Identifying Technology Transfer in Foreign Direct Investment: Influence of Industry Conditions and Investing Firm Motives

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Firms have different motives for investing abroad, most notably to exercise existing capabilities, but also to build new capabilities by accessing knowledge located abroad. Recognizing this heterogeneity helps determine whether foreign investments transfer technology to their host industries. Using host industries' initial level of competition to differentiate when each of these dichotomous motives is more likely, I examine change in productivity resulting from inward FDI in US manufacturing industries for 1987 through 1991. While controlling for change in industry competition, I find that relatively uncompetitive industries experience productivity growth while competitive industries experience productivity stagnation from FDI. This differential outcome is consistent with heterogeneous investment motives.

With inward foreign direct investment (FDI), whether foreign entrants transfer technology to incumbent firms has historically interested researchers. Internationalizing firms are a conduit with clear potential for transfer. Multinational firms possess unique capabilities and use these capabilities both at home and abroad. To obtain the greatest returns, multinationals transfer their capabilities across national boundaries to their foreign subsidiaries.

While multinationals transfer technology within themselves, a related and potentially more interesting question is whether some of these capabilities are also transferred to other firms. Do unaffiliated firms and therefore the host industry overall also gain from the presence of the multinational's subsidiaries? If so, how much and under what conditions? Before these capabilities become common knowledge, those firms better positioned to observe, absorb, and utilize

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these new capabilities would have an advantage over their competition.

Research inquiry into knowledge leakage has long existed. For example, Mansfield and Romeo (1980) use a survey to ask US multinationals that expanded abroad how quickly their capabilities are imitated by incumbent competitors. Clearly demonstrating this foreign-to-incumbent transfer remains a challenge due to lack of appropriate data. Data has mostly been unavailable that both distinguishes foreign entrants from incumbent firms and permits construction of outcome measures that reflect technology transfer. For outcome, most researchers focus on FDI's relationship to productivity. Caves (1974) and Globerman (1979) show that greater foreign presence is correlated with greater labor productivity in Australia and Canada. More recently, Haddad and Harrison (1993) find that greater foreign presence reduces dispersion in multi-factor productivity among local Moroccan firms during in the late 1980s. For Mexico in the 1970s, Kokko (1994) finds that local establishments' labor productivity level significantly lags in industries characterized by complex technologies and high foreign share of production; technology gaps paired with high foreign ownership reduce technology spillovers.

While these studies suggest that unaffiliated firms receive transfers, clearly identifying technology transfer is stymied by only examining how FDI affects productivity. Caves (1996: pg. 185) cautions against concluding that multinationals transfer substantial technology without accounting for other potential sources of productivity growth. Importantly, Caves (1996) notes FDI's effect on productivity occurs via two channels: technology transfer and heightened competition. While some studies include measures for the level of competition, Caves's point is that change in level of competition is associated with increased productivity. Productivity increases as marginal, inefficient firms are forced out and remaining firms improve their efficiency to ensure their survival. Therefore to identify technology transfer, not only level of competition but also change in level of competition has to be accounted for, otherwise any correlation between FDI and productivity growth may actually be the result of enhanced competition and not technology transfer.

Also making detection of technology transfer difficult is the motive of investing firms. The classic multinational view is that expanding firms possess useful skills that they have to take abroad themselves because of the inherent difficulties of transferring these skills to others. Another view has also emerged: instead of utilizing the capabilities already in hand, firms may expand abroad in search of skills. Kogut and Zander (1992) argue that knowledge is partially tacit and transfer requires frequent interaction. Thus certain types of knowledge are localized by nature. Accessing localized knowledge requires physical proximity. For example, Jaffe, Trajenberg, and Henderson (1993) use patent citations to show that inventors are more likely to cite other inventors who are geographically proximate. Therefore Wesson (1993) argues to access new knowledge, to gain new capabilities, a firm may have to expand internationally to "source" the desired knowledge. More recently, investigations into the internationalization of R&D have strongly demonstrated the knowledge sourcing motive. Prominently, Florida (1997) finds that foreign multinationals establish R&D facilities in the US to obtain access to science and technology and develop links to the US technological community.

The recent research that focuses on this "sourcing new knowledge" motive of multinational firms typically use host industry conditions such as high R&D intensity to demonstrate the significance of the knowledge sourcing motive. In a cross industry analysis, Barrell and Pain (1997) show that the stock of patents held by domestic British and German firms are strong determinants of inward FDI into Britain and Germany. In a richer study among 32 multinationals, Kuemmerle (1999) shows that differences in R&D intensity between home and host industry strongly determines whether multinationals establish R&D laboratories to exploit existing skills or to augment existing skills with new skills; augmenting skills is more likely when the host nation is relatively more R&D intensive. Similarly, Pearce and Papanastassiou (1999) note two important strategic roles for multinational firms' R&D labs: to customize the multinational's existing skills for use in the host market and to conduct specialized research in those areas in which the host market is particularly skilled. Notably, these studies demonstrate that FDI is heterogeneous and that this heterogeneity depends upon market conditions.

In this paper, to identify whether technology transfer takes place, I construct a multi-equation model that reflects three critical facts. First, investing firms' motives are heterogeneous: firms may invest to exploit existing capabilities or to source new capabilities. These new capabilities need not only be R&D related, but may also be production, process, or managerial in nature. Second, investing firms' motives will be strongly determined by the characteristics of the market they are entering. Exploiting existing capabilities is appropriate for some markets, while sourcing new capabilities is appropriate for others. Third, technology transfer from foreign entrants is just one explanation for why productivity increases in the host market; the other competing explanation is that foreign entry heightens competition which forces productivity improvement. This model acknowledges that technology transfer is endogenous. Firms self-select based upon their own capabilities relative to the target market with technology transfer more likely when the investing firms have superior capabilities to incumbents; when the investing firms' are exploiting existing capabilities.

