

Shouldn't Physical Capital *Also* Matter for Multinational Enterprise Activity?

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Abstract

The foreign direct investment (FDI) literature has generally failed to find strong systematic evidence of “vertical” motivations in bilateral aggregate FDI and foreign affiliate sales (FAS) data, despite recent evidence of vertical FDI in firm-level data. Moreover, a Bayesian analysis of the empirical determinants of FDI (and FAS) flows reveals that the parent country's *physical capital* per worker has a strong positive effect on FDI alongside typical gravity-equation variables; however, this variable is ignored in the knowledge-capital (KC) model and most empirical work. We address these two puzzles by introducing relative factor endowment differences into the three-factor, three-country knowledge and physical capital extension of the $2 \times 2 \times 2$ KC model. Using a numerical version of our model, we show that horizontal and vertical multinational enterprises' (MNEs') headquarters surface in different parts of the Edgeworth box relating the parent country's skilled labor share relative to its physical capital share (of the parent's and host's endowments). The key economic insight is that horizontal MNE headquarters will be relatively more abundant than vertical MNE headquarters in countries that are abundant in physical capital relative to skilled labor, because of the multi-plant (single-plant) structure of horizontal (vertical) MNEs—assuming plants (headquarters) use physical capital (skilled labor) relatively intensively in their setups. The theoretical relationships suggest augmenting empirical FAS gravity equations with (polynomials of) the parent's skilled labor share alongside the parent's physical capital share to explain in aggregate bilateral data the coexistence of horizontal and vertical FAS. The theoretical and empirical results shed light on the positive effect of parent's physical capital share on FAS flows, but also suggest that MNE headquarters may be prominent in parent countries with relatively high and low skilled labor shares—once physical capital is accounted for—a result not suggested by the two-factor KC model.

It seems clear that vertical motivations are not prevalent in the general FDI patterns. (Bruce Blonigen, 2005)

1. Introduction

This paper addresses the issue of finding evidence of vertical multinational enterprise (MNE) activity alongside horizontal MNE activity in aggregate bilateral data by examining the seemingly “schizophrenic treatment” of physical capital in modern analyses of foreign direct investment (FDI) and foreign affiliate sales (FAS). On the one hand, the modern general equilibrium theory of MNE activity focuses upon the role of intangible assets of firms—such as knowledge capital—for explaining MNEs' existence, cf. Markusen (2002). Using the knowledge capital model, most empirical analyses have focused upon the roles of relative economic sizes to explain “horizontal” MNE activity and relative skilled-to-unskilled labor ratios to explain “vertical”

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MNE activity, cf. Carr et al. (2001, 2003), Blonigen et al. (2003), Markusen and Maskus (2001, 2002), Braconier et al. (2005), and Davies (2008). Motivated by a two-factor model with only skilled and unskilled labor, physical capital plays no role theoretically or empirically in these analyses.

On the other hand, Blonigen and Piger (2011) found evidence that bilateral aggregate FDI outflows are strongly and positively influenced by parent countries' physical capital per worker. Moreover, the extension of the international economics literature to recognize "heterogenous productivities" among national, exporting, and multinational enterprises reveals that MNEs tend to be very physical-capital intensive (as well as skilled labor intensive) firms and MNEs tend to be headquartered in relatively physical-capital abundant (as well as skilled-labor abundant) countries, cf. Bernard et al. (2005), Helpman et al. (2004), and Helpman (2006). Even one of the measures of FDI in the US Bureau of Economic Analysis (BEA) data uses the share of a MNE's real investment in physical plant and equipment in a foreign affiliate. This schizophrenic treatment of physical capital in the MNE literature and the apparent absence of "vertical motivations" for FDI in the bilateral aggregate data suggests re-considering a role for physical capital.

In reality, of course, *both* relative physical capital to unskilled labor (K/U) and skilled labor to unskilled labor (S/U) ratios are likely to influence aggregate bilateral FDI/FAS flows in general equilibrium, alongside economic size and similarity as well as investment costs. This paper addresses physical capital's role theoretically and empirically, and offers two potential contributions. First, we introduce differences in relative physical capital endowments—alongside differences in relative skilled and unskilled labor endowments—into the three-factor, three-country, two-good "Knowledge and Physical Capital" model of Bergstrand and Egger (2007) and provide some testable hypotheses for predicted vertical and horizontal FAS that are different than those suggested by the workhorse $2 \times 2 \times 2$ "Knowledge Capital" (KC) model. Bergstrand and Egger (2007) presented a three-country, three-factor, two-good extension of Markusen's two-country, two-factor, two-good KC model, but assumed identical relative factor endowments to focus only on the roles of gross domestic product (GDP) size and similarity for explaining the coexistence of horizontal bilateral FAS/FDI flows and intra-industry trade flows for countries with identical absolute and relative factor endowments and for motivating a theoretical rationale for estimating "gravity equations" of bilateral FAS and FDI flows alongside bilateral trade flows. Vertical MNEs played no role in Bergstrand and Egger (2007). We find here that general equilibrium relationships between relative skilled-to-unskilled labor ratios and bilateral FAS are sensitive to relative endowments of physical capital. A key theoretical economic insight is that horizontal MNE headquarters will be relatively more abundant than vertical MNE headquarters in countries that are abundant in physical capital relative to skilled labor, because of the multi-plant (single-plant) structure of horizontal (vertical) MNEs—assuming plants (headquarters) use physical capital (skilled labor) relatively intensively in their setups. An implication of this is that physical capital rich economies will tend to have high levels of bilateral horizontal FAS when skilled labor is scarce relative to physical capital and such economies will tend to have high levels of bilateral vertical FAS when skilled labor is abundant relative to physical capital (for given levels of unskilled labor). This suggests that the relationship between a parent country's skilled labor share (of two countries' joint skilled labor endowment) and the FAS of the parent country may be a fourth-order polynomial.¹

Second, empirical explanations for determinants of bilateral international trade flows have long used the "gravity equation," the workhorse of international trade.

Moreover, the gravity equation is also the workhorse for empirical analysis of determinants of bilateral FAS and FDI flows.² Using a Bayesian moving average (BMA) analysis, Blonigen and Piger (2011) found inclusion probabilities of 100% for standard gravity variables such as parent and host countries' GDPs and the bilateral distance between two countries. Moreover, they also found an inclusion probability for the parent's capital stock per worker of 94%, but an inclusion probability of only 54% for the parent's education level. Our theoretical analysis suggests a rationale for the inclusion of parent's physical-capital share (of parent and host countries' physical capital). Moreover, our theoretical analysis suggests a rationale for including fourth-order polynomials of the parent's skilled labor share and of the parent's physical capital share in an augmented gravity equation. We find that the inclusion in a FAS gravity equation of fourth-order polynomials of the parent country's shares of (two countries i and j) skilled labor and physical capital helps to explain the patterns of aggregate bilateral FAS. Three empirical findings are notable. First, the parent's skilled labor share has the expected fourth-order polynomial relationship with bilateral FAS. In fact, the empirically predicted bilateral FAS flows reveal two "peaks" in the empirical Edgeworth-box space, one where horizontal MNE activity should be maximized and one where vertical MNE activity should be maximized—consistent with the corresponding theoretical Edgeworth-box predictions. Second, the parent's physical capital share also has a significant effect on bilateral FAS, and the fourth-order polynomial empirical relationship corresponds also with the model's theoretical predictions. Third, the parent's unskilled labor share has the expected negative, monotonic relationship with FAS. In the context of our model, our empirical results provide evidence for vertical motivations for FAS in the bilateral aggregate data, alongside horizontal motivations.³ In fact, we find evidence suggesting—consistent with firm-level categorizations in Alfaro and Charlton (2009) of horizontal and vertical MNEs—that vertical MNE (VMNE) motivations are as important as horizontal MNE (HMNE) motivations.

The remainder of the paper is as follows. In section 2, we discuss the limitations of the two-factor KC model for identifying vertical MNE activity separately from horizontal MNE activity in aggregate bilateral FAS data. In section 3, we summarize the three-factor, three-country, two-good Knowledge and Physical Capital (KAPC) model in Bergstrand and Egger (2007), allowing now asymmetric relative factor endowments. In section 4, we use the numerical version of our model to postulate theoretical hypotheses about relationships between relative factor endowments and FAS. In section 5, we examine empirically the determinants of bilateral aggregate FAS flows. Section 6 concludes.

