WORKING PAPER SERIES*

DEPARTMENT OF ECONOMICS

ALFRED LERNER COLLEGE OF BUSINESS & ECONOMICS

UNIVERSITY OF DELAWARE

WORKING PAPER NO. 2010-11

KNOWLEDGE-CAPITAL, INTERNATIONAL TRADE AND FOREIGN DIRECT INVESTMENT: A SECTORAL ANALYSIS

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*http://lerner.udel.edu/economics/workingpaper.htm

Draft: March 11, 2010. Forthcoming in *Economic Inquiry*

Knowledge-Capital, International Trade and Foreign Direct Investment: A Sectoral Analysis

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Abstract

The knowledge-capital (KC) model of MNEs is now a widely adopted empirical approach to explaining the location and production decisions of global firms based on both horizontal and vertical motivations. While most of the existing studies have focused on highly aggregated national data, we extend this model to sectoral data consisting of broad manufacturing industries and explicitly account for the dynamic nature of international investment data. The empirical results from a dynamic panel data analysis indicate that that the predictions of the KC model regarding MNE behavior vary by the type of industry. Production processes in electronics and transportation-equipment are more characterized by efficient vertical specialization of R&D activities and assembly, while other sectors display more complex motivations.

Keywords: FDI, knowledge-capital model, exports, GMM
JEL Codes: F14, F23, L23

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1. Introduction

The relationship between foreign direct investment (FDI) and international trade has long generated great interest. This interest is sharpened by the phenomenal growth in the magnitude of global FDI flows in the last two decades. FDI arises from decisions of multinational enterprises (MNEs) either to capture local markets abroad through horizontal investments in similar products (Markusen, 1984; Horstmann and Markusen, 1992) or to take advantage of lower-cost factors offshore through vertical investments in labor-intensive assembly stages (Helpman, 1984). The knowledge-capital (KC) model of MNEs, as described in Markusen (2002) and initially estimated by Carr, Markusen, and Maskus (CMM, 2001), is now a widely used empirical approach for explaining the location and production decisions of global firms in an integrated framework. The model provides predictions about the nature of firms that arise endogenously in response to changes in market sizes, country similarity, factor endowments, impediments to trade and investment, and various interactions among them. The firms can be national exporters or either horizontal or vertical MNEs. The model also can be used to analyze joint decisions between production for local markets and exports, making it a theory of both investment and trade (Markusen and Maskus, 2002). Recently it has been extended to the context of three factor endowments (Bergstrand and Egger, 2007).

The contributions of this paper are three-fold. First, we investigate whether the KC model predictions hold for sectoral investment. The analysis examines the relationship between relative endowments of knowledge-based factors and other FDI determinants on local affiliate sales and exports. Specifically, we estimate the model for all manufacturing industries (aggregated) and several manufacturing industry sub-sectors (chemicals and allied products; electronics; food and kindred products; industrial machinery and equipment; transportation equipment). Surprisingly, few previous investigations have applied the knowledge-capital model to sectoral data.

Interest in industry-level analysis arises to the extent that firms in an industry display the KC model's basic characteristics of increasing returns associated with headquarters services. Those headquarters services include marketing, research and development (R&D), strategic planning, and related centralized activities that generate knowledge. Because the resulting information advantages may be shared at low cost among multiple locations, knowledge becomes the essential determinant of strategic decisions by MNEs. All manufacturing industries share these characteristics to some extent, though some are more R&D-intensive or marketing-intensive than others. At the same time, the underlying heterogeneity of firms suggests that different industries would react in varying ways to changes in the basic determinants of the KC model (Helpman, Melitz, and Yeaple, 2004). Accordingly, it becomes interesting to assess this variation, something that has not been widely studied to date.

Second, we adapt the three-endowment KC approach of Bergstrand and Egger (2007), which they applied solely to aggregate FDI data, to explicitly account in the empirical work for the role of differences in relative physical capital endowments on investment decisions at the sectoral level. Introduction of this third factor should offer a more robust explanation of industry-level MNE activities than relying only on skilled-labor and total labor.

Third, given the dynamic nature of investment decisions, we apply the generalized methods of moments (GMM) technique to a panel data set involving thirty-nine FDI-recipient countries over the fifteen-year period 1985-1999. This approach is an improvement on most previous empirical studies of the knowledge-capital model, for they adopted a static regression framework.

The main finding from this study is that differences in relative skilled-labor and physical-capital endowments have a positive and significant effect on foreign affiliate sales and exports across various industries. These results suggest that horizontal (market-seeking) FDI motivation for MNE activities is prevalent at the industry-level. The notable exceptions are in the electronics and machinery manufacturing sectors, where the empirical results show that differences in relative skill labor endowments have a positive effect on affiliate sales (suggesting vertical fragmentation) while differences in relative physical capital endowments reduce affiliate sales (suggesting market-seeking FDI in countries with similar capital stocks).

The remainder of this article is organized as follows. In Section 2 we lay out the KC model and note its predictions for affiliate sales and exports. In Section 3 we summarize the empirical methodology and discuss the data. In Section 4 we describe the empirical results and in Section 5 we present our conclusions.

2. The Knowledge-Capital Model

In this section we review earlier major studies of the KC model and discuss its theoretical underpinnings.

