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Predicting the factor content of foreign trade: Theory and evidence

by

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GEP Leverhulme Centre for Research on Globalisation and Economic Policy

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Abstract

This paper examines the multi-cone specification of the factor proportion theory of international trade. I show that Helpman's bilateral restrictions on the factor of content of trade, which have found recent empirical support by Choi and Krishna (2004), need to be amended to account for multilateralism. I identify additional restrictions and show that these restrictions form the building block for a multi-cone factor content prediction which generalizes Alan Deardorff's well-known chain of comparative advantage prediction to multiple countries and factors. Applying Choi and Krishna's data set to this multi-lateral specification, I find little empirical support for the multi-cone prediction.

JEL classification: F11

Keywords: Factor content of trade, multi-cone Heckscher-Ohlin model.

Outline

Non-Technical Summary

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"It is not possible through merely bilateral comparison to develop a…theory of efficient multilateral specialization". (Lionel McKenzie, 1954, p. 180)

1. Introduction

In a recent paper in this journal Choi and Krishna (2004) claim to provide a significant advancement in testing the Heckscher-Ohlin theory of international trade. The authors provide empirical support for a prediction on the bilateral factor content of trade, originally developed by Helpman (1984). Helpman's bilateral specifications have the attractive features of relying on 'post-trade' factor price comparisons and claim to hold under nonequalization of factor prices and in the absence of any assumptions regarding consumer preferences.[1]

This paper makes two contributions. On the theoretical side, I show that Helpman's (1984) prediction in which the bilateral trade flows between country's *i* and *j* are predicted solely by the factor price difference between these two countries is an inappropriate Heckscher-Ohlin specification in a multi-country world. The intuition for this is that in Helpman's formulation factor prices embody information about a country's underlying factor scarcities. As a result, a prediction on the pattern of trade between countries *i* and *j* must also incorporate information about the relative factor prices of any third country *k*. In fact, in a general trading equilibrium the pattern of international specialization must be predicted by factor scarcity measures of *all* trading partners.

Building on Helpman's proof for deriving bilateral restrictions, I incorporate multi-lateralism into the model. I identify additional restrictions that have to hold in a trading equilibrium. I show that these restrictions define country-specific cones of

[1] Helpman and Krugman (1985, pp. 24-27) and Feenstra (2004, pp.58-60) provide detailed discussions of Helpman (1984). Building on Choi and Krishna (2004), Lai and Zhu (2006) provide further empirical support for a bilateral prediction that incorporates technological differences.

diversification where the theory predicts that the factor content of any export flow, *bilateral or multilateral*, must lie within this cone. This multi-cone specification generalizes Alan Deardorff's (1979) well-known chain of comparative advantage prediction to multiple factors and countries.

In the second part of the paper, I apply the multi-cone Heckscher-Ohlin specification to Choi and Krishna's (2004) OECD data set. Overall, I find little empirical support for the multi-lateral specification. I revisit Choi and Krishna's empirical approach and interpret their empirical findings as evidence for factor price equalization rather than international specialization in goods with distinct factor intensity differences. My findings are compatible with previous evidence which suggests that the endowments of the capital-rich OECD countries are sufficiently similar to occupy a single cone (Debaere and Demiroglu, 2003). As a result, observed free trade factor price differences within the OECD are expected to be poor predictors for the direction of trade as they do not embody information about underlying factor endowment differences.

The paper is organized as follows. Section 2 revisits Helpman (1984) and shows that Helpman's prediction will coincide with Deardorff's (1979) multi-cone chain of comparative prediction only in the two-country case. Section 3 derives a multi-cone Heckscher-Ohlin theorem in the case of multiple countries. Section 4 provides a brief summary of Choi and Krishna's (2004) data set. Section 5 gives the empirical results and section 6 contains the conclusion.

2. Revisiting the chain of comparative advantage

Helpman's specification aims to extend Deardorff's (1979) and Brecher and Choudhri's (1982) two-country, two-factor "chain formulation" to multiple countries and factors. The central theme in these papers is to provide predictions in the spirit of Heckscher-Ohlin, but in the absence of factor price equalization. All three papers investigate the property of a competitive free trade equilibrium with two key characteristics. First, all countries possess identical production functions. Second, countries' factor endowments are assumed to be sufficiently dissimilar so that countries' free trade factor prices are different.

Formally, consider a competitive equilibrium with *m* countries, *n* goods, *l* factors and a common technology matrix, $A(.)=<a_{v\tau}(.)>$, where $a_{v\tau}$ are the units of factor *v* necessary to produce 1 unit of good *τ*. Although identical technologies imply the same functional forms for $a_{v\tau}$, the equilibrium least-cost input coefficients will depend on country specific factor prices.

If T^{ij} denotes the vector of gross imports of country *j* from country *i*, F^{ij} denotes the factor content of T^{ij} evaluated at the exporter's input techniques, i.e. $F^{ij}=A(w^i)T^{ij}$, where w^i is the free-trade factor price vector of the exporting country *i*. For two countries, *i* and *j*, who are engaged in bilateral trade, Helpman (1984) derives the following prediction on the bilateral factor content of trade F^{ij}:

$$(w^j-w^i)'F^{ij} \geq 0. \quad (1)$$

By symmetry, we obtain an equivalent prediction on the gross trade flow from country j to country i:

$$(w^i-w^j)'F^{ji} \geq 0. \quad (2)$$

Adding (1) and (2) results in a bilateral prediction on the net trade flow between countries i and j:

$$(w^j-w^i)'(F^{ij}-F^{ji}) \geq 0. \quad (3)$$

Inequality (3) has been interpreted as saying that factors embodied in trade should flow towards the country with the higher factor price. If factor v has a higher absolute price in country *j*, $w^j_v - w^i_v > 0$, then *j* will, "on average", be a net importer of that factor relative to country *i*, i.e. $F^{ij}_v - F^{ji}_v > 0$.