2. Limitations of the $2 \times 2 \times 2$ Knowledge-Capital for Finding Vertical MNEs

We argue here that the evidence against the KC model in favor of just HMNEs explaining bilateral aggregate FAS flows should actually come as no surprise if one examines closely the theoretical predictions of the KC model—limited to a 2-factor, 2-country world. In the following, reference to the "KC model" necessarily implies a 2-factor, 2-country world. Figures 1a and 1b from Markusen (2002) and Figure 1c from BNU help to illustrate this point, based upon the KC model. Figure 1a presents the Edgeworth box (figure 7.1 from Markusen, 2002, p. 143) relating country i 's (j 's) share of the two countries' skilled labor stocks along the vertical axis, country i 's (j 's) share of the two countries' unskilled labor stocks (also called by Markusen the "composite factor") along the horizontal axis, and the equilibrium "regimes" of types of firms (see

Figure 1a's index). Depending upon relative skilled to unskilled labor ratios, HMNEs ("Multinational firms only"), VMNEs ("Vertical firms"), NEs ("National firms only"), or "Mixed regimes of national and multinational firms" may be found in equilibrium. cursory examination of this figure suggests two main propositions evaluated in the KC literature. First, when two countries are identical in economic size and relative factor endowments, both countries will have only HMNEs in equilibrium; there will be no VMNEs (nor NEs or international trade, for that matter) in equilibrium. Second, however, when country *i* is moderately relatively skill abundant (moving left from the center cell, or towards the left vertical axis), HMNEs based in *i* will still exist in equilibrium (because HMNEs' headquarters setups use relatively more skilled labor than NEs' headquarters setups). Yet when country *i* becomes even more relatively skill abundant (further left), Figure 1a suggests that HMNEs cease to exist in *i*. However, HMNEs are actually joined by VMNEs (because it becomes profitable for *i* to "outsource" final goods production to *j* and ship output anywhere in the world), as explained below.

Initial empirical estimation of the KC model to find both HMNEs and VMNEs in *i* was virtually doomed to fail for the following reason. Figure 1b (actually table 7.2 from Markusen, 2002) reports the sum of different types of operations in existence in equilibrium, which is the data underlying Figure 1a. Consider three results. First, at the center cell (when the two countries are identical in absolute and relative factor endowments), both countries have HMNEs headquartered in their own countries, with plants in their home and foreign markets; no VMNEs or NEs are profitable ($0.011 = 0.010 + 0.001$), consistent with Figure 1a. Second, moving leftward, country *i* eventually becomes relatively smaller and more skilled-labor abundant, making HMNEs based in *i* the only profitable firms (0.010), consistent with Figure 1a. Third, continuing leftward, the three columns on the far left indicate that relatively skilled-labor abundant *i* will headquarter both HMNEs and VMNEs ($2.010 = 2.0 + 0.010$), as explained in Markusen (2002, p. 145). That is, for the ratio of skilled-to-unskilled labor in *i* shown in the far left column and middle row, FAS for home country *i* in host country *j* is motivated by both horizontal and vertical activity! In fact, careful examination of the entire first (left-hand side) column of Figure 1b reveals that HMNEs exist in equilibrium for moderate levels of skill abundance, but VMNEs exist also for high, moderate, and low levels of skill abundance. The fundamental problem with using the $2 \times 2 \times 2$ KC model to distinguish VMNE from HMNE activity is this: overlap of vertical and horizontal MNEs (cells in Figure 1b with values of either 2.01, 12.01, or 102.01) comprise 18% of the 190 cells in the upper-left quadrant of Figure 1b, making it very difficult to distinguish VMNE from HMNE activity using only relative factor endowments of skilled to unskilled labor.

Thus, Carr, Markusen, and Maskus (2001), or CMM (2001), econometric estimation of the KC model to find both HMNEs and VMNEs was compromised from the start because the Edgeworth surface described bilateral FAS motivated by both HMNEs and VMNEs at the same skilled to unskilled labor ratio—even if the central regression "specification" was mapped *directly* from the theory as in Braconier et al. (2005), or BNU, i.e. factor shares of the Edgeworth box.⁴ BNU made a useful contribution to this literature by generating a regression specification that mapped "directly" from the theoretical framework, taking into account properly the geometric considerations of Edgeworth boxes. Motivated by this important analytical consideration alongside employing a broader data set (in terms of country pair coverage) of FAS bilateral flows, BNU argued that—when properly specified—VMNEs could be found in the data, alongside HMNEs. Figure 1c (from Braconier et al., 2005) illustrates their

“empirically predicted” FAS_{ij} . However, while their empirically predicted FAS surface is visually similar to the theoretically predicted FAS surface in Markusen (2002, figure 10.1, p. 221), the problem still remains. Where BNU predict the “peak of vertical FDI_{ij} ” in Figure 1c—when i is economically smaller and skilled-labor abundant relative to j —the data cells in Figure 1b inform us that both vertical and horizontal MNEs can be headquartered in i (note the cell entry 2.010 in the far left column in rows 9, 10, 11, and 12). Thus, BNU does not resolve the issue empirically because the problem lies in finding—in Edgeworth-box space—relative factor endowment configurations where VMNE headquarters can be clearly distinguished from HMNE headquarters.

3. Theoretical Framework: A Summary of the Knowledge and Physical Capital Model

The model we use is a more general version of the three-country, three-factor, two-good KAPC model in Bergstrand and Egger (2007) by allowing differences in relative skilled to unskilled labor (S/U) ratios and relative physical capital to unskilled labor (K/U) ratios, consequently generating horizontal and vertical MNEs as well as national exporting enterprises (NEs) in equilibrium. Bergstrand and Egger (2007) is an extension of the $2 \times 2 \times 2$ KC model in Markusen (2002) with national exporters (NEs), horizontal MNEs (HMNEs), and vertical MNEs (VMNEs). However, Bergstrand and Egger (2007) assumed identical relative factor endowments to focus on the roles of economic size and similarity and provide a theoretical foundation for gravity equations of trade, FAS, and FDI simultaneously; consequently, no VMNEs surfaced in that paper, except in one sensitivity analysis. The demand side in the model is analogous to that in the KC model.

The key difference between our KAPC model and Markusen’s KC model is that we add a third factor, physical capital (K), the services of which can be used at home or transferred abroad (via FDI) either as a “greenfield” investment or an acquisition (and not necessarily a costless transfer). We assume that all three internationally immobile primary factors are used in the production of the differentiated good: unskilled labor (U), skilled labor (S), and private physical capital (K). Moreover, following evidence from Griliches (1969), Goldin and Katz (1998), and Slaughter (2000), we assume that skilled labor and physical capital are complements in production, which is also consistent with evidence in Bernard et al. (2005) that MNEs tend to be relatively abundant in countries that are relatively abundant in both skilled labor and physical capital. However, for the setups of headquarters and plants, we assume that the services of only skilled labor are used to setup headquarters and the services of only physical capital are used to setup plants. HMNEs headquartered in any country i , for example, arise endogenously, and the services of home physical capital are “used up” (owing to their “rival” nature) to setup a plant in the home country or abroad to maximize firm profits (with an implied no-arbitrage incentive for rates of return on physical capital; no profits are left “on the table”), but physical capital need not actually move internationally. In the presence of imperfect international (financial) capital mobility, firms may choose to have financial claims to physical capital at home or—via FDI—abroad. The key distinction from knowledge capital is that claims to physical capital are rival, and FDI—owing to foreign government restrictions—may not move costlessly between countries. The second distinction of our model from the KC model is to introduce a “third country,” Rest-of-World (ROW). The presence of the third country helps explain the observed complementarity of bilateral FAS and trade flows with respect to a country pair’s economic size and similarity and that bilateral FDI

and FAS tend empirically to be as well explained by a gravity equation as bilateral trade flows are. Since the structure and calibration of the model is described explicitly in Bergstrand and Egger (2007), to conserve space we present the model in Appendix A and a description of the calibration of the model in Appendix B of this paper (both available online at www.nd.edu/~jbergstr).

4. Theoretical Hypotheses

The numerical version of our general equilibrium model can be used to generate (at least) three “testable propositions” relating pairs of countries’ relative factor endowments to aggregate bilateral FAS activity. We focus first on predicting theoretically the numbers of HMNEs based in home country i with plants in i , j , and/or ROW, the numbers of VMNEs based in home country i with plants in j or ROW, and the aggregate bilateral FAS of parent country i in host country j —contingent upon different configurations of relative factor endowments. We use these predictions to suggest three testable hypotheses about the relationship between a country pair ij ’s relative factor endowments and the FAS of headquarters country i with a foreign affiliate in country j .

