Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States[1]

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Abstract

We estimate international technology spillovers to U.S. manufacturing firms via imports and foreign direct investment (FDI) between the years of 1987 and 1996. Our results suggest that FDI has led to significant productivity gains of U.S.-owned firms, while the evidence on imports-related spillovers is mixed. We also find that benefits from spillovers are increasing with R&D expenditures of U.S. firms. The size of FDI spillovers is economically important: we estimate that they accounted for at least 14% of U.S. productivity growth between 1987 and 1996.

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1. Introduction

Few economists doubt that the rate of productivity growth is of fundamental importance for economic welfare: certain inputs, such as the work time in a day for instance, simply cannot be augmented without limits. Moreover, recent research has established that differences in income levels across countries can be to a large extent traced back to differences in productivity levels across countries (Prescott 1998, Hall and Jones 1999). Correspondingly, differences in productivity growth have been the major determinant of differences in income growth, both over time as well as across countries (Easterly and Levine 2001).

Why do these differences in productivity exist? Instead of the view that this is simply due to technological change occurring at different rates across countries, some authors have argued that the international diffusion of technological knowledge between--more or less--open economies is key to understanding cross-country productivity differences. Recent estimates that domestic productivity growth is derived ultimately from foreign sources in most countries of the world (Eaton and Kortum 1999, Keller 2002a) supports this view.[5]

When an economy liberalizes to become more open, broadly speaking, there might be market- as well as non-market mechanisms through which the

[5] The emphasis on barriers to technology adoption (e.g., Parente and Prescott 2000) is consistent with this.

technological knowledge of foreign firms can affect domestic productivity. First, foreign firms might exert competitive pressures that force domestic firms to change their pricing behavior, eliminate inefficiencies and become thus more productive. Market mechanisms can also operate even with fully competitive markets: the change in relative prices associated with trade liberalization, e.g., can lead to productivity gains through a more efficient pattern of specialization. Foreign firms might also be the source of a particular set of externalities--sometimes called technology spillovers--that raise the productivity of domestic firms through non-market channels. It is these externalities that we will try to quantify in this paper for the United States between the years of 1987 and 1996.

Our focus will be on externalities associated with U.S. imports and the activities of multinational enterprise (MNE) subsidiaries associated with foreign direct investment (FDI) into the United States. These two channels have been most emphasized by theoretical and empirical work.[6] Importing a technologically advanced commodity might trigger learning that allows producing a similar good at lower costs domestically. Another possibility is that the price does not fully reflect the quality of imported good, due to issues associated with market power and problems of appropriability.

FDI might be associated with spillovers for domestic firms because workers that 'embody' the firm-specific knowledge asset of the MNE subsidiary can be attracted to domestic firms, or because domestic firms use local intermediate goods supplier chains whose productivity has been raised through

[6] Also externalities associated with export activity ('learning-by-exporting'), as well as other channels have been analyzed; see Keller (2001) for a broader discussion.

the know-how of the MNE. In these and other instances, it is a priori plausible that market prices do not necessarily reflect the full value of the transaction to all parties, and there is at least some, albeit often anecdotal evidence to which we turn briefly in section 2 that this might be empirically important.

We use data on a sample of about 750 large U.S. firms between the years of 1987 and 1996 to examine whether technology spillovers arising from U.S. imports and the activity of foreign-owned subsidiaries are important in affecting the productivity of U.S. firms.[7] We estimate the impact of differences in imports and FDI activity across fairly disaggregated U.S. manufacturing industries on the productivity of the firms in our sample. We also take into account the U.S. firms' own technological investments in form of their R&D spending, which is well-known to be positively correlated with productivity (Griliches and Mairesse 1984).

Our results are consistent with substantial technology spillovers from foreign-owned subsidiaries to U.S. firms. According to our preferred estimates, a lower bound for the extent to which technology spillovers from FDI account for U.S. productivity growth between 1987-96 is 14%. We believe, however, that this estimate is conservative and that the actual spillover effects might even be considerably larger. We also estimate that FDI spillovers are stronger for U.S. firms that invest heavily into R&D, a finding that is consistent with the idea that a relatively high absorptive capacity (Cohen and Levinthal 1989) allows firms to increase their benefits from external technology creation. In contrast, our results on imports-related technology spillovers are more mixed at this point, and their

[7] We have also assembled a larger data with about 1,300 firms. Future versions of this paper will include results from both samples.

interpretation is conditional on the exact mechanism through which these spillovers work.

We now briefly review the available evidence, before discussing the data and our approach in section 3. All estimation results can be found in section 4, while section 5 contains some preliminary concluding discussion.

2. Technology Spillovers through Imports and FDI

The empirical literature on technological externalities associated with trade and FDI activity has grown rapidly in recent years but from a relatively small base. Given its relatively short history, dating back to only about the mid-1990s, the literature has established few truly robust results to date.[8]

Coe and Helpman (1995), and Xu and Wang (1999) who have strengthened Coe and Helpman's results, have argued that their results point to international technology spillovers that are to some extent related to imports. At the same time, Keller (1998) generates almost as strong results with counterfactual instead of observed import data. This underlines that the evidence for imports-related technology spillovers on the basis of these regressions is not strong. More recent research has sought to provide a more powerful empirical framework by employing more disaggregated data and allowing for alternative spillover channels in addition to imports. This has produced mixed results so far: for instance, Keller's (2002b) industry-level analysis of technology spillovers among the G-7 countries finds evidence in support of imports-related effects,

[8] See Keller (2001) for more details on the following.

while Kraay, Isoalaga, and Tybout (2001) in their study of firm productivity dynamics in three less developed countries do not.

As for foreign direct investment, the focus in recent work is on multinational enterprises owning firm-specific technological knowledge assets that are internationally transferred between parent and subsidiaries (Markusen and Maskus 2001). This asset could be the basis for technology spillovers from inward FDI. However, the evidence that this occurs at all, and moreover, that this is quantitatively important for domestic productivity growth, is quite weak so far.

