Estimating the Knowledge-Capital Model of the Multinational Enterprise: Reply

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1.   <u>Introduction</u>

For many years, perhaps decades, economists tended to think of foreign direct investment in terms of capital flows from capital rich to capital poor nations, or equivalently locating stages of production with different factor intensities in locations where the intensive factors were cheap. We now term this a vertical approach. Markusen is one architect of a very different approach in which firm-level scale economies and trade costs lead firms to choose multiple locations of production for the same goods or services, implying a large volume of cross investment among similar countries. This finding is closely consistent with the data which are in turn at odds with the predictions of the vertical model. Later, Markusen proposed a hybrid approach which includes both vertical and horizontal investments in the same general equilibrium framework and termed this the "knowledge-capital model" (KK).

Blonigen, Davies and Head (BDH) have produced a paper that argues that the Carr, Markusen, and Maskus (CMM) estimation of the knowledge-capital model has misspecified the underlying theory in its central estimating equation.   They argue that when the regression equation is correctly specified, then a horizontal model cannot be rejected in favor of the integrated knowledge-capital model. The first point that we should make is that Markusen in particular is not bothered or threatened by a paper whose main point gives strong support to a horizontal model of multinational firms. He is probably the chief proponent of the horizontal model, and wrote a series of theory papers supported by stylized facts at a time when the vertical model seemed the (often implicitly assumed) dominant conceptual model as just noted.

The second point is that the knowledge-capital model, a hybrid of a vertical and a horizontal model, as a conceptually difficult one for estimation. Relationships predicted by the model are not only non-linear but non-monotonic. The implication of this is that there is room for reasonable disagreement as to what the appropriate estimating equation should be. Moreover, the anticipated signs of some coefficients depend on the nature of the process generating the data, which can vary across investment partners. In fact, our specification is appropriate for capturing the direct impacts of skill differences within our data sample, as we will discuss below.

Our third point is that there is some confusion between estimation and testing. CMM carefully and deliberately chose the world "estimating" rather than "testing" the model and estimating is precisely what we did. We took the theory rather literally in trying to estimate that model and did not formulate the problem as an explicit test of the theory against some alternative. However, in later publications some of which are referenced by BDH, we did turn to testing and nested a horizontal and vertical model within the KK model (Markusen and Maskus 2002a, Markusen 2002). When we do that, we get the same results that BDH get, namely that the restrictions of the horizontal model cannot be rejected in favor of the KK model. We have also noted the result that US outward investment is skilled labor seeking (Markusen and Maskus, 2001, 2002bc, Carr, Markusen and Maskus, 2002). So we already know these results from quite a number of published/forthcoming articles. While we reject the "misspecification" assertion, we have thus already agreed with their principal finding in several publications.

Our final point, to which we now turn, is that BDH's proposed alternative "absolute-difference" estimating equation makes no sense from the point of view of the theory. It proposes relationships that cannot be consistent with (i.e., are misspecified with respect to) *any* existing theory as we show in the next section. It can however, be interpreted as a crude test to chose between a horizontal and the vertical model, but certainly not the KK model. The horizontal model fits the data better but again, there is already strong published evidence on this point.

2.   Evaluation

BDH concentrate on the effect of skilled-labor-endowment difference on the production of affiliates of country i firms in country j. Their right-hand side variables (ignoring trade and investment cost controls) are:

GPD sum of parent and host countries $(GDP_i + GDP_j)$
GPD difference squared $(GDP_i - GDP_j)^2$
Abs value of skill difference of parent and host countries $|SK_i - SK_j|$
Abs value of skill diff times abs value of GPD difference $|SK_i - SK_j|*|GDP_i - GDP_j|$

whereas CMM used levels for the last two: $(SK_i - SK_j)$, $(SK_i - SK_j)*(GDP_i - GDP_j)$

Let $RSALES_{ij}$ be the real sales of country j affiliates of firms headquartered in country i. Again leaving out the trade and investment cost controls (or assuming that they are the same in both directions), note that BDH give us the symmetric equations:

$$RSALES_{ij} = RSALES_{ji} = \alpha + \beta_1(GDP_i + GDP_j) + \beta_2(GDP_i - GDP_j)^2 + \beta_3|SK_i - SK_j|$$

$$+ \beta_4|SK_i - SK_j|*|GDP_i - GDP_j| + ...$$

The BDH formulation is not consistent with any theory we are aware of. If you look at the four variables above, reversing which country is which leaves the values of all four variables the same. It predicts that affiliate sales by i-owned firms in country j will always be the same as by j-owned firms in country i.