Owing to the presence of three factors, three countries, and highly nonlinear relationships, there are potentially an enormous number of relationships to explain. To make the testable hypotheses tractable in a world with three factors, three countries, and two goods, we use the “workhorse” tool of international trade—the Edgeworth box—for studying relationships between relative factor endowments and FAS, as used in Markusen (2002) and BNU. However, all the papers just noted assumed two-factor worlds; we have a three-factor world.

In a three-factor world, Edgeworth boxes actually are slices from an Edgeworth “cube,” showing the relationship between a flow and two countries’ shares of two factors—for any given shares of the two countries of the third factor (and for any given level of ROW’s endowments). To focus initially on the relationships between physical capital, skilled labor, unskilled labor, and horizontal and vertical MNEs, we consider first the Edgeworth box relationship between country i ’s share of countries i ’s and j ’s physical capital stocks (k_i) for a given physical capital stock in ROW, country i ’s share of i ’s and j ’s skilled labor stocks (s_i) for a given skilled labor stock in ROW, and the numbers of HMNEs and VMNEs headquartered in i —at the mean of u_i , which is i ’s share of i ’s and j ’s unskilled labor endowments (for a given unskilled labor endowment in ROW). Henceforth, FAS_{ij} denotes the theoretically predicted bilateral FAS of parent/home country i in host country j ; later in the empirical work, FAS_{ij} (without italics) denotes the empirically predicted bilateral FAS of MNEs with headquarters in i and plants in j .

Since we are examining the relationships among k_i , s_i , and determinants of FAS_{ij} , our relationships are conditional upon the level of u_i (a third factor) as well as the economic size of ROW (a third country). Because we will pursue a regression analysis later, it will be useful to show slices of the Edgeworth cube at the empirical mean of the implicit third factor, say u_i . The reason is that—in a regression of bilateral FAS on numerous variables—the interpretation of, say, the coefficient estimate for k_i would be holding constant s_i and u_i at their “means”; thus, the theoretical predictions relating, say, the numbers of HMNEs in i with plants in j with k_i and s_i are being made at the mean of u_i . However, it will be convenient now to note that the *empirical* means for k_i , s_i , and u_i all range between 0.53 and 0.56. Hence, for convenience, the mean of each factor share is effectively 0.50.⁵

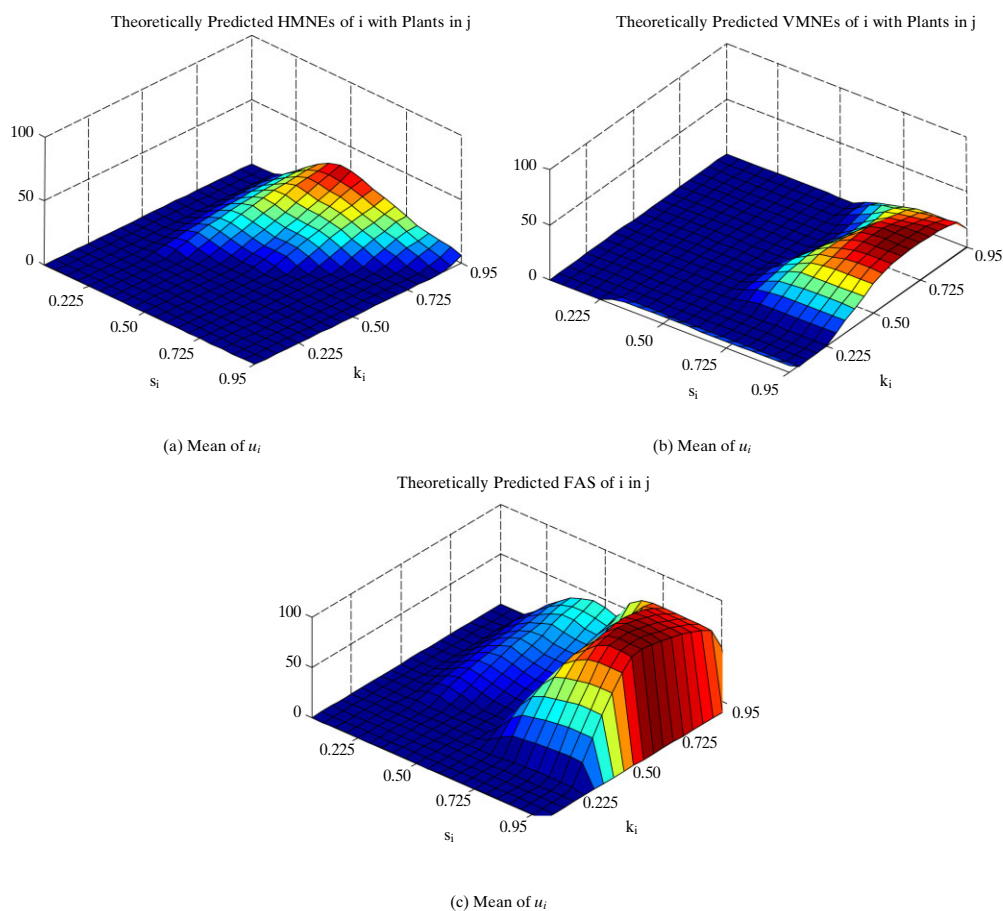


Figure 2(a–c). Theoretically Predicted Numbers of HMNEs, Numbers of VMNEs, and Foreign Affiliate Sales (a) Mean of u_i (b) Mean of u_i (c) Mean of u_i

Our first testable hypothesis (Hypothesis 1) builds on two theoretical results:

Result 1: The number of HMNEs based in i with plants in j , will be maximized when i is abundant in physical capital relative to skilled labor relative to j , owing to the multi-plant structure of HMNEs and plant (headquarters) setups being physical capital (skilled labor) intensive; and

Result 2: The number of VMNEs based in i with a plant in country j will be maximized when i is abundant in skilled labor relative to physical capital relative to j , owing to the single-plant structure of VMNEs alongside the assumed physical capital intensity of plant setups relative to headquarters setups.

Figures 2a and b illustrate the relationships between k_i , s_i , and the numbers of HMNEs based in i with plants in j (and ROW) and VMNEs based in i with plants in j , respectively, evaluated at the empirical mean of u_i (effectively, 0.5). Consider Figure 2a first. HMNEs are multi-plant structures, whose plant setups are physical capital intensive (specifically, such setups are intensive in the internationally-mobile “services” of physical capital via FDI). Consequently, HMNEs will be abundant in country i if i is abundant in physical capital relative to skilled labor (and also to

unskilled labor), as shown in Figure 2a (i.e. $k_i > s_i$). By contrast, VMNEs require only one plant (located abroad) along with its headquarters (located at home). Since headquarters setups use skilled labor services and plant setups use physical capital services, VMNEs will be prominent in i when skilled labor and physical capital are both abundant relative to j (and assuming $u_i = 0.5$) and skilled labor is only slightly more abundant in i than physical capital (as all MNE headquarters setups require more skilled labor than NE setups). Figure 2b illustrates the theoretical relationships between k_i , s_i , and the number of VMNEs headquartered in i with a plant in j at the mean of u_i . Figure 2b suggests that VMNEs will be prominent in i when skilled labor is slightly more abundant than physical capital, as a result of the single-plant, single-headquarters structure of VMNEs. The key economic insight is that—assuming plants (headquarters) are physical capital (skilled labor) services intensive in setups—countries that are physical capital abundant (scarce) relative to skilled labor should tend to headquarter HMNEs (VMNEs), for given u_i and given endowments in ROW.

Figures 2a and b together suggest that empirical FAS_{ij} may in a regression be fourth-order polynomial function of s_i , as illustrated in Figure 2c. Figure 2c provides the model's depiction of theoretical FAS_{ij} . Consider first s_i . If we are interested in the relationship between variation in s_i and FAS_{ij} , then we must hold constant k_i and u_i at their means (about 0.5). Figure 2c represents the relationships between s_i , k_i , and FAS_{ij} —evaluated at the mean of u_i ($u_i = 0.5$). In Figure 2c, we see from varying s_i from 0 to 1 at the mean of k_i ($k_i = 0.5$), and knowing that this Edgeworth “slice” is at $u_i = 0.5$, that there are three inflection points. This implies that FAS_{ij} is a fourth-order polynomial function of s_i , as horizontal FAS_{ij} is generated by HMNEs of country i with plants in j and vertical FAS_{ij} is generated by VMNEs of country i with plants in j . Specifically, at $k_i = u_i = 0.5$, assume $s_i = 0$ initially. There will be no HMNEs or VMNEs headquartered in i . As s_i increases from 0, the relative abundance of physical capital (since $k_i = 0.5$) causes HMNEs in i to become profitable first and the number of HMNEs increases (Figure 2a) and FAS_{ij} rises above 0. However, as s_i continues to rise past 0.5, physical capital becomes scarce relative to skilled labor (as $k_i = 0.5$), reducing the profitability of HMNEs in i , but increasing the profitability of VMNEs in i since VMNEs have only one plant to setup abroad, requiring less physical capital than an HMNE. This suggests testable Hypothesis 1:

Hypothesis 1: Empirical FAS_{ij} in a regression should be a fourth-order polynomial function of s_i at the means of k_i and u_i ($k_i = u_i = 0.5$).