Among the recent studies using micro data, Aitken and Harrison (1999) find that an increase in the presence of foreign-owned subsidiaries at the industry-level is associated with lower productivity in a sample of Venezuelan plants in the late 1970s and 1980s. The authors attribute this result to strong competition and average cost effects—e.g., incoming foreign-owned subsidiaries hire the most highly skilled workers away from domestic plants—that far outweigh any positive FDI spillovers that might exist.

Girma and Wakelin (2001) as well as Haskel, Pereira, and Slaughter (2001) have recently studied inward FDI for the United Kingdom; these authors have tried to control for changes in the degree of competition to isolate FDI spillovers. Both studies find evidence for positive FDI spillovers, although the estimated productivity effects for U.K. plants are small: according to Haskel, Pereira, and Slaughter, e.g., the roughly 50% increase in the share of foreign employment—the measure of FDI--accounts for only about 5% of the TFP growth in British manufacturing in the two decades from 1973 to 1992.

Finally, Kinoshita (2001) has studied FDI spillovers in the Czech Republic using a short panel of firm-level data (the years 1995 to 1998). Arguably, firm-level data is best suited for studying international technology transfer and FDI spillovers, because the MNE's knowledge asset operates at the firm- and not the plant- (or establishment-) level. Corresponding to this, Kinoshita can incorporate the Czech firms' R&D expenditures into the analysis. In her analysis, she finds evidence for FDI spillovers for Czech firms that invest heavily into R&D—consistent with the notion of absorptive capacity--, but not for all domestic firms in general.[9]

Summarizing, there is some evidence for imports-related technology spillovers, but this evidence is far from ubiquitous, and in particular, it becomes weaker when micro data and relatively structural econometrics is being employed. Regarding FDI, there too is stronger evidence for spillovers when more aggregated data is employed. Among the recent studies that have employed micro data, only two find statistically significant positive productivity effects. Even here though, the estimated effects are small in an economic sense, and they are obtained by abstracting from all other mechanisms through which technology spillovers might operate. This is the background for our empirical analysis of imports- and FDI-related technology spillovers in the United States that follows.

3. Data and Econometric Approach

[9] See also the results by Baldwin, Braconier and Forslid (1999) and Xu (2000) who analyze industry-level data, as well as Branstetter (2000) who studies FDI spillovers between Japanese and U.S. firms by examining their patent citations.

The results presented in this draft are for relatively large and publicly traded manufacturing firms in the U.S. from Standard and Poor's Compustat database. A first selection criterion that we have employed is that all firms in the sample have data on sales for all ten years (1987-96). This means that we will not be able to address issues related to firm entry and exit at this point. At the same time, our sample covers the majority of U.S. manufacturing during this period in terms of employment and R&D (53.7% and 58.4% in 1992, respectively).[10]

The productivity of firms in the U.S. during this period has on average been relatively high, and perhaps higher than in any other country of the world. It might therefore be at first somewhat surprising that we try to identify technology spillovers to these already productive firms. Two points are worth noting in this respect. First, as we have discussed above, so far the evidence for technology spillovers is at least as strong for more- relative to less developed countries, which is consistent with the idea that a certain minimum, or threshold level of productivity is in fact needed for spillovers to materialize. When analyzing large, publicly listed U.S. firms, one can be fairly sure that this possible threshold level of productivity has been surpassed.

Second, and more importantly, we know from many recent studies that there is a lot of heterogeneity in terms of productivity across firms within one country. It is well established that MNE subsidiaries tend to be relatively productive compared to the average firm, even in the United States (e.g. Doms and Jensen 1998). Thus, even if foreign spillovers to the relatively productive

[10] We have prepared a larger, unbalanced data sample in the meantime, and are in the process of analyzing that sample. That sample covers up to 73% of all manufacturing R&D expenditures.

U.S.-owned firms were too small for us to identify, we should still be able to estimate those to U.S.-owned firms at the bottom of the productivity ranking in the United States, if there are any.[11] We are also able to distinguish U.S.-owned from foreign-owned firms that are located in the United States, as the Compustat data base has an identifier for foreign incorporated firms. This means that we can focus on spillovers to domestically owned firms in the United States.

To analyze firm productivity, we regress Compustat data on net sales for output (Y) on data on employment (L), capital stock (K), as well as materials (M) as standard inputs, plus other variables X' to be discussed below:[12]

(1) $$\ln Y_{it} = X_{it}' + a_1 \ln L_{it} + a_2 \ln K_{it} + a_3 \ln M_{it} + e_{it},$$

where i, i=1,…I is the firm indicator, and t, t=1,…,T, is the year indicator from 1987 to 1996.

Firm sales are deflated by a common deflator at the three-digit SIC level that we have constructed from the Bartelsman and Gray (2001) NBER Productivity data base, while the deflators for the capital stock come from the Bureau of Labor Statistics. We add the firm's R&D stock (R), which is derived from the firm's R&D expenditures using the perpetual inventory method. Not all data is available for all firms; for instance, a significant number of firms (about 15%) do

[11] Note that our foreign spillover estimates are up and beyond the externalities that one U.S.-owned firm might generate for another U.S.-owned firm.
[12] Firm data on the flow of materials usage is estimated from the change in the firm's stock of materials; for this and other details of the variables' definitions, see the Appendix A.

not report material input usage. In some cases we have had to fill in small amounts of missing data, typically for the firms' capital stocks.[13]

Our primary interest is whether productivity, conditional on the firm's R&D investments, is related to the importance of imports and foreign-owned subsidiaries in the firm's relevant economic environment. Of course, what this environment is is determined by the particular model one has in mind. Recall that the research on international technology spillovers is still in its infancy—questions of their existence are still at issue, and not so much yet specific mechanisms. In this paper, we therefore take a relatively broad approach, which also allows comparing our results with earlier research.

