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An Explanation of OECD Factor Trade with Knowledge Capital and the HOV Model

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Abstract

This study examines the international factor trade of the developed (OECD) countries within the Heckscher-Ohlin-Vanek (HOV) model. Previous empirical work largely has not supported the HOV predictions for OECD trade, perhaps because of the similarity in factor abundance among those countries. In this paper a previously unexplored factor -- knowledge capital (measured by cumulative R&D stock) -- is introduced into the HOV framework. Knowledge capital likely plays an important role in determining comparative advantage among OECD countries because they specialize in high-tech products and also show dissimilarity in knowledge abundance. By using a new dataset for fifteen OECD countries, I find strong support for the strict HOV model with the addition of knowledge capital. Moreover, the introduction of knowledge spillovers further improves performance of the HOV model.

F11: Neoclassical Model of Trade
O33: Technological Change; Choices and Consequences; Diffusion Processes
Keywords: Heckscher–Ohlin; Trade, International Transfer of Technology

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In the last twenty years, theories based on increasing returns to scale (IRS) and differentiated products (e.g., Helpman and Krugman 1985) have been invoked to explain bilateral trade among OECD countries, in the belief that the HOV model cannot account for the large volume of such trade. Evenett and Keller (2002) analyzed the gravity equation to find the extent to which the two workhorse theories, IRS and Heckscher-Ohlin, are responsible for the empirical success of the gravity equation. They found that increasing returns better explain the volume of North-North bilateral trade and that factor-abundance explains the volume of North-South trade. Thus, their results were consistent with Debaere's claim that the factor abundance (HOV) model is inappropriate to explain OECD trade.

The point of departure of the current study is conceptually similar to the contributions by Dollar (1993) and Davis (1997). Dollar argued that knowledge capital (R&D stock) was potentially a major source of comparative advantage among developed countries. Institutions that generate new knowledge and technology from ongoing R&D activities can be a source of comparative advantage, particularly for high-technology industries. These advantages may persist for important periods of time, even ifTw 12 0 0 1a5opriat nations (France, Germany, Japan, the United Kingdom, and the United States) account for 88 percent of total OECD knowledge, with the U.S. share being 45 percent.[2]

The literature on productivity and the creation of ideas is founded on knowledge as an input (e.g., Grilliches 1986, Romer 1986, and Adams 1990). Yet there is little treatment of knowledge capital in the context of the factor-abundance model. An exception is Ekholm (1998), who applied the knowledge capital model of multinational enterprises (Carr, Markusen, and Maskus 2001) to the revealed factor abundance model. This model assumes that services of knowledge-based and knowledge-generating activities, such as R&D, advertising, and management, can be geographically separated from production and supplied at low cost to multiple production facilities. Using data for the United States, Ekholm showed that omission of intra-firm knowledge transfers leads to biased measures of revealed factor abundance.

Rather than considering direct transfers of knowledge, the present study rests on the HOV foundation and treats knowledge as an immobile factor, with products embodying knowledge capital. Knowledge capital is defined as the discounted sum of R&D expenditures within each country and represents a stock of newly developed ideas permitting the introduction of new products and higher-quality goods. For example, the cutlery of Solingen, Germany is famous for its quality, design, and level of details. The product embodies not only centuries of craftsmanship but also recent efforts to update product quality. Even though both Germany and Vietnam produce cutlery, the quality of their products differs and the former are knowledge-intensive compared with the latter.

I construct a comprehensive dataset of 15 OECD countries. These data show considerable support for business knowledge capital as a separate, and fundamentally important,

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[2] These figures are set out in Table 3 below. The share of these five countries for physical capital (labor) is 77 percent (80 percent).

2. Knowledge Capital

To characterize knowledge capital as an economic factor, I discuss the essential properties of knowledge (Rom multinational firms choose to transfer it to foreign affiliates. In this paper I do not pursue knowledge spillovers related to multinational firms, focusing instead on the geographic because the HOV model focuses on national-level factor endowments, which might include public R&D

industrial business knowledge is concentrated in four industries: chemicals (18.2 percent), electrical equipment (37.2 percent), motor vehicles (13.1 percent) and other transportation (14.6 percent). Therefore, it is important to control not only cross-country but also cross-industry size of business knowledge.

I first calculate the multilateral TFP index of Caves, Christensen, and Diewert (1982).[5] The multilateral “superlative” TFP index is defined as: $\ln TFP_{cit}=(\ln V_{cit}-(1/C)\Sigma_{c}\ln Y_{cit})-\sigma_{cit}(\ln L_{cit}-(1/C)\Sigma_{c}\ln L_{cit})-(1-\sigma_{cit})(\ln K_{cit}-(1/\mathrm{C})\Sigma_{c}\ln K_{cit})$ where C is the number of countries in the dataset, V_{cit} is real value added for country c, industry i, and time t, L_{cit} is labor (adjusted by working hours), K_{cit} is physical capital (fitted values), and σ_{cit} is the fitted values of the labor-compensation share (labor compensation over value added). These figures are displayed in Figure 1 for each determines the strength of the distance-weighted foreign knowledge effect on TFP growth. As the industry size of the home country (*L*

States. These countries together accounted for approximately 75 percent of world GDP in 1997 and a larger share of global business and public R&D. For business knowledge, the G5 countries (United States, United Kingdom, France, Germany, and Japan) generated 88 percent of total knowledge capital in the 15-country sample, with the U.S. share close to half, at 44.5 percent. Interestingly, the business R&D-scarce countries perform relatively larger amounts of public R&D. For example, in Australia the public R&D stock was 120 percent of the business R&D stock, with analogous figures for Spain (95 percent) and Italy (80 percent). For this reason the share of the United States decreases to 42 percent when the public R&D stock is included.

Spillovers from business knowledge stocks had strong impacts on the non-G5 OECD countries. While those countries found their knowledge increased from foreign sources by around 50 percent of domestic stocks, the large G5 countries had it rise by around 20 percent. For instance, Canada and the Netherlands absorbed large amount of foreign knowledge from geographic spillovers, with total spillovers being 101 percent of domestic knowledge for Canada and 71 percent for the Netherlands. These countries are located close to leading knowledge producers, respectively the United States and Germany.

2B. Knowle

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(S1). Models 2 through 5 employ CRS technology with the different type of knowledge capitals (S1-S4, respectively). Finally, Model 6 posits a CRS technology without knowledge capital.

Estimation results with robust standard errors are in Table 3.

knowledge capital (Models 2 through 5) outperform the CRS model without knowledge capital (Model 6). Thus, with respect to CRS production functions the inclusion of knowledge capital seems to be an appropriate extension of standard production theory.

3. Knowledge Capital in the HOV Model

Assume that all countries have identical CRS production functions with three factors: physical capital, knowledge capital, and aggregate labor. Markets for goods and factors are perfectly competitive. There are no barriers to trade or transport costs in goods but factors are immobile across borders. I also assume that the distributions of factors are consistent with integrated equilibrium so that factor prices are equalized across countries.

I begin the derivation of the strict HOV model with the identity equation of the net export vector for country *c*. The sectoral net-export vector (of dimension N) is the difference between the net production vector and the final consumption vector:

$$T_c = (I - B_c)Q_c - C_c \qquad (9)$$

where T_c is an N×1 vector of net exports, Q_c is an N×1 vector of gross output, and C_c is an N×1 vector of final consumption. B_c is an N×N input-output (indirect) matrix of the unit intermediate requirements so that $(I-B_c)Q_c$ equals the net output vector Y_c. The direct technology matrix for country *c*, A_c, is of dimension F×N (F factors and N industrial sectors) and its elements (a_{cif}) represent the amount of a factor (*f*) needed for one unit[12] trade is the difference between f

involves regressing measured factor contents of trade on predicted factor contents of trade without a constant. If the HOV model held, the regression coefficient (and coefficient of determination) would g 0 12 105.24252nity

3A. Overview of the Dataset

My dataset of 15 OECD countries and 23 industries consists of four elements. First are factor endowments, including physical capital (K_{cit}), aggregate labor (L_{cit}), and various measures of knowledge capital (S_{cit}) from 1987 to 2001. Second are country-specific technologies, involving three-factor direct technology matrices (A_{ct}) from 1987 to 2001 and indirect (intermediate usage) technology matrices (B_c) for 1997. Third are production data, incorporating real gross output (Q_{cit}) and real value added (Y_{cit}) from 1987 to 2001. Finally are figures on net output (Y_{ci}), net-exports (T_{ci}), and final consumption (C_{ci}) for 1997, which come from each country's input-output structures.[13] The dataset is similar to that of Hakura (1999) who developed a 23-sector dataset of four European countries with seven factors (including various skill groups), and to that of Davis and Weinstein (2001) who constructed a 35-sector dataset of 10 OECD countries with two factors. As in other studies of this kind, sectoral aggregation of the dataset might cause statistical bias.[14] Further, in my data sectoral labor cannot be disaggregated into various skills. Nonetheless, the dataset covers most of the economic activities of the world.

3B. Results of Testing the HOV Model with Knowledge Capital

In Table 4, I present the initial test results, beginning with physical capital and aggregate labor. Here, equation (12) is designated the HOV model and equation (14) the pair-wise HOV model. As may be seen, both physical capital and aggregate labor perform poorly. Although the proportions of sign fits are strictly better than a coin toss for physical capital in both specifications, the slope tests and variance ratios indicate serious missing trade. For example, the HOV model achieves slightly positive slopes but the variance ratios are essentially zero for

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[13] See Appendix A for detailed discussion of data development and manipulation.

[14] Aggregation may cause systematic bias for factor contents of trade as discussed in Feenstra and Hanson (2000). See Hakura (1999) as well. 0)

both factors. The variance ratios improve under the pair-wise HOV model but the slope coefficient of aggregate labor is estimated to be negative, a clear rejection of the HOV reasoning.

This poor performance of conventional factors confirms the basic result of previous literature involving the strict HOV model (Bowen, Leamer, and Sveikauskas 1987; Trefler 1995; Davis and Weinstein 2001; and Hakura 2001). Additional results indicate that the United States is estimated to be an importer of both physical capital and aggregate labor, which is confirmed by the predicted factor contents of trade.[15] This tendency is consistent with Trefler's (1993) data but differs from Bowen, Leamer, and Sveikauskas (1987), who found that United States imported aggregate labor services but exported physical capital services in 1966.

Compared with physical capital and aggregate labor, however, knowledge capital performs impressively. As shown in Table 4, in the case of business knowledge capital, the HOV model predicts 73 percent sign fits and the pair-wise HOV model predicts 81 percent sign fits. Further, there is far less evidence for missing trade, as the variance ratios rise to 0.34 for both HOV and pair-wise HOV. These results improve still further if public knowledge is introduced. The sign fit of HOV improves to 80 percent (twelve of fifteen countries). Moreover, the variance ratio rises to 0.41. This tendency also holds for the pair-wise HOV model, which obtains 83 percent sign fits and a variance ratio of 0.43.

Figure 2-1 depicts the statistical relationship between predicted and measured business knowledge capital contents of trade for all countries in the sample. Japan, Germany, France, and Sweden are estimated to be the main net exporters of knowledge, which is confirmed by the indicates that there exists heterogeneity in the sectoral unit requirements of knowledge capital. Other vehicles (including airplanes), electrical equipment (including semiconductors), chemicals (including pharmaceuticals), and motor vehicles are the four most knowledge-intensive sectors. It is likely that the strong predictive performance of knowledge capital in the HOV model reflects the influence of these sectors through trade. Japan and Germany are two major producers and exporters of motor vehicles, France is one of two main producers of commercial airplanes, Australia and Canada are importers of electrical equipment, and the United Kingdom is an importer of motor vehicles.

Before examining the results with knowledge spillovers, I discuss the interpretation of diffused knowledge in the context of the HOV model and whether it should be included in the world aggregate knowledge stock. For instance, if knowledge invented by France could spillover to Belgium, there are two possibilities for computing world Io2e Tm(t, and t.0008 Tntry) if knOesults w capital contents for Belgium, Denmark and the United States achieve the correct sign concordances after technology spillovers are taken into account. Thus, incorporating diffused knowledge stocks estimated from geographic and technological distances improves sign fits and narrows the gap between measured and predicted factor contents of trade for most countries.

However, the amount of geographic spillover is disproportionately low for countries located far from Europe and North America. In particular, Australia and Japan receive little foreign knowledge, amounting to less than 1 percent of domestic knowledge. As a result, the sign fit of the pair-wise HOV model deteriorates to 76 percent by 5 percent. Another important result is that the United States becomes an importer of knowledge capital in terms of both predicted and measured factor contents of trade after spillovers are introduced. Overall, the improved fit of HOV and pair-wise HOV with knowledge stocks suggests that knowledge is an important element to explain international trade between OECD countries.

3C. Indirect Effects of Knowledge on Factor Productivities

Prior literature has demonstrated the importance of productivity adjustm framework in which each factor, including knowledge capital, is affected by unmodeled determinants as Hicks-neutral TFP.

Hicks-neutral differences in total factor productivities (normalized by U.S. levels) were already estimated in Table 3 for Models 2-5, using the Cobb-Douglas CRS production function:

$$Y_{cit} = M_c M_i e^{\lambda_i t} K_{cit}^{\alpha_{1i}} S_{cit}^{\alpha_{2i}} L_{cit}^{1-\alpha_{1i}-\alpha_{2i}} \qquad (15)$$

where M_c represents country-specific TFP.

These Hicks-neutral productivities may be used to 12 n9 /<MCe n whic. c -0.001L-equivalent 0 its2 Tc -0

measured in productivity-equivalent units. Let w_{cf} be the price per units of V_{cf} and let w^*_{cf} be the price per unit of V^*_{cf}. Since one unit of V_{cf} provides productivities (π

sign fits of all four cases now over 75 percent. In particular, knowledge capital with technology spillovers improves to 82 percent and there is no evidence of missing trade. Combining the fact that knowledge capital fits the HOV model well and knowledge intensities can account for international differences in factor-productivities to a great extent, it seems that knowledge (R&D stock) is an important determinant of comparative advantage among OECD countries.

explanation for OECD trade, as conceptualized by Dollar (1993) and Davis (1997), by shedding light on the unexplored factor input of knowledge capital.

In the cases of knowledge spillovers, I borrow ideas from

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Appendix A: Data Development

I develop the dataset of value added (volume), gross output (volume), labor, physical capital (volume), and business knowledge capital (volume) for 15 OECD countries (Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the United Kingdom, and the United States) and 23 industries [see Table A-1] from 1987 to 2001. In addition, corresponding 23-sector Input-Output tables (total use) for these countries are developed for the year 1997. The data of exports, imports, final consumptions, net output, and intermediate usages are derived from the I-O tables.

Table A-1: Sectorsof Industrial Activities

sectors	Branches of Activities

O database (2002). Belgium (1995), Italy (1995), Spain (1995), and Sweden (1995) are from the Statistical Office of the European Communities (Eurostat). The I-O tables from the OECD I-O database employ ISIC Rev.3 classification containing 41 industrial groups and the I-O tables from the Eurostat employ NACE/CLIO classification containing 59 groups. These two different classifications are aggregated into 23 industrial groups of ISIC Rev.3. The number of industrial groups is sm

2) Factor Endowment Data

(A) Physical Capital Stock

Capital stock is developed by the perpetual inventory method (Keller 1999). Gross fixed capital formation values (GFCF) are derived from the OECD structural analysis (STAN) database (2004) and unreported data are estimated from the ISIC Rev.2 version of the OECD each sector according to the shares developed from the OECD STAN database.[22] Unfortunately, I cannot adjust "agriculture" (sector 1). Therefore, special attentions must be made when the data from sector 1 is related to the analysis. To convert the GFCFs into real series, the deflators for business investment (non-residential) from the OECD Economic Outlook (2006) are used. After converting into a real local currency series, I develop real capital stock with a depreciation rate of 0.1333 (see; Leamer 1984; Bowen, Leamer, and Sveilauskas 1987; and Davis and Weinstein 2001). Then, the real capital stock is converted into 1997 U.S. dollars by purchasing power parities. For Japan, sectoral GFCF data are unavailable from the OECD STAN database (2004). Therefore, total GFCF series are derived from the OECD National Accounts Statistics (2006) and sectoral shares are obtained from the nominal investment matrix tables of the ESRI-Histat database.[23]

(B) Labor

Sectoral labor inputs (total employments) are derived from the OECD STAN databases (1998 and 2004), the Eurostat, and the OECD Employment by Activities and Status (2006). To interpolate unreported data, I use the available share of the nearest year to allocate the sub-totals to each detailed sector.[24] Country-level average working hours from the OECD Employment and Labor Market Statistics (2006) are used to adjust the international difference in average working hours with the normalization of U.S. working hours.

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[22] I use the dataset developed from the OECD STAN database directly for Belgium. In case of Norway, to separate "housing investment

(C) Knowledge Capital

The data on business R&D expenditure are obtained from the OECD STAN R&D database (1998 and 2004), the OECD Science and

R&D stock with a depreciation rate of 0.10. Then, the real R&D stock is converted into 1997 U.S. dollars by using purchasing power parities.

3) Value Added and Gross Output (Production)

Value added (nominal), value added (volume), and gross output (nominal) series are obtained from the OECD STAN database (1995, 1997, 1998, and 2004) and the Eurostat. The number of unreported data items is much smaller (less than one percent) than that of business R&D expenditures and GFCFs. Most of the unreported data are filled in with interpolation and with the corresponding growth rates of sub-totals. Some unreported data of gross output are filled in with the growth rates of nominal value added. The sectoral-level deflators are developed from nominal and real value added series. By using these 23-sector deflators, the index for gross output (volume) is developed. I choose 1997 as the base year of both value added (volume) and gross output (volume). In the case of base year data of gross output (volume), the values from the I-O tables are employed. All the series are converted into 1997 U.S. dollars by purchasing power parities.

Table A-2. Details of Dataset (year 1987-2001, 15 countries, and 13 manufacturing industries: 1997 PPP $US)

	Value Added (GDP)		Physical Capital		Labor (adjusted employment)		Business R&D stock	
	Growth (%)	Share (%,1997)	Growth (%)	Share (%,1997)	Growth (%)	Share (%,1997)	Growth (%)	Share (%,1997)
Australia	2.11	1.47	1.37	1.50	-0.62	1.88	11.66	0.55
Belgium	2.77	1.20	4.17	1.49	-1.25	0.95	7.04	0.99
Canada	3.16	3.46	2.06	2.86	0.21	3.25	10.73	1.52
Denmark	1.51	0.53	-0.43	0.60	-0.98	0.60	11.67	0.30
Finland	4.84	0.68	-1.18	0.78	-1.04	0.71	11.49	0.49
France	2.57	6.46	1					

$$\ln(Y_{cit} / L_{cit}) = m_c + m_i + \lambda_i t + \alpha_{1i} \ln(K_{cit} / L_{cit}) + \alpha_{2i} \ln(S_{cit} / L_{cit}) + \beta_{1i} \ln(L_{cit}) + \varepsilon_{cit} \qquad \text{(B2)}$$

where $m_c=ln(M_C)$, $m_i=ln(M_i)$, $\beta_{1i}=\alpha_{1i}+\alpha_{2i}+\alpha_{3i}-1$ and β_{1i} is a convenient measure of the extent to which the industry production function differs from constant returns to scale. This equation is the same as equation (12) in Harrigan (1999), except that knowledge capital is introduced here.

Starting from the baseline equation (B2), the constant returns to scale assumption ($\beta_{1i}=0$) is imposed:

[redacted]

Table 3. Estimations of Production Functions (with robust standard errors)

Data: 15 countries, year 1987-2001, and 13 industries (2,925 observations)
Dependent variable: log(GDP/Labor)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	(No restrictions)	(CRS/R&D stock)	(CRS/R&D stock)	(CRS/R&D stock)	((	

Table 4. Results of Strict HOV Models (Year 1997)

A. HOV Model: 15 observations (across country)

	Capital	Labor	R&D Stocks (S1) Business	(S2) National (+Public)	(S3) Spillover (Geography)	(S4) Spillover (Technology)
Sign Test	0.667	0.467	0.733	0.800	0.800	0.933
Slope Test	0.021	0.019	0.401	0.541	0.316	0.432
standard error	0.012	0.020	0.113	0.093	0.114	0.063
R-squared	0.173	-0.003	0.473	0.703	0.352	0.766
Variance Test	0.002	0.006	0.337	0.412	0.278	0.241

B. The Pair-Wise HO

Table 6. Results of the HOV models with Productivity Adjustments (Year 1997)