Overview of Previous Studies

Prior to the development of the KC model, previous analyses presented separate models for the two main types of FDI. In the case of horizontal FDI, MNEs set up duplicate production plants through affiliates in a foreign country in order to meet domestic demand in the host country. Thus, the potential determinants of horizontal FDI include market size and national income. Several studies have found empirical support for the importance of market size and income (Kravis and Lipsey, 1982; Schmitz and Bieri, 1972; CMM, 2001). Since horizontal FDI could potentially substitute for exports to host countries, the effect of trade barriers on FDI has also been widely debated. For example, under the tariff-jumping hypothesis FDI will be encouraged when there are obstacles to trade (Smith, 1987; Blonigen and Feenstra, 1997). Hence, when trade costs are low, trade liberalization is expected to reduce the level of horizontal FDI as goods can move more freely across countries. The empirical evidence has been mixed. While some studies found a positive relationship between trade barriers and FDI (Barrell and Pain, 1999), others have found conflicting results (Culem, 1988; Blonigen and Feenstra, 1997).

In the context of vertical FDI, MNEs exploit low-cost inputs by fragmenting their production processes into stages across countries so that skilled-labor-intensive (knowledge-based) production occurs at the skilled-labor abundant home country and unskilled-labor-intensive production (e.g., assembly processes) occurs in the foreign host country. Since vertical FDI often requires the export of final goods from host to home country, the ease of re-export is a key determinant of vertical FDI. While host nations' demand factors (e.g., market size and income) are not as important to vertical FDI, relative factor prices and trade costs are more relevant. Hence, previous empirical investigations of the determinants of vertical FDI have examined factors such as labor costs, trade openness, investment, and trade costs (Brainard, 1997; Markusen and Maskus, 2002).

Theoretical Model Structure

In this section we briefly overview the theoretical model developed in Markusen (2002) and CMM (2001). This approach includes three principal assumptions. First, the blueprints, manuals, formulas, and other services developed by knowledge-generating activities, such as R&D, may be performed at a centralized location and supplied to multiple production facilities at low cost. Second, these centralized activities are knowledge-intensive, and therefore skilled-labor intensive, relative to production. Third, such services are joint inputs and may be used simultaneously by many production plants. The first two assumptions are consistent with vertical fragmentation of the firm, locating R&D where skilled-labor is abundant and production where unskilled-labor is abundant. Further, if there are scale economies at the plant level, larger local market sizes will encourage inward production location. The third assumption, that knowledge is jointly used, supports organization-level scale economies and motivates horizontal investments to replicate activities in different locations.

The basic KC model assumes there are two goods, two countries, and two factors, unskilled-labor and skilled-labor, which are internationally immobile.[1] One good is labor-intensive and produced under constant returns to scale in a competitive industry. The other is skilled-labor-intensive and experiences both plant-level and firm-level increasing returns to scale. Firm-level increasing returns come by assuming that the total fixed costs of headquarters and two production plants are less than the total fixed costs of two single-plant firms. There is Cournot competition in this good under free entry and exit. Within a firm producing this good, headquarters services are centralized and a firm may have plants in one or both countries.

There are three types of firms in this model. First, there are horizontal MNEs that have production plants in both countries but headquarters in just one country. Second, there are national firms that maintain a single plant and headquarters in one of the countries. Third, there are vertical MNEs with a production plant in one country and headquarters in the other.

The determination of how prominent these firm types are in equilibrium depends on various country characteristics. The emergence of national firms is most likely when the home country is both large and skilled-labor abundant, encouraging such firms to combine headquarters services and production in one location, exporting to the other country. National firms also are most likely when the two nations are similar in size and relative factor endowments, while trade costs are low. In this case there is little payoff to vertical investment, while horizontal investment is discouraged by low transport costs. National firms are also likely where foreign investment barriers are high.

Horizontal MNEs are more likely to emerge when the nations are similar in size and relative endowments and transport costs are high. In this case MNEs will have headquarters in their home countries but locate production plants in each other's market. This is the classic case of market-seeking investment. Similarity in size is important for if there were a large disparity, firms in the larger country would avoid investing in costly capacity in the smaller country. Similarity in endowments matters because if the countries varied in relative skill and labor supplies the incentive would be to locate headquarters in the skill-abundant location and production plants in the labor-abundant place. This analysis therefore also suggests that vertical MNEs are favored where there are substantial endowment differences unless trade costs are high.

Predictions for export behavior in the KC model come under an assumption of identical and homothetic preferences and we simply describe them here (Markusen and Maskus, 2002). In cases where national firms tend to dominate there will be two-way trade in manufactured goods produced under increasing returns. As incentives for horizontal MNEs become stronger, either due to more similarity in relative endowments and size or to higher trade costs or lower investment costs, local affiliate sales will displace international trade. Here, horizontal investment is a substitute for international trade in goods.

However, where vertical MNEs are prevalent, due to significant differences in endowments and country size, exports from the host country to the parent country will be significant and dependent on trade costs. Further, while this possibility does not arise in the two-country KC model, affiliate production could be aimed at exports to third markets. In this case the investment could follow a mix of market-seeking horizontal incentives (e.g., Ireland within the larger EU) and factor-based vertical incentives (e.g., Mexico within NAFTA). Moreover, in this case trade and FDI could be complements as more investment supports more exports of assembled final goods (Blonigen, 2001).

In this context, differences among sectors become interesting. Some industries may be more likely to display essentially horizontal motivations for FDI and affiliate production, with limited exports back to the parent country and even to third markets. Others may reflect export-platform investment, following a mix of incentives (Ekholm, Forslid, and Markusen, 2007). Still others may be essentially vertical in nature, tending to fragment production according to relative factor costs. In short, location decisions are complex (Yeaple, 2003).

3. Econometric Specification

We turn next to our estimation approach and describe variable construction and data sources.