We measure the importance of imports for a given firm by the share of U.S. imports in imports plus total shipments at the industry level (denoted by IM) and correspondingly, the importance of FDI is measured by the share of foreign subsidiary employment in total employment by industry (denoted by FI). For both imports and FDI, our analysis is at a relatively detailed industry level (two to three-digit SIC level). This is determined by the roughly 50 industries in which the U.S. Bureau of Economic Analysis (BEA), responsible for reporting U.S. FDI data, is classifying total manufacturing activity; see Table 1 for a list of the industries.

Data on employment by foreign subsidiaries comes from confidential affiliate level data collected by the BEA in its annual surveys. This data is aggregated

[13] The data is cleaned from obvious errors, and we have further developed a data quality classification system, with four main categories. The results shown in the tables of this draft are based on the sample of domestically owned firms that report materials usage and whose data is relatively good (primarily based on year-to-year noise); these are 475 firms.

from the affiliate level to the level of the industry classification that we use. The employment figures are by the industry classification corresponding to the activity of the employee rather than the industry classification of the affiliate. The former is preferred, because it avoids the sudden shifts of a large number of employees from one industry to another industry that is associated with data on employment by affiliate if the affiliate's primary industry of sale changes. The imports data is obtained from Feenstra (2002), and the values for total shipments and employment by industry come from Bartelsman and Gray (2001).

These measures of imports and FDI are broadly capturing the prevalence, and more precisely the intensity, of foreign economic activity in a particular U.S. industry. If specialized imports are important in triggering technology spillovers, or if foreign subsidiaries generate positive externalities for U.S. firms by building up more efficient supplier chains or a pool of highly skilled technicians, it is plausible that this is correlated with the intensity of foreign presence in that industry.[14]

A number of other variables will be employed in our attempt to isolate the possible externalities associated with imports and FDI. First, we include a variable that picks up the degree of capacity utilization (denoted as CU), for instance hours worked in the case of labor. The number of workers a firm hires is likely to be positively related to both hours worked as well as sales, which means that we might be overestimating the coefficient on labor if capacity utilization is not controlled for.

[14] Our measures will not be able to pick up externalities that are generated between major industries (vertical production specialization); however, many important buyer-supplier relationships will be within our still relatively broadly defined industry classification.

Second, in discussing the existing literature, we have noted above that it is important to control for changes in the degree of market competition associated with changes in foreign penetration if one's goal is to isolate any technology spillover effects. We follow Nickell (1996) and others and use the firm's market share in the industry (denoted by MS) as well as the ratio of net rents (or profits) to sales (denoted by PI) to capture these effects. To the extent that a higher market share or higher profits indicate less competitive pressures, we expect that a firm's productivity growth slows down, all else equal.

There is a substantial degree of heterogeneity across firms in our sample that we cannot observe. For the most part, we therefore estimate the relationship between sales on the one, and the inputs, imports, and FDI on the other hand by time-differencing the data. This will eliminate determinants of firm productivity that are invariant over time. Simultaneity might affect our estimation results to the extent that the unobserved firm effect is not time-invariant. In addition, endogeneity of imports and FDI could be an issue. For instance, FDI could be attracted to industries in which productivity is growing relatively fast on average. This would also lead to a positive correlation of FDI and productivity, but it would not be evidence in favor of FDI-related technology spillovers.

To address the issue of simultaneity of input choice, we have also computed productivity along the lines of the Olley and Pakes (1996) model. That paper provides a structural framework for studying firm productivity dynamics that does not rely on the assumption that firm heterogeneity is invariant over time. The endogeneity issue of foreign presence, imports and/or FDI, and productivity is currently primarily by considering not only the contemporaneous relationship between productivity and foreign penetration, but also that of current productivity with lagged imports and FDI.[15]

Finally, we will also consider industry and time fixed effects, a_j and a_t, respectively, to control for other unobserved differences in productivity growth. Thus, we will estimate the following equation:

$$\text{(2)} \qquad \begin{aligned} \Delta y_{it} = a_j + a_t + b_1 \Delta l_{it} + b_2 \Delta k_{it} + b_3 \Delta m_{it} + b_4 \Delta r_{it} + \\ b_5 \Delta CU_{it} + b_6 \Delta ms_{it-2} + bPI_{it-2} + g_1 \Delta IM_{it} + g_2 \Delta FI_{it} + e_{it}, \end{aligned}$$

where the symbol ΔX indicates time-differences of any variable X. Lower-case variables denote the natural logarithm of the corresponding capital letter variable, and we assume that the error e_{it} has mean zero and constant variance.[16]

4. Empirical results

It is useful to analyze the main trends in productivity, imports, and FDI by industry before discussing the regression results. This draft focuses on the sub sample of U.S.-owned firms that report materials usage and that have relatively high quality data; as noted above, this reduces the sample to 475 firms. Among these firms and over the period of 1987-96, sales have grown on average by 6.3%, while employment and capital have grown by 1.5% and 5.6%, respectively.

[15] To develop a structural framework that incorporates also the choice of firms to import or interact with foreign-owned subsidiaries is left for future work.

[16] Correspondingly, for the Olley-Pakes estimation, a productivity growth residual computed from output, labor, capital, and materials is regressed on the remaining variables on the right hand side of equation (2).

Materials usage has grown by 5.4%, considerably less than R&D growth, which was at 7.5%.

There are large differences across industries. For instance, there are three industries for which in our sample, the firms' labor input is declining on average by more than 5% annually (SIC 204, SIC 208, and SIC 230), while at the same time there are four industries for which employment is growing annually by more than 5% per year on average (these are SIC 283, SIC 341, SIC 352 and SIC 355). Our sample period also covers the year of 1991, which witnessed the most recent recession before the current one in the United States.

The U.S. firms in our sample have increasingly been exposed to import competition; see Table 2 for some major trends in imports and FDI over the sample period. In 1987, the average (median) ratio of imports to shipments (which we will refer to as import share) was 18.5% (11.6%), while by 1996, the average (median) import share had risen to 25.8% (18.1%). The annual growth of imports these firms were facing was almost twice as high as the growth in industry shipments. In addition, this increase in the import share over time is more or less monotonic.