For robustness, we generated the theoretical k - s surfaces for the numbers of VMNEs and HMNEs in i also for u_i at the 30th and 70th percentiles. The shapes of the theoretical surfaces are qualitatively the same; figures omitted for brevity, but available on request.⁶

We now consider the theoretical relationship between k_i and FAS_{ij} . If we are interested in the relationship between variation in k_i and FAS_{ij} , then we must hold constant s_i and u_i at their means (0.5). Figures 3a and b present the theoretical Edgeworth boxes relating k_i , u_i , and the numbers of HMNEs and VMNEs headquartered in i with affiliates in j , respectively, at $s_i = 0.5$. Figure 3a shows that HMNE headquarters will be prominent in i when physical capital is abundant; this makes intuitive sense since multi-plant HMNEs require physical capital for setups. However, at $s_i = u_i = 0.5$, as k_i falls from 1, the number of HMNEs headquartered in i declines. But as shown in Figure 3b, as k_i falls closer to 0.5, skilled labor becomes abundant in i relative to physi-

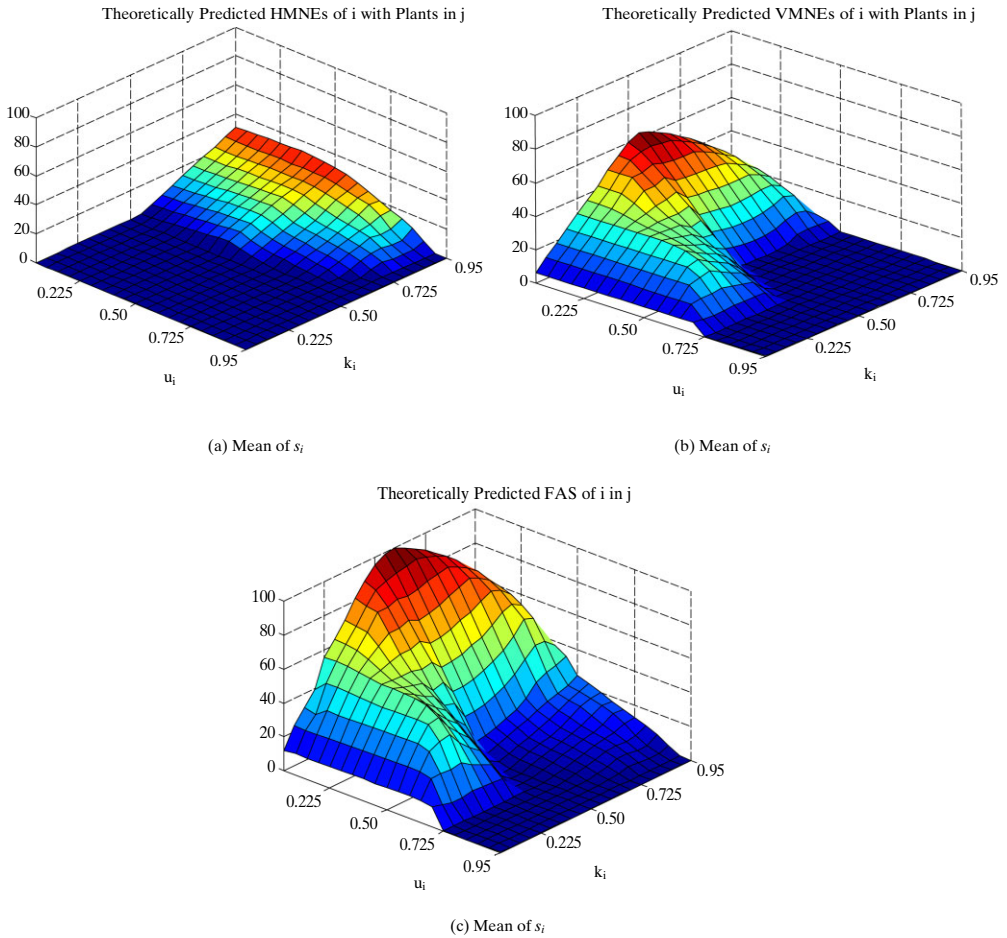


Figure 3(a–c). Theoretically Predicted Numbers of HMNEs, Numbers of VMNEs, and Foreign Affiliate Sales (a) Mean of s_i (b) Mean of s_i (c) Mean of s_i

cal capital, making it profitable for VMNEs to surface in i . This suggests that the relationship between k_i and FAS_{ij} is also a fourth-order polynomial. This suggests testable Hypothesis 2:

Hypothesis 2: Empirical FAS_{ij} in a regression should be a fourth-order polynomial function of k_i at the means of s_i and u_i ($s_i = u_i = 0.5$).

For completeness, Figure 3c shows the relationships between k_i , u_i and FAS_{ij} . Figure 3c requires careful inspection; it is both quantitatively and qualitatively different from Figure 3b at $u_i = 0.5$. In Figure 3b, at $u_i = 0.5$ when i is very physical capital abundant ($k_i = 1.0$), there are no VMNEs headquartered in i . However, Figure 3c shows that at $u_i = 0.5$ and $k_i = 1.0$ there is positive FAS_{ij} ; this FAS_{ij} is entirely horizontal FAS_{ij} (see Figure 3a). As k_i decreases from $k_i = 1.0$ along $u_i = 0.5$, horizontal MNEs decline in Figure 3c owing to the fall in physical capital abundance relative to skilled labor, but vertical MNEs increase. However, as k_i continues to decline toward 0, even VMNEs headquartered in i become unprofitable. Thus, we expect empirical FAS_{ij} to be a fourth-order polynomial function of k_i at the means of s_i and u_i (0.5).

In anticipation of our empirical results, we offer one note of clarification. Note that the z -axes in all figures (measuring FAS_{ij}) are indexed to 100. Hence, the more limited effect of HMNEs FAS in Figure 3c relative to vertical FAS reflects the calibration of the model. In the numerical simulations, at the peaks vertical MNE FAS activity is larger than HMNE FAS activity. This is apparent also in Figure 2c. It should be noted that our hypotheses are only qualitative predictions, not quantitative ones; we do not necessarily expect vertical FAS_{ij} to exceed horizontal FAS_{ij} . Indeed, earlier empirical evaluations suggest that, if anything, horizontal FAS activity should dominate vertical FAS activity. Our goal here is to introduce physical capital in such a manner as to suggest an empirical regression specification to better distinguish vertical FAS from horizontal FAS. We leave it to the data to reveal the relative quantitative importance of the two sources of FAS activity.

Finally, Figures 3a, 3b, and 3c all suggest Hypothesis 3, which is also potentially testable:

Hypothesis 3: Empirical FAS_{ij} should be a negative monotonic function of u_i .

The reason is that at $k_i = 0.5$ and $s_i = 0.5$ an increase in u_i is associated with an unambiguous decline in FAS_{ij} . The economic rationale is straightforward. If country i 's share of unskilled labor increases, i 's comparative advantage in production—of either differentiated good X or homogeneous good Y —increases, and consequently it loses a comparative advantage in hosting multinational headquarters, either horizontal or vertical ones.

This expected relationship is confirmed for FAS_{ij} in s_i - u_i space; again, FAS_{ij} is decreasing in u_i monotonically.⁷ For robustness Figures 4a–b depict the relationships in s_i - u_i space, which correspond to the axes in BNU. Figure 4a shows the theoretical relationship between numbers of HMNEs with headquarters in i and plants in j (as well as in i and ROW), s_i , and u_i at $k_i = 0.5$. Figure 4b shows the theoretical relationship between numbers of VMNEs with headquarters in i and plants in j , s_i , and u_i at $k_i = 0.5$. As expected, when u_i is low and s_i is low, more HMNEs are headquartered in i . When u_i is low and s_i is high, more VMNEs are headquartered in i .