If country i is small and skilled-labor abundant, the other country is large and skilled-labor scarce. In their formulation, BDH are imposing the assumption that affiliate sales in both directions are the same. Sales of US firms in Peru must be the same as the sales of Peruvian firms in the US. This is inconsistent with any version of the theory, whether horizontal, KK or especially the vertical model which always predicts that $RSALES_{ij} = 0$ if i is skilled-labor scarce.

Figure 1 shows a simulation of three cross-sections through the world Edgeworth box for three different levels of differences in country size. The horizontal axis is a roughly NW-SE locus along which countries differ in relative endowments but have roughly constant incomes.

If you consider a point such as 0.75 on the horizontal axis and a corresponding point 0.25, it is immediately clear that the model predicts more outward investment from the skilled-labor abundant country so that the former point has higher outward sales than the latter. But BDH treat these points as the same, and do not allow the data to distinguish between them. Markusen and Maskus (2002ab) or the relevant chapters in Markusen (2002) show that this prediction is also true for the horizontal model, a point to which we will return shortly.

Similarly, our Figure 1 indicates that, for a given level of skill differences, the difference in country size has a crucial effect on outward affiliate activity. Yet BDH's proposed "correction" using absolute values treats as observationally equivalent the case where country i has 25% of world income (and j has 75%) and when it has 75% of world income. Such a restriction is completely inconsistent with the theory and has no sensible motivation.

To see the problem, consider the United States and Mexico. U.S.-owned affiliate sales in Mexico in 1990 were $16.5 billion, while Mexican-owned affiliate sales in the United States were $1.6 billion, differing by a factor of ten. Asking the regression to identify coefficients in which these values are predicted to be the same, except for the influence of trade and investment costs, places great stress on the coefficients of the cost variables. Indeed, in the BDH Tobit results in their Table 1, we find a coefficient on investment costs of 229.8, which is *positive* and significant, suggesting improbably that higher local investment costs raise affiliate activity. Further, if we calculate the marginal effect of trade costs, which would be - 227.3 + 6896*(0.016), where 0.016 is the mean of squared skill differences, we find that trade costs have a significantly *negative* effect on affiliate sales. *This outcome is inconsistent with the horizontal model that the authors claim to have supported*. Finally, note that the intercept terms in the BDH absolute value regressions differ markedly from those in CMM, presumably an artifact of the
constraints imposed by the specification.

It is clear from Figure 1 that the theory is complicated by non-linearities and non-monotonicities. Specifying a central regression equation is a difficult task. But we think that the picture also makes it clear why we chose the equation that we did. "On average", outward investment from country i to country j is higher when country i is skilled-labor abundant than when it is skilled labor scarce. This relationship is indeed nonmonotonic, but it is equally important to note that the reversal point is not when the countries have identical skill ratios. Given where most of the sample points lie as indicated in Figure 1, it is not unreasonable to simply model outward investment as increasing in the skill difference.

BDH note that by pooling outward and inward affiliate sales data for the United States, we combine cases where the difference in skill ratios (SKDIFF) is positive and where it is negative, leading to a problem of interpretation about the effect of an increase in that variable. That is, where SKDIFF is positive, an increase in its value reflects a divergence in endowments, but where SKDIFF is negative, an increase in its value reflects a convergence in endowments. Thus, holding the difference in GDP levels constant, our specification claims that in both cases there would be a rise in affiliate sales, the essential claim that BDH dispute.