Also the share of foreign employment by industry has been growing over time, from 7.7% in 1987 to 11.4% in 1996. However, in this case, we can distinguish to separate phases of FDI dynamics into the United States. Between 1987 and 1993, FDI grew particularly strongly, from 7.7% to 12.3%. In the aftermath of the 1991 recession, however, foreign investors receded somewhat from the U.S. market.[17]

4.1 Baseline Estimation Results

We now turn to the regression results. Table 3 shows results for several versions of equation 2 from above. These are one-year differences (or, annual growth rates) for sales, capital, employment, and so on. The market share and profits variables on the right hand side are lagged by two years to reduce endogeneity problems. The imports variable (IM), defined as the share of imports in imports plus shipments, and the FDI variable (FI), defined as the share of employment in foreign-owned subsidiaries in total employment, both at the industry level, enter as the absolute change in these ratios.

In the upper part, we report the production function estimates, R&D, and the control variables, whereas the imports and FDI estimates are found in the lower part of Table 3. Specifications (1) to (3) have both time as well as industry fixed effects, whereas specifications (4) to (6) have only time fixed effects. In general, we estimate elasticities for labor, capital, and materials of about 0.45, 0.2, and 0.12, respectively, all significantly different from zero at standard levels (White heteroskedasticity-consistent standard errors are reported in parentheses).[18] The R&D elasticity is estimated between 5% and 9%, and

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[17] The trend towards greater internationalization has continued also in terms of FDI, however. According to the latest available figures from the BEA and the Bureau of Labor Statistics (BLS), in 1999, the share of foreign employment in U.S. manufacturing was 14.1%.

[18] The elasticity estimates for capital, and perhaps that for materials, are relatively low; this is a well-known consequence of the strategy of differencing to eliminate firm-level heterogeneity, see Griliches and Mairesse (1995) for a discussion. Using the Olley and Pakes (1996) method suggests that the capital coefficient is between 0.28 and 0.30.

generally significant, at least at a 10% level. This range of estimates is essentially the same as in influential earlier estimates of firm-level R&D elasticities (Griliches 1995).

What about the control variables? First, the definition of the capacity utilization variable is the change of the capital stock over production worker hours in the industry. To the extent that hours are adjusted faster to changes in demand than the capital stock, this is a measure of changes in capacity utilization over the business cycle as well as other shocks. The negative coefficient confirms that some changes in sales are due only to changes in the utilization of a given set of inputs, in contrast to a higher or lower number of inputs as such. Second, both a higher market share and higher rents are associated with lower sales growth, all else equal, although the coefficients are not always significantly different from zero. These results are consistent with MS and PI being indicators of market power that is associated with less output growth and the 'leisurely life of the monopolist'.

Turning to the foreign economic activity variables, specification (1) includes both the import share as well as the FDI share. Moreover, because little is known to date on what the time horizon is over which such technology spillovers might operate, we include both the contemporaneous as well as lagged effects (one and two years of lag). The coefficients for the change in the import share effects in (1) are all estimated to be negative. This would suggest that an increase in the import share is associated with lower, not higher productivity growth. However, the import share coefficients are estimated quite imprecisely, and none of the estimates is significantly different from zero at standard levels. The result of no significant effect from imports is confirmed by the F-test at the bottom of the table.

In contrast, the FDI share estimates are positive, and in two cases also significant. These results are consistent with positive spillovers associated with FDI activity. In specifications (2) and (3) we have separated the contemporaneous from the once- and twice-lagged effects; however, the results are overall quite similar.

Specification (4) is the same as (1), except that we drop the industry fixed effects. This turns out to change the import share estimates qualitatively. Now, we estimate a large positive association of changes in import shares and productivity, consistent with technology spillovers from imports. As the results for specifications (5) and (6) show, this is not dependent on considering only contemporaneous or only lagged imports. For the FDI variables, dropping the industry fixed effects leads to somewhat lower point estimates, especially for the twice-lagged coefficient, which is now negative. The overall relationship between FDI and productivity based on the full specification (4), with all lags, is still estimated to be positive.

Even though it will be shown below that the estimates with and without industry fixed effects do in fact not qualitatively differ with respect to the effect of imports,[19] for now we note that using these fixed effects in the estimation is strongly preferred: otherwise it is easy to imagine picking up some cross-industry

[19] The result differences have largely to do with the influence of the shipments variable, the denominator in our import share variable; see below.

differences in productivity growth and changes in foreign presence due to some unobserved third factor, a factor that is correlated with both. In contrast, with the inclusion of industry fixed effects, we allow for exogenous differences across industries in their average productivity growth and changes in foreign presence, and the spillover estimates are only identified from differences in growth and foreign presence relative to these industry-specific means.

4.2 Robustness: Long Differences, LSDV, and Olley-Pakes Productivity Residual

In Table 4 we report a number of additional specifications to examine the robustness of our estimates.[20] First, we consider longer instead of one-year differences, both for the regression with and without industry fixed effects. The first two columns of Table 4 show estimates based on two-year differences, while the next two columns are three-year differences results. With industry fixed effects, changes in the import share remains negatively related with productivity growth, and changes in the FDI share have a positive point estimate. However, with longer differences, the coefficients are increasingly imprecisely estimated, and the FDI effect is not always statistically significant.

This has primarily to do with the smaller sample size. Taking longer, non-overlapping differences means that we rapidly lose observations compared to the one-year differences case. Moving from one-year to two-year differences roughly

[20] We do not report the production function coefficients and those on R&D and the control variables to economize on space; there are no major differences in these except that the coefficient on K falls to between 0.13 and 0.15, while the labor elasticity rises to between 0.62 and 0.69. These results are available upon request.

halves the sample size, for instance. While taking long differences might have a number of advantages (e.g., it reduces measurement error problems), we think that here, this is outweighed by the disadvantage of an increasingly small number of observations for each industry, from which we identify the FDI and imports effects. Columns (2) and (4) in Table 4 show the two- and three-year differences results without industry fixed effects. They confirm the Table 3 results in that there is a strong positive cross-sectional correlation of import share growth and productivity growth—but not necessarily evidence for technology spillovers through imports.