For the empirical test, I collapse the multiple equations into a single equation. Using FDI entering United States manufacturing industries from 1987 through 1991; I find that, while controlling for change in competition level, increased foreign presence in US manufacturing only significantly effects change in productivity when heterogeneous investment motives are acknowledged. Once the initial level of industry competition is introduced to reflect industries where one entry motive is more likely than another, I find that increased foreign presence in relatively uncompetitive industries is subsequently associated with productivity increase, not attributed to competition change; and increased foreign presence in relatively competitive industries is subsequently associated with productivity stagnation, not attributed to competition change. These findings are consistent with technology transfer occurring from foreign-to-incumbent firms in those U.S industries that lag behind best practices, while the best U.S. industries attract less productive foreign entrants motivated to absorb new capabilities.

That FDI's host industry effect is conditional on the investing firms' motives has several implications. While many developing nations encourage FDI assuming that FDI is beneficial, the possibility of detrimental outcomes suggests that nations reconsider their FDI policy. If a nation's industries are technical laggards, then promoting inward FDI makes sense. If a nation's industries are technical leaders, then policy makers might consider other actions. The entry of foreign entrants wanting to source new technology more quickly dissipates the knowledge stock accumulated by a nation's firms. And since the nation contributed to its firms' knowledge stock through basic R&D spending, national laboratories, and support of secondary educational systems; policy makers may want to make their nation's firms' capabilities less of an international public good.

Strategic behavior by the investing foreign firms leads to managerial implications for incumbents. All foreign entries are not equal opportunities for unaffiliated incumbents to benefit from unintended technology transfers. Indeed, the exact opposite may occur. In highly competitive markets, managers of incumbent firms should consider actions to slow leakage of their capabilities to foreign entrants intent on obtaining them. In turn, given this possible response, foreign firms investing to source new capabilities may want to make their motives more opaque.

I proceed as follows. First, I briefly summarize Caves's arguments for why detecting technology transfer from foreign entrants requires explicitly accounting for changes in competition. Next I introduce the equation system that reflects heterogeneous investment motives and that firms self-select their investment motives based upon their capabilities relative to market conditions. I collapse this equation system into a single equation for empirical testing. I describe the data for the empirical test. The results of the test and a discussion of the results follow. Finally, I conclude by linking the current results to extant research.

IDENTIFYING TECHNOLOGY TRANSFER IN FDI

Caves (1974; 1996: pg. 183) argues that inward FDI increases host industry productivity via two channels. In the first channel, FDI disciplines the host industry, raising competition. Heightened competition improves the resource allocation at both the firm and industry level. Foreign firms enter and force marginal incumbents to exit, which Caves terms allocative efficiency. Remaining incumbents must improve their own efficiency to ensure their continued survival, which Caves terms technical efficiency. To improve their efficiency, besides reducing known sources of waste, incumbents may develop capabilities internally to improve efficiency or seek such capabilities from other parties.[1] Studies examining several sources of heightened competition conclude that productivity gains result from improved technical and allocative efficiency; see for example Tybout, de Melo, and Corbo (1991), Baldwin (1995), and Nickell (1996).

The second mechanism through which inward FDI increases productivity is technology transfer from foreign entrants to incumbent firms. A necessary starting assumption is that foreign entrants possess intangible capabilities. These intangible capabilities might be purposefully or inadvertently transferred to incumbents. While multinationals may purposefully transfer knowledge to affiliated firms and suppliers, other incumbent firms may also reverse engineer product and process innovations. Applying the new capabilities increases the incumbent firms' productivity, which then aggregates up to productivity improvement at the industry level.

While establishing a positive link between FDI and host industry productivity, empirical studies have had limited success in showing technology transfer's significance for two reasons. First, most studies do not examine productivity growth, they examine productivity levels. Labor productivity levels in cross-sectional regressions are found to be strongly correlated with foreign presence; see for example Caves (1974), Globerman (1979), Blomström (1986), Kokko (1994), and Blomström and Sjöholm (1998). While this positive correlation strongly suggests technology transfer, causality is not established. Second, as Caves (1996: pg. 185) notes, when examining productivity growth, its other sources need to be accounted for, notably heightened competition. In the first study that looks at change in productivity levels, Haddad and Harrison (1993) find that change in foreign presence is positively linked to improved allocative and technical efficiency, which is consistent with the effect of heightened competition.

Thus successful identification of technology transfer requires examining productivity growth while also accounting for change in competition. Change in competition captures this other explanation for productivity growth: the disciplining influence of inward FDI, as well as other potential discipline mechanisms such as imports.

MARKET CONDITIONS, INVESTMENT MOTIVES, AND TECHNOLOGY TRANSFER

The productivity outcome for the host industry will be contingent upon the motives of foreign firms investing. Either foreign entrants transfer technology to the host market and productivity rises, else foreign entrants absorb technology from the host market with little positive effect on productivity. In turn, firms' motives for investing are partially dependent upon how developed the target market is. Best-practice markets, where market conditions force firms to regularly innovate, are more likely sources for new capabilities; while lagging markets are likely suitable for applying existing capabilities.