If we were testing between vertical and horizontal specifications in this paper, their criticism would be correct and we accounted for this in our later paper (Markusen and Maskus, 2002a). However, in CMM we were estimating contours of the KK model given the available data. Look again at Figure 1. Suppose we take the case where country i is large, with 75% of total GDP, which corresponds closely to our data sample for U.S.-owned foreign affiliate sales. Then starting from SKDIFF = 0.0 (0.50 on the horizontal axis) a rise in SKDIFF, with the United States becoming consistently more skill abundant, increases sales until SKDIFF = 0.30 (0.65 on the axis), then falls off. If most of our affiliate sales observations lie within this range of skill differences, the econometric approach will capture this side of the non-monotonic relationship.

Next, take the case where i is small, with 25% of total GDP, which corresponds closely to our data sample for foreign-owned affiliate sales in the United States. The starting from SKDIFF = -0.30 (0.35 on the axis) a rise in SKDIFF to 0.0 (0.50 on the axis) also raises affiliate sales, even though this reflects a convergence in endowments rather than a divergence as in the earlier case. Going beyond this point continues to raise sales as the U.S. becomes increasingly more skill abundant. The implication of this theory is that, so long as our sample of SKDIFF observations lies essentially between -0.30 and +0.30, a unidirectional coefficient is consistent with the model. As may be seen from CMM, Table 1, the actual range on SKDIFF is from -0.277 to +0.277.

The implication is that a unidirectional coefficient is appropriate as long as we are interested in the net volume of affiliate sales, whether it is generated largely by horizontal or vertical motives. Our approach does not distinguish sharply between these motives but it does capture the underlying prediction for direct impacts of endowment differences on sales volumes.

Secondly, country size clearly has an important interaction with skill differences. Outward affiliate sales will be high when the skilled-labor-abundant country is small but we can also infer from the diagram that affiliate sales must be zero if this is reversed and the parent country is skilled-labor-scarce and large. Yet the BDH formulation insists that these are the same thing. The CMM formulation shown above captures this interdependency by using the levels rather than absolute values of the third and fourth variables list above (although again, it doesn't deal well with the non-monotonicity when the parent-host skill difference becomes large). CMM most definitely does not predict a symmetric relationship between i and j. It conforms to the theory by predicting more outward sales by a skilled-labor-abundant country relative to a skilled-labor scarce country, and more outward sales when the skilled-labor abundant country is also moderately small.

Now let's turn to BDH's suggestion to break the sample into observations where the parent has the higher skill (positive skill difference) share versus a lower share (negative skill difference). Alternatively, they break it into a US outward and US inward sample. This is more promising and a more theoretically appropriate approach. One problem with this is that each regression is restricted to a small section of the Edgeworth box with special results for the theory. The positive difference sample is primarily US outward observations, but the US is also

far larger than the other countries in the sample. Thus this positive skill difference sample and of course the US outward sample are points where the parent country is both skilled-labor abundant relative to the host and also very large relative to the host. Refer again to Figure 1, and consider the curve where the parent is 75% of the joint economy. Here we see the non-monotonic relationship very clearly, and depending on the data points, it may well be that on average a convergence in skill rations raises outward investment. This is a finding of BDH but it is clearly also a finding in CMM. In Result 4 of CMM (p. 706), we clearly state that US outward investment is attracted to skilled-labor-abundant countries. Once again, we have already reported this result in CMM and also in Markusen and Maskus (2001, 2002bc), Carr, Markusen and Maskus (2002), and Markusen 2002 and furthermore, it is not in any way inconsistent with the knowledge capital model as Figure 1 shows. It is an artifact of where in the world Edgeworth box the observations are drawn from.

BDH's proposal to use OECD data in Table 4 is a promising attempt to get around this problem by adding observations from small, skilled-labor abundant countries (unfortunately, they use investment stocks rather than production and sales data, the latter being the focus of theory). This is very welcome; however, they retreat here to the absolute value formulation which we have criticized above rather than the more appropriate approach they use in Table 2.

To summarize to this point, we have argued that BDH's formulation in Table 1 makes no sense in terms of the theory, and that Table 2 arrives at findings that are not only consistent with the knowledge-capital model but findings which we have already reported in at least three articles and chapters. The use of OECD data is promising, but it should used with the estimation method in Table 2, not with the absolute-value approach.