Instead of eliminating unobserved heterogeneity at the firm level through time differencing, another frequently used method is the within (LSDV) estimator, which is the basis for specifications (5) and (6) in Table 4. The dependent variable is now the log of sales, and also the right hand side variables are transformed into level variables. In addition to the firm and time fixed effects, we include also industry-specific time trends. In this level specification, these trends capture exogenous industry differences in productivity growth, corresponding to the industry fixed effects in the time-differencing (growth) regressions from above. In the specification with industry-specific time trend (5), the effect of imports is not significant, whereas that of FDI is significant at 0.446. As the last column of Table 4 shows, eliminating the industry-specific time trend leads to a large positive coefficient on imports, whereas the effect of FDI falls to zero or below that. Thus, our within results are similar to the time-differencing results from above.

As noted earlier, we have also started to compute firm productivity series along the lines proposed by Olley and Pakes (1996). In their model, investment is used to identify firm productivity, which allows to address the possibility of firm productivity that varies over time. Moreover, we take into account the effect of firm exit on the coefficient estimates.[21] When we regress Olley and Pakes-type productivity growth on the FDI variable and controls, we find similar results, both qualitatively and quantitatively, as with the differencing specifications.

To sum up our results so far, we find evidence for positive technology spillovers from FDI in this sample of U.S. firms. Quantitatively, our point estimates for the effect of changes in the FDI share on productivity differ, but for the preferred specifications—see (1) and (2) of Table 3--, they are about 0.25 for the contemporaneous effect, and 0.70 for the cumulative effect of FDI (including lags). A discussion of what these estimates mean on the importance of FDI for productivity growth is provided further below; at this point, we simply note that these estimates suggest that FDI spillovers influence productivity growth in a major way.

With respect to imports, our results so far show no robust evidence for technology spillovers. We find a positive correlation of changes in the import share and productivity growth in the cross-section, but there are good reasons to believe that these cross-sectional correlations are spurious as evidence on spillovers. Does that mean that there are positive spillovers from FDI, but not from imports? Perhaps. But notice that our foreign presence variables IM and FI

[21] The probability of exit and a firm's size (e.g., its capital stock) are negatively correlated, because typically it requires a succession of bad shocks to drive a large firm out of business, whereas one shock might be enough in the case of a small firm.

are the changes in ratios. These are not only affected by changes in imports and foreign employment, but also by the dynamics of industry employment and shipments, the denominators of the FI and IM variables, respectively. In the next section, we isolate the relationships of imports and foreign employment on the one, and productivity growth on the other to make sure that our results are not driven by particular industry-level U.S. trends across industries.

4.3 FDI and Imports Dynamics versus U.S. Industry Trends

The FDI variable on the right hand side of equation (2) is the (absolute) change in foreign employment over total employment, while the imports variable is the change in U.S. imports over total industry shipments. We now analyze whether a change in foreign employment by itself, conditional on the share of foreign employment, has a significant effect on productivity; and analogously for imports.

Instead of the variable FI, we thus include the lagged employment share (denoted by f_{t-1}/e_{t-1}), the rate of growth of foreign employment (equal to $(f_t-f_{t-1})/f_{t-1}$), and the interaction of these two as separate regressors. Note that the interaction term is of particular interest, because it is equal to $(f_t-f_{t-1})/e_{t-1}$, which measures the effect of a change in foreign employment, holding total employment at the initial level. There are three regressors for imports that are analogous, with the interaction term measuring the effect of a change in imports, holding industry shipments at the initial level. The results of this can be seen in Table 5.[22]

In specification (1), we include the three regressors both for current (that is, contemporaneous) as well as one year lagged FDI and imports. The coefficients on the FDI interaction variable are 0.729 and 0.456, respectively, and as the F-tests at the bottom of the table indicate, the effects from both current and lagged FDI are jointly significant at standard levels. These are consistent with our earlier findings, and the results from specifications (2) and (3) indicate that this result holds also for the current and lagged effect from FDI taken one at a time.

In contrast, for imports our results are now different from those of Table 3. Here, the point estimate of the interaction of import growth and lagged import share is positive throughout, ranging from 0.138 to 0.408, and not negative, as was typically the case when employing the import share as the regressor (see Table 1). The individual coefficients are not all significantly different from zero, but as the F-tests at the bottom of Table 5 indicate, in three out of four cases (not for lagged imports in specification (1)), the joint effect of imports has a significantly positive effect on productivity growth.

This analysis suggests that the earlier results of Table 3 to the contrary are largely driven by a strong cross-industry correlation of productivity growth and changes in shipments, together with the parameter restrictions that one imposes by using the import share variable. This constitutes some evidence in

[22] These specifications are based on one-year differences, with time and industry fixed effects, as in (1) to (3) of Table 3; we do not report in Table 5 the production function-, R&D-, and control variable coefficients.

favor of imports related technology spillovers. At the same time, the evidence for FDI spillovers is stronger than that for import spillovers in our analysis, because it is more robust. Before turning to a brief analysis of the effects on productivity that are implied by these estimates, in the next analysis we consider the interaction of foreign presence and firm-level R&D investments.

4.4 Foreign technology spillovers and absorptive capacity

In the context of technology spillovers between domestic firms, there is evidence that the benefits that a firm receives through the externalities provided by others is increasing in the firm's own R&D spending. This notion has been emphasized first by Cohen and Levinthal (1989), who called it 'absorptive capacity'. The following extends this idea to the open-economy context by showing some preliminary results on the interaction of foreign presence and domestic technological investments, as measure by firm-level R&D spending.

We interact our FDI and imports variable of Table 3 (that is, the change in the share of foreign employment, and the share of imports in imports plus shipments, respectively) with the growth rate of the firm's R&D stock. It turns out that we do not estimate significant effects associated with imports at this point.[23] With respect to FDI, the following picture emerges. In specification (2) for instance, which focuses on the contemporaneous relationship of FDI and productivity, we estimate a coefficient of 0.128 for the change of foreign employment, and a coefficient of about 1.694 on its interaction with R&D growth.