These interactions suggest an endogeneity: that the outcome from and market choice of FDI is contingent upon market characteristics. Developing markets will draw foreign firms seeking to exploit their existing capabilities; these markets will experience productivity growth as the foreign entrants force economic discipline and development. Marginal firms will be forced out and remaining firms will have to improve their efficiency to ensure their survival. In contrast, best practices markets will draw foreign firms wanting to learn these practices and enhance their own capabilities. The foreign entrants sourcing best practices likely are not as competitive as the incumbents that they are interested in learning from. The presence of less competitive entrants may then drag on the market's productivity.

Thus, arguing and testing whether productivity outcome is a linear function of inward FDI without accounting for this endogeneity is potentially misleading. This endogeneity suggests using an explicit model to capture these interactions.

First, we need to differentiate between two types of FDI: (1) foreign investment undertaken to use a firm's existing capabilities in additional markets ($FDI_{exploiting}$) and (2) foreign investment that is undertaken to supplement a firm's capabilities by accessing knowledge localized in foreign markets ($FDI_{sourcing}$). This dichotomy is analogous to Kogut and Chang (1991) exploring whether Japanese FDI is motivated by "exploitation of home technical advantages" or "sourcing of US locational advantages in technology"; or what Kuemmerle (1999) terms "exploiting" and "augmenting" for R&D specific FDI occurring among Japanese, European, and US firms. Here the technology need not be R&D specific, but also encompasses product, process, and managerial knowledge. For example, while examining foreign research laboratories in the US, Florida (1997) finds that these foreign facilities do not use home country managerial practices, but "emulate and learn from prevailing US approaches. . . to organization and management."

With these dichotomous motivations, market conditions help determine what type of FDI is attracted on average.[2] A prominent market condition is the level of competition. Researchers have used the level of competition to reflect among other things the nature of inter-firm rivalry, the height of entry and exit barriers, incumbents' propensity to seek efficiency and invest in technological improvement; for a review see Schmalensee and Willig (1989). Similarly, in this context, the level of competition is a useful proxy for available profit margins and the presence of new capabilities, which are the objectives for these two types of FDI. High competition indicates small margins, and vice versa. Indeed, margins and competition are so tightly linked that margins are one of the most common measures for competition level.

The level of competition also indicates the likelihood of new capabilities being present; high competition spurs firms to seek new sources of advantage, while low competition allows firms to stagnate. This is a main argument of Porter (1990), that certain national conditions promote intense rivalry that gives rise to competitive advantage. New capabilities are likely to be found in highly competitive markets because firms are forced to innovate. These efficiencies are likely subtle product, process, and managerial improvements that have a high tacit content making imitation difficult. Yet these subtle improvements can yield substantial competitive advantage. For example, Toyota inventing the just-in-time production systems was the direct result of an extreme lack of resources following World War II. Lack of capital forced Toyota to economize in all stages of its business operations. These subtle improvements constitute a capability that other auto-manufacturers initially found difficult to learn and adopt.

Markets with large profit margins will attract foreign entrants wanting to share in the rents.[3] Markets where location specific capabilities reside, will attract foreign entrants wanting to absorb these capabilities. Recognizing that a market's initial level of competition reflects the likelihood of unique capabilities and the level of available rents, combined with the possibility of dichotomous investment motives suggests the following two relationships.

$$\Delta\_FOR_{exploiting,t} = f(\overset{-}{COMP}_{t-1}) \quad (1)$$

$$\Delta\_FOR_{sourcing,t} = f(\overset{+}{COMP}_{t-1}) \quad (2)$$

"Δ_FOR" is change in foreign investment. "COMP" is the prevailing level of competition experienced by an industry. Equation 1 suggests that a high level of competition deters investments by foreign firms exploiting their existing stocks of capabilities. When the level of competition is high, profit margins are small, making entry unwarranted. In contrast, equation 2 suggests that a high level of competition attracts investments by foreign firms sourcing new capabilities. A competitive environment forces incumbents to develop new sources of advantage, which draws foreign firms wanting to observe and absorb these new capabilities.

A key underlying point of both these arguments is that firms will self-select for entry; certain markets are more suitable for achieving certain motives. Only those firms expecting a high likelihood of success in observing and absorbing new capabilities would enter high competition markets. Similarly, only those firms believing in the strength of their existing capabilities would enter industries with high available rents. These high rents must exist because of high entry barriers or similar industry structure. Given such hurdles, only those firms that believe they can successfully surmount them will self-select to enter.

These two equations do not suggest that only one type of entry occurs into a particular market; rather they suggest that a particular market, with a given initial level of competition, on average draws more of one type than the other. When the initial level of competition is moderate, entrants of both types are likely to be present. When the initial level of competition is at one extreme; mostly only the corresponding type of entrant will be present.

In turn, these dichotomous types of FDI will clearly have different effects on market outcomes. FDI exploiting existing capabilities should clearly have positive influences upon competition and productivity. These foreign firms enter expecting to successfully use their existing capabilities, which suggests that market incumbents may have something to learn from these entrants.