However, the predictions in (1)-(2) seem to be at odds with the fact that in a general equilibrium with multiple countries, any trade flow must be determined by relative measures of factor scarcities of all trading partners. In particular, the predictions on F^{ij} and F^{ji} take into account only information on bilateral factor price differences of the two trading partners, without considering the factor prices of any other third countries. In what follows, I will show that (1)-(2) generalizes Brecher and Choudhri's (1982) factor content version of Heckscher-Ohlin to multiple factors, but not to multiple countries.

Figure 1: Multi-cone commodity-content prediction

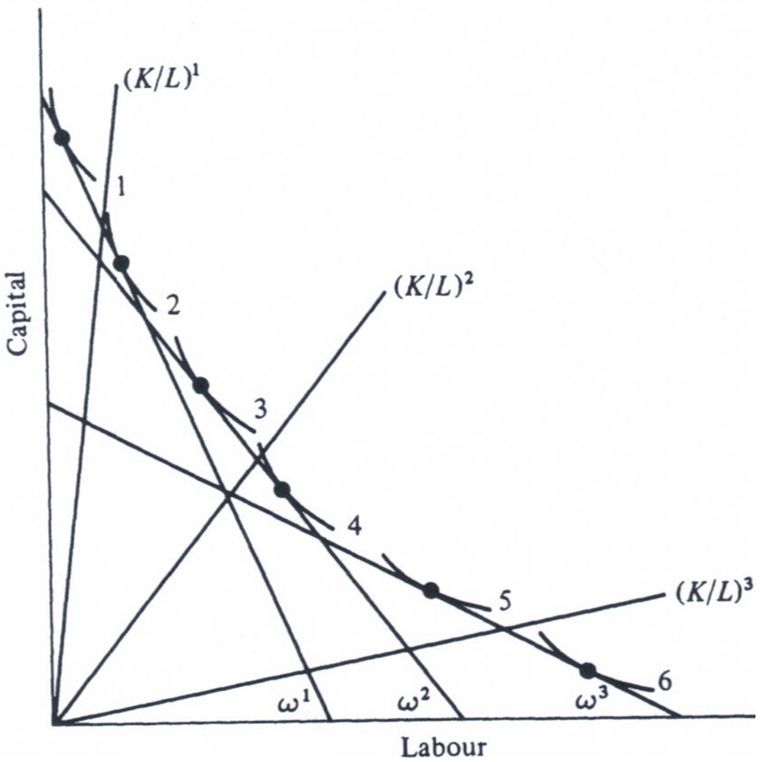


Figure 1 depicts the Lerner-Pearce diagram for the case of 6 goods, 2 factors (labour and capital) and 3 countries. The goods' isoquants, numbered from 1 to 6, depict the input combinations that can produce $1 worth of output at the free trade prices. The goods numbering pertains to their capital-intensity ranking, where good 1 is most capital-intensive and good 6 is least capital-intensive. The rays $(K/L)^i$ denote the countries' capital labour ratios and ω^i $(=(w^i/r^i))$ represent the countries' free trade wage-rental ratios (i=1,..3). The implicit assumption behind this specification is that there is a one-to-one correspondence between the factor endowment ranking and the ranking of free trade equilibrium factor price ratios ω^i $(=(w^i/r^i))$: $(K/L)^1 > (K/L)^2 > (K/L)^3 \iff (w^1/r^1) > (w^2/r^2) > (w^3/r^3)$. In any pair-wise comparison, the more capital-abundant country is expected to have a higher equilibrium wage-rental ratio.

Since countries' factor endowments are assumed to be in different cones of diversification, the three countries will specialize in the production of different goods.[2] In a trading equilibrium, the most capital-abundant country 1 will produce and export the most capital-intensive goods 1 and 2; country 2 will produce and export goods 3 and 4 and the most labour abundant country 3 will produce and export the most labour-intensive goods 5 and 6.[3]

Alternatively, instead of considering the pattern of commodity trade, this framework makes also predictions on factor content of trade. In reference to Figure 1, Helpman (1984, p. 90) writes:

"It is now a simple matter to observe that the more capital-rich a country is, the more capital and less labour is uses per dollar output in all lines of production (more generally, it never uses less capital and more labour). Hence, whatever trade there may exist between two countries, exports of the relatively capital rich country will embody a higher capital-labour ratio than exports of the relatively labour rich

[2] There are three cones of diversification, defined by the lines (not drawn) between the origin and the 6 depicted tangencies.

[3] Although this framework doesn't make any explicit assumption about preferences, it implicitly assumes that preferences are such that the free trade equilibrium actually exists. In particular, to ensure that there is some trade, one needs to assume that consumers care about foreign-produced goods.

country. This describes a clear bilateral factor content pattern of trade (see Brecher and Choudhri, 1982)".

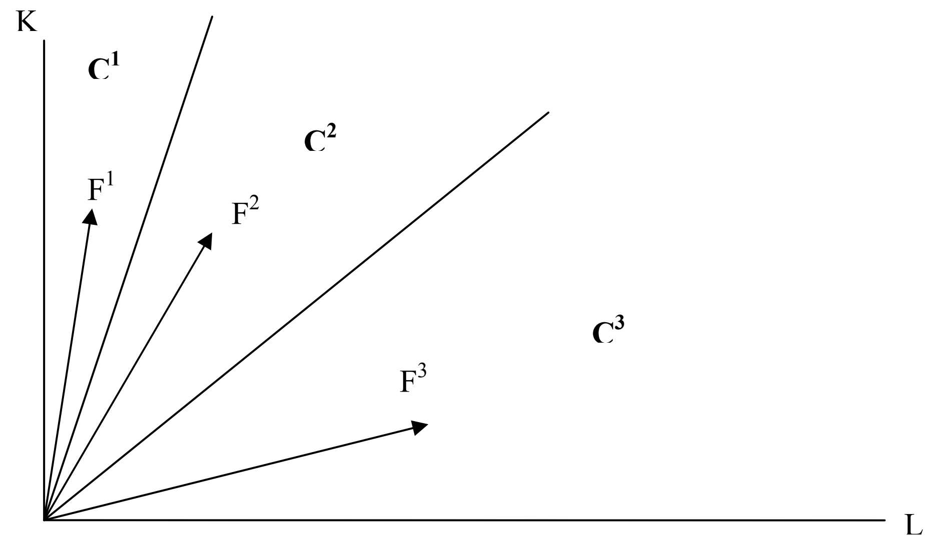
The key point here is that the factor content comparison pertains to *all* exports by countries *i* and *j*: bilateral, multi-lateral, and independent of destination. Consequently, the emphasis of (1)-(3) on bilateral trade is misleading, unless we are in Brecher and Choudhri's (1982) two-country framework where there is no distinction between bilateral and multi-lateral trade.