[23] Because this is likely to be in part due to the influence of shipment growth—see the analysis in Table 5--, we take these results to be very preliminary.

As indicated by the F-test at the bottom, the FDI effects are jointly significant at a 5% level.

Comparing these results with those of specification (2) in Table 3, which is identical except for the R&D interaction, illustrates the role of the firm's own technological investments. In Table 3, we estimated a coefficient on FDI, common to all firms, of 0.243, while it is now only 0.128. The interaction effect differentiates the U.S. firms in how much they benefit from the technology spillovers associated with FDI. The average R&D growth rate, as noted above, is 7.5%, times the coefficient of 1.694 equals 0.127. Thus, the total effect associated with FDI for the firm with average R&D growth is 0.128 plus 0.127 equals 0.255, which is only slightly above the estimate from Table 3 without the R&D interaction. However, a firm at the twenty-fifth percentile of annual R&D growth in this sample exhibits only a growth rate of 0.011, whereas at the seventy-fifth percentile, it is 0.118. On the basis of the estimated coefficients, this translates into a total spillover effect of 14.7% for the lower R&D growth-firm, and an effect of 32.8% for the higher R&D growth-firm. Thus, our results suggest that the FDI spillovers reaped by high-R&D firms are considerably higher than those for low-R&D firms, which is consistent with the notion of absorptive capacity. We now turn to a preliminary summary and discussion of our results.

5. Summary and discussion (preliminary)

In this paper, we have examined the evidence on imports- and FDI-related spillovers to U.S. firms between the years of 1987 and 1996. While clearly preliminary, the analysis has produced some interesting results. First, we estimate that U.S. manufacturing firms on the whole benefit significantly from technology spillovers associated with inward FDI into the United States. This finding is robust to employing a variety of different estimation techniques, from differencing to Olley and Pakes (1996) type regressions. Second, we have also shown that these spillovers vary substantially in magnitude, and specifically, they are increasing in the U.S. firm's own technological investments in terms of R&D. In some specifications, we also find evidence for spillovers associated with imports, although our analysis in this respect is more preliminary.

We have already noted above that our FDI spillover estimates are large compared to earlier estimates. In the end, the major question is how important the estimated spillovers are for overall productivity growth, because this is the central issue from a policy point of view. A rough calculation that illustrates economic magnitudes is as follows.

The share of foreign employment in U.S. manufacturing rose between 1987 and 1996 from 7.7% to 11.4%, or by 3.7 percentage points. Our preferred estimate of the FDI spillover elasticity lies between about 0.25 and 0.70.[24] According to the Bureau of Labor Statistics (2002), multifactor productivity growth in U.S. manufacturing between 1987 and 1996 was 6.7%. This means that an estimate for the share of U.S. manufacturing productivity growth that is associated with contemporaneous FDI spillovers according to our estimates is

[24] These are the contemporaneous and the cumulative effects, respectively, from specifications (1) and (2) of Table 3.

0.25*0.037/0.067, or about 14%, and the effect from both current and lagged FDI might be substantially larger than that.

It will of course be important to see whether our results turn out to be robust in further analysis, and the specific magnitudes that we have just calculated might also depend to some extent on our particular sample of firms, as well as on the specifics of the period of 1987 to 1996.[25] We speculate that our results are not so much special to a particular set of firms, time period, or country, though. Rather, we think that we estimate stronger productivity effects through FDI spillovers than the earlier literature because we measure FDI changes better—thus it should be possible to replicate our result with other samples once the better data becomes available.[26] In any case, if our results hold up, they would constitute the strongest evidence that we are aware of that could support the provision of subsidies to attract FDI from a viewpoint of social welfare. The next question, of course, would be whether a socially optimal policy is indeed implemented, given the political-economic realities of local electoral competition.

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[25] For one, we might consider other measures of multi-factor productivity (MFP) growth. According to the NBER Manufacturing Productivity database, four-factor MFP grew between 1987-96 on average by 9.3% (if industries are weighted by value added); note that none of these measures of MFP control for the effect of R&D, which would reduce these figures further. A second possibility is to compute MFP growth in our Compustat sample, but this is complicated by the fact that we estimate a scale elasticity of less than one. Imposing constant returns to scale, we estimate that the median firm's MFP grew between 1987 and 1996 by 6.25%.

[26] Recall that our FDI measure by industry is foreign employment by detailed activity within the affiliate, not the foreign employment by the affiliate as a whole. If instead we use the latter, as most of the existing literature, we estimate no or much smaller FDI spillovers as well.

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Appendix A: Variable definitions and sources

- Sales (denoted Y): Net sales, from Compustat's Industrial data file (data item 12); deflated by industry-level price index aggregated up from Bartelsman and Gray (2001).
- Labor (L): Number of employees, from Compustat (data item 29).
- Capital (K): value of property, plant and equipment, net of depreciation, from Compustat (data item 42); deflators are from the BEA satellite accounts.
- Materials (M): Estimated from Compustat's firm-level data on year-end raw materials inventory (data item 76), and the correlation of raw materials inventory and raw materials usage across 4-digit SIC industries, from Bartelsman and Gray (2001) and Manufacturing Census data kindly provided by Wayne Gray; deflators from Bartelsman and Gray (2001).
- R&D (denoted by R): Research and development expense, from Compustat (data item 46); R&D stocks are constructed from the R&D expenditure data using the perpetual inventory method (R&D depreciation rate is assumed to be 10%). The initial R&D capital stock is estimated from R&D expenditures between 1972-82 whenever data was available; for the remainder of firm's, we have made the assumption that in 1982, firms were in steady-state, and used the perpetual inventory method from there; deflators are from the BEA satellite accounts until 1992; beyond that, we have estimated them using the variation across industries and over time of the deflators for capital.
- Capacity utilization (CU): is defined as the ratio of capital stock over total hours of production workers, at the BEA industry level; aggregated up from the 4-digit SIC data in Bartelsman and Gray (2001).
- Rents (PI): Defined as firm's net income, from Compustat (data item 172), over sales.
- Market share (MS): Defined as firm sales over total BEA industry sales (constructed from Bartelsman and Gray 2001).
- Import share (IM): U.S. imports by industry, from Feenstra (2002), over U.S. imports plus total shipments by industry; the latter from Bartelsman and Gray (2001).
- FDI share (FI): Foreign affiliate employment by industry of activity, aggregated from the affiliate level to the BEA industry level, over total U.S. employment by BEA industry; source: confidential affiliate level FDI data at the BEA.