The influence of FDI conducted to source new capabilities on the host market is less clear. These entrants want to obtain new capabilities from the host market, and are potentially less competitive than the average incumbent. Therefore their influence on change in level of competition might be non-significant. Also their influence on productivity via technology transfer is likely to be non-significant since they themselves enter wanting to learn from incumbents. These expectations for change to competition (Δ_COMP) and change to productivity (Δ_PROD) are shown below as equations 3 and 4.

$$\Delta\_COMP_t = f(\Delta\_\overset{+}{FOR}_{exploiting,t-1}, \Delta\_FOR_{sourcing,t-1}) \quad (3)$$

$$\Delta\_PROD_t = f(\Delta\_\overset{+}{COMP}_{t-1}, \Delta\_FOR_{exploiting,t-1}, \Delta\_\overset{+}{FOR}_{sourcing,\, t-1}) \quad (4)$$

Equation 3 and 4 are the mathematical representation of Caves's arguments for identifying technology transfer, modified to account for dichotomous investment motives. "Δ_PROD" is change to industry level productivity: how much more output is obtained having accounted for increases in inputs. Change to industry productivity occurs through two channels: FDI heightens competition (equation 3) and transfers technology (equation 4). Productivity change that cannot be attributed to change in competition must result from technology transfer (equation 4) and other residual explanations. Thus in equation 4, by controlling for change in competition (Δ_COMP) any significance attracted by $\Delta\_FOR_{exploiting}$ and $\Delta\_FOR_{sourcing}$ is the result of technology transfer and other residual explanations. The obvious residual explanation is that foreign entrants themselves may be included when industry average productivity is calculated. As a result, $\Delta\_FOR_{sourcing}$ may attract a negative sign if these foreign entrants are indeed less productive than the market incumbents they are trying to learn from.

The expectations reflected by equation 4 are for the average investment. Certainly there will be situations where a foreign entrant comes from a less competitive, less advanced home market and enters a highly competitive, advanced host market; but still has unique capabilities that might be transferred to the advanced indigenous firms. While such situations can readily be envisioned, these will be the exceptions and on average the relationships in equation 4 should hold.

Trying to test equation 4 reveals a logistical impediment: separating investments into the dichotomous types – those made to exploit existing capabilities versus those made to source new capabilities. While managers of foreign subsidiaries could be surveyed, collecting a large sample is problematic as always. There is also the difficulty of what an entry's intended purpose was versus what its emergent purpose is.

Instead we can use industries' level of competition as a proxy. Equations 1 and 2 jointly suggest that when a market's initial level of competition is low, a greater portion of the foreign entrants expect to exploit their existing capabilities; and when a market's initial level of competition is high, a greater portion of the foreign entrants will be sourcing new capabilities. Firms will self-select.

Making use of the initial level of competition, equation 4 can be modified to account for this conditional outcome. Initial competition will be strongly correlated with the type of FDI; the type of FDI then determines likelihood of technology transfer. This suggests an interaction between FDI and level of competition so that when the initial level of competition is low, increase in FDI will enhance productivity; but when the initial level of competition is high, this positive influence should lessen. Thus equation 4 becomes equation 5.

$$\Delta\_PROD_t = f(\Delta\_\overset{+}{COMP}_{t-1}, \Delta\_\overset{+}{FOR}_{t-1}, \Delta\_\overset{-}{FOR}_{t-1}{*}COMP_{t-2}, COMP_{t-2}) \quad (5)$$

Equation 5 integrates the prior equations' relationships by omitting unobserved parameters and grouping remaining ones on the right-hand-side of a single equation. Equation 5 suggests two hypotheses to be empirically tested.

We expect the coefficient attracted by Δ_FOR to be positive. When level of competition is low, FDI should positively effect productivity; low competition draws investing firms utilizing existing capabilities that spillover to incumbents, which raises market productivity. More formally, this suggests:

Hypothesis 1: While controlling for change in competition, inward foreign direct investment will increase host industry productivity when prevailing industry competition is low.

We expect the coefficient attracted by Δ_FOR*COMP to be negative. As the level of competition heightens, FDI's positive influence should lessen. High competition draws investing firms sourcing new capabilities, from whom incumbents gain little. When competition is high, the presence of firms sourcing new capabilities might even drag on market productivity, causing a negative productivity effect.

Hypothesis 2: While controlling for change in competition, the higher the prevailing level of industry competition, the less inward foreign direct investment will increase host industry productivity.

EMPIRICAL MODEL AND DATA

The empirical setting is U.S. manufacturing for 1987 through 1991 at the 4-digit standard industrial classification (SIC) level. The U.S. is an attractive setting because its manufacturing industries are heterogeneous enough to draw foreign investment with differing motives; during this period, the U.S. simultaneously had industries that were best in the world and industries that lagged significantly behind best practices. The actual number of observations used for analysis is drastically reduced by imperfect overlap of the data for dependent and independent variables – many industries have productivity measures but no measures for FDI or level of competition. The final set contains 121 4-digit SIC manufacturing industries with 353 industry-year observations.

Industry Productivity: TFP Measurement

The dependent variable is Δ_PROD, the yearly percent change in industry total factor productivity, TFP. TFP growth is output unexplained by input growth, with greater unexplained output growth being greater TFP growth. To obtain industry level TFP, I use data from Bartelsman and Gray's (1996) National Bureau of Economic Research Productivity Database. They provide output produced by and inputs used by 450 4-digit SIC industries between 1958 and 1991 using establishment data aggregated to the industry-level from Census of Manufacturers and Annual Survey of Manufacturers. The Census and Annual Survey include domestic and foreign firms, so the resulting TFP measure reflects the contribution of both domestic and foreign firms to the industry average. Full documentation by Bartelsman and Gray is available via anonymous FTP from ftp.nber.harvard.edu.