3.   Testing versus Estimation

CMM *estimates*, it does not *test*. Markusen and Maskus (2002a) and Markusen (2002) explicitly introduce a nesting procedure so that a horizontal model and a vertical model are restricted versions of the KK model. These papers show that the restrictions of the horizontal model cannot be rejected, which is a finding similar to that of BDH although the latter do not have any formal approach to this issue. The difficulty just alluded to is shown in Figure 2 below. When the parent country is not small relative to the host, the KK model and a restricted horizontal model produce roughly the same picture (this is a slice through the center of the world Edgeworth box where both countries are the same size - the result also applies to when the parent is larger). Thus when the parent country is large and skilled-labor abundant, there is not much "power to the test" to distinguish between the horizontal and the KK model. Yet this is precisely the handicap of the data: the US is large and skilled labor abundant in the very large majority of the observations. Thus it is should be no surprise that the estimation cannot reject the restrictions of the horizontal model and, to belabor the point, this has already been carefully noted and explained in at least two forthcoming publications (Markusen and Maskus 2002a, Markusen 2002)..

BDH may be interested in a recent paper by Braconier, Norbaeck and Urban (2002), in which they add Swedish data to Markusen-Maskus data set. This is motivated by precisely the point just discussed. Adding the Swedish data gives many observations in which the parent country is small and skilled labor abundant and thus, by the above argument, should allow the data to distinguish between the horizontal and KK models. They find more support for vertical investment and the KK model, thereby also adding evidence for our "power of the test" argument. Again, BDH have a chance to do something similar with their OECD data but fall back on the inappropriate absolute-value approach.

4.   An Interpretation of BDH: Testing the Horizontal versus Vertical Model

We would like to close by offering an interpretation of what BDH have done in their Table 1 estimation using absolute values. What they have done is to artificially impose a restriction shown in Figure 3. For a given difference in country size, the estimation can only arrive at the finding that outward affiliate sales should be a symmetric U or an inverted U. The former corresponds to predictions of a vertical model, but *only* when the parent is skilled-labor abundant (left-hand branch of the U). The latter (inverted U) corresponds very crudely to the predictions of a horizontal model (but the horizontal model does *not* predict symmetry around zero skill differences as shown in Figure 2!). Their formulation does not permit an estimate such as the monotonic curve shown in Figure 1 for the case of the parent country small. This is excluded by assumption.

As a consequence, one reasonable interpretation of what they have done is that they are testing the horizontal model versus the vertical model. (Although there is a second huge problem noted earlier: their formulation treats a small and large parent country as producing exactly the same relationship). Insofar as this is true, they have an interesting result, that the horizontal model completely dominates the vertical model. However, once again we have to point out that we have already pointed to the same conclusion in several papers, as has Lael Brainard (1997).

5.   Conclusions

We are the first to note that the predictions of the knowledge-capital model are complicated by non-linearities and non-monotonicities. The scatter plot in BDH's Figure 1 poses a question and a challenge to the theory. We are sure that it is possible that improvements to the estimating equation or equations can be made and we look forward to seeing such improvements. However, BDH is not successful in this regard and we have to reject the suggestion that CMM "misspecify" the problem.   Their alternative formulation in Table 1 is at best interpreted as a test of the horizontal versus vertical model and most certainly not a test of the KK model versus the horizontal model. These comments also apply of course to their Table 4 which uses a promising alternative OECD sample but the same flawed technique. Their alternative approach in Table 2 has more theoretical promise, but it is significantly hampered by

the fact that almost all observations in the data are drawn from a small region in the Edgeworth box where there is no power to the test between the KK and horizontal models. And, once again, we have already reported these same results, including the finding that US outward investment is skilled-labor seeking, in a number of published forthcoming publications (Markusen and Maskus, 2001, 2002abc, Carr, Markusen and Maskus, 2002, and Markusen 2002).

