A global value chain perspective on trade, employment, and growth

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Chapter 2

Estimating and Explaining Bilateral Factor Exports

2.1 Introduction

What do countries trade with each other? Neo-classical theories, such as the Heckscher-Ohlin model, take an endowment-driven perspective and suggest that the export pattern of a country should reflect its structure of factor endowments. Developing countries are expected to export low-skilled labour- and natural resources intensive products, while developed countries should export skill- and technology-intensive products.

However, in the recent decades the empirical evidence seems to be increasingly contradictory to theoretical predictions. Trade statistics suggest that technology-intensive products are comprising a rapidly increasing share in the export by some developing countries; they seem to quickly overtake the developed world by a large margin. For example, in 1995 electronics made up already 26.3% of the bilateral gross exports from China to the U.S., and it increased further to 42.9% in 2011. But the share of electronics in the gross exports from U.S. to China has *decreased* from 24.1% in 1995 to 20.0% in 2011. On the other hand primary products (agricultural products, minerals, and wood) only have a strikingly small share of 1.2% in the Chinese gross exports to the U.S. in 2011, but the same share is 9.0% in the gross exports from the U.S. to China (based on the WIOD database, Timmer *et al.* 2015).

Are the standard theories deficient or is America already not great anymore? It might be the case that neither of them is true, and the seemingly paradoxical pattern of gross export is a consequence of globalized production. Under globalized production, different tasks in the production process of a single product are unbundled and offshored to different countries, such that the comparative advantages of countries are realized at the task level. Gross export data in products, therefore, can sometimes be illusionary for economic studies. For instance, being an exporter of electronics does not reveal whether the country is specialized in producing electrical chips, or just in assembly.

In this paper, I argue that in the presence of pervasive offshoring, trade theories can be better tested based on the underlying factors that has been exchanged between countries. The main aim of this paper is to introduce a *new measure* of the *bilateral trade in factors*. Using this new measure, I test the fitness of neo-classical theories on factor export by a *new test*, which investigates whether the direction of *bilateral* net factor export between each pair of countries is in line with the theoretical prediction based on the differences in two countries' endowment structures. I find strong and robust evidences supporting the endowment-driven view of trade.

Originally neo-classical theories, like the Heckscher-Ohlin model, are developed to explain and predict the patterns of trade in products; a country should intensively export the product(s) which intensively uses its abundant factor(s). This prediction relies on the assumptions that production factors, especially labour, are perfectly immobile across countries, and the products exported are fully made by the exporting country itself. These assumptions are reasonable in the era of Heckscher and Ohlin since the costs of transportation and communication were so high that trade mostly took place at the final goods level. But they are no longer suitable, due to the rapid reduction in the costs of logistics and telecommunication which have enabled the *de facto* international mobilization of labour via offshoring and trade in intermediates. That is, to given an example, when coordinating costs plus the shipping costs of intermediates back and forth between the U.S. and China are smaller than the low-skilled wage differences between two countries, it is cheaper for U.S. firms to unbundle their production process and to offshore some or all the low-skilled tasks to China (Baldwin 2006). Goods are no longer produced within countries but in the so-called *Global Value Chains* (GVCs), and such *de facto* usage of foreign labour embedded in intermediates is rapidly increasing, as documented in Timmer, Los, Stehrer and de Vries (2016) that the trade volume in intermediates has now already surpassed the trade in final products.

Under offshoring, developing countries may export high-skill intensive products like smartphones, but most of the key components are imported from the developed world. Developed countries may export traditional products like bags, shoes and cookware, with all production tasks offshored but the high-skilled design and coordinating tasks and the final stage of quality checking remain domestically. What a country exports is not always closely tied with what a country does for export. As a result, gross export data is less informative for many economic studies in which the identification of actual economic activities in the local economy is important. In this paper, I argue that bilateral trade of *factor content* provides a better analytical perspective in linking trade and endowments. Compared with gross export data, this new measure is directly related to the actual tasks that are performed for export and the respective factors that are employed in these tasks. One is able to tell, for example, whether offshoring indeed offers low-income countries a sudden upgrading in their actual tasks, or the actual tasks stay unchanged after the "upgrading" in gross export.