Model Specifications and Hypotheses

We follow the basic specification set out in Carr, Markusen, and Maskus (2001), which was designed to capture the complex non-linearities implied in the KC model. That specification is as follows:

$$AFFACT_{ujt}^{k} = \beta_o + \beta_1 GDPSUM_{ujt} + \beta_2 GDPDSQ_{ujt} + \beta_3 SKLDIFF_{ujt} + \beta_4 [GDPD_{ujt} * SKLD_{ujt}] + \beta_5 IC_{jt} + \beta_6 TC_{jt} + \beta_7 [TC_{jt} * SKLDSQ_{ujt}] + \beta_8 TC_{ut} + \varepsilon_{ujt}^{k} \quad (1)$$

where the subscript u indicates the United States (always the home nation), j indexes the destination (host) country, k designates the industry, and t denotes the year. The variables are defined as follows. *AFFACT* is a measure of the price-adjusted sectoral activity of affiliates in the host country, taken here to be total sales, sales in the local market, total exports, exports to the parent country, or exports to third countries. For some sectors there are not enough disclosed observations in the data to estimate equations for the last two variables.

GDPSUM is the sum of host-country GDP and parent-country GDP. We use only the outward FDI data in the publicly available database from the Bureau of Economic Analysis (BEA), implying that the parent country is always the United States. Its GDP varies over time but for any year the only variation across countries in *GDPSUM* is provided by the host-country figures. *GDPSUM* is a measure of total bilateral market size and should have a positive coefficient in all equations.

GDPDSQ is the squared difference in real GDP. The coefficient should be negative because the KC theory predicts that affiliate sales volume in horizontal production increases as market sizes become more equal. Again, the prediction is less clear for exports: higher affiliate total sales are needed to support more exports (a component of sales) but it is possible that a rise in local sales could substitute for exports, generating a negative coefficient on the latter.

SKLDIFF is the difference in the ratio of skilled employment to total employment between the parent and host countries. Because the United States is the parent in all our observations and is more skill-abundant than most countries in the panel data, this measure is positive in the bulk of cases, permitting us to avoid the problem with two-way data pointed out by Blonigen, Davies, and Head (2003).[2] The coefficient on this variable should be positive, because firms tend to have their headquarters in the skill-abundant country and an increase in this difference should expand incentives for vertical FDI. In subsequent specifications we add *PKDIFF*, or differences in physical-capital endowments (capital per worker) and estimate equations with both relative endowments included. The impacts of physical capital should be qualitatively similar to those of skills in this extended model.

The next variable is the product of the difference in GDP and the difference in relative skill endowments *(GDPD*SKLD)*. *GDPD* is positive in all observations, given the large size of the US economy. From the basic KC theory it is possible to predict that this coefficient should be negative. The United States is considerably larger in GDP than its investment partners. Giving the United States more skilled-labor (an increase in *SKLDIFF*) in this situation would diminish incentives for horizontal FDI relative to expanded incentives for vertical investment. In short, this variable is designed to capture the tradeoffs as the data depart from similar relative endowments, given large differences in country size.

The variable *IC* is a measure of perceived investment costs in the host country and should have a negative coefficient. Trade costs in the host country are measured by TC_j and it should have a positive coefficient on sales and local sales. Trade costs in the parent country are measured by TC_u and it should have a negative impact on sales and exports to the United States. We also include an interaction term between host-country trade costs and squared skill-labor endowment differences. This variable attempts to capture the ideas that increases in trade costs could encourage horizontal FDI, while diminishing vertical FDI. Recall that because horizontal incentives are greatest when relative skill endowments are close together. Thus, for given level of trade costs an increase in endowment differences should reduce horizontal FDI and the coefficient should be negative. However, this is a weak prediction given the multiple tradeoffs involved. [3]

General Method of Moments (GMM) Estimation

Given the availability of panel data, a simple pooled ordinary least-squares (OLS) regression of equation (1) would be inappropriate since it would not adequately address the problem of unobserved heterogeneity, nor adequately exploit the time variation in our variables. Pooled OLS regression estimates may suffer from omitted variable bias because of unobserved heterogeneity effects. Error-component models (e.g., fixed-effects and random-effects models) are commonly used to remedy the problem of unobserved heterogeneity.

Furthermore, since many economic relationships are dynamic in nature, the static model specification in equation (1) may be too restrictive (Baltagi, 2005, p. 135). This is particularly true in the case of investment decisions by multinational enterprises, whose past activities could have a significant effect on current (and future) FDI levels. Thus, it is more appropriate to specify a dynamic version of the model by including a lagged endogenous variable on the right-hand side. We reformulate equation (1) as a general dynamic panel regression model of the form:

$$y_{ujt}^{k} = \alpha y_{ujt-1}^{k} + \beta x_{ujt} + \eta_j + \lambda_t + \varepsilon_{ujt}^{k} \quad (2)$$

where y_{ujt}^{k} is sectoral FDI activity by affiliates, x_{ujt} is the vector of explanatory variables for which cross-sectional and time-series data are collected; η_j and λ_t are unobserved host-country-specific (e.g., geographic location and culture) and time-specific (e.g., policy reforms) parameters, respectively. The term ε_{ujt}^{k} denotes a random error, and the subscripts u, j, k and t denote home country, host country, sector, and time periods, respectively.