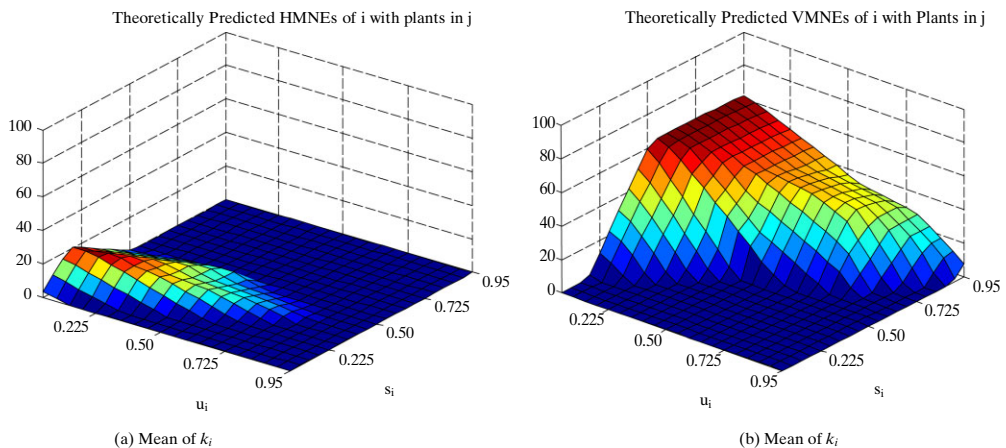


Figure 4(a,b). Theoretically Predicted Numbers of HMNEs and VMNEs (a) Mean of k_i (b) Mean of k_i

5. Empirical Framework and Results

Empirical Framework

The three-factor, three-country, two-good theoretical framework and empirical evidence in Bergstrand and Egger (2007) provides the starting point for a central regression specification—that is, a gravity equation—to capture economic size and similarity and bilateral trade and investment costs in determining bilateral horizontal FAS and bilateral intra-industry trade, consistent with Blonigen and Piger's (2011) Bayesian Moving Average analysis that confirmed the empirical importance of gravity-equation variables.⁸ However, Bergstrand and Egger (2007) provided no conceptual guidance on the specification of relative factor endowments.

BNU provided three important contributions to empirical investigation of the roles of relative factor endowments for explaining FAS flows in the two-factor, two-country KC model. One contribution was to extend empirical analysis from just US inward and outward FAS flows to a broad sample of countries. We follow this suggestion using bilateral FAS data from the United Nations Conference on Trade and Development (UNCTAD) country profiles for 1986–2000 among 36 countries listed in the Data Appendix; unfortunately, a consistent bilateral FAS data set among a larger number of countries is unavailable. Second, BNU measured relative factor endowments of skilled and unskilled labor using factor endowment share measures implied directly by Edgeworth-box (geometric) considerations (i.e. s_i and u_i). We follow this suggestion as well, and detail in the next paragraph how we adapt it to our three-factor, three-country setting. Third, BNU summarized the empirically predicted FAS values (based upon their final regression specification) using an Edgeworth box to confirm visually the “goodness of fit,” alongside conventional R^2 measures; we adopt this later.

The second BNU methodological innovation just noted reminds us that a country's factor shares measure precisely the “location” of a pair of countries in an Edgeworth box. First, we know from the $2 \times 2 \times 2$ KC literature that a traditional two-dimensional Edgeworth box can be used theoretically to reflect the relationship between s_i , u_i , and bilateral FAS of headquarters country i in affiliate country j (FAS_{ij}). Hence, a regression equation trying to capture the theoretical surfaces relating vertical FAS and horizontal FAS to relative factor endowments implied by the Edgeworth box should include s_i and u_i explicitly. Moreover, in a three-factor setting, we are in an Edgeworth “cube.” Hence, to evaluate a slice of the cube—say, for a given k_i —the regression must include k_i to hold it constant (at its mean). For given absolute endowments, a regression specification for capturing the relationships between FAS_{ij} , s_i , u_i , and k_i should include—on the right-hand side— s_i , u_i , and k_i explicitly in some functional form suggested by theory.

Second, a critical assumption of an Edgeworth box is that absolute factor endowments are held constant. In the two-country case, this is accounted for by including the two countries' GDPs, as the gravity equation would suggest; in cross-section, as is well established, the correlation between GDP and absolute factor endowments is very high (so that inclusion of GDP for economic size is sufficient). However, the three-country methodology of Bergstrand and Egger (2007) suggests that the GDPs of countries i , j , and ROW need to be accounted for. In a large cross-section, ROW GDP variation is virtually zero, and so need not be included. In a panel, changes in ROW GDP are easily accounted for using time dummies.

Consequently, our regression specifications to explain bilateral FAS flows basically “wed” the methodological contributions of Bergstrand and Egger (2007)—suggesting a standard gravity equation to account for economic size (or absolute factor endowments), trade costs, and investment costs—and of BNU—suggesting the use of factor shares s_i , u_i , and k_i to account for relative factor endowments. Typical gravity equation specifications include several variables to capture bilateral trade and/or investment costs. In this regard, we include standard time-invariant bilateral “cost” variables: the log of bilateral distance, a dummy variable for common land border (1 if adjacent, and 0 otherwise), and a dummy variable for common official language (1 if the same, and 0 otherwise). Following Markusen (2002), we also include cross-sectional and time-varying logarithms of multilateral measures of country trade resistance and investment resistance indexes from CMM (2001): $\log(Tc_i)$, $\log(Tc_j)$, and $\log(Inv_j)$. Unfortunately, data constraints preclude bilateral measures, which would be preferable. Third, in the specifications below, we include a time “dummy” for each year (except one, because of the constant) to capture potentially time-varying ROW GDP; however, for brevity we do not report the coefficient estimates for the intercept and time dummies.⁹

For estimation, we use a Poisson quasi-maximum likelihood (PQML) approach, which has become widely accepted. The reason for the PQML estimation method is the following. First, because of the multiplicative relationship between levels of flows and their economic determinants and owing to Jensen’s inequality, in the presence of heteroskedasticity ordinary least squares (OLS) estimation of log-linearized equations may lead to biased coefficient estimates for right-hand side variables. The PQML estimation method can address this concern, cf. Santos Silva and Tenreiro (2006). Second, PQML can be applied with dependent variables that include zero and positively valued observations, such as FAS flows. PQML exploits variation from both zero and non-zero observations, and our theoretical model predicts a large number of zeros and our empirical FAS data set has a large number of zeros. Data sources are listed in the Data Appendix.

Empirical Results

Regression results Table 1 reports various specifications for PQML regressions for bilateral FAS flows. The first two columns in Table 1 provide, respectively, a list of the right-hand side variables and their expected coefficient signs. The third through ninth columns report coefficient estimates and z -statistics (in parentheses) for specifications 1–7 for explaining bilateral FAS.

Specification 1 provides the results of estimating a traditional gravity equation for FAS_{ij} , where right-hand side variables capture economic size (a proxy for absolute factor endowments) and similarity and various factors that either impede or enhance flows. Since $GDP_i GDP_j = (GDP_i + GDP_j)^2 \{ [GDP_i / (GDP_i + GDP_j)] [GDP_j / (GDP_i + GDP_j)] \}$, we include separately $\log(GDP_i + GDP_j)$ and $\log(\text{Similarity}_{ij})$ where $\text{Similarity}_{ij} = [GDP_i / (GDP_i + GDP_j)] [GDP_j / (GDP_i + GDP_j)]$. Economic size and similarity have the expected positive and statistically significant relationships with FAS_{ij} . The two coefficient estimates suggest a clear “horizontal motivation” for MNE activity, as in Bergstrand and Egger (2007).