In addition, for the Olley and Pakes (1996) productivity estimates, we have used

- Investment: Capital expenditures, from Compustat (data item 128); investment deflators by 4-digit SIC industry are from Bartelsman and Gray (2001).

Following Jovanovic and Rousseau (2002), we have also computed and used an alternative investment series that takes into account acquisitions (Compustat data item 129) and divestitures (Compustat data item 107).

Table 1: Industry Classification of the Bureau of Economic Analysis (BEA)

BEA Code	BEA Name	BEA Code	BEA Name
	Food and kindred products		**Textile and Apparel**
208	Beverages	220	Textile mill products
201	Meat products	230	Apparel and other textile products
203	Preserved fruits and vegetables		
204	Grain mill products		**Wood and Furniture**
209	Other food and kindred products	240	Lumber and wood products
		250	Furniture and fixtures
	Chemicals and allied products		
281	Industrial chemicals and synthetics		**Paper**
283	Drugs	262	Pulp, paper, and board mills
284	Soap, cleaners, and toilet goods	265	Other paper and allied products
287	Agricultural chemicals		
289	Chemical products, nec	270	**Printing and publishing**
	Primary metal industries		**Rubber and Plastic**
331	Ferrous	305	Rubber products
335	Nonferrous	308	Miscellaneous plastics products
	Fabricated metal products		**Glass, Stone, and Mineral**
341	Metal cans, forgings, and stampings	321	Glass products
342	Cutlery, hardware, and screw products	329	Stone, clay, concrete, etc
343	Heating equip., plumbing and structural		
349	Metal services, ordnance, and nec		**Transport Equipiment**
		371	Motor vehicles
	Machinery	379	Other transportation
357	Computer and office equip.		
351	Engines and turbines		**Instruments**
352	Farm and garden	381	Measuring, scientific, and optical
353	Construction, mining, and material handling	384	Medical and ophthalmic
354	Metalworking	386	Photographic equipment
355	Special industry		
356	General industrial		**Other Manufacturing**
358	Refrigeration and service industry	210	Tobacco
359	Industrial machinery, nec	310	Leather
		390	Miscellaneous
	Electronic		
363	Household appliances		
366	Audio, video, and communications		
367	Electronic components and accessories		
369	Electronic, nec		

TABLE 2: Foreign Penetration by Aggregated BEA Industries

	FDI Share			Import Share		
	1988	1992	1996	1988	1992	1996
Food and Kindred Products	10.8	11.9	9.3	3.6	3.7	4.1
Textile Mill Products	4.6	6.7	7.5	7.4	8.8	10.1
Apparel and Oth. Textile	1.5	3.2	4.6	23.9	29.1	33.4
Wood and Furniture	2.2	2.6	2.1	7.4	8.5	11.2
Paper	6.8	7.5	8.5	8.8	8.0	9.0
Printing and Publishing	6	6.6	7.2	1.2	1.2	1.5
Chemicals	27.2	32.1	30.7	7.9	9.2	11.4
Rubber and Plastic	10.8	14.8	14.7	6.7	7.5	8.6
Stone, Glass, and Mineral	15.7	20.8	21	8.7	9.5	10.5
Primary metals	10.6	15.9	14.1	14.3	15.0	18.1
Fabricated Metals	5.9	8.3	8.6	4.9	5.6	6.6
Industrial Machines	7.5	11.2	11	18.9	22.9	24.5
Electronics	13.7	17.2	18	20.8	25.2	27.3
Motor Vehicles	7.4	11	14.2	27.6	26.0	26.7
Other Transport	2.3	4.9	3.6	7.6	9.2	12.9
Instruments	8.2	11.9	12.8	11.6	12.5	15.6
Other Manufacturing	6.3	10.2	7.6	30.3	31.9	37.1

TABLE 3: BASELINE, ONE-YEAR DIFFERENCES

Dependent Variable = Change log Sales

	(1)	(2)	(3)	(4)	(5)	(6)
Employment	0.463	0.472	0.465	0.452	0.462	0.453
	(0.031)	(0.028)	(0.031)	(0.030)	(0.027)	(0.029)
Capital	0.200	0.196	0.194	0.209	0.201	0.207
	(0.035)	(0.031)	(0.035)	(0.035)	(0.032)	(0.035)
Materials	0.128	0.122	0.128	0.121	0.114	0.121
	(0.017)	(0.016)	(0.017)	(0.018)	(0.017)	(0.018)
R&D	0.053	0.049	0.054	0.084	0.09	0.086
	(0.035)	(0.032)	(0.035)	(0.034)	(0.031)	(0.034)
Capacity Util.	-0.002	-0.002	-0.002	-0.0007	0.001	-0.0005
	(0.0008)	(0.0008)	(0.0008)	(0.0007)	(0.0007)	(0.0007)
Lag Rents	-0.022	-0.025	-0.023	-0.029	-0.03	-0.03
	(0.015)	(0.014)	(0.014)	(0.017)	(0.016)	(0.016)
Lag Market Share	-0.130	-0.148	-0.146	-0.119	-0.109	-0.118
	(0.088)	(0.096)	(0.095)	(0.066)	(0.068)	(0.065)
Import Share						
Current	-0.25	-0.306		0.191	0.802	
	(0.320)	(0.294)		(0.304)	(0.272)	
Lagged One	-0.323		-0.312	1.428		1.434
	(0.334)		(0.333)	(0.29)		(0.292)
Lagged Two	-0.121		-0.137	1.676		1.662
	(0.307)		(0.305)	(0.269)		(0.266)
FDI Share						
Current	0.318	0.243		0.231	0.122	
	(0.128)	(0.107)		(0.123)	(0.108)	
Lagged One	0.379		0.342	0.24		0.225
	(0.125)		(0.126)	(0.124)		(0.124)
Lagged Two	0.067		-0.005	-0.25		-0.296
	(0.128)		(0.123)	(0.123)		(0.121)
Industry Fixed Eff.	YES	YES	YES	NO	NO	NO
Year Fixed Eff.	YES	YES	YES	YES	YES	YES
N	3,333	3,809	3,333	3,333	3,809	3,333
R-squared	0.492	0.494	0.491	0.443	0.435	0.442
F-stat (imports)	0.48	1.08	0.51	27.95	8.72	41.06
p-value	(0.69)	(0.299)	(0.600)	(0.0000)	(0.003)	(0.0000)
F-stat (FDI)	4.43	5.15	3.68	3.75	1.26	4.14
p-value	(0.0041)	(0.0233)	(0.025)	(0.0106)	(0.26)	(0.016)