While the static case (equation (1)) could be estimated with either a fixed-effects or random-effects model, this may not be appropriate for the dynamic panel model. Endogeneity concerns become an issue in the estimation of equation (2) because the lagged endogenous regressor will be correlated with the error term (Baltagi, 2005, p. 135). Thus, regression estimates from both fixed-effects and random-effects estimators will be biased and inconsistent in panels with large cross sections and a small time span. To address this problem, an instrumental variable (IV) estimator is needed. Thus, to estimate equation (2) we apply the generalized methods of moments (GMM) estimator proposed by Arellano and Bond (1991) and Arellano and Bover (1995). The GMM panel estimator controls for country-specific fixed effects and the potential endogeneity of the explanatory variables. The country-specific fixed effects are eliminated by taking first differences of equation (2) such that:[4]

$$y_{ujt}^{k} - y_{ujt-1}^{k} = \alpha(y_{ujt-1}^{k} - y_{ujt-2}^{k}) + \beta(x_{ujt} - x_{ujt-1}) + (\varepsilon_{ujt}^{k} - \varepsilon_{ujt-1}^{k}) \qquad (3)$$

or alternatively, $\Delta y_{ujt}^{k} = \alpha \Delta y_{ujt-1}^{k} + \beta \Delta x_{ujt} + \Delta \varepsilon_{ujt}^{k}$

Next, the potential endogeneity issues and the correlation between the lagged dependent variable and error term in equation (3) are addressed via the use of instruments. For panels with a short time span, Blundell and Bond (1998) showed that the there are potential efficiency gains by using lagged differenced variables as instruments. The GMM dynamic panel estimator requires the following moments condition:

$$E[y_{ujt-s}^{k} \Delta \varepsilon_{ujt}^{k}] = 0 \qquad t = 3, \ldots, T \text{ and } s \geq 2 \qquad (4)$$

$$E[x_{ujt-s} \Delta \varepsilon_{ujt}^{k}] = 0 \qquad t = 3, \ldots, T \text{ and } s \geq 2 \qquad (5)$$

Equation (4) implies that the values of y lagged two or more periods may be used as instruments in the GMM model. Also, based on equation (5), the explanatory variables x_{it} could serve as additional instruments. Thus, in the estimation process, lags of the endogenous and exogenous variables are suitable instruments for the differenced GMM equations. Note that the consistency of the GMM technique depends on the validity of the instruments employed in the estimation.

Arellano and Bond (1991) proposed two tests for checking the validity of the instruments and whether the residuals are serially correlated. First, the Sargan test for over-identifying restrictions may be used to determine the validity of the instruments. Rejection of the null hypothesis of no misspecification implies that the model is not appropriate. Second, the Arellano-Bond m_1 and m_2 statistics may be used to test the null hypothesis of zero first-order and second-order serial correlation, respectively. A rejection of m_1 and a failure to reject m_2 implies that the error term is not serially correlated. We estimate these equations for all industries aggregated and separately for individual sectors.

Data Sources and Variable Definitions

We assembled a panel data set involving 39 FDI-recipient countries over the 15-year period 1985-1999, with information on affiliate activities coming from the BEA.[5] Annual sales values and exports were converted into millions of 1990 U.S. dollars using an exchange-rate-adjusted local wholesale-price index, with exchange rates and price indexes taken from the *International Financial Statistics* (IFS). Annual real GDP figures were also converted into dollars and obtained from the IFS.

Skilled-labor abundance is defined as the sum of occupational categories 0/1 (professional, technical, and kindred workers) and 2 (administrative workers) in employment in each country, divided by total employment. These figures are compiled from annual surveys reported in the *Yearbook of Labor Statistics* published by the International Labor Organization. In cases where some annual figures were missing, the skilled-labor ratios were taken to equal the period averages for each country. Thus, the variable SKLDIFF is the relative skill endowment of the parent country (United States) less that of the host country. Physical capital endowments measure the real stock of capital per worker, in thousands of 1990 U.S. dollars, in each country. This data was constructed from the Penn World Tables using a perpetual-inventory method and is further described in Baier, Dywer, and Tamura (2006).[6]

Following CMM (2001), the cost of investing in the affiliate country is a simple average of several indices of perceived impediments to investment, reported in the *World Competitiveness Report* of the World Economic Forum. The investment barriers include restrictions on the ability to acquire control in a domestic company, limitations on the ability to employ foreign skilled-labor, restraints on negotiating joint ventures, strict controls on hiring and firing practices, market dominance by a small number of enterprises, an absence of fair administration of justice, difficulties in acquiring local bank credit, restrictions on access to local and foreign capital markets, and inadequate protection of intellectual property. The resulting indices are computed on a scale from zero to 100, with a higher number indicating higher investment costs.

A trade cost index is taken from the same source and is defined as a measure of national protectionism, or efforts to prevent importation of competitive products. It also runs from zero to 100, with 100 being the highest trade costs. All of these indices are based on extensive surveys of multinational enterprises. It should be noted that both the investment cost and trade cost indices are qualitative and ordinal. Thus, regression coefficients capture the partial effects of changes in the perceived investment and trade costs across countries.

The resulting data set contains 39 countries (for which adequate data are available), two aggregated industries (all industries and total manufacturing) and eight sub-sectors, of which we analyze the five in manufacturing.[7] It should be noted that, even at this high level of aggregation there are a number of years in which particular variables on affiliate activity were not disclosed in the BEA data due to confidentiality reasons. Thus, there are a few missing observations in the sectoral data.[8] In particular cases (i.e., machinery and transportation equipment) where observations on affiliate activities were reported as zero, we estimate both a GMM and Tobit model specification. Although the magnitude of the estimates vary across estimators, both the GMM and Tobit results yield very similar conclusions regarding the signs and statistical significance of the parameter estimates. Thus, we only discuss details of the estimated coefficients from the GMM analysis. Tobit model results are available upon request from authors.

