knowledge created in the United States than does South Korea.

The results point to a heterogeneous web of global knowledge transfer where knowledge flows are at times embodied in goods and at other times not. To go further, I develop and test a model of trade and FDI, together with Yeaple, that puts at the center the choice between embodied and disembodied knowledge transfer.

Knowledge and Gravity¹¹

Economists like to describe the trade between two countries by an equation analogous to the gravity equation in physics. Trade in iPads, for example, depends on the masses (or incomes) of both coun-

tries and on the trade costs for iPads—that is, their weight. How about the transfer of knowledge—does it defy gravity as one might expect from knowledge as an intangible? I cast the question in terms of the operations of multinational firms. Not only do they account for much of the world's R and D but they also have every incentive to supply offshore affiliates with their knowledge as efficiently as possible.

Based on the global operations of U.S. multinationals included in data at the Bureau of Economic Analysis (BEA), it turns out that individual multinational affiliates sell less the further away they are from their home country—just like gravity in trade. Moreover, the gravity effect is strongest for the most R and D-, or knowledge-intensive, goods. Why is gravity so strong for goods that have low weight-to-value ratios?

My explanation focuses on the difficulties of communicating knowledge from one person to another (disembodied transfer) versus the costs of moving knowledge in goods (embodied transfer). Because of its non-codifiability, communicating knowledge between the multinational parent manager and the offshore plant manager is prone to costly errors.¹² The relatively high costs of knowledge-intensive production lead to both lower affiliate sales and the multinational firm's shifting its mix from offshore production (FDI) to onshore production, followed by exports.

Empirical analysis using the BEA micro data shows that this mechanism generates the gravity patterns in the data, even in light of competing explanations. Moreover, the extent to which multinationals use trade that embodies knowledge rises in knowledge intensity, and switching to offshore production to avoid trade costs is harder for knowledge-intensive goods, as the relatively high communication costs would imply. Also, the effects are quantitatively important. In the pharmaceutical industry, for example, our estimates suggest that the costs of communicating knowledge abroad raise the costs of offshore production by roughly 9 percent relative to domestic production. This suggests that unless the sav-

ings in shipping and production costs from producing abroad exceed this level, the firm will choose to produce domestically. Most previous analyses of FDI, however, have focused only on the latter costs, thereby overstating the incentives for off-shore production in knowledge-intensive industries. Frictions in knowledge transfers make multinational firms far less foot-loose than is generally presumed

Summary and Outlook

Because knowledge is non-rival it is often presumed to be universally available. My research indicates that while this is not the case much can be learned about the location and scale of economic activity from examining the ways in which knowledge is transferred across countries. Within countries, knowledge transfer costs might be just as important as across countries, and might help to explain the structure and activity of multi-plant firms.¹³ Future work on which knowledge transfers occur in-house versus at arm's length seems to be also a promising area of research.

in W. Keller, "Geographic Localization of International Technology Diffusion," NBER Working Paper No. 7509, January 2000, and *American Economic Review* 92, 1(2002): pp. 120–42.

² See the surveys of business executives cited in N. Hovhannisyan and W. Keller, "International Business Travel: An Engine of Innovation?," NBER Working Paper No. 17100, May 2011.

³ See W. Keller, "International Trade, Foreign Direct Investment, and Technology Spillovers," *op. cit.*, pages 6–7. The idea that knowledge can be in part non-codifiable has been most fully explored in Polanyi (1958).

⁴ N. Hovhannisyan and W. Keller, "International Business Travel: An Engine of Innovation?," *op. cit.*

⁵ A frequently mentioned mechanism is labor turnover, where employees of the multinational quit and then join a domestic firm without having fully paid for the knowledge acquired in the multinational through lower wages.

⁶ H. Görg and D. Greenaway, "Much Ado about Nothing? Do Domestic Firms Really Benefit from Foreign Direct Investment?," *World Bank Research Observer* 19, 2 (2004), pp. 171–97; W. Keller, "International Trade, Foreign Direct Investment, and Technology Spillovers," *op. cit.*

⁷ W. Keller and S. R. Yeaple, "Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States," NBER Working Paper No. 9504, February 2003, and Review of

Economics and Statistics, November 2009, 91(4), pp. 821–31.

⁸ See N. G. Howenstine and W. J. Zeile, "Characteristics of Foreign-Owned U.S. Manufacturing Establishments," *Survey of Current Business*, January 1994, pp. 34–9.

⁹ In most countries, foreign firms are only classified by their main industry (largest fraction of sales). In contrast, U.S. FDI data identifies the eight largest industries in which each foreign affiliate is active separately.

¹⁰ R. C. Acharya and W. Keller, "Technology Transfer Through Imports," NBER Working Paper No. 13086, May 2007, and *Canadian Journal of Economics* Vol.42, No.4 (2009), pp. 1411–48; this approach extends work by Zvi Griliches, "Issues in assessing the contribution of R and D to productivity growth," *The Bell Journal of Economics*, 10,1 (1979), pp. 92–116.

¹¹ See W. Keller and S. R. Yeaple, "The Gravity of Knowledge," NBER Working Paper No. 15509, November 2009, revision issued in April 2011.

¹² Arrow argues that knowledge transfer costs are mainly communication costs between teacher and student; see K. J. Arrow, "Classificatory Notes on the Production and Transmission of Technological Knowledge," *American Economic Review* 59, 2 (1969), pp. 29–35.

¹³ See evidence in A. Hortacsu and C. Syverson, "Why Do Firms Own Production Chains?," *mimeo*, University of Chicago, January 2012.

¹ W. Keller, "International Trade, Foreign Direct Investment, and Technology Spillovers," NBER Working Paper No. 15442, October 2009, and *Handbook of the Economics of Innovation*, Chapter 19, B. H. Hall and N. Rosenberg eds., North-Holland: Elsevier, 2010. The original finding is