Δ_PROD is then yearly percent change in output minus the sum of yearly percent change of each input weighted by its factor cost share. The production function uses five inputs: skilled labor, unskilled labor, capital, materials, and energy. Use of cost shares assume that firms on average employ factors in direct proportion to each factors' marginal contribution to output. Constant returns to scale is assumed to obtain the cost shares for capital – capital's cost share is one minus the sum of the other four cost shares. Note that output and inputs are industry-level observations aggregated from establishment data. Individual, establishment-level observations are not available.

Independent variables

For change in FDI (Δ_FOR), I use year-over-year change in percent of industry sales accounted for by foreign affiliates reported by the US Department of Commerce, Bureau of Economic Analysis "Foreign Direct Investment in the United States: Establishment Data for Manufacturing" from 1987 through 1991. This measure of "foreign presence" is identical to what prior researchers have used.[4] The Bureau of Economic Analysis reports the yearly value of shipments from foreign owned affiliates in the US scaled by the total value of shipments for the industry, or the percentage of sales accounted for by foreign affiliates. I first-difference these percentages between years for my measure of Δ_FOR, change in percent foreign sales.

To represent the level of competition, COMP, I use price markup (MARKUP), the ratio of price divided by marginal cost. When markup is high – a value greater than 1.0, when firms charge much in excess of their marginal costs, competition is low. In contrast, when price markup is low – near a value of 1.0 with price equaling marginal costs, competition is high. Price-cost markup $\left(\frac{p}{MC}\right)$ is clearly a linear transformation of the price-cost margin / Lerner Index $\left(\frac{p-MC}{p}\right)$, a historic and widely accepted measure of competition.[5]

I do not have separate information for price and separate information for marginal cost. Rather, through an econometric technique pioneered by Hall (1988), I use variation in firms' sales and input costs to impute the ratio of price divided by marginal cost for an industry. The equation to be estimated is shown below:

$$dq_{it} = \left(\frac{p_t}{MC_t}\right)[\alpha^L_{it}dl_{it} + \alpha^M_{it}dm_{it} + \alpha^K_{it}dk_{it}] + f_{it}(\lambda_t + \mu_{it})$$

Estimating industry markup requires firm-level information on: (i) percent change in output (dq_{it}), (ii) percent change in factor inputs (dl_{it}, dm_{it}, and dk_{it} (respectively labor, materials, and capital)), and (iii) factor cost shares (α^L_{it}, α^M_{it}, and α^K_{it} (respectively labor, materials, and capital)). I use some eleven thousand firm-year observations from Compustat. For details see Levinsohn (1993), Kang (1995), or Chung (2001).

While the technique is potentially imposing, the basic intuition is simple: firms that have high sales and inexpensive production costs must be obtaining high markup on their output. In contrast, firms that have low sales and expensive production must be obtaining low markup. The multitude of firm observations in each industry provides variation to obtain a point estimate of an industry's markup. MARKUP is an industry's annual point estimate value. For change in competition, Δ_COMP, I use change in markup (Δ_MARKUP). Δ_MARKUP is the difference between yearly point estimates of MARKUP. Decreased markup indicates heightened competition, firms' prices decrease towards cost.

The use of MARKUP and Δ_MARKUP reverses the signs in equation 5 because markup is a "reverse coding" scheme for competition; high markup is low competition and vice versa. With these changes, equation 5 becomes equation 6 below.

$$\Delta\_PROD_t = f\,(\overset{-}{\Delta\_MARKUP_{t-1}}, \overset{-}{\Delta\_FOR_{t-1}}, \overset{+}{\Delta\_FOR_{t-1} * MARKUP_{t-2}}, MARKUP_{t-2}) \quad (6)$$

All independent variables are lagged one time period, except MARKUP which is lagged two time periods. Since Δ_MARKUP_{t-1} is equal to $MARKUP_{t-1}$ minus $MARKUP_{t-2}$, the appropriate starting time frame for the initial level of competition is two lagged time periods.

In addition, I also include fixed effects for both industries and years to capture other explanations that are not explicitly included. Industry differences in capital and R&D intensity may affect productivity levels and therefore percent change in productivity levels. Similarly, yearly fluctuations in factor costs may affect productivity change.

Descriptive statistics for these variables are shown as Table 1.

Productivity (Δ_PROD) decreased 0.856% during the sample period for the represented 4-digit US manufacturing industries. Semiconductors and computers gained the most, while asphalt paving/roofing materials and construction machinery decreased the most. Foreign presence, sales from foreign owned firms increased by 1.708%. Radios-televisions-stereos and hydraulic cement had the highest foreign presence, while aircraft and aircraft engines had the lowest. Oil field machinery and lawn/garden tractors exhibited the largest increases in foreign presence, while pumps and industrial furnaces/ovens had the largest decreases. The average level of price markup was 1.065; these industries were on average obtaining 6.5% margins over their costs. Ophthalmic equipment and mining machinery

TABLE 1
DESCRIPTIVE STATISTICS

Correlations	1	2	3	4	5
1 Δ_PROD	1.000	−0.021	−0.073	−0.008	0.037
	0.00	0.69	0.17	0.88	0.48
2 Δ_FOR	−0.021	1.000	−0.113	0.979	0.012
	0.69	0.00	0.03	0.00	0.83
3 Δ_MARKUP	−0.073	−0.113	1.000	−0.131	−0.118
	0.17	0.03	0.00	0.01	0.03
4 Δ_FOR*MARKUP	−0.008	0.979	−0.131	1.000	0.102
	0.88	0.00	0.01	0.00	0.06
5 MARKUP	0.037	0.012	−0.118	0.102	1.000
	0.48	0.83	0.03	0.06	0.00
Summary statistics					
Cases	354	354	354	354	354
Mean	−0.856	1.708	−0.011	1.827	1.065
Std. Dev.	3.485	3.218	0.062	3.726	0.203

significance levels below correlations

Δ_PROD and Δ_FOR are year-over-year percent change in levels. MARKUP is the estimated ratio of price divided by marginal cost. Values much greater than 1.0 indicate low levels of competition.