We now discuss the other “traditional” gravity-equation variables included in specification 1. As often found, the log of bilateral distance has a negative and statistically significant coefficient estimate and a conventional value throughout all the specifications (and so we will provide no further discussion of it). Of course, as in the KC

Table 1. *Bilateral FAS PQML Regressions*

<i>Variables</i>	<i>Expected sign</i>	<i>FAS (1)</i>	<i>FAS (2)</i>	<i>FAS (3)</i>	<i>FAS (4)</i>	<i>FAS (5)</i>	<i>FAS (6)</i>	<i>FAS (7)</i>
$\log(\text{GDP}_i + \text{GDP}_j)$	+	2.08* (20.21)	2.07* (19.71)	2.06* (19.69)	2.19* (22.76)	2.10* (20.03)	2.33* (19.86)	2.36* (18.35)
$\log(\text{Similarity}_{ij})$	+	0.13* (2.36)	0.17* (2.72)	0.16* (2.46)				
$\log(\text{Distance}_{ij})$	—	-0.70* (-15.41)	-0.67* (-15.41)	-0.67* (-14.27)	-0.69* (-14.88)	-0.66* (-15.30)	-0.64* (-14.94)	-0.61* (-13.98)
Contiguity	?	0.25* (2.61)	0.27* (2.84)	0.35* (3.11)	0.36* (3.08)	0.33* (2.97)	0.27* (2.40)	0.25* (2.23)
Language	+	0.02 (0.13)	0.03 (0.21)	-0.00 (-0.00)	-0.03 (-0.21)	0.11 (1.01)	-0.07 (-0.68)	-0.06 (-0.55)
$\log(\text{Invc}_i)$	—	-0.69* (-5.37)	-0.69* (-5.35)	-0.92* (-6.85)	-0.84* (-6.12)	-0.86* (-6.78)	-0.85* (-6.56)	-0.79* (-6.01)
$\log(\text{Tc}_j)$?	-0.03 (-0.31)	-0.14 (-1.57)	-0.10 (-1.20)	-0.11 (-1.35)	-0.19* (-2.24)	-0.14 (-1.62)	-0.12 (-1.31)
$\log(\text{Tc}_i)$	—	0.59* (6.23)	0.74* (7.42)	0.67* (6.46)	0.54* (5.40)	0.62* (6.71)	0.56* (6.15)	0.57* (6.42)
s_i	+		0.93* (2.89)	0.32 (0.88)	0.02 (0.06)	26.63* (7.69)	11.83* (2.92)	9.90* (2.26)
s_i^2	—					-89.37* (-6.40)	-55.65* (-3.64)	-43.90* (-2.87)
s_i^3	+					113.89* (5.56)	80.86* (3.55)	52.07* (2.13)
s_i^4	—					-49.23* (-4.93)	-36.61* (-3.27)	-21.74 (-1.79)
k_i	+			2.39* (5.77)	2.48* (5.68)	3.06* (6.95)	24.93* (6.77)	29.25* (7.36)
k_i^2	—						-67.71* (-4.86)	-93.09* (-5.26)
k_i^3	+						85.72* (4.21)	118.67* (5.04)
k_i^4	—						-38.34* (-3.96)	-54.87* (-4.80)
u_i	—		-0.97* (-3.18)	-2.98* (-7.30)	-2.87* (-6.63)	-3.79* (-8.95)	-3.73* (-9.00)	-5.19* (-6.07)
$s_i k_i$?							7.95 (1.22)
$s_i u_i$?							0.41 (0.08)
$k_i u_i$?							1.92 (0.43)
No. of Obs.		1370	1370	1370	1370	1370	1370	1370
Pseudo R^2		0.61	0.61	0.63	0.63	0.66	0.67	0.67

Notes: * Denotes statistically significant at 5% in two-tailed z -test. Numbers in parentheses are z -statistics. Coefficient estimates for the constant and time dummies are not presented for brevity.

literature, actual “distance” has no theoretical role, but is often interpreted as an investment “friction” and typically included. We specify the expected sign on contiguity as ambiguous for FAS_{ij} . The reason is that—if FAS has a horizontal motivation—then FAS is a substitute for trade, and contiguity may have a negative effect (lower trade costs cause more trade and less FAS). If contiguity reduces information costs, then it may have a positive effect on FAS_{ij} . In all the FAS specifications, Contiguity has a positive and statistically significant effect. A common language is likely to enhance information flows, and the expected effect is positive; in all the FAS specifications, the coefficient estimate is effectively zero and statistically insignificant. The log of the investment cost index in j ($\log(InvC_j)$) is expected to have a negative effect on FAS_{ij} , representing a barrier to either vertical or horizontal investment in j . Throughout the FAS specifications, this variable has the expected negative sign and is statistically significant. Finally, we include two indexes of “trade costs,” one multilateral trade-cost index for j ($\log(TC_j)$) and one such index for i ($\log(TC_i)$). For $\log(TC_j)$, we have no unambiguous sign expectation. The reason is that, if FAS has a horizontal motivation, we would expect a positive coefficient, as FAS and trade are substitutes. However, in reality, even HMNEs based in i with plants in j require some intermediate inputs from i , for which trade costs in j would impede FAS_{ij} . It turns out that the coefficient estimates for $\log(TC_j)$ tend to be effectively zero for most FAS specifications. Distance may be effectively capturing much of this variable’s cross-sectional effect. Finally, the expected coefficient sign for $\log(TC_i)$ is negative. If FAS_{ij} has a vertical motivation, then we would expect goods to flow from j to i ; trade costs in i would diminish these flows. Hence, FAS_{ij} may indirectly be reduced because of trade costs in i ; this creates a negative expected effect. However, the coefficient estimates for $\log(TC_i)$ are positive and statistically significant for all the FAS specifications, which is unexpected. The overall pseudo- R^2 value for specification 1 is 0.61, which is about the same (0.58) as that for a similar gravity specification for FDI flows in Bergstrand and Egger (2007).

We now turn to the focus of this paper, the effect of relative factor endowments on FAS flows. Specification 2 enhances the FAS gravity equation, adding just s_i and u_i to the previous specification. The reason for reporting this specification—even though our theoretical model suggests that s_i should be included as a fourth-order polynomial—is to determine if we can find a similar (positive) effect as for the variables $SKILL_{ij}$ ($= s_i/u_i$) in BNU and $SKDIFF_{ij}$ (measured as the difference in i 's and j 's skilled labor stocks as shares of total labor force) in CMM (2001). We confirm this.¹⁰ Holding u_i constant, s_i has a positive and statistically significant coefficient estimate and—holding s_i constant— u_i has a negative and statistically significant coefficient estimate; this suggests that there is some “vertical motivation” for FAS. Of course, this specification is not motivated by our theoretical Edgeworth boxes and is subject to the same potential specification concern as raised in Blonigen et al. (2003). However, it is useful to ascertain that this simple specification “accords” with earlier results of CMM and BNU motivated by the two-factor, two-country KC model. Finally, we note that none of the other (gravity equation motivated) variables’ coefficient estimates change materially, and so there remains evidence of “horizontal motivation” for FAS as well.

In specification 3, we consider for the first time the role of physical capital endowments by adding k_i to the previous specification. Interestingly, the only variable whose coefficient estimate changes materially is i 's skilled labor share, s_i . This is interesting because it suggests that measures of relative skilled labor endowments in previous studies may have been effectively a proxy for relative physical capital endowments in

explaining FAS. Only physical capital (k_i) and unskilled labor (u_i) factor endowment shares—of the three relative endowment variables s_i , k_i , and u_i —are statistically significant.

As noted earlier, the inclusion of variables s_i , k_i , and u_i maps relative factor shares *directly* from the theory. However, also noted earlier, variation in any one variable—such as s_i —for given values of k_i and u_i —necessarily (in an Edgeworth box) changes relative economic sizes of i and j . Thus, one can argue that the change in any one factor share (vertically or horizontally in the box) changes relative factor endowments and economic size, so that the inclusion of $\log(\text{Similarity}_{ij})$ is inappropriate. By these considerations, we ran specification 4 which differs from previous specification 3 only by the exclusion of $\log(\text{Similarity}_{ij})$. The important outcome is that the exclusion of $\log(\text{Similarity}_{ij})$ does not create any significant omitted variables bias; none of the other variables' coefficient estimates changes materially. Consequently, in the remaining specifications we exclude $\log(\text{Similarity}_{ij})$; however, for robustness all subsequent specifications' results are largely insensitive to its absence (and available on request).

Theoretical discussion in section 4, theoretical Figures 2a–c, and Hypothesis 1 imply that—for given k_i and u_i — FAS_{ij} should be a fourth-order polynomial function of s_i . Specification 5 modifies the previous specification by including s_i , s_i^2 , s_i^3 , and s_i^4 . The expected signs for these four variables' coefficients in specification 5 for a fourth-order polynomial function to follow the shape suggested by theoretical Figure 2c at the means of k_i and u_i (about 0.5) are listed in the second column of Table 1. Specification 5 shows that the coefficient estimates have the expected signs and all are statistically significant. Hence, in a comparison of specifications 4 and 5, s_i in specification 4 (without the fourth-order polynomial function) is economically and statistically insignificant, but using a fourth-order polynomial s_i has the expected theoretical relationship with FAS_{ij} . Moreover, none of the other variables' coefficient estimates changes materially between specifications 4 and 5. Thus, Hypothesis 1 is confirmed empirically.