Let T^i denote any equilibrium export flow by country *i* . The corresponding factor content of exports is then defined as $F^i=A(w^i)T^i$. In the two-factor case, the factor content prediction is given by:

$$\frac{K^1}{L^1} \geq \frac{K^2}{L^2} \geq \frac{K^3}{L^3}, \qquad (4)$$

where $F^i=(K^i,L^i)$ is any factor content of export vector for country *i*. The prediction in (4) is the factor content version of the commodity prediction from Figure 1. Geometrically, it corresponds to a three-cone partitioning (C^1, C^2, C^3) of the labour-capital space, where the cones are defined by the equilibrium capital-labour ratios of the respective commodities. Figure 2 illustrates that the theory predicts that $F^i \in C^i$ for all *i*. For example, any factor content of exports vector F^1 of country 1 must have a capital-labour ratio that is higher than its least-capital-intensive good, i.e. good 2. The capital-labour ratio of any export vector F^2 of country 2 must be between the capital-labour ratios of good 2 and good 4 and the capital-labour ratio of any export vector F^3 of country 3 must be lower than the capital-labour ratio of good 4.

Figure 2: Multi-cone factor-content specification



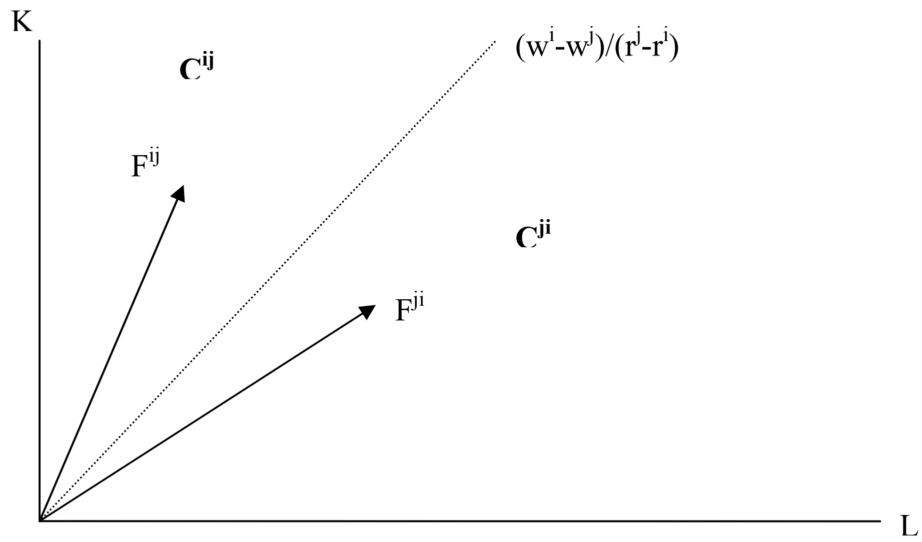
We can compare this now to Helpman's predictions (1)-(2). Assuming that country *i* is capital abundant relative to country j, i.e. $w^i/r^i > w^j/r^j$, (1) and (2) lead to the following inequalities[4]:

$$\frac{K^{ij}}{L^{ij}} \geq \frac{w^i - w^j}{r^j - r^i} \geq \frac{K^{ji}}{L^{ji}} \qquad (5)$$

Figure 3 captures (5) geometrically and illustrates the difference to the multi-cone specification given in Figure 2. In the case of three countries, Helpman's predictions correspond to three different two-cone partitionings (C^{ij}, C^{ji}) of the labour-capital space, one for each country pair. It is immediately clear that (5) will coincide with the multi-cone specification only in a two-country world.

[4] Without loss of generality we have assumed that $w^i > w^j$. The identical technology assumption implies then that $r^j > r^i$, which guarantees that the ratio of factor price differences is positive.

Figure 3: Helpman's bilateral 'two-cone specification'



3. Deriving multi-cone factor content of trade predictions

In this section I derive general factor content of trade predictions and show that they generalize the predictions in Figure 2 to multiple factors and countries. I accomplish this by using Helpman's strategy for deriving (1) and (2). Helpman arrives at (1) through two steps: (i) a 'thought experiment' on a factor endowment gift and (ii) the concavity property of GDP function. In a free trade equilibrium a country's GDP can be written as $G(p,V^j)= p'Y^j=w^{j\prime} V^j$, where V^j denotes the country's endowment vector, Y^j its production vector and p the free trade equilibrium goods price vector. Helpman postulates then the following relationships:

$$w^iF^{ij} =pT^{ij} \leq G(p,V^j+F^{ij})-G(p,V^j), \quad (6)$$

$$G(p,V^j+F^{ij})-G(p,V^j) \leq w^{j\prime} F^{ij}. \quad (7)$$

Inequalities (6) and (7) can be interpreted as providing lower and upper bounds for the gain in revenue, $G(p,V^j+F^{ij})-G(p,V^j)$, economy *j* would obtain from a hypothetical endowment gift of F^{ij}. Inequality (7) follows directly from the concavity property of the GDP function: the gain in revenue must be smaller than the gift F^{ij} valued at the shadow price w^j associated with V^j. Inequality (6) is based on factor price differences between countries. If country *j* were given a factor endowment gift of F^{ij}, then the assumption of identical technologies implies that it would be feasible for country *j* to produce T^{ij} itself and obtain the revenue $p' T^{ij}$.[5] However, since factor prices in country *j* are different than in *i*, country *j* could do ‘potentially better’ than that. Consequently $p' T^{ij}$ provides a lower bound for the revenue gain $G(p,V^j+F^{ij})-G(p,V^j)$. Using the zero-profit condition, $p' T^{ij}=w^{i\prime} F^{ij}$, and combining (6) and (7), we obtain (1).