4. Empirical Results

We now discuss the econometric results, organized by form of MNE activity.

Total Affiliate Sales

Table 1 presents the results from the GMM model for total affiliate sales, the variable most closely associated with the basic KC model predictions. There are two specifications in each case, one including just skill differences as the relative endowment measure and one incorporating also relative physical capital endowments. The first two columns cover all manufacturing. The market-size variable (GDPSUM) and dissimilarity variable (GDPDSQ) have the anticipated impacts on sales and are significant. Thus, the larger the bilateral area and the more similar the countries are in size, the greater are affiliate real sales. The variable SKLDIFF exerts a negative influence on affiliate sales, suggesting that total manufacturing activity is dominated by horizontal motivations. The size of this coefficient grows larger and becomes significant with the introduction of physical-capital endowment differences, PKDIFF.

The variables in which factor endowment differences are interacted with GDP differences has a negative impact, as expected, though only the PKDIFF interaction is significant. In this specification (and in most others), measured host country's investment costs (ICH) have a negative and statistically significant effect on affiliate sales volumes. In addition, host-nation trade costs (TCH) have statistically insignificant effect on sales volumes in total manufacturing. These findings are similar to those in CMM (2001), where the coefficients on investment costs were generally negative and significant, while those on trade costs were insignificant. However, they did not include country effects or account for dynamic properties of the panel data. The parent (US) trade cost (TCP) has the expected negative effect on affiliate sales. Overall, the basic knowledge-capital variables -- country size, similarity, and differences in factor endowments -- all strongly affect manufacturing affiliate activity in the aggregate.

Of central interest here are the results for individual (though still highly aggregated) sectors. As shown by the estimates from regressions (3) and (4), the food-manufacturing sector behave similarly to overall activity in terms of the market-size variables. The fact that larger differences in GDP reduce sales supports the notion that there is much horizontal (market-seeking) FDI in the food-manufacturing sector, which generally consists of differentiated goods. However, there is a significant difference as regards factor endowments. Higher differences in the supplies of skilled-labor expand affiliate sales, supporting the idea of fragmentation of production between headquarters activity and affiliate assembly. In this regard, the food-manufacturing sector displays strong elements of both types of FDI incentives. Multinational firms both seek large markets to extend their sales overseas and engage in labor-intensive assembly operations. Overall, the food-manufacturing sector seems to follow the KC model closely. The other sectoral results may be interpreted analogously. In the chemicals sector (regressions 5 and 6) the effect of market size factors is consistent with the predictions of the KC model indicating a positive relationship between market size and affiliate sales. However, skill and capital endowments have statistically insignificant impacts on affiliate sales volumes. This result likely reflects the fact the chemical industry has higher than average numbers of local production affiliates working under license to U.S. parents that produce typically for the domestic market (Maskus, 2000). Because this is true in both developed and developing host economies the specific role of endowments may be limited in this sector. In contrast, in the machinery manufacturing sector (regressions 7 and 8), differences in both skilled-labor and capital endowments reduce sales, while investment costs in the host country (ICH) tend to reduce affiliate sales. These results suggest that machinery is more characterized by market-seeking investment than by fragmentation incentives.

Results from regressions (9) and (10) for electronics exhibit a distinctive pattern, supporting the need for incorporating both skills and physical capital. In regression (9) we find that the direct influence of SKDIFF is to increase affiliate sales significantly (suggesting fragmentation) while that of PKDIFF is to reduce sales (suggesting market-seeking FDI in countries with similar capital stocks). The former impact is anticipated as electronics are perhaps the best example of products where assembly may be divided from design. Meanwhile, in this sector the host-country's trade costs, interacted with skill differences, sharply reduce sales, consistent with fragmentation of assembly. The coefficient on host-country investment costs is significantly negative as expected. The last sector we include is transportation equipment in columns (11) and (12). Here we also find an indication of horizontal FDI associated with skilled-labor and physical capital endowment differences. In general, the various regression results confirm the KC model in that joint market size, differences in endowments, host country's investment costs (ICH) and trade costs (TCH) have a statistically significant effect on sales volumes. However, there are detectable differences in these influences across manufacturing industries.

Local Affiliate Sales

The results in Table 2 consider local sales of the affiliate as a second measure of affiliate activity. In principle, such effects should be more sensitive to market-seeking factors. Inspection of the table shows that the coefficients are generally smaller than those in Table 1, which reflects the fact that local sales are a subset of total sales. Otherwise the qualitative conclusions are quite similar. We highlight here a few differences of interest in the sectoral regressions. First, in the food-manufacturing sector (regressions 3 and 4) we find that the direct influence of SKLDIFF is to increase affiliate sales, suggesting fragmentation. However, PKDIFF has a negative effect on affiliate sales, suggesting market-seeking FDI in countries with similar capital stocks. Second, in machinery the interaction term on skill differences and host trade costs is significantly negative in the local sales regression, suggesting that in this sector domestic sales are highly responsive to trade barriers for given differences in endowments. In other words, where endowment differences are large, countries with high trade costs are not likely to attract machinery plants, even for local markets. While this outcome also holds for transportation equipment it is not significant. Moreover, it does not hold for the food-manufacturing and electronics sectors. Finally, the coefficient on parent-country trade costs is significantly negative for chemicals and electronics.

Affiliate Exports

Table 3 turns to affiliate exports (both to the United States and third markets) in order to isolate the impacts of knowledge-capital determinants on international trade. In general we would expect the GDP variables (size and dissimilarity) to be less important and the endowment difference variables to be more important in explaining exports than affiliate sales. Comparison of tables 1 and 3 shows this to be the case in many sectors. The interactions between size differences and endowment differences are somewhat smaller, though retaining their expected signs. In total manufacturing, both trade and investment costs in the host country significantly reduce affiliate exports.

