The influence of technology on foreign direct investment

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Does technology play a role in the location of direct investment? When explaining the existence of multinationals one often notes that these enterprises have inherent advantages, such as technology, over other firms they might compete with in the local economy. So perhaps multinationals look for differences in technology between themselves and their foreign competitors. On the other hand, international organizations, such as the International Monetary Fund and World Bank, often state there must be a minimal amount of technology in emerging market economies for these countries to attract direct investment (DI). One can imagine instances where multinationals might want technology to be close to what they are bringing over so production processes run smoothly. This paper attempts to quantify the role of technology in horizontal and vertical DI decisions.

Looking at data on productivity, which is strongly influenced by technology, one finds that two countries with comparable levels of output per hour tend to have more DI between them. Figure 1 plots country j's real DI position in country i versus the productivity ratio of country i to j. In this figure we combine both U.S. DI abroad across countries and time (denoted by squares) and DI into the United States across countries and time (denoted by triangles). Since output per hour in the United States is relatively high, most observations for U.S. DI abroad tend to lie to the left of 1 on the x axis, and most observations associated with DI into the United States lie to the right of 1. We see the closer the foreign country's productivity is to the United States', the more U.S. multinationals (MNEs) invest in that country; this is reflected in a correlation of 0.25 between the series. Similarly for DI into the United States, the closer a

foreign country's technology is to the United States, the more foreign MNEs invest in the United States; this is captured in a -0.26 correlation.

One issue that arises when discussing DI and technology is diffusion. Could it be that productivity levels are close because DI promotes catch up for the recipient country's technology? One often hears about spillovers from training or demonstration. If this was a big part of the story, then the data for DI into the United States would not necessarily be the mirror image of that of U.S. DI abroad. Also, looking at a single country over time, where diffusion should be occurring, especially from advanced to emerging markets, we do not find statistical evidence that an increase in DI subsequently leads to an increase in the productivity level.[1]

By using the Carr, Markusen and Maskus (CMM) (2001) empirical model of DI, which is motivated by a knowledge-capital theoretical model, we estimate how technology affects both horizontal and vertical DI decisions. We find, for both U.S. DI abroad and DI into the United States, that the closer (further) a country's level of productivity is to the world average, the larger its stock of horizontal (vertical) DI.

I. Model and Data

We augment the CMM model to see how technology differences across countries amplify or dampen horizontal and vertical DI. The equation we estimate is as follows:

real DI from country j to country i = Eqn 1

$$h1 * sumgdp + h2 * sumgdp * tech + h3 * gdpdiff2$$
$$+ v1 * skilldiff + v2 * skilldiff * tech + v3 * skilldiff * gdpdiff$$
$$+ controls$$

where tech is defined as $| A^i/A^{world} -1|$, A^i=output per hour in country i and A^{world}=average output per hour across all countries in the world. We define the technology term as the absolute value of the productivity ratios relative to 1 so that when we consider DI into the United States or U.S. DI abroad, an observation with tech near zero indicates the recipient (host) country has technology similar to that of the average country in the world.[2] That is, if tech is zero, the country hosting the DI has the same level of productivity as the world average. The further tech is from zero, the further the host country's level of productivity is from the world average.

The first three terms of equation 1 are related to the horizontal motive for DI and are linked to the countries' sizes. The coefficient on sumgdp, which is the sum of country i and j's GDPs, should be positive to reflect the fact that horizontal MNEs are most common between large countries of similar size. The second term, which interacts technology with sumgdp, captures how much technology differences amplify or dampen horizontal DI. If the coefficient estimate on this term is negative (positive), then the closer country i's technology is to the world average, the more (less) horizontal DI it receives. The coefficient on gdpdiff2, which is the square of the difference in the countries' GDPs, should be negative since larger differences in the countries' GDP dampens the incentive for horizontal DI.

The next three terms capture the vertical motive for DI. Skilldiff is the absolute value of the skilled labor difference between country i and j. The coefficient of this variable should be positive, as the larger the skill difference between countries, the more likely a firm will move a stage of production to another country that is more abundant in a specific type of labor that is scarce in the home economy. For the United States, we think of MNEs moving labor-intense productions to low-skill abundant countries. The second term, which interacts technology with

skilldiff, captures how much technology difference amplify or dampen vertical DI. A negative (positive) coefficient estimate on this term indicates that the closer a country's technology is to the world average, the more (less) it attracts vertical DI. The coefficient on skilldiff*gdpdiff is expected to be negative.

The remaining variables in the regression are control variables for trade and investment frictions (see CMM for details). Excluding the productivity data, all data were graciously provided by Bruce Blonigen (see Blonigen and Davis (2004) for data descriptions and sources). Productivity data are from the Groningen Growth and Development Centre and The Conference Board, Total Economy Database. Tech, the productivity measure we use in the regressions, averages 0.15 for DI into the United States, and 0.23 for U.S. DI abroad, meaning that on average the United States has a productivity level closer to the world average than the countries that the United States invests in.