However, it has remained unnoticed in the literature that the underlying logic applies to *any* other third country *k* and to *any* exports by country *i*. Consider any export vector T^i by country i. For example, if country *k* were given an endowment gift of $F^i=A(w^i)T^i$, the country’s increase in GDP, $G(p,V^k+F^i)-G(p,V^k)$, would be at least as large as $p' T^i$, i.e.

$$w^iF^i = pT^i \leq G(p,V^k+F^i)-G(p,V^k). \tag{8}$$

On the other hand, the endowment gift F^i evaluated at country *k*’s equilibrium or shadow price vector w^k provides an upper bound for the revenue gain of country k:

$$G(p,V^k+F^i)-G(p,V^k) \leq w^{k\prime} F^i. \tag{9}$$

Combining (8) and (9), one obtains

$$(w^k-w^i)'F^i \geq 0, \qquad \text{for all } k\neq i, \tag{10}$$

Inequality (10) differs from Helpman’s bilateral restriction (1) in two ways. First, (10) yields restrictions on the factor content of any exports by country *i*, *bilateral or multilateral*. Second, each factor content of exports F^i is restricted by the difference between the factor price in country *i* and the factor price in each of its (*m*-1) trading partners. The intuition behind (10) is that in this specification of the neoclassical trade model, free trade factor prices embody information about countries’

[5] It is implicitly assumed that the factor reallocation does not affect the equilibrium price vector p.

underlying factor scarcities. As a result, in a world with more than 2 countries, a factor flow between countries *i* and *j* can't be accurately predicted by using only information about factor scarcities of countries i and j, but must incorporate factor price information of all trading partners. This leads us to state the main theoretical result of the paper

Multi-cone Heckscher-Ohlin Theorem

Consider a free trade equilibrium which is characterized by country-specific factor price vectors $(w^1,...,w^m)$. Then we can define a country-specific cone C^i in the factor endowment space, $C^i = \bigcap_{k \neq i} \{F \in \mathbf{R}^l \mid (w^k - w^i)F \geq 0\}$, where the theory predicts that $F^i \in C^i$ for any factor content of exports F^i by country *i*.

The key points here are that each cone is country-specific and that each is constructed by using factor prices of all trading partners, i.e. $C^i = C^i(w^1,\ldots w^m)$. To illustrate that the theorem generalizes the factor content prediction of Figure 2, let us construct the C^is in the two-factor, three-country case. We assume, without loss of generality, that the free trade equilibrium is characterized by a factor price ordering, $w^1>w^2>w^3$ and $r^1<r^2<r^3$, which is compatible with Figure 1. Applying the factor price data to (11), the cones are given by:

$$C^1=\{(K,L) \mid \frac{K}{L} \geq \max\{\frac{w^1-w^2}{r^2-r^1}, \frac{w^1-w^3}{r^3-r^1}\}\}, \quad (11a)$$

$$C^2=\{(K,L\} \mid \frac{w^2-w^3}{r^3-r^2} \leq \frac{K}{L} \leq \frac{w^1-w^2}{r^2-r^1}\}, \quad (11b)$$

$$C^3=\{(K,L) \mid \frac{K}{L} \leq \min\{\frac{w^1-w^3}{r^3-r^1}, \frac{w^2-w^3}{r^3-r^2}\}\}. \quad (11c)$$

To make it more concrete, assume the following free trade factor prices: w^1=7, w^2=5, w^3=3, r^1=1, r^2=2, and r^3=4. Applying these numbers to (11a)-(11c) we obtain the three-cone partitioning of the labour-capital space given in Figure 2, where C^1= $\{(K,L)| \frac{K}{L} \geq 2\}$, C^2=$\{(K,L\}|1 \leq \frac{K}{L} \leq 2\}$ and C^3 =$\{(K,L)| \frac{K}{L} \leq 1\}$. Consequently, the theorem generalizes Brecher and Choudhri's (1982) factor content prediction to multiple countries.

4. Data

I test the predictions of the multi-cone Heckscher-Ohlin Theorem using the same data that was used by Choi and Krishna (2004). Since the latter paper provides a detailed discussion of the data, I will be brief highlighting just the main features of the data. The data set consists of internationally comparable data on factor prices and the factor content of exports for 8 countries: the United States, Canada, Denmark, France, Germany, the United Kingdom, the Netherlands and Korea. All data pertain to 1980.

A. Factor prices

The production technology is assumed to consist of five factors of production: four types of labour and capital. The factor prices of labour pertain to the wages of the following four labour groups: (i) production workers, (ii) managerial workers, (iii) clerical workers and (iv) others.[6] The factor prices were collected from various national and international sources.

The data set consists of two measures of the returns to capital at the economy level, denoted by Capital I and Capital II. Capital I is found by dividing the annual

[6] In addition to the 4-group labour classification, Choi and Krishna (2004) consider also a 2-group labour classification where managerial, clerical and others are aggregated into a single "non-production" category. However since Table 1 reveals considerable wage variation between these 3 categories (see Table 1), I use just the 4-group classification.

operating surplus of the economy by the economy's net capital stock.[7] Capital II is determined by the ratio of the total return to capital to the net capital stock, where the total return to capital is calculated as the difference between GDP and the total employee compensation. Since Capital I is net of taxes on production, while capital II is gross of indirect taxes, the latter will provide a higher estimate than the former.