With the exception of the food-manufacturing sector, the results for exports are quite similar across specific sectors. For example, manufactured food exports display a pattern similar to the results for affiliate sales (see table 1). The estimates for differences in skilled labor endowments have the expected positive signs, indicating that assembly for exports takes advantage of different labor skills, and are statistically significant. Squared differences in GDP have a negative impact on affiliate exports, suggesting that US investments meant for re-export in this sector in small countries is minimal. Investment and trade costs have insignificant effect on affiliate exports in manufactured food. In summary, in this sector market size is important for local sales but not exports. The picture that emerges is one in which US parent companies in food and kindred products invest for market-seeking purposes in larger and more skill-abundant and capital-abundant countries, and for purposes of assembly and exports in smaller and less skill and capital-abundant countries, while the latter effect is attenuated by higher local trade barriers (Table 2). Here, the food-manufacturing sector departs from some others, including chemicals and machinery, in which exports behave similarly to local sales. It is most similar to electronics (regressions (9) and (10)), where GDP differences expand exports, as do differences in skill endowments. In contrast to results from the food-manufacturing sector, investment and trade costs have a significant impact on exports in several other sectors.

5. Summary and Concluding Remarks

Relative to international trade, foreign direct investment (FDI) has experienced phenomenal growth in the past few decades. The rapid growth in FDI relative to traditional trade has generated much interest among economists regarding the nature of the location and production decisions of multinational firms. Until recently, due to theoretical and data constraints, it has not been possible to simultaneously model the two major motivations for the behavior of MNEs: horizontal (market-seeking) and vertical (lower factor cost-seeking) FDI. However, CMM (2001) and Markusen and Maskus (2001, 2002) recently proposed the knowledge-capital (KC) model, which provides a general-equilibrium modeling framework for simultaneously testing both motives for FDI.

In this paper, we extend the KC model of MNEs by investigating whether its predictions hold at the sectoral level for affiliate sales and exports. We also extend the methodological framework to examine the role of differences in physical-capital endowments (see Bergstrand and Egger, 2007) and we explicitly account for the dynamic nature of international investment data via the use of the GMM technique. Specifically, we estimate the KC model for all manufacturing industries (aggregated) and five manufacturing sectors, over a panel data set involving 39 FDI-recipient countries over a 15-year period.

The empirical results indicate that in a number of sectors, including food manufacturing and chemicals, squared differences in GDP reduce affiliate sales, bespeaking the importance of market-seeking investment incentives across destination countries. At the same time, differences in relative skilled-labor endowments have a positive and significant effect on foreign affiliate sales and exports in food products and electronics . These results suggest that vertical FDI motivations are also important for MNE activities in these industries. In contrast, the machinery sector exhibits evidence of primarily horizontal FDI behavior, as affiliate sales are negatively affected by differences in both skill and physical-capital endowments. For its part, the transportation-equipment industry demonstrates more vertical fragmentation as a result of skilled-labor and capital-stock variations across host nations. This result likely reflects the significant global networks that have emerged in automobile assembly and trade in intermediate automobile parts.

Thus, our empirical results imply that the predictions of the KC model regarding MNE behavior vary by the type of industry. It is plausible to expect significant differences in the behavior of MNEs who specialize in diverse areas of production (e.g., food products versus electronics products). While production processes in electronics and transportation-equipment are more characterized by efficient vertical specialization of R&D activities and assembly, other sectors have more complex motivations, as suggested by Yeaple (2003). Therefore, empirical analyses that only focus on highly aggregated data at the national level may not adequately reflect the diversity of MNE activities across various industries. Future research could extend this analytical approach to the firm level when appropriate data become available.

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Table 1. GMM Regression Results: Total Affiliate Sales

Variables	Total Manufacturing		Food and Kindred Products		Chemicals		Machinery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SALES LAGGED	0.73 *	0.74 *	0.69 *	0.67 *	0.50 *	0.62 *	0.64 *	0.61 *
GDPSUM	7.46 *	8.36 *	0.80 *	0.76 *	1.25 *	0.85 *	1.62 *	1.67 *
GDPDSQ	-2.54E-04 *	-3.32E-04 *	-3.16E-05 *	-2.76E-05 *	-4.85E-05 *	-3.46E-05 *	1.17E-05	1.12E-05
SKLDIFF	-20839.42	-66970.94 *	15532.59 *	21328.50 *	251.39	-3645.22	-28270.08 *	-9626.99
PKDIFF		0.35 *		-0.01		0.01		-0.19 *
GDPD*SKD	-1.86	3.31	-1.90 *	-2.68 *	-0.38	0.00	-1.16	-4.95 *
GDPD*PKD		-2.64E-05 *		2.97E-06		6.19E-07		2.10E-05 *
ICH	-51.62 **	-13.15	-0.21	2.85	-22.09 *	-12.75 **	-33.70 *	-33.98 *
TCH	5.13	-27.98	-8.89	-9.82 **	1.05	-4.03	1.09	8.94
TCH*SKDSQ	424.97	-247.25	201.14	-107.02	236.82	138.51	244.43	553.21
TCH*PKDSQ		2.20E-08		7.81E-09 **		2.21E-09		-1.30E-08
TCP	-57.22 *	-45.78 *	-2.20	-2.48	-16.97 *	-16.07 *	0.09	-3.19
observations	443	443	329	329	409	409	309	309
Diagnostics								
Sargan test for over-identifying restrictions:								
Chi-squared	439.45	360.52	286.48	289.02	460.37	495.03	377.74	375.34
P-Value	0.28	0.20	0.40	0.14	0.18	0.21	0.48	0.23
Arellano-Bond test serial correlation:								
Ho: no autocorrelation of 1st order								
Z-Value	-10.75	-9.96	-7.70	-7.52	-5.48	-6.09	-4.99	-4.97
Ho: no autocorrelation of 2nd order								
Z-Value	1.32	1.22	-0.42	-0.40	0.37	0.38	-1.05	0.89