Standard Errors Shown in parentheses are heteroskedasticity-consistent (White)

TABLE 4: Robustness

	Two-year differences*		Three-year differences**		Within estimator***	
	(1)	(2)	(3)	(4)	(5)	(6)
Import Share	-1.05	1.282	-0.762	1.71	-0.325	3.48
	(0.364)	(0.329)	(0.450)	(0.338)	(0.323)	(0.250)
FDI Share	0.435	0.103	0.175	-0.053	0.446	-0.323
	(0.147)	(0.152)	(0.174)	(0.168)	(0.155)	(0.154)
Industry Fixed Eff.	YES	NO	YES	NO	NO	NO
Year Fixed Eff.	YES	YES	YES	YES	YES	YES
Industry trends	NO	NO	NO	NO	YES	NO
Firm Fixed Eff.	NO	NO	NO	NO	YES	YES
N	1,905	1,905	1,425	1,425	3821	3821
R-squared	0.707	0.612	0.765	0.654	0.82	0.72
F-stat (imports)	8.31	15.23	2.87	25.56	1.01	193.94
p-value	(0.00)	(0.00)	(0.09)	(0.00)	(0.31)	(0.00)
F-stat (FDI)	8.72	0.46	1.01	0.34	8.26	4.41
p-value	(0.00)	(0.50)	(0.32)	(0.75)	(0.00)	(0.04)

* Dependent variable: two-year change in log sales
** Dependent variable: three-year change in log sales
*** Dependent variable: log sales
All regressions include also the following variables: employment, capital, materials, R&D, capacity utilization, rents, and profits
Standard errors shown in parentheses are heteroskedasticity-consistent (White)

TABLE 5: Imports- and foreign employment dynamics

Dependent variable: change in log sales

	(1)	(2)	(3)
Imports - Current			
Lagged Import Share	0.285	0.446	
	(0.432)	(0.183)	
Growth in Real Imports	0.056	0.057	
	(0.042)	(0.041)	
Interaction	0.347	0.408	
	(0.255)	(0.248)	
Imports-Lagged One			
Lagged Import Share	0.138		0.292
	(0.388)		(0.177)
Growth in Real Imports	-0.053		-0.064
	(0.039)		(0.038)
Interaction	0.138		0.332
	(0.292)		(0.254)
FDI - Current			
Lagged FDI share	-0.223	0.253	
	(0.390)	(0.122)	
Growth in FDI employ	-0.069	-0.075	
	(0.025)	(0.025)	
Interaction	0.729	0.799	
	(0.182)	(0.185)	
FDI - Lagged One			
Lagged FDI share	0.356		-0.112
	(0.361)		(0.104)
Growth in FDI employ	0.029		0.028
	(0.025)		(0.025)
Interaction	0.456		0.095
	(0.339)		(0.160)
N	3,809	3,809	3,809
R2	0.499	0.498	0.496
F-Test Import Current	3.23	5.97	
	(0.022)	(0.001)	
F-Test Import Lagged	1.13		2.78
	(0.335)		(0.040)
F-Test FDI Current	5.62	6.26	
	(0.001)	(0.0003)	
F-test FDI lagged	2.61		3.31
	(0.050)		(0.019)

Note: Fixed effects by industry and year
Controls and firm variables are included, but not reported
Standard errors in parentheses are heteroskedasticity-consistent (White)

TABLE 6: The Interaction of R&D with FDI and Imports

	(1)	(2)	(3)
R&D - Current	0.099	0.048	0.103
	(0.059)	(0.037)	(0.057)
R&D - Lagged	-0.041		-0.039
	(0.049)		(0.050)
Imports - Current			
IMPSH	-0.232	-0.181	
	(0.364)	(0.363)	
IMPSH*RD	-0.545	-1.484	
	(2.71)	(2.624)	
Imports - Lagged			
IMPSH	-0.025		0.009
	(0.355)		(0.347)
IMPSH*RD	-3.65		-3.766
	(2.617)		(2.474)
FDI - Current			
FDI	0.161	0.128	
	(0.128)	(0.127)	
FDI*RD	1.686	1.694	
	(1.200)	(1.206)	
FDI - Lagged			
FDI	0.318		0.281
	(0.144)		(0.145)
FDI*RD	0.045		0.403
	(1.100)		(1.09)
N	3809	3809	3809
R-Squared	0.496	0.494	0.495
F-test Imports-Current	0.46	0.69	
	(0.629)	(0.502)	
F-test Imports-Lagged	1.59		1.68
	(0.204)		(0.187)
F-test FDI-Current	3.94	3.25	
	(0.020)	(0.039)	
F-Test FDI-Lagged	4.01		3.81
	(0.018)		(0.022)

Note: One-year differences specification
Heteroskedasticity-consistent (White) standard errors in parentheses