Table 1 reports the factor prices for each factor category and country in US dollars. The figures suggest quite a bit of factor price variation in the labour categories across countries. Not surprisingly, Korean wages are the lowest in all labour categories by a substantial margin. Comparing the Korean wage with the sample median (which excludes Korea), the Korean wage ranges from 12% ("others") to 27% ("managerials") of this median. Since Korea has also the highest rental price of capital (for both capital measures) Korea occupies the 'lower boundary cone' in the labour-capital space, i.e. it is the least capital-abundant country.

The contenders for the most capital abundant country are capital-measure specific: Denmark for Capital I and the US for Capital II. Both take a middle position in their nominal labour costs (i.e. their labour costs are, on average, below the median of the sample excluding Korea). Denmark has the lowest rental rate of capital using Capital I and the US has the lowest rental rate of capital for Capital II. However, the relative capital abundance is a bit more pronounced for Denmark than for the US: Capital I for Denmark is 58% of the sample median whereas Capital II for the US is only 87% of the sample median.[8]

[7] The operating surplus is part of the cost component decomposition of an economy's GDP, where GDP is decomposed into (i) employees' compensation, (ii) operating surplus and (iii) other cost components like indirect taxes and subsidies.

[8] These sample medians are again exclusive of Korea.

Table 1: Factor Prices

Category	US	Canada	Denmark	France	Germany	UK	Netherlands	Korea
A. Labour (in U.S. Dollars)								
Production	13,059	12,592	13,333	14,715	18,789	12,595	18,177	1,638
Managerial	26,589	21,165	24,985	40,855	34,011	21,011	36,670	7,189
Clerical	14,869	11,460	17,313	16,221	16,389	9,323	18,363	2,910
Others	21,578	16,960	15,788	22,859	24,544	14,529	25,083	2,495
B. Capital								
Capital I	0.08	0.103	0.053	0.078	0.091	0.075	0.097	0.155
Capital II	0.165	0.19	0.174	0.18	0.203	0.203	0.185	0.234

Source: Choi and Krishna (2004)

B. Factor content of trade

The factor content of trade vectors are constructed by combining data from a 17 sector ISIC classification with the corresponding country-specific technology matrices. From the 17 sectors, nine are two-digit manufacturing industries and eight are one-digit non-manufacturing sectors. The industries and their classification numbers are listed in Table A1 of the Appendix.

The country-specific technology matrices give the total (direct and indirect) factor inputs required to produce one dollar of net output in each industry. Each technology matrix $\boldsymbol{A}^c$ is constructed by multiplying a country's direct input matrix $\mathbf{B}^C$ (factor by industry categorization) with its input-output matrix $\check{\boldsymbol{T}}^c$ (industry by industry categorization) such that $\boldsymbol{A}^c = \mathbf{B}^C(\mathbf{I} - \check{\boldsymbol{T}}^c)^{-1}$.[9] This specification of the technology matrix guarantees that the factor content takes into account only domestically produced intermediate goods.

5. Empirical results

I apply the above data set to predictions on the factor content of gross and net exports. Section 5.1 contains the empirical results on the factor content of gross

[9] The direct input matrix $\mathbf{B}^C$ measures how much direct input of each factor is required to produce one dollar of gross output in each industry. The input-output matrix $\check{\boldsymbol{T}}^c$ measures how much output an industry must buy from another industry to produce one dollar of its gross output.

exports and section 5.2 examines net trade flows. Although the underlying theory makes predictions on the pattern of gross exports, we also investigate the implications for bilateral export flows to allow for a direct comparison with Choi and Krishna (2004).

5.1 Predicting the factor content of gross exports

First, I examine the multi-lateral specification (10) and investigate whether the countries' gross exports fall in the country-specific cones, i.e. fulfil the predictions of the multi-cone Heckscher-Ohlin theorem.[10] Given that there are 8 countries, we have a sample of 56 bilateral and 8 multi-lateral exports, where the latter is defined as the factor content of a country's exports to all 7 trading partners. Table 2 summarizes the results from testing the multi-lateral specification. The findings are quite stark. Table 2 reveals that either all or none of a country's exports fall in its cone with no systematic differences between bilateral and multi-lateral trade flows.[11]

Table 2

Exports falling in the correct multi-lateral cones

	Capital I		**Capital II**	
	Correct	**share of total**	**Correct**	**share of total**
United States	0	0.00	0	0.00
Canada	0	0.00	0	0.00
Denmark	8	1.00	0	0.00
France	0	0.00	0	0.00
Germany	0	0.00	0	0.00
United Kingdom	0	0.00	0	0.00
Netherlands	0	0.00	0	0.00
Korea	8	1.00	8	1.00
all countries	**16**	**0.25**	**8**	**0.125**

Total of 64 exports (7 bilateral and 1 multi-lateral flow per country)

[10] It is important to notice that the multi-cone specification requires factor price information of all trading partners. Focusing only on a subset of trading partners creates a bias towards a confirmative finding. Consequently, increasing the sample size can only lead to a weakening of the results as it will be accompanied by an increase in the number of restrictions that need to be fulfilled.

[11] Since I didn't find any different results when considering trade flows to a subset of trading partners (e.g. US exports to France and Germany only), I report only the findings for the multi-lateral exports to all sample trading partners.

Overall, the results suggest poor support for the multi-lateral specification: the success rate is 25% for the capital I measure and 12.5% for the capital II measure. While all Korean exports are compatible with the predictions, Danish exports fall in this country's cone for the capital I measure, but not for the capital II measure. None of the exports of the other 6 countries fall in the respective cones.