The concept of factor trade is not new, and can be dated back to as early as Leontief (1953) and Vanek (1968) who argue that as an alternative perspective trade can be viewed "*with reference to amounts of factor-services embodied in goods traded, rather than with reference to products*" (Vanek 1968, pp. 749) – to put it in a modern terminology: *trade in tasks*. It seems that the "conversion" from product export to factor export has already become a standard practice in international economics. However, there are still two issues that worth further attention. Firstly, although there are many influential studies that estimate factor exports from each country (i.e. the factor exports by domestic country to the rest of world, see e.g. Bowen, Leamer and Sveikauskas 1987, Trefler 1995, Davis and Weinstein 2001, Hakura 2001), the research on *bilateral* factor trade is scarce. There are only a limited number of estimates, and the early literature mostly estimates factor trade between two specific countries for which data are available (Tatemoto and Ichimura 1959 on factor trade between the U.S. and Japan, Wahl 1961 and Brecher and Choudhri 1993 between Canada and the U.S.). Only recently, the scope of research been extended to multiple countries (Choi and Krishna 2004 for 8 OECD countries, Zhu and Lai for 41 countries/regions in the GTAP dataset, Artal-Tur, Gastillo-Gimenez, Llano-Verduras and Requena-Silvente 2011 between 17 Spanish regions).

Secondly, most past studies in factor exports relied on a similar methodology, which I will refer to as the "conventional" measure, that calculates domestic contents embodied in the bilateral gross export flows between countries. The conventional measure uses a production cost share matrix, derived from domestic production technology, to convert the products in gross export into domestic factor contents.[1] The conventional measure of (bilateral) factor exports only uses the information that is within the domestic country's statistical registry. As a result, the conventional measure lacks the ability in tracing factors embodied in traded intermediates. The potential problem of the conventional measure can be intuitively seen in a multi-country world. Recall the international production process of the cars as illustrated by figure 1.2(b) in the first chapter. The car uses a Germany-made engine, but is assembled in Mexico and is subsequently sold to the U.S. In this particular GVC, the conventional measure will not register any factor export from Germany to the U.S., because there is simply no direct gross export flow between them. On the other hand, the German factors that are used in producing engines will show up as the factor exports to Mexico, although all factor contents are finally passed on to the U.S. for final consumption. Even in a two-country world (i.e. domestic economy and the rest-of-world), as I will show, this problem of the conventional measure still exists.

This paper contributes to the literature by using new data and a new strategy to measure bilateral factor exports. I follow Johnson and Noguera (2012, 2016) and measure factor trade by identifying the origin and final destination of value-added. Formally, the export of factor f from country i to j, denoted by E_{ij}^{f}, is defined as the value added in country i by the tasks performed by factor f that finally ends up in country j's final use. Defined in this way, my measure is directly linked with the actual economic activities in creating exported value added, which is according to Trefler and Zhu (2010) economically meaningful and relevant for the tests of trade theories. This measure is also invariant to the organization of a value chain, provided that the country under investigation is still performing the same tasks. A car sold to the U.S. with a Germany-made engine will always carry the factor export from Germany to the U.S. that is related with engine manufacturing, regardless of whether the car is assembled in Mexico or in Germany itself.

To construct the indices of bilateral factor exports, I used the recently available World Input Output Database (henceforth WIOD, Timmer *et al.* 2015). WIOD and its

1. For instance, if country A exports \$100 of a certain good to B, and assume that the cost shares of domestic low-skilled worker, high-skilled worker and imported intermediate inputs in its production are

accompanying Social-Economic Account (SEA) database provide information on globalized production structure, trade, consumption, and factor usage for 40 countries over the period from 1995 to 2009. Traded intermediates are separated from the trade in final products, and are coupled to the countries and industries that produce and use these intermediates. This is crucial for the derivation of bilateral factor exports as defined in this paper. I find that my measure differs considerably from the conventional measure based on the decomposition of bilateral gross export flows. Within a particular GVC, the conventional measure underestimates factor export from countries that are located upstream in the GVCs to the final destination of consumption, and overestimate factor export to the countries that process traded intermediate inputs. Whether bilateral factor exports are over- or under-estimated depends on the two countries' positions in the globalized production at an aggregated level. The disparity between the two measures can be enormous; substantially large differences are widely observed including in many large country pairs, like Russia and the U.S.