Table 1. Continued

Variables	Electronics				Transportation Equipment			
	(9)		(10)		(11)		(12)	
SALES LAGGED	0.77	*	0.77	*	0.68	*	0.68	*
GDPSUM	0.94	*	0.93	*	1.72	*	1.76	*
GDPDSQ	-1.11E-05		-9.58E-06		-1.50E-05		-3.60E-05	
SKLDIFF	12967.06	*	16688.65	*	16085.76		14699.53	
PKDIFF			-0.06	*			0.26	*
GDPD*SKD	-1.69	*	-2.44	*	-1.78		-0.44	
GDPD*PKD			8.05E-06	*			-1.60E-05	*
ICH	-18.03	**	-20.33	*	-19.81		-11.54	
TCH	9.49		4.39		-20.75		-28.85	
TCH*SKDSQ	-648.97	*	-570.22	*	348.41		-227.65	
TCH*PKDSQ			7.51E-09				2.09E-08	
TCP	-1.38		-0.40		-9.75		-6.38	
Observations	315		315		274		274	
Diagnostics								
Sargan test for over-identifying restrictions:								
Chi-squared	235.18		237.64		227.34		231.24	
P-Value	0.47		0.88		0.18		0.78	
Arellano-Bond test serial correlation								
Ho: no autocorrelation of 1st order								
Z-Value	-10.64		-10.65		-9.36		-9.60	
Ho: no autocorrelation of 2nd order								
Z-Value	-0.64		-0.55		-0.59		-0.49	

Note: Statistical significance is indicated as: 5 percent (**) and 10 percent (*) levels, respectively.

Table 2. GMM Regression Results: Affiliate Sales on Local Market

Variables	Total Manufacturing		Food and Kindred Products		Chemicals		Machinery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SALES LAGGED	0.74 *	0.74 *	0.40 *	0.46 *	0.59 *	0.55 *	0.25 *	0.25 *
GDPSUM	5.53 *	6.07 *	0.81 *	0.58 *	1.47 *	1.80 *	2.14 *	2.30 *
GDPDSQ	-2.22E-04 *	-2.47E-04 *	-1.71E-05	-3.80E-05 **	-8.61E-05 *	-1.04E-04 *	-6.07E-05 *	-6.56E-05 *
SKLDIFF	5883.55	-13512.01	12405.00 **	7584.96	1886.22	-864.19	-79.52	3423.05
PKDIFF	-0.69	0.16 **		-0.05		0.01		-0.04
GDPD*SKD		0.99	-1.38 **	-0.31	0.47	1.02	-0.60	-0.77
GDPD*PKD		-1.20E-05		7.97E-06		-1.90E-06		7.54E-07
ICH	-14.61	-7.87	-8.28	-8.74	-8.73	-9.27	-10.49	-11.71
TCH	0.24	-13.00	-15.54 *	-5.29	3.96	3.24	35.47 *	32.55 *
TCH*SKDSQ	-205.63	-868.53	364.47	-13.45	59.87	-200.17	-1305.69 *	-1601.66 *
TCH*PKDSQ		2.33E-08		3.36E-09		7.63E-09 **		8.61E-09
TCP	-15.13	-10.92	5.63	3.02	-12.97 *	-12.53 *	-0.76	-0.78
Observations	341	341	209	209	333	333	232	232
Diagnostics								
Sargan test for over-identifying restrictions:								
Chi-squared	341.91	344.68	203.61	123.83	329.89	310.00	286.78	284.35
P-Value	0.44	0.12	0.66	0.95	0.40	0.25	0.16	0.65
Arellano-Bond test serial correlation:								
Ho: no autocorrelation of 1st order								
Z-Value	-8.03	-7.68	-5.00	-5.16	-9.37	-8.46	-3.41	-3.33
Ho: no autocorrelation of 2nd order								
Z-Value	-0.49	-0.82	0.95	0.46	0.66	0.46	0.33	-0.30

Table 2. Continued

Variables	Electronics				Transportation Equipment			
	(9)		(10)		(11)		(12)	
SALES LAGGED	0.727	*	0.679	*	0.220	*	0.168	*
GDPSUM	0.645	*	0.543	*	0.987	*	0.742	*
GDPDSQ	-2.81E-05	*	-2.22E-05		3.25E-06		3.77E-05	**
SKLDIFF	7316.963		10496.820		38150.140	*	45921.360	*
PKDIFF			-0.057				-0.058	
GDPD*SKD	-1.701	**	-2.296	*	-2.277	**	-4.072	*
GDPD*PKD			9.09E-06	*			5.71E-06	
ICH	-0.642		1.280		1.784		-0.530	
TCH	-1.148		-0.529		10.764		-1.697	
TCH*SKDSQ	167.023		274.152		-344.981		-184.469	
TCH*PKDSQ			-4.02E-09				3.15E-10	
TCP	-12.666	**	-12.262	**	-1.592		4.201	
Observations	229		229		212		212	
Diagnostics								
Sargan test for over-identifying restrictions:								
Chi-squared	168.620		155.310		167.170		251.030	
P-Value	0.989		0.767		0.122		0.174	
Arellano-Bond test serial correlation:								
Ho: no autocorrelation of 1st order								
Z-Value	-7.290		-6.940		-3.910		-3.960	
Ho: no autocorrelation of 2nd order								
Z-Value	-0.460		-0.650		-1.350		-1.320	

Note: Statistical significance is indicated as: 5 percent (**) and 10 percent (*) levels, respectively.