Table 3

Exports falling in the (country-pair specific) bilateral cones

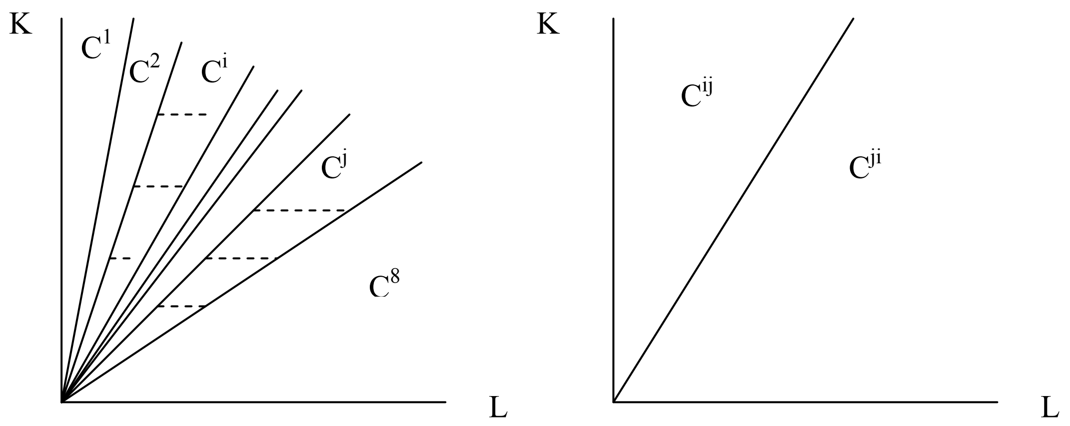
	Capital I		**Capital II**	
	correct	**share of total**	**correct**	**Share of total**
United States	3	0.43	6	0.86
Canada	4	0.57	5	0.71
Denmark	7	1.00	5	0.71
France	3	0.43	3	0.43
Germany	1	0.14	0	0.00
United Kingdom	6	0.86	4	0.57
Netherlands	0	0.00	1	0.14
Korea	7	1.00	7	1.00
all countries	**31**	**0.55**	**31**	**0.55**
excluding Korea	**24**	**0.49**	**24**	**0.49**

56 bilateral exports (7 per country); 49 exports excluding Korea

To allow a comparison with Helpman's bilateral specification, we applied the data to the bilateral restrictions given in (1). The results are reported in Table 3. The average success rate of the bilateral specification is 55%. Although there is considerable variation across countries, ranging form 0% (Capital I for Netherlands) to 100% (Korea), the sample average is the same for both capital measures. Although the bilateral specification is just based on a single restriction, the success rate is slightly over 50%. If we exclude the Korean exports, the bilateral specification is about as successful as the toss of a fair coin, i.e. 49%.

Figure 4 provides the basic intuition for the results reported in Table 2 and 3. The additional restrictions implied by the multi-lateral specification yield much smaller cones for each country than suggested by the bilateral specification. The high "success rate" of Korea's exports in the multi-lateral specification can be explained by its relative "factor price distinctiveness", resulting in Korea occupying the relatively large boundary cone C^8 within the capital-labour space. On the other hand, (12b) suggests that similarity of factor prices corresponds to "middle cones" that are fairly close to each other and the predictions are not likely to hold.

Figure 4: Multi-cone versus bilateral specification with 8 countries



One might argue that the lack of empirical support for the multilateral specification might be the result of the relative strictness of the multi-cone Heckscher-Ohlin prediction since it predicts that an export flow must fulfil all seven restrictions. However, small measurement errors might prevent this from happening. For example, if a country's export vector fulfills only six of the seven restrictions, it would not qualify to fall into this country's cone, although one would consider this to be only a minor violation of the prediction. To investigate this, we now deviate from grouping the restrictions into cones and investigate the sign of the restrictions separately. Specifically, we test the following restrictions on the factor content of bilateral trade

$$(w^k-w^i)'F^{ij} \geq 0, \qquad \text{for all } j \neq i,\ k \neq i. \qquad (12)$$

For 8 countries, (12) implies a total of 49 restrictions for each country: 7 bilateral exports are each restricted by 7 different factor price differences. The results, which are reported in Table 4, are similar to the numbers reported in Table 3.

Table 4

Summary of sign restrictions on gross exports

	Capital I		**Capital II**	
	correct	**share of total**	**correct**	**share of total**
United States	26	0.53	42	0.86
Canada	28	0.57	41	0.84
Denmark	49	1.00	35	0.71
France	22	0.45	21	0.43
Germany	7	0.14	0	0.00
United Kingdom	42	0.86	25	0.51
Netherlands	0	0.00	7	0.14
Korea	49	1.00	49	1.00
all countries	**223**	**0.57**	**220**	**0.56**
excluding Korea	**174**	**0.51**	**171**	**0.50**
392 restrictions (49 per country); 343 restrictions excluding Korea				

Overall the restrictions perform very poorly for Germany and the Netherlands (14% and 0%), perform fairly well for Denmark (100% and 71%) and fit perfectly for Korea. For the US, Canada and the UK the success rate is fairly sensitive to the capital measure: it fluctuates between 50% and 80%. For France, the success rate is in the 40% range for both capital measures. Although there is quite a bit of variation across countries, the average success rate is 57% and 56% for Capital I and Capital II, respectively. As before, the magnitude of the average is driven by Korea; excluding Korea, the success rate is around 50%.

The results reported in Tables 2 through 4 beg an explanation for the high success rate of the restrictions on Korean exports. The factor price data from Table 1 provide a possible clue to the answer. In particular, the large factor price differences between Korea and the other 7 OECD countries are more likely to reflect differences in factor productivity rather than differences in factor endowments. While the identical technology assumption seems to be justifiable for the 7 OECD countries, it becomes suspect if one includes Korea.