What is the pattern of factor trade as suggested by this new measure? I find that my new bilateral factor export indicators show a quite different picture compared to trade in products. The pattern of factor exports is consistent with country's structure of factor endowment. As a quick diagnostic check, in table 2.1 I illustrate the bilateral exports between China and the U.S. for the year 2007. In terms of trade in products, the structure of China's gross export to the U.S. looks quite comparable to the gross export from the U.S. to China, with modern manufacturing industries having the largest share. However, in terms of factor trade, a very different picture emerges. When we focus on the export shares within labour,[2] low-skilled labour plays the most important role in the factor export from China to the U.S. While on the factor export from the U.S. to China, low-skilled labour only contributes a negligible share of 4%, and medium- and high-skilled labour both contributed about half of the labour contents that are exported. The pattern of bilateral factor export between China and the U.S. therefore fits the prediction by standard trade theories.

To provide a more systematic test on the endowment-driven view of trade, I extend the model in Trefler and Zhu (2010) and build a sign test on the direction of net factor trade between countries. In brief, the direction of net factor export within a pair of countries is predicted by the difference in two countries' endowment structures after accounting for their trade balances. The one with a higher relative abundance of a factor is predicted to be the net exporter of that factor, while running a trade deficit lowers the probability in being an exporter of any factor. The sign test I perform is in analogy with the Heckscher-Ohlin-Vanek (HOV) prediction (Vanek 1968). However, it is a *new* test with the focus on bilateral factor trade, which differs from the standard HOV prediction on the factor export from each country to all the rest of world. Past HOV tests are infamous for the poor empirical performance (see, e.g. Trefler 1995 who finds that the standard HOV's predictive power is not better than tossing a coin). I find that using the

0.2, 0.3, and 0.5, respectively. The export of low- and high-skilled labour contents are then estimated to be $20 and $30. More discussions will follow in the next section.

2. Capital has a dominant share of 63.5% in the export from China to the U.S. And according to the data China *indeed has* a large relative endowment in capital. This is because the dataset identifies capital by the location of residence and not by ownership. Due to high level of inward FDI, a large part of capital in China may comes from abroad and the capital income generated in China may eventually go to the foreign capital owners.

Table 2.1: Bilateral Export in Products and Factors (2007)

A. Export from China to the U.S.

Export of Products			Export of Factors		
Electronics, Machinery & Cars	170.3	58.7%	Capital	152.2	63.5%
Light Industries	45.5	15.7%	Low-skilled labour	45.5	19.0%
Heavy Industries & Chemicals	36.4	12.5%	Medium-skilled labour	33.6	14.0%
Services	34.7	11.9%	High-skilled labour	8.5	3.5%
Agriculture & Resources	3.7	1.3%			
Total	290.6			239.8	

B. Export from the U.S. to China

Export of Products			Export of Factors		
Electronics, Machinery & Cars	44.9	43.6%	Capital	27.3	38.7%
Services	24.3	23.6%	Medium-skilled labour	21.4	30.4%
Heavy Industries & Chemicals	18.5	17.9%	High-skilled labour	19.7	27.9%
Agriculture & Resources	9.4	9.1%	Low-skilled labour	2.1	3.0%
Light Industries	5.8	5.7%			
Total	102.9			70.5	

Note: Unit of measurement: billion U.S. dollar at current prices. The product export data is fetched from the WIOD database and the factor export is based on author's own calculation.

new measure of bilateral factor export, the HOV-like sign test in my paper has a high predictive power on the direction of net factor trade between 40 countries in WIOD, and the results are also highly stable across the 15-year period from 1995 to 2009.

As a further exploration of the relevance of my bilateral factor export indicator in economic studies, I investigate whether endowment also predicts the volume of bilateral factor export. Under certain standard assumptions in the trade literature, for example assuming a world with homogeneous preference and frictionless trade, a so-called "consumption similarity" condition arises such that the factor export between two countries equals the exporter's endowment of that factor, times the share of consumption of the importing country in world GDP (see also Trefler and Zhu 2010). This prediction on bilateral factor export can be naturally tested in a gravity-like equation system, which has not yet been done in the literature. Due to the research scope of my paper, I do not try to distinguish the alternative models that predicts consumption similarity, nor do I search for exact theoretical reasonings behind the violation of this condition. I am interested in the predicting power of the simple gravity equation in explaining actual factor export data, and how do trade barriers like distance affect the trade in different kinds of factors differently.

I find that the factor export elasticities are close to unity in exporter's size of factor endowment and importer's total consumption, which support consumption similarity in traded factors. I find that the so-called "home bias" is the most important violation to consumption similarity, namely a country's consumption of its own factor is much larger than the prediction under frictionless trade – or equivalently, a majority of factors is deployed in the tasks that are exclusively for domestic consumption. Home bias is found to be pervasive in the economy, which is not limited to the factors that are deployed in producing non-tradable products. Similar as in gross exports, distance also reduces the trade of factors. The impediment due to distance has declined significantly during 1995 to 2007, and the largest changes are found in the trade of high-skilled labour and capital. Furthermore, the relative importance of language barrier is found to increase in the trade of all factors.

The rest of my paper is organized as follows. The next section provides details on the derivation of my new measure of bilateral factor exports as well as its methodological different with the conventional measures. I will also discuss the data I use for my study. Section 3 is an empirical comparison of the two measures. I first illustrate how the estimating bias of conventional measure arises in globalized production, and then compare the empirical estimates of two measures based on the WIOD dataset. In section 4 I perform the new sign test to see whether endowment differences between country pairs predict the direction of their net bilateral factor trade. This is followed by section 5 in which I estimate the gravity equation system on factor exports. Section 6 concludes.

2.2 Measuring Bilateral Trade in Factor Content

2.2.1 Derivation of the New Measure

In this subsection, I derive a new measure for bilateral exports in factor contents. Most past studies, for example influential works by Choi and Krishna (2004) and Davis and Weinstein (2001), uses a conventional definition for (bilateral) factor export, which is the domestic factor content embodied in bilateral gross export flows (or gross exports to all other countries). In brief, the conventional measure is a decomposition of the gross export between country i and j, denoted by $\boldsymbol{X}_{ij}$. Based on the production technology of the exporting country i, a domestic factor cost share matrix $\boldsymbol{\Psi}_i$ is computed which contains the share of value-added by domestic labour and capital in producing \$1 of each kind of product (see also footnote 1). Applying this matrix to gross export, and the conventional bilateral factor export is derived as $\boldsymbol{\Psi}_i\boldsymbol{X}_{ij}$ (see also chapter 2 of Feenstra 2003).[3]

In this paper I propose a different measure of bilateral factor export. Formally, the export of factor f from country i to j, denoted by E^f_{ij}, is defined as the value-added that is generated by the tasks using factor f in country i that are ultimately absorbed as final consumption[4] in country j. Intuitively, I investigate how the final consumption of country j is made in globalized production, and what are the contributions by country

3. In many studies in international economics, the domestic factor cost share matrix $\boldsymbol{\Psi}_i$ are referred to as "technology matrix", and is annotated by the symbol "$\boldsymbol{A}$". This may create confusion due to a collision with the usual terminology in input-output literature, in which matrix $\boldsymbol{A}$ is reserved for the so-called *technical matrix* that contains input-output coefficients. As I will discuss below, the $\boldsymbol{A}$ matrix in the IO literature is *different* from the