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Figure 1: Affiliate sales by country i firms in country j: countries differ in relative endowments, graphed for three differences in country size
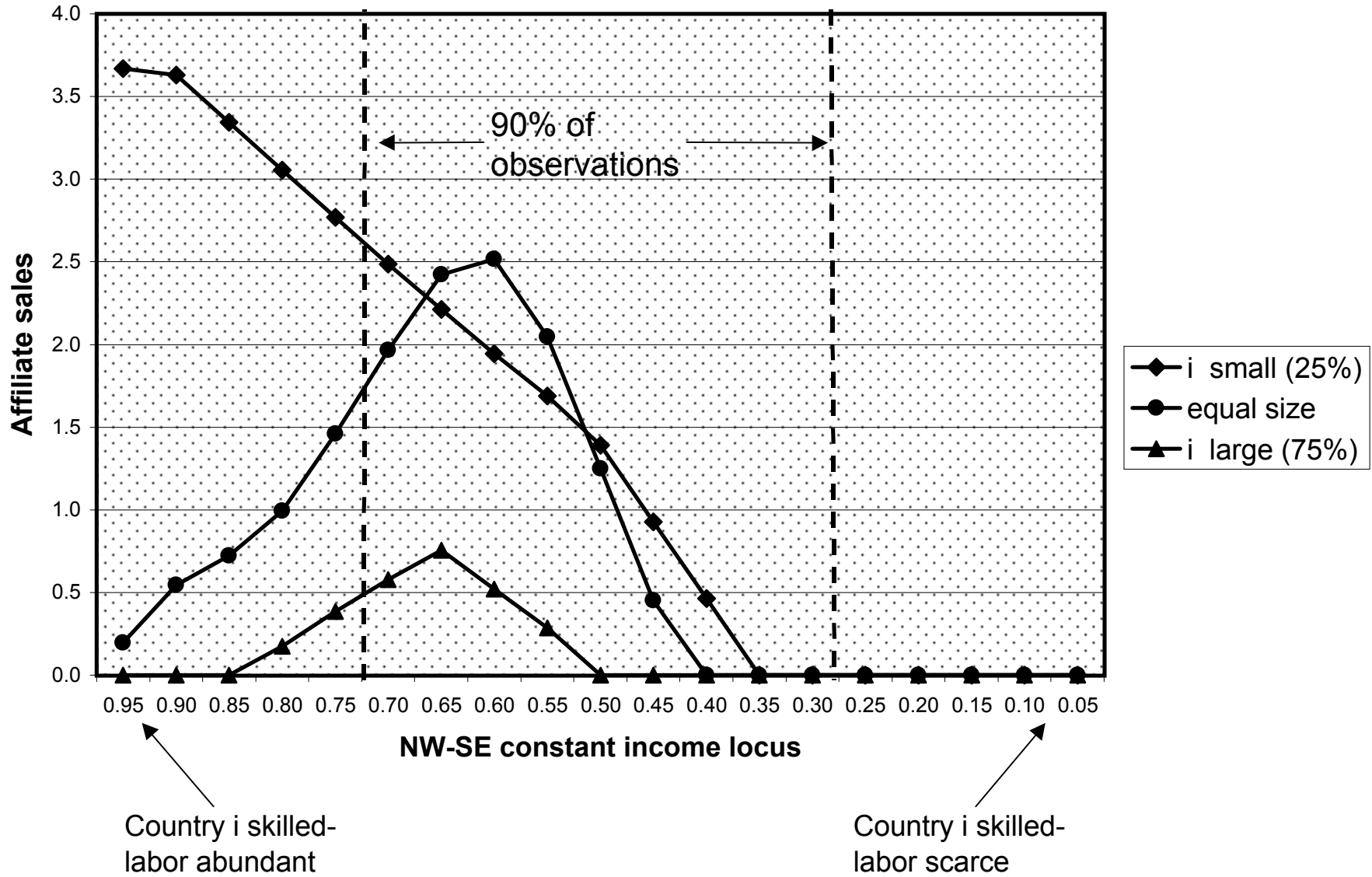

Affiliate sales (y-axis)

NW-SE constant income locus (x-axis)

90% of observations

- i small (25%)
- equal size
- i large (75%)

Country i skilled-labor abundant

Country i skilled-labor scarce

Figure 2: Affiliate sales by country i firms in country j: countries differ in relative endowments, country size the same