Section 4, theoretical Figures 3a–c, and Hypothesis 2 imply that—for given s_i and u_i — FAS_{ij} should be a fourth-order polynomial function of k_i . Specification 6 modifies the previous specification by including k_i , k_i^2 , k_i^3 , and k_i^4 . The expected signs for these four variables' coefficients in specification 6 for a fourth-order polynomial function to follow the shape suggested by theoretical Figures 3a–c at the means of s_i and u_i (0.5) are listed in the second column of Table 1. Specification 6 shows that the coefficient estimates follow a fourth-order polynomial function with coefficient estimate signs corresponding precisely to the expected ones, and all coefficient estimates for these four variables are statistically significant. Moreover, none of the other variables' coefficient estimates changes materially between specification 5 and 6. Thus, Hypothesis 2 is confirmed empirically.

We note across all six FAS specifications that u_i has the expected negative coefficient sign with statistical significance, confirming Hypothesis 3. This accords with the intuition that FAS of MNEs based in i will be lower the relatively more unskilled labor abundant i is, because unskilled labor raises its comparative advantage in production over forming MNE headquarters. Theoretical Figure 3c suggests a monotonic negative relationship between FAS_{ij} and u_i . Indeed, FAS_{ij} and u_i are negatively correlated with a statistically significant coefficient estimate.

Even though the fourth-order polynomial functions for s_i and k_i captured the theoretical relationships in Edgeworth-box space, as a robustness check we were curious to see if specification 6's results were sensitive to interaction terms, commonly used in the KC literature. While many interaction terms are possible, we considered adding only the interaction terms $s_i k_i$, $s_i u_i$, and $k_i u_i$ —that is, interactions among the key factor-

share variables. Specification 7 reports the results of adding these interaction terms. Interestingly, none of the coefficient estimates of the interaction terms was statistically significantly different from zero. Moreover, their inclusion had no material impact on the other coefficient estimates.

Empirically-predicted FAS flows In this section, we draw upon one of the innovations in BNU—which employed the empirically-predicted bilateral FAS flows using its central regression equation—to examine the similarity of the Edgeworth boxes using the theoretically predicted FAS_{ij} and those using empirically predicted FAS_{ij} . Moreover, we must extend this approach in our three-factor setting to slices of an Edgeworth “cube,” evaluating the Edgeworth slices at the empirical means of the third factor.

Figure 5a provides the Edgeworth box relating empirically predicted FAS_{ij} from Specification 6 to k_i and s_i at the empirical mean of u_i (about 0.5) and provides empirical support for one of the main economic insights of this paper. This figure corresponds to theoretical Figure 2c (except for the relative quantitative importance of HMNE vs VMNE activity). Predicted (empirical) FAS_{ij} reaches a maximum when

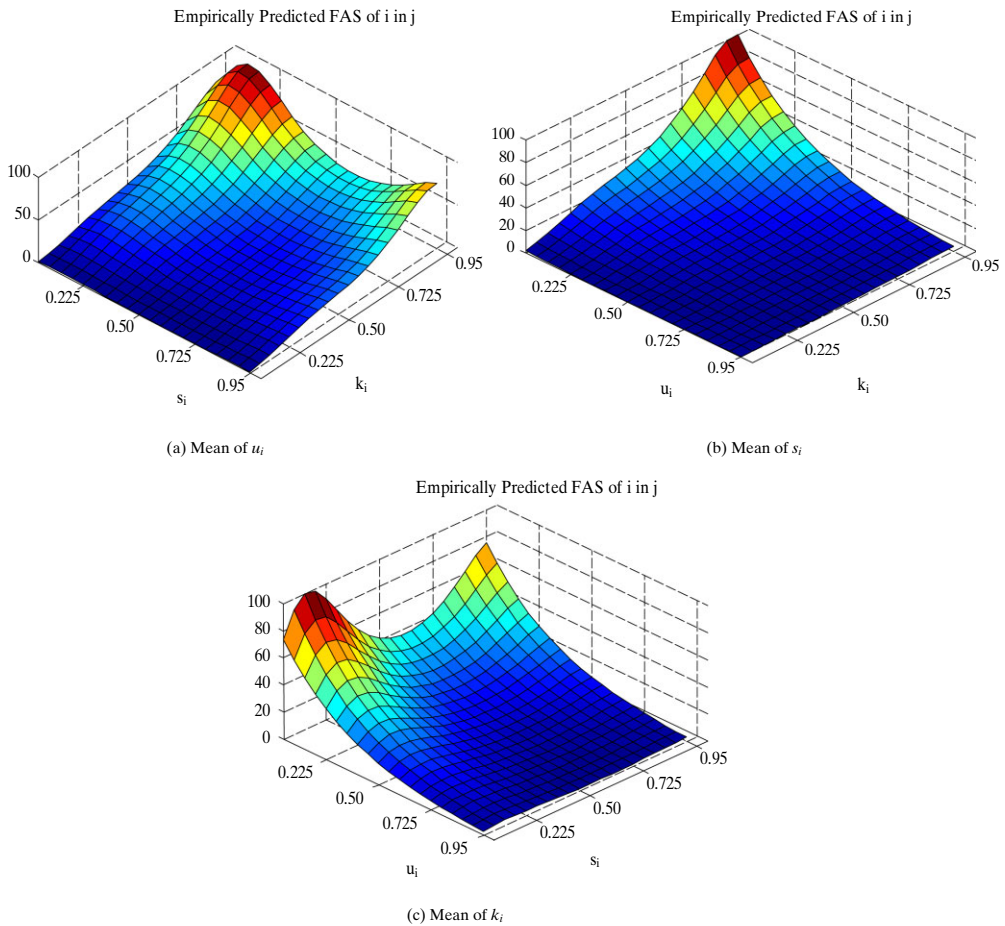


Figure 5(a–c). Empirically Predicted Foreign Affiliate Sales (a) Mean of u_i (b) Mean of s_i (c) Mean of k_i

either country i is abundant in skilled labor and physical capital (relative to unskilled labor)—which favors VMNE activity (see theoretical Figure 2b)—or country i is abundant in physical capital relative to skilled labor—which favors HMNE activity (see theoretical Figure 2a). Figure 5a confirms empirically that both horizontal and vertical FAS are important—but with HMNE activity more important empirically in the aggregate bilateral data—and each type of FAS attains its maximum in the Edgeworth box approximately where Figures 2a–c predict. Figure 5a is consistent with Hypothesis 1; FAS_{ij} is a fourth-order polynomial of s_i at the means of k_i and u_i .

Figure 5b confirms Hypotheses 2 and 3, but only upon careful examination. Figure 5b provides the Edgeworth box relating empirically-predicted FAS_{ij} to k_i and u_i at the empirical mean of s_i and provides empirical support for two other main economic insights of this paper: FAS_{ij} is a fourth-order polynomial function of k_i and a monotonic negative function of u_i . The figure is the empirical analogue to theoretical Figure 3c (except for the relative quantitative importance of HMNE vs VMNE activity). It is clear—when comparing Figure 5b with Figures 3a and b—that HMNE activity tends to dominate FAS activity in the bilateral aggregate data. However, vertical MNE activity is not trivial; it is important to recall that the predicted (empirical) FAS_{ij} surface in Figure 5b is generated by the statistically significant fourth-order polynomials in k_i and s_i . Indeed, careful examination of Figure 5b reveals that empirically predicted FAS_{ij} 's are a fourth-order polynomial of k_i for any given value of u_i (and recalling that $s_i = 0.5$). Moreover, at $u_i = s_i = 0.5$, the peak of vertical FAS empirical activity in Figure 5b is at k_i equal to approximately 0.225, which corresponds precisely to that in Figures 3b and c (at $u_i = s_i = 0.5$).

Finally, Figure 5c shows the empirical relationship between predicted FAS_{ij} with s_i and u_i at $k_i = 0.5$. Consistent with the results above, vertical FAS co-exists with horizontal FAS, but horizontal MNE activity is more prevalent.