Table 3. GMM Regression Results: Affiliate Exports

Variables	Total Manufacturing		Food and Kindred Products		Chemicals		Machinery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EXPORTS LAGGED	0.74 *	0.74 *	0.64 *	0.66 *	0.48 *	0.43 *	0.62 *	0.61 *
GDPSUM	1.56 *	1.57 *	0.30 **	0.27	0.55 *	0.79 *	0.25	0.51
GDPDSQ	-1.92E-04 *	-1.87E-04 *	-4.64E-06	-2.54E-07	-5.39E-05 *	-8.15E-05 *	-1.10E-05	-1.77E-05
SKLDIFF	-21688.28	-30049.93	15363.39 *	24152.43 *	-3898.11	-10258.73	-27118.11 *	-34242.32 **
PKDIFF		0.00		-0.05		0.08 **		-0.10 **
GDPD*SKD	-0.61	-1.31	-1.68 *	-3.16 *	0.46	1.76	-0.51	0.51
GDPD*PKD		8.80E-06		9.54E-06 *		-7.36E-06		3.83E-06
ICH	-68.17 *	-63.73 *	4.25	5.11	-8.73	-3.00	-24.85	-37.55 **
TCH	-45.65 *	-49.89 *	4.16	5.23	13.79 **	18.07 *	-0.74	1.08
TCH*SKDSQ	1772.71 *	1957.04 *	-86.00	-292.75	-108.78	47.45	1002.76	1368.10 **
TCH*PKDSQ		-3.29E-09		3.83E-09		-6.60E-09		-5.95E-09
TCP	-32.91 *	-28.65	0.63	-0.04	-12.70 *	-12.86 *	-32.05 *	-35.82 *
Observations	259	259	114	114	188	188	198	198
Diagnostics								
Sargan test for over-identifying restrictions:								
Chi-squared	300.330	301.290	99.420	94.930	150.180	131.460	219.150	188.010
P-Value	0.150	0.972	0.305	0.903	0.659	0.352	0.115	0.345
Arellano-Bond test serial correlation:								
Ho: no autocorrelation of 1st order								
Z-Value	-5.390	-5.390	-2.790	-2.870	-5.110	-4.860	-3.760	-3.770
Ho: no autocorrelation of 2nd order								
Z-Value	0.740	0.710	-0.530	-0.450	1.430	1.440	0.800	0.820

Table 3. Continued

Variables	Electronics				Transportation Equipment			
	(9)		(10)		(11)		(12)	
EXPORTS								
LAGGED	0.64	*	0.71	*	0.77	*	0.90	*
GDPSUM	0.30	**	0.25		0.06		0.40	
GDPDSQ	0.00	*	0.00	*	0.00		0.00	
SKLDIFF	6837.82		13194.35	**	19966.07	*	3491.63	
PKDIFF			-0.03				0.15	**
GDPD*SKD	-0.87		-1.30	*	-2.25	*	-0.72	
GDPD*PKD			0.00				0.00	
ICH	-14.13	**	-9.95		-6.34		-0.21	
TCH	7.18		3.95		-8.32		-11.22	
TCH*SKDSQ	-195.74		-493.94	**	183.87		132.19	
TCH*PKDSQ			0.00				0.00	
TCP	3.41		4.64		1.10		1.00	
Observations	185		185		196		196	
Diagnostics								
Sargan test for over-identifying restrictions:								
Chi-squared	207.85		202.39		234.79		153.83	
P-Value	0.30		0.13		0.28		0.79	
Arellano-Bond test serial correlation:								
Ho: no autocorrelation of 1st order								
Z-Value	-4.36		-4.47		-4.33		-6.64	
Ho: no autocorrelation of 2nd order								
Z-Value	-1.14		-1.47		-0.69		-0.28	

Note: Statistical significance is indicated as: 5 percent (**) and 10 percent (*) levels, respectively.

ENDNOTES

[1] In the empirical analysis we consider capital stock as a third endowment.

[2] Carr, Markusen, and Maskus (2003) in their reply point out that the alternative specification is unlikely to capture relationships in the underlying data given its strict interpretation.

[3] Carr, Markusen and Maskus (2001) also include a bilateral distance variable but since this measure is time-invariant we exclude it from our analysis, which is based on dynamic panel regression methods.

[4] The year fixed effects are included in the estimation.

[5] The BEA data underwent a significant sectoral revision in 2000, making it difficult to extend the data meaningfully beyond 1999.

[6] These figures were kindly provided by Professor Peter Egger.

[7] The list of countries used in the analysis includes: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Costa Rica, Denmark, Egypt, Finland, France, Germany, Greece, Hong Kong, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, and Venezuela. The list of sub-sectors includes: food and kindred products, chemicals and allied products, industrial machinery and equipment, electronics, primary and fabricated metals, transportation equipment, other manufacturing, and wholesale trade. However, we exclude the aggregate of all industries, primary and fabricated metals, and wholesale trade in order to focus on sectors that are strictly manufacturing.

[8] Summary statistics at the aggregate level and by sectors are available on request.