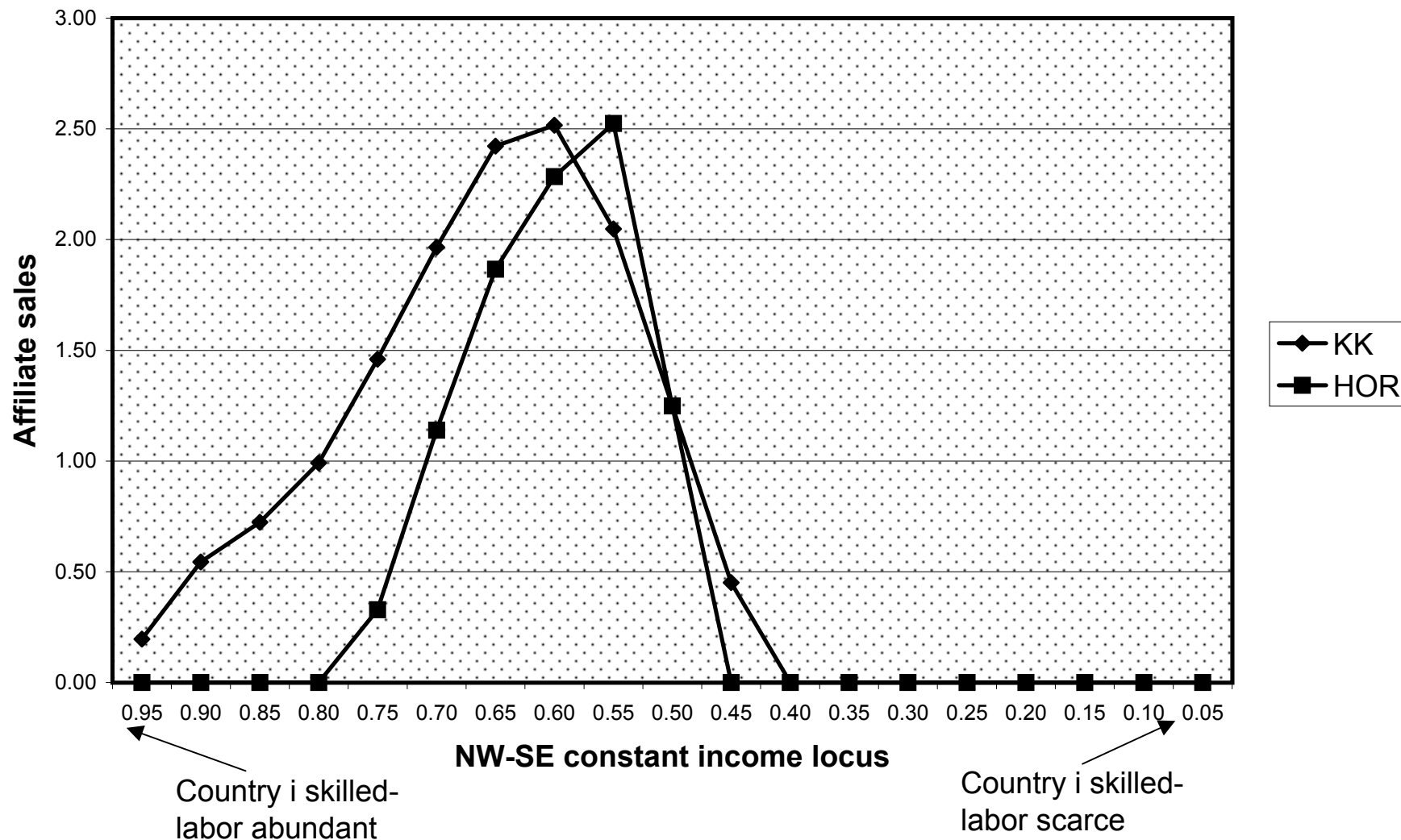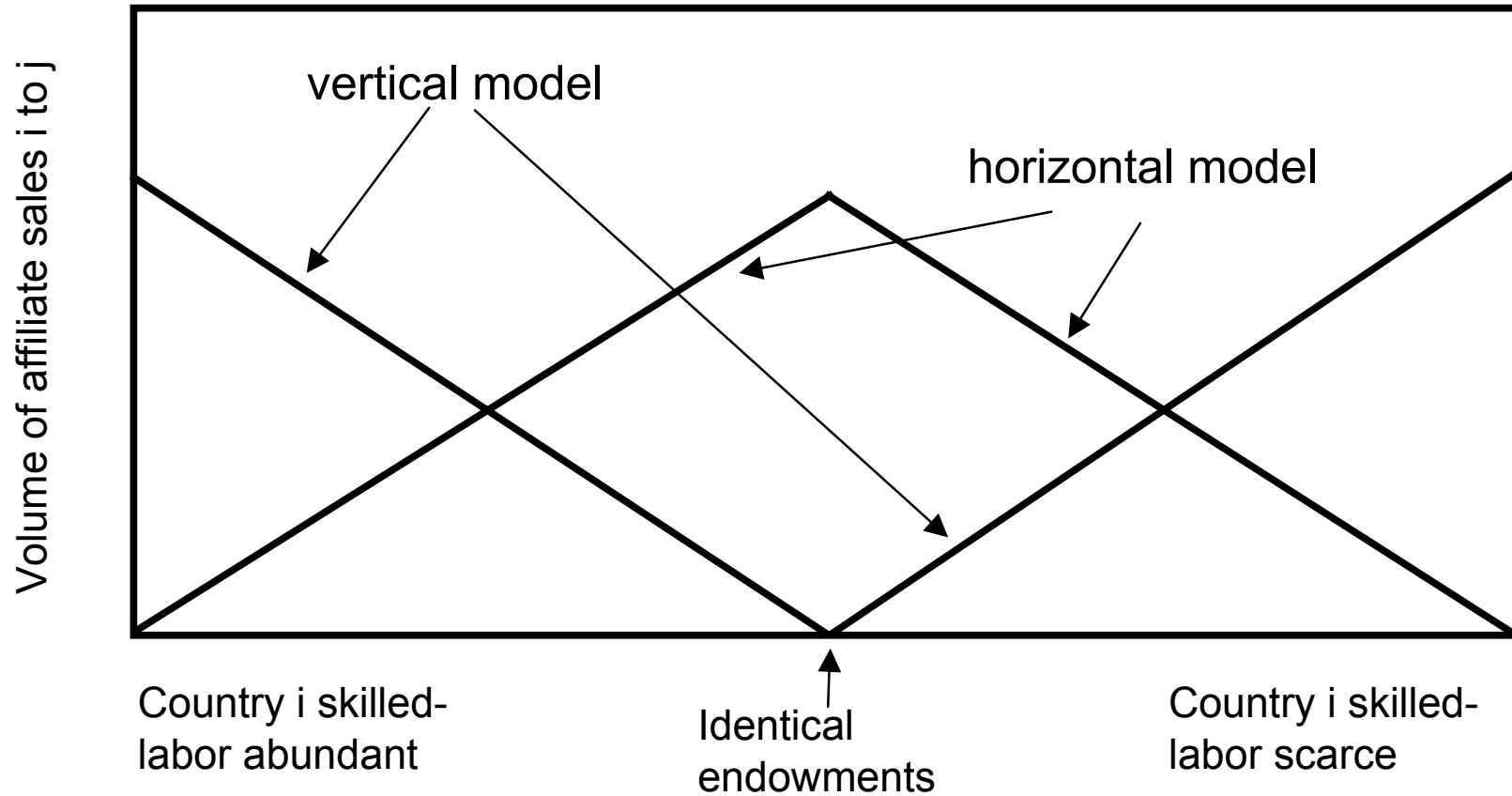Figure 3: Blonigen et. al. force the data to choose between a symmetric horizontal and symmetric vertical model

vertical model

horizontal model

Volume of affiliate sales i to j

Country i skilled-labor abundant

Identical endowments

Country i skilled-labor scarce

Second problem: their estimates must be exactly the same whether or not country i has 25% of two-country total income or 75% of total income