TABLE 2
FDI'S EFFECT ON US MANUFACTURING PRODUCTIVITY FOR 1987-91

	Full Sample			Sample Split by MARKUP	
	(1)	(2)	(3)	High (4)	Low (5)
Δ_FOR	−0.0118	−0.0213	−0.8996***	0.1168*	−0.2602***
	(0.0658)	(0.0661)	(0.3716)	(0.0849)	(0.1032)
Δ_MARKUP		−4.2012*	−6.1398	−7.0797*	0.3149
		(3.1318)	(5.7295)	(4.7167)	(3.9614)
Δ_FOR*MARKUP			0.7925***		
			(0.3282)		
MARKUP			−5.8214		
			(8.6192)		
Industry effects	included*	included*	included**	included*	included***
Year effects	included***	included***	included***	included***	included*
Joint test vs. model 1					
F-statistic (Prob)		1.76 (.186)	2.56 (.055)*		
d.o.f. restrictions		1	3		
n	354	354	354	173	180
R-squared	0.422	0.427	0.442	0.444	0.493
Adjusted R-sq	0.111	0.115	0.131	0.122	0.220
F-statistic (Prob)	1.35 (.027)**	1.36 (.024)**	1.41 (.013)**	1.34 (.087)*	1.76 (.004)***
d.o.f.	124	125	127	64	64

*, **, ***significant at 10%, 5%, and 1% level for 1-tailed tests with Δ_FOR, D_MARKUP, D_FOR*MARKUP, and MARKUP since Hypotheses/expectations are directional. Standard errors in parentheses.

Change in industry productivity is yearly percent change in total-factor-productivity (Δ_PROD). All independent variables are lagged one year from the dependent variable, except MARKUP which is lagged two years.

had the highest markups while sealant and sawmills had the lowest. On average markup changed by −0.011, or markup decreased 1.1%.

RESULTS

I regress percent change in total-factor productivity on lagged values of percent change in foreign presence and several control variables. All specifications include two-way fixed effects for both industries and years. In the results below, joint F-tests show that industry and year effects are always significant. The results of five specifications are shown on Table 2.

Column 1 of Table 2 presents a benchmark model similar to prior empirical tests – how FDI affects that industry's productivity. This is FDI's aggregate influence on productivity; FDI's effect via technology transfer is not isolated since no control for change in level of competition is included. For this aggregate effect, the coefficient estimate for Δ_FOR is not significantly different from zero. This finding is not inconsistent with prior results. While most prior tests show that greater foreign presence is correlated with higher productivity, these tests typically use developing nations as their study contexts.[6] For the U.S., what aggregate outcome should be expected is unclear, especially when industry conditions and investment motives are not accounted for.

Column 2 introduces Δ_MARKUP, change in level of industry competition. This specification parallels Caves's suggestion that FDI's influence upon productivity occurs via the two channels of heightened competition and technology transfer. Inward FDI escalates competition, which is captured by Δ_MARKUP. Δ_MARKUP also captures change in other unobserved variables that affect competition and that would also discipline the industry to become more efficient. For example, Δ_MARKUP implicitly reflects any changes in import competition since Levinsohn (1993) shows that industry markup drops as imports increase.

As expected Δ_MARKUP_{t-1} is significantly negatively correlated with Δ_PROD_t, at the 10% level for a 1-tailed test. A 1-tailed test is used since prior research suggests that heightened competition is followed by subsequent rise in productivity.[7] The negative coefficient attracted by Δ_MARKUP is consistent with this expectation; decreased markup (increased competition) is followed by productivity rise.

With Δ_MARKUP accounting for change in level of competition, Δ_FOR reflects productivity change attributed to technology transfer. The coefficient attracted by Δ_FOR_{t-1} is not significantly different from zero. This non-significant finding is consistent with heterogeneous investment motives: if differential motives exist with both positive and negative technology transfer influences and these differential motives are not separated, the net outcome could easily be not significantly different from zero.

Column 3 parallels equation 6 above, using the initial level of industry competition to distinguish between dichotomous investment motives. Foreign entrants exploiting existing capabilities should be drawn to relatively less competitive industries; foreign entrants wanting to learn new capabilities should be attracted by relatively more competitive industries. With dichotomous motives, differing productivity outcomes will result. MARKUP and the interaction Δ_FOR*MARKUP are included to reflect that the influence of foreign firms will be co-determined by the initial level of competitiveness.