6. Conclusions

Finding vertical MNE activity has remained relatively elusive in econometric analyses of bilateral aggregate FAS data. This paper has offered an approach to try to better understand empirically and theoretically the relationships between horizontal and vertical MNEs' bilateral aggregate foreign affiliate sales (FAS) and countries' relative factor endowments. By extending the KC model with only skilled and unskilled labor to include a third factor (physical capital) and a third country (ROW) as in Bergstrand and Egger (2007), we could explain theoretically the complex, nonlinear, nonmonotonic empirical relationships between bilateral FAS flows of two countries and their relative endowments of skilled labor, unskilled labor, and physical capital. Our empirical evidence suggests that both horizontal and vertical motivations for FAS exist in the bilateral aggregate FAS data—and physical capital matters in the explanation.

Data Appendix

Bilateral foreign affiliate sales data are from UNCTAD (country profiles) for 1986–2000. GDPs are from the World Bank's *World Development Indicators* (2004). We followed Carr et al. (2001) by deflating nominal foreign affiliate sales in US dollars by host country producer price indices (base year 2000) taken from the *World Development Indicators*. Physical capital stocks are computed by using the perpetual inventory

method following Leamer (1984), using gross fixed capital formation and investment deflator data from the *World Development Indicators* and assuming a depreciation rate of 13.3%. Data on human capital endowments were kindly provided by Scott Baier and are based on information in the *World Development Indicators* on school enrollment (see Baier et al., 2006). Remaining workers are classified as unskilled. Bilateral distance was computed using “great circle” distances. The country trade resistance and investment resistance indexes are from Carr et al. (2001), kindly provided by Keith Maskus. The exporting (FAS parent) and importing (host) countries include the following: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Denmark, Egypt (imports/FAS host only), Finland, France, Germany, Greece, Hong Kong, Ireland, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Philippines, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, UK, USA, and Venezuela.

References

- Alfaro, Laura and Andrew Charlton, “Intra-industry Foreign Direct Investment,” *American Economic Review* 99 (2009):2096–119.
- Anderson, James E. and Eric van Wincoop, “Gravity with Gravitas: A Solution to the Border Puzzle,” *American Economic Review* 93 (2003):170–92.
- Baier, Scott L., Gerald P. Dwyer, Jr., and Robert Tamura, “How Important are Capital and Total Factor Productivity for Economic Growth?” *Economic Inquiry* 44 (2006):23–49.
- Baier, Scott L. and Jeffrey H. Bergstrand, “Do Free Trade Agreements Actually Increase Members’ International Trade?” *Journal of International Economics* 71 (2007):72–95.
- , “Bonus Vetus OLS: A Simple Method for Approximating International Trade-cost Effects using the Gravity Equation,” *Journal of International Economics* 77 (2009):77–85.
- Bergstrand, Jeffrey H. and Peter Egger, “A Knowledge-and-physical-capital Model of International Trade Flows, Foreign Direct Investment, and Multinational Enterprises,” *Journal of International Economics* 73 (2007): 278–308.
- , “Gravity Equations and Frictions in the World Economy,” in Daniel Bernhofen, Rod Falvey, David Greenaway, and Udo Kreickemeier (eds), *Palgrave Handbook of International Trade*, New York, NY: Palgrave Macmillan (2011).
- Bernard, Andrew B., J. Bradford Jensen, and Peter K. Schott, “Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trade Goods,” Tuck School of Business at Dartmouth working paper 2005–17 (2005).
- Blonigen, Bruce A., “A Review of the Empirical Literature on FDI Determinants,” *Atlantic Economic Journal* 33 (2005):383–403.
- Blonigen, Bruce A. and Jeremy Piger, “Determinants of Foreign Direct Investment,” National Bureau of Economic Research working paper 16704 (2011).
- Blonigen, Bruce A., Ronald B. Davies, and Keith Head, “Estimating the Knowledge-capital Model of the Multinational Enterprise: Comment,” *American Economic Review* 93 (2003):980–94.
- Braconier, Henrik, Pehr-Johan Norbäck, and Dieter Urban, “Reconciling the Evidence on the Knowledge-capital Model,” *Review of International Economics* 13 (2005):770–86.
- Carr, David, James R. Markusen, and Keith E. Maskus, “Estimating the Knowledge-capital Model of the Multinational Enterprise,” *American Economic Review* 91 (2001):693–708.
- , “Estimating the Knowledge-capital Model of the Multinational Enterprise: Reply,” *American Economic Review* 93 (2003):995–1001.
- Davies, Ronald B., “Hunting High and Low for Vertical FDI,” *Review of International Economics* 16 (2008):250–67.
- Goldin, Claudia and Lawrence Katz, “The Origins of Technology–Skill Complementarity,” *Quarterly Journal of Economics* 113 (1998):693–732.

- Griliches, Z., "Capital-Skill Complementarity," *Review of Economics and Statistics* 51 (1969):465–68.
- Helpman, Elhanan, "Trade, FDI, and the Organization of Firms." *Journal of Economic Literature* 46 (2006):589–630.
- Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple, "Export Versus FDI with Heterogeneous Firms," *American Economic Review* 94 (2004):300–16.
- Leamer, Edward E., *Sources of International Comparative Advantage: Theory and Evidence*, Cambridge, MA: MIT Press (1984).
- Markusen, James R., *Multinational Firms and the Theory of International Trade*. Cambridge, MA: MIT Press (2002).
- Markusen, James R. and Keith E. Maskus, "Multinational Firms: Reconciling Theory and Evidence," in Magnus Blomstrom and Linda Goldberg (eds), *Topics in Empirical International Economics: A Festschrift in Honor of Robert E. Lipsey*, Chicago: University of Chicago Press (2001).
- , "Discriminating Among Alternative Theories of the Multinational Enterprise," *Review of International Economics* 10 (2002):694–707.
- Santos Silva, J.M.C. and Silvana Tenreyro, "The Log of Gravity," *Review of Economics and Statistics* 88 (2006):641–58.
- Slaughter, Matthew J., "Production Transfer withing Multinational Enterprises and American Wages," *Journal of International Economics* 50 (2000):449–72.

Notes

1. This is implied by two peaks in the Edgeworth box relating the parent country's skilled labor share to FDI/FAS, one for horizontal FDI/FAS flows and one for vertical FDI/FAS flows.
2. Most FDI studies using the gravity equation simply justify using it by analogy to the theoretical foundations for the trade gravity equation. However, see Bergstrand and Egger (2007) for a theoretical foundation for gravity equations of bilateral FDI and FAS flows, simultaneously with one for trade flows, in the presence of national and multinational firms. See Bergstrand and Egger (2011) for a survey of the literature.
3. Braconier et al. (2005) find some evidence of vertical FAS. However, their $2 \times 2 \times 2$ approach has a limitation because there may exist HMNEs in the factor-endowment space where VMNEs are supposed to be uniquely identified, as discussed in the next section.
4. In fairness, Carr et al. (2003) candidly indicated that finding a "central regression specification" is a very difficult task.
5. We note now that the discussion above has important implications for hypotheses about the relationship between GDP similarity and FAS_{ij} . In our three-factor, three-country world, when u_i is at its mean the cell in the middle of the Edgeworth box relating k_i and s_i may not be where i and j are identically sized in absolute factor endowments (for some given endowments for ROW), because u_i may not be precisely 0.5 (but as noted above, it will be close). Moreover, a proportionate reduction in k_i and s_i —such that k_i/s_i is unchanged—but holding u_i at its mean—changes i 's and j 's relative economic sizes and also their relative factor endowments. This differs from the two-factor KC world examined in all the previous studies (also with only two countries) where a movement along the Southwest–Northeast (SW–NE) diagonal implies a change in relative economic sizes (absolute factor endowments) of the two countries without a change in relative factor endowments. In our three-factor world, a movement along this diagonal also changes relative factor endowments.
6. We have done extensive sensitivity analyses for various alternative values of the parameters, and the results are qualitatively robust and available on request.
7. Note that all figures are indexed between 0 and 100. Hence, the theoretical figures are not designed to predict effects quantitatively, just qualitatively.
8. Recall that formal theoretical foundations for the gravity equation are based upon N -country worlds, so the ROW is taken into account.

9. Regarding other “third-country” effects such as ROW trade and investment barriers, these effects are more difficult to capture because any country-specific dummies would preclude cross-section variation in s_i , k_i , and u_i , cf. Anderson and van Wincoop (2003) or Baier and Bergstrand (2009). Moreover, in a panel, such effects would require country and time dummies, which would also preclude variation in s_{it} , k_{it} , and u_{it} , cf. Baier and Bergstrand (2007). We leave this issue for researchers to address in the future.
10. Variables s_i , k_i , and u_i are not expressed in logs, so their coefficients are not reflecting “elasticities.”