II. Estimation Results

Tables 1 and 2 report coefficient estimates from weighted least squares of equation (1) for U.S. DI abroad and DI into the United States, respectively. We report the regression of the entire sample and then for DI into/from advanced and emerging market economies respectively.[3] The sample period of the regressions is limited by the productivity data, starting in 1979Q1 for most countries and ending in 2000Q4. The R2 statistics are quite high for a sample with such cross-section variation.

Looking across the U.S. DI abroad regressions, Table 1, the coefficient estimates from the original CMM model (h1, h3, v1, and v3) support the horizontal motive for DI across all samples, and the vertical motive for DI in the emerging market data. This results can be thought

of as mending the differences between CMM and Blongien, Davis and Head (BHD, 2003). That is, CMM find both the horizontal and vertical motive of DI is supported by their regressions. BDH, however, point out an empirical issue related to the skill difference variable in the CMM sample. By adjusting the skill difference variable to the absolute value of the skill difference BDH no longer find support for vertical DI. Here we use the BDH formulation with tech terms added and find vertical DI is a motive for investment in emerging market economies. Our results are consistent with a priori expectations: horizontal DI occurs between the United States and other advanced economies where there are similarities in endowments, whereas vertical U.S. DI abroad tends to be in countries where skilled labor differences are the greatest (i.e., emerging economies).

Focusing on the technology terms (h2, v2), we find the coefficient estimate of sumgdp*tech is always negative and significant, indicating that the closer country i's productivity level is to the world average, all else equal, the more horizontal DI we see from the United States into country i. If we consider technology as another factor of production, then the horizontal motive of DI says U.S. multinationals are looking for similarities in capital, labor and technology when making investment decisions. Combining the first two terms of the regression we have sumgdp(h1+h2*tech). The mean value of tech for the entire sample of U.S. DI abroad is 0.23, implying (h1+h2*tech)>0, as expected in the CMM model. A one standard deviation decrease in tech (the host country's productivity moves closer in the world average) implies the coefficient on sumgdp increases by approximately 30 percent. That is, if tech declines by one standard deviation, then the host country becomes a more attractive location for horizontal DI, and this translates into DI increasing by 1 percent.

The coefficient estimate of skilldiff*tech is always positive and significant, suggesting that the closer country i's productivity level is to the world average, controlling for other factors, the less vertical DI occurs from the United States into country i. A one standard deviation increase in tech (the host country's productivity moves further from the world average) implies the host country becomes a more attractive location for vertical DI, and for the mean level of skilldiff, this translates into DI increasing by about 50 percent. Recall that vertical DI from the United States tends to be firms that are shipping labor-intense processes to labor-abundant countries for cost minimizing purposes. The less technology the recipient country has, the lower its marginal product (i.e., wage) for a given skill level. So the results indicate U.S. multinationals that are considering vertical DI look for labor abundant, relatively low technology countries.[4] Combining the fourth and fifth terms we have skilldiff(v1+v2*tech); for the emerging market economies, v1+v2*tech>0, as expected.

Overall, the regressions suggest that U.S. horizontal DI abroad establishes in any region, and the closer the host country's level of technology is to the world average, the more DI the country attracts. U.S. vertical DI abroad, on the other hand, tends to gravitate towards host countries with relatively low levels of skilled labor and technology. Empirically, the vertical motive of DI is only supported by the emerging market data.

Shifting to DI into the United States, Table 2, the estimation results are similar to what we found in the U.S. DI abroad data. The coefficient estimates of the original CMM variables again suggest there is horizontal DI into the United States across all country samples, while the vertical motive for DI is only supported (in sign) in the emerging market data. Not finding much evidence of vertical DI is reasonable; firms looking to source low-wage activities will not find

this in the United States. Focusing on the technology terms, we find the coefficient estimates of sumgdp*tech are negative in all regressions, while the coefficient estimates on skilldiff*tech are positive in all regressions and significant for the advanced economies. Just as before, the model suggests horizontal DI is amplified by technology near the world average, but vertical DI is attracted to a country where technology is far from the world average. Given that the United States is relatively skilled labor abundant, most DI is horizontal. And, the amount of horizontal DI is amplified by the fact that U.S. productivity is relatively close to the world average (tech is 0.15).

III. Conclusion

This paper adds technology to the benchmark CMM model of DI and finds that horizontal DI is attracted to countries whose technology is near the world average, whereas vertical DI is amplified in countries with relatively low levels of technology. The results are robust to using real sales data of multinationals instead of their positions and to adding country and year dummies to the regressions. Since horizontal DI transfers the entire production process with the subsidiary, it is understandable that the firm is looking for a location where its process will be established with little complications, and this may be more likely to happen in countries with technology levels comparable to the world average. Vertical DI, on the other hand, is typically done by firms looking to cut costs of production, and less technology abundant countries should have lower wage demands on the firm.

Figure 1 - Real DI Position versus Relative Productivity Levels

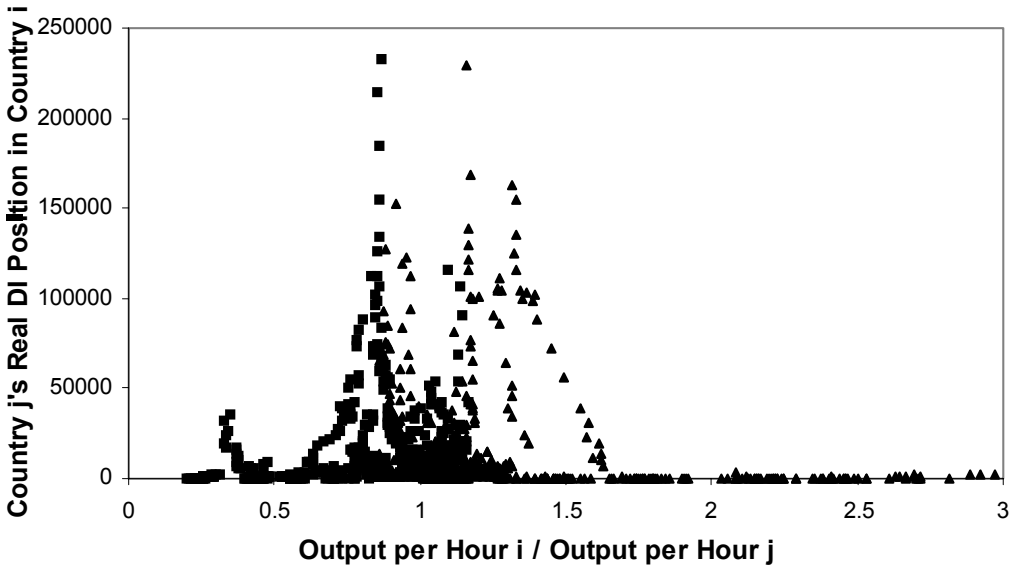

Table 1 - Weighted Least Squares Regressions for U.S. DI abroad

	All	Advanced Economies	Emerging Market Economies
sumgdp	7.27** (3.01)	7.81** (3.52)	14.45*** (4.94)
sumgdp*tech	-11.31*** (1.53)	-14.57*** (2.53)	-2.83* (1.52)
gdpdiff2	-0.00*** (0.00)	-0.00*** (0.00)	-0.00** (0.00)
skilldiff	-8778.07* (4540.68)	-9773.25* (5836.34)	12577.62*** (2936.53)
skilldiff*tech	12486.56*** (2377.51)	16716.54*** (3505.50)	6747.79*** (1788.37)
skilldiff*gdpdiff	0.31 (0.53)	0.28 (0.67)	-1.59*** (0.29)
No Observations	464	387	77
Adj R2	0.61	0.61	0.91

Standard errors in parenthesis. Only key variables reported in the table.

Table 2 - Weighted Least Squares Regressions for DI into United States

	All	Advanced Economies	Emerging Market Economies
sumgdp	14.28*** (5.48)	14.62** (6.39)	0.65 (0.53)
sumgdp*tech	-7.44 (21.56)	-12.48 (25.15)	0.48 (1.38)
gdpdiff2	-0.00*** (0.00)	-0.00*** (0.00)	-0.00** (0.00)
skilldiff	-34314.22*** (8689.14)	-39893.77*** (10838.16)	763.02 (768.56)
skilldiff*tech	111359.50*** (37779.58)	148468.30*** (47837.53)	967.69 (2004.08)
skilldiff*gdpdiff	1.52*** (0.57)	2.02*** (0.70)	-0.05 (0.05)
No Observations	497	405	92
Adj R2	0.62	0.65	0.56

Standard errors in parenthesis. Only key variables reported in the table.

References

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Footnotes

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1. See Keller and Yeaple (2002) for a discussion of the latest evidence on DI and spillover.

2. Alternatively we considered the ratio of output per hour of country i to country j with somewhat stronger results. We report the results using A^i/A^{world} so that we are separating the effect of technology difference on DI decisions from the skill difference between countries.

3. Advanced economies are defined as the countries in the OECD as of 1994.

4. These results do not contradict the statements that argue there needs to be some minimal technology infrastructure; there must be some minimal technology before DI will be attracted to a country, but this threshold level is not modeled here.