The joint F-test shows that including Δ_MARKUP_{t-1}, $\Delta\_FOR_{t-1}*MARKUP_{t-2}$ and $MARKUP_{t-2}$ significantly improved model fit over the benchmark model in column 1. Individually, the coefficient attracted by Δ_MARKUP and MARKUP are not significantly different from zero. This is not surprising since by construction these three variables are highly correlated; $\Delta\_MARKUP_{t-1} = MARKUP_{t-1} - MARKUP_{t-2}$. This high correlation increases standard error estimates. In cases where variables are highly correlated, individual parameter t-tests need to be supplemented with joint F-tests that inquire whether the additional constraints significantly raise the sum of squared error. The joint F-test indicates that the inclusion of these three variables significantly improve overall model fit at a 5.5% level of significance.[1]

The coefficients attracted by Δ_FOR_{t-1} and $\Delta\_FOR_{t-1}*MARKUP_{t-2}$ support the expected varying productivity outcome. The coefficient attracted by Δ_FOR is strongly negative, while the coefficient for the interaction of Δ_FOR*MARKUP is strongly positive. 1-tailed tests are used since expectations are directional, though 2-tailed tests yield similar significance levels. Interpreting these coefficients, recall that MARKUP is "reverse coded". High markup is equivalent to low competition. Also important are the coefficient magnitudes of −0.8996 and 0.7925 and the average value for MARKUP reported in Table 1 of 1.065. The resulting equation after moving Δ_FOR outside of the brackets is:

$$\Delta\_PROD_t = \Delta\_FOR_{t-1}*(-0.8996 + (0.7925*MARKUP_{t-2}))$$

This equation shows that foreign presence's influence on productivity change via technology transfer is either positive or negative depending upon the initial level of industry competition. When MARKUP is large enough, when 0.7925*MARKUP overcomes −0.8996, the net effect is positive. This suggests that when competition is relatively low, technology transfer occurs.

Conversely, when MARKUP is low, the −0.8996 begins to dominate, reducing the overall positive influence. When competition is higher, productivity gains shrink as both foreign entrants exploiting existing capabilities and foreign entrants sourcing new capabilities compose the inward FDI flow. In the extreme, if MARKUP is low enough, say 1.0 or "perfect competition", the overall effect is negative. When the FDI flow is mostly composed of less productive foreign firms entering to learn new capabilities from incumbents, these entrants drag down the industry's average productivity.

Recognizing that collinearity among independent variables may inflate t-tests, I also conduct another test to supplement the F-tests mentioned above. I split the sample by industries' initial level of competition into high and low groups using industries' average markup from 1987-91. This avoids the collinearity introduced by the interaction Δ_FOR*MARKUP but reduces statistical power since the number of observations is halved. We would expect industries with low initial levels of competition (high markup), to experience productivity growth; while industries with high initial competition (low markup), to experience little productivity growth or productivity decline. These results are shown in Columns 4 and 5 of Table 2 and fit these expectations.

The results might be influenced by where the inward FDI originates from. Unfortunately the Bureau of Economic Analysis FDI data does not indicate source; but using data from the International Trade Administration, Department of Commerce for 1987-1991, I find that most investment came from Japan, which may be driving the results. Anecdotal and academic evidence suggests that the Japanese were world-class in some industries like automobiles and machine tools but also lagged behind in others like biotechnology.[9]

As a final test, I widen the independent variables' time window since some sources of productivity change, like investing in new plant and equipment, may manifest more slowly. Instead of one year change, I use the change from between two years and repeat specifications shown in Table 2. Given my narrow panel, two years is the maximum that I can widen the independent variables while still including year and industry dummies to capture unobserved effects. Using two year change, the coefficient estimates for Δ_FOR and Δ_FOR*MARKUP are similar to those reported before: the same signs, less significant, but larger.[10] Importantly, the magnitudes suggest that the effect on productivity change across representative values of Markup is positive, though less positive for high competition industries. This combined with the original, 1-year lag results suggest that the negative productivity influence in high competition industries is short term; with a longer window, FDI in high competition industries only slows productivity growth.

CONCLUSIONS

Researchers have only been partially successful in determining whether foreign entrants transfer technology to incumbent firms. While foreign entrants definitely transfer technology to their own subsidiaries or suppliers, to what degree unaffiliated firms and thus the host industry overall also benefit remains uncertain. Past research shows that foreign presence is linked to increased industry productivity, but whether this increase results from technology transfer or other explanations has been unclear.

To help identify productivity increase attributable to technology transfer, this study incorporates three pieces of information into an empirical test. First, besides technology transfer the other major explanation for productivity increase is FDI heightening competition. Heightened competition forces productivity improvement. Second, firms have heterogeneous motives for investing in foreign markets. Sometimes firms enter to exploit existing capabilities, other times they enter wanting to learn new capabilities. Third, investing firms' motives will be strongly influence by the initial level of competition in the market they are entering.

To reflect this information I use several simple equations. Since some of the variables in these equations are unobserved, I collapse them into a single reduced form equation that is then tested for U.S. manufacturing from 1987-1991.

The empirical results are intuitively appealing. When the possibility of differential influence due to heterogeneous investment motives is ignored, changing foreign presence's affect on productivity via technology transfer is not significantly different from zero. The results change dramatically once the industries' initial level of competition is included to distinguish between those industries where firms are likely exploiting existing skills versus sourcing new skills. The results show with changing foreign presence that productivity increases in less competitive industries but stagnates in more competitive ones. These findings are consistent with positive technology transfer occurring in less competitive industries where firms enter to exploit existing skills, and are consistent with less productive foreign firms entering more competitive industries to learn best-practices.

This dramatic change in results parallels other recent studies that demonstrate the importance of accounting for firm heterogeneity. When ignored, certain results emerge; once heterogeneity is included, earlier results change. For example, Shaver (1998) examines how mode choice of foreign firms entering U.S. manufacturing affects survival. Following earlier studies, Shaver initially shows that greenfield investments seem to have survival advantages over acquisitions; but these results disappear once firm heterogeneity is introduced. Not accounting for heterogeneity can lead to incorrect or misleading results.

The empirical tests do have some shortcomings, notably that they are based upon a short data panel and when Japan dominated inward FDI. While the current empirical tests demonstrate statistical significance consistent with expectations, greater economic significance might result when using a longer panel. While some technology transfer can occur rapidly, full transfer and application of these techniques likely takes several years. This suggests that some positive influences have yet to manifest and may be currently unobserved. A test using several years of lags might show greater economic significance in terms of coefficient magnitudes and variance explained.

While further long term investigation is needed, this study's findings of varying outcomes from technology transfer in the U.S. complements other studies in developing nations. In Mexico, Kokko (1994) also finds varying outcomes; foreign presence is correlated with significantly higher productivity when large technology gaps do not exist between foreign and Mexican firms. Together, these studies demonstrate FDI's complex influence upon the host market, supplementing the classic view that FDI transfers technology. We see at least three outcomes: (i) foreign firms enter, technology transfer is available, but incumbents are unable to absorb the new capabilities; (ii) foreign firms enter, technology transfer occurs and overall productivity rises; and (iii) foreign firms enter sourcing new capabilities, these entrants are relatively less productive, and overall productivity stagnates.

Several policy implications arise. While the classic view suggests that inward FDI is always beneficial, FDI is clearly heterogeneous and under certain market conditions, such as high competition, this heterogeneity can have undesirable host market outcomes – at least in the short term: overall industry productivity may decrease as less productive foreign entrants enter to siphon knowledge. To reduce exposure to these negative outcomes, policy makers might selectively welcome FDI only into certain sectors, limit foreign entrants to certain geographic areas, or encourage establishment of foreign subsidiaries that conduct more than only research. Such steps would make the capabilities of firms in their nation less of an international public good.

Investing foreign firms acting strategically suggests that incumbents respond strategically. Foreign entrants are unequal opportunities for unaffiliated incumbents to benefit from unintended transfers. Indeed, the exact opposite may occur. Managers of incumbents in highly competitive markets might identify knowledge-seeking competitors and act to slow leakage of their capabilities. Engineers, scientists, and managers should be warned about informal knowledge exchanges with counterparts from other firms; compensation should be adjusted to retain key personnel. When entering alliances, assessing whether, what, and how fast capabilities might be lost should be part of the calculus. Given this possible response, foreign firms investing to source new capabilities may want to preempt by making their motives more opaque to reduce the aforementioned incumbent actions.

Overall this study highlights the importance of FDI heterogeneity. Building on Florida's (1997) observation that "R&D FDI is a heterogeneous process, with considerable variation in the nature and activities. . .", this study acknowledges this heterogeneity for manufacturing in general and asks what this heterogeneity means for host market outcomes. Recognizing this heterogeneity, we deepen our understanding beyond simple linear relationships. Using market competition to differentiate when a certain type of FDI is more likely, a differential outcome appears in FDI's effect upon host productivity via technology transfer. Strong empirical results that are consistent with our theoretic expectations emerge where initially linear tests found none. Incorporating indicators of firm heterogeneity to other areas of FDI research such as location choice may also yield interesting results.

1. Powell (1990) notes that alliances provide another possible mode for obtaining capabilities between markets and hierarchies. Testing this, Mowery, Oxley, and Silverman (1996) use patent citations to show that alliance activity results in partners' technical capabilities overlapping more.

2. The use of market conditions is consistent with past research showing that investment motives are functions of industry conditions. See for example Kogut and Chang (1991), Kummerle (1999), and Pearce and Papanastassiou (1999).

3. Caves (1996: pg. 83-85) argues that foreign entrants are more effective than domestic entrants at reducing industries' profit margins. As ongoing concerns foreign entrants often already possess industry specific capabilities that new domestic entrants do not.

4. See for example Caves (1974), Globerman (1979), Blomstrom (1986), and Haddad and Harrison (1993).

5. Markup is now used more than the Lerner Index because of accuracy. While markup – the ratio of price over cost – is econometrically estimated, the Lerner index requires the investigator know price. Price information is rare, so the investigator has to assume a proxy, which typically is sales.

6. See for example Haddad and Harrison (1993) who examine Morocco and Kokko (1994) who examines Mexico.

7. See for example Tybout, de Melo, and Corbo (1991), Baldwin (1995), and Nickell (1996).

8. Wary of including insignificant variables in subsequent interpretation, I conducted additional F-tests among Δ_FOR, Δ_FOR*Markup, and Markup. I tested the joint significance of the below four specifications (which include dummy variables) versus a baseline specification of just industry and year dummies:

(1) Δ_FOR, Δ_FOR*Markup, Markup
$F_{3,226} = 2.91$ (Pr = 0.035)**
(2) Δ_FOR, Markup
$F_{2,227} = 0.49$ (Pr = 0.609)
(3) Δ_FOR*Markup, Markup
$F_{2,227} = 0.44$ (Pr = 0.644)
(4) Δ_FOR, Δ_FOR*Markup,
$F_{2,227} = 4.29$ (Pr = 0.015)**

This disaggregation indicates that only Δ_FOR and Δ_FOR*Markup are significant. Tests that also add Δ_Markup continue to show Δ_FOR and Δ_FOR*Markup as significant and Markup as non-significant.

9. See for example Clark and Fujimoto (1991) and Florida (1997).

10. Δ_FOR attracts –1.148* and Δ_FOR*Markup attracts 1.2593**, while coefficients on Δ_Markup and Markup are not significantly different from zero.

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