To illustrate the potential misspecification that arises from the inclusion of Korea, we relax the identical technology assumption and assume Hicks-neutral factor efficiency differences. In particular, assume that all input factors in any of the OECD countries is more productive than those in Korea by a fixed factor of Φ, where Φ>1. Using the logic from section 3, one can derive a productivity adjusted restriction on the gross exports of Korea,

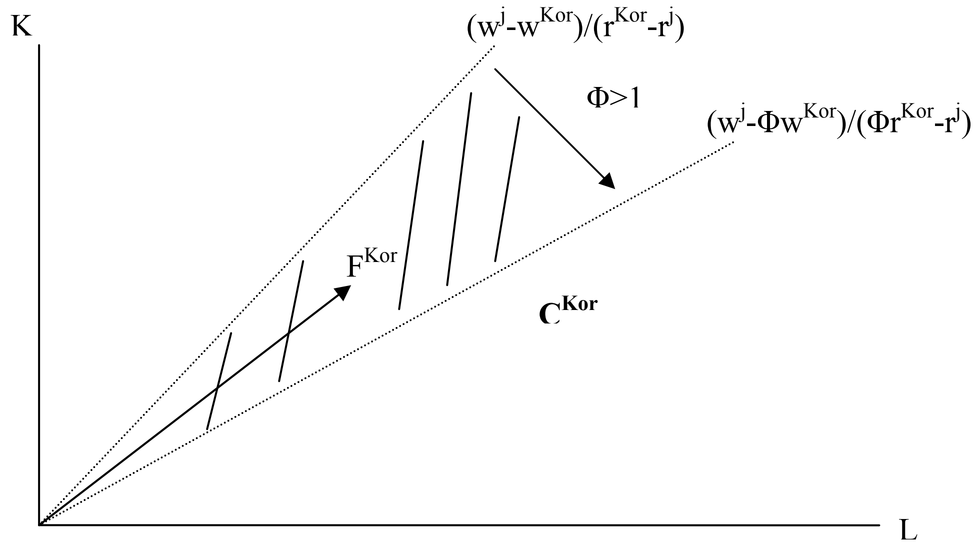
$$(w^j - \Phi w^{Kor})' F^{Kor} \geq 0, \qquad (13)$$

where the factor content of any of Korea's export vector F^{Kor} is restricted by the factor difference between the factor price vector w^j in country j and the productivity adjusted Korean factor price vector Φw^{Kor}.

Figure 5 illustrates the effects of technological differences in the two-factor case. Ignoring the productivity difference results in an acceptance region for the restriction which is larger than the true, productivity adjusted acceptance region.[12] The magnitude of the specification error is reflected in the size of the shaded area. As a result, if Korea's export vector F^{Kor} falls into that area it will satisfy (12), but not (13).

[12] Formally, $(w^i - w^{Kor})F^{Kor} \geq (w^i - \Phi w^{Kor})F^{Kor}$.

Figure 5: Effect of technological differences



5.2 Revisiting Choi and Krishna (2004)

In this section we test the multi-lateral restrictions on the two-way trade flows between countries i and j, which allows for a direct comparison with the findings in Choi and Krishna (2004). Instead of testing the predictions (1) and (2) on gross exports F^{ij} and F^{ji} separately, Choi and Krishna test the restrictions on net exports F^{ij}-F^{ji} given in (3)[13] These restrictions can be rewritten as follows:

$$\frac{w^j F^{ij} + w^i F^{ji}}{w^i F^{ij} + w^j F^{ji}} \geq 1 \qquad (14)$$

The left-hand side of inequality (14) has the following interpretation. For a given country pair, the denominator is the sum of the production costs of the bilateral exports. The numerator can be interpreted as the counterfactual production costs that results from valuing the factor content of exports by the importers factor prices. Since

[13] In a previous working paper version of their 2004 article, the authors test (1) and (2) separately.

the counterfactual production costs can't be smaller, the ratio must be greater than or equal to 1.

Table A2 in the Appendix contains a replication of Choi and Krishna's test of the 28 restrictions suggested by (14).[14] The tests perform remarkably well; the success rate is 86% using Capital I and 71% using Capital II. Remarkably, the ratios that are below 1 violate (14) by only very small margins.

However, the previous analysis suggests that there are many more ratios to be considered. Specifically, applying (12) to the two-way trade flows F^{ij} and F^{ji}, we obtain the following set of restrictions:

$$\frac{w^k F^{ij} + w^l F^{ji}}{w^i F^{ij} + w^j F^{ji}} = \theta \geq 1 \qquad \text{for all } k \text{ and } l. \qquad (15)$$

It is immediately clear that (14) is a special case of (15) and that the latter implies many more counterfactual cost comparisons. In particular, the numerator in (15) is the sum of the counterfactual costs that results from valuing the factor content of bilateral exports using the factor prices of *any* other country in the sample. The theory predicts that the ratio must be greater than or equal to 1 for all factor price configurations. While (14) implies only a single restriction for a given country pair, (15) yields 49 different restrictions per country pair, resulting in a total of 1372 restrictions.

[14] Despite using the same data set, the magnitudes in Table A2 deviate a bit from the corresponding entries in Tables 3 and 4 in Choi and Krishna (2004, p. 901-902). A possible explanation is the use of different rounding strategies; we chose not to round up until the final results.

Table 5

Testing inequality (15) (each entry contains the share of restrictions that satisfy θ ≥ 1)

Capital I

	Canada	Denmark	France	Germany	UK	Netherlands	Korea
US	0.55	0.84	0.49	0.20	0.67	0.49	1.00
Canada		0.88	0.51	0.18	0.76	0.45	1.00
Denmark			0.92	0.37	0.96	0.47	1.00
France				0.06	0.63	0.12	1.00
Germany					0.31	0.02	1.00
UK						0.51	1.00
Netherlands							1.00
All	**0.62**	(% of correct signs of 1372 restrictions (28 country pairs))					
excl. Korea	**0.49**	(% of correct signs of 1029 restrictions (21 country pairs))					

Capital II

	Canada	Denmark	France	Germany	UK	Netherlands	Korea
US	0.78	0.78	0.59	0.16	0.73	0.57	1.00
Canada		0.82	0.53	0.10	0.67	0.51	1.00
Denmark			0.92	0.12	0.71	0.39	1.00
France				0.04	0.41	0.20	1.00
Germany					0.12	0.00	1.00
UK						0.49	1.00
Netherlands							1.00
All	**0.59**	(% of correct signs of 1372 restrictions (28 country pairs))					
excl. Korea	**0.46**	(% of correct signs of 1029 restrictions (21 country pairs))					

Table 5 contains the results from testing the restrictions in (15). Since there are 49 restrictions for each country pair, each entry gives the share of restrictions which satisfy (15). Overall, the results are consistent with our findings in Table 4. The success rate is perfect for the bilateral trade flows that involve Korea and fairly high for bilateral trade flows that involve Denmark. The restrictions perform rather poorly for trade flows involving the Netherlands and Germany and are mixed for Canada, the US, the UK and France. Taking the average over all country pairs, the success rate is 62% for Capital I and 59% for Capital II; excluding Korea the success rate drops to under 50%.

Overall, the results reported in Tables 2 and 5 suggest that observed factor price differences are, on average, poor predictors for the direction of the factor content trade between the sample of 7 OECD countries (i.e. excluding Korea). A possible explanation for this finding is that the observed factor price differences do not reflect factor endowments differences that are large enough for justifying the assumption that countries all occupy different cones.[15] If countries occupy a single cone then the left-hand side will be equal to 1. Hence, testing whether $\theta=1$ provides evidence for factor price equalization. Table A3 in the Appendix reports the average magnitudes of θ for each country pair. Although there is substantial variation in the average values among the country pairs, the overall average of the 1029 restrictions (excluding Korea) is remarkably close to 1: 1.01 using for Capital I and 1.00 for Capital II. This confirms the conjecture that this set of OECD countries does not fulfil the assumption of the underlying theoretical specification.

6. Conclusion

This paper has contributed to the Heckscher-Ohlin trade literature in two dimensions. On the theoretical side, I have developed a multi-cone Heckscher-Ohlin factor content prediction which generalizes Alan Deardorff's (1979) well-known two-factor commodity chain prediction to an arbitrary number of factors and countries. A corollary of this is that Helpman's (1984) bilateral factor content prediction coincides with this multi-cone prediction only in the two-country case.

On the empirical side, I have revisited Choi and Krishna's (2004) empirical implementation of Helpman. Applying Choi and Krishna's OECD data set to the multi-lateral specification, I have found little empirical support for the multi-cone factor content prediction. The data analysis provides evidence for factor price equalization rather than specialization due to differences in relative factor prices. This

[15] This is consistent with the empirical findings of Debaere and Demiroglu (2003).

is consistent with previous empirical evidence suggesting that the OECD countries do not occupy different cones.

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Appendix

Table A1: Industry classification

Industry Description	ISIC Code
Agriculture, hunting, forestry and fishing	1
Mining and quarrying	2
Food, beverages, and tobacco	31
Textiles, apparel, and leather	32
Wood products	33
Paper, paper products and printing	34
Chemical products	35
Nonmetallic mineral products	36
Basic metal industries	37
Fabricated metal products and machinery	38
Other manufacturing	39
Electricity, gas and water	4
Construction	5
Wholesale and retail trade, retaurants and hotels	6
Transport, storage and communication	7
Finance, insurance, real estate and business services	8
Community, social and personal services	9

Table A2: Replication of Choi and Krishna (2004) (left-hand side of (14))

Left-hand side of (14)

Capital I

	CA	**DE**	**FR**	**GER**	**UK**	**NE**	**KO**
US	1.00	1.03	1.05	1.00	0.98	1.18	1.72
CA		1.14	1.06	1.01	1.01	1.17	1.62
DE			1.08	0.99	1.04	1.03	2.45
FR				0.99	1.04	1.01	2.73
GER					0.97	1.00	2.35
UK						1.10	1.88
NE							3.62
Average		**1.37**		28 restrictions with Korea			
w.out KO		**1.04**		21 restrictions without Korea			
≥1	24	28	**0.86**	% of correct sign			
w.out KO	17	21	**0.81**	% of correct sign			

Capital II

	CA	**DE**	**FR**	**GER**	**UK**	**NE**	**KO**
US	1	0.9976	1.06	0.99998	1.01	1.14	1.53
CA		1.03	1.04	0.99	0.9953	1.14	1.48
DE			1.08	0.99	1.03	1.02	1.99
FR				0.99	1.03	1.01	2.29
GER					0.99	0.99	2
UK						1.07	1.65
NE							3.01
Average		**1.27**		28 restrictions with Korea			
w.out KO		**1.03**		21 restrictions without Korea			
≥1	20	28	**0.71**	**% of correct sign**			
w.out KO	13	21	**0.62**	**% of correct sign**			

Table A3: Average Magnitude of θ (left-hand side of (15))

Each entry is the average of 49 ratios for each country pair

Capital I

	CA	DE	FR	GER	UK	NE	KO
US	1.02	1.14	1.00	0.89	1.08	0.99	1.99
CA		1.18	1.00	0.88	1.10	0.96	2.04
DE			1.15	0.97	1.23	0.99	2.80
FR				0.86	1.05	0.87	2.74
GER					0.94	0.79	2.08
UK						1.04	1.76
NE							3.34
Total average		**1.35**		1372 restrictions (28x49)			
w.out KO		**1.01**		1029 restriction (21x49)			

Capital II

	CA	DE	FR	GER	UK	NE	KO
US	1.06	1.07	1.04	0.92	1.05	1.03	1.78
CA		1.07	1.01	0.90	1.05	1.00	1.85
DE			1.15	0.93	1.06	0.98	1.91
FR				0.87	0.99	0.93	2.33
GER					0.91	0.84	1.81
UK						1.05	2.06
NE							2.89
Total average		**1.27**		1372 restrictions (28x49)			
w.out KO		**1.00**		1029 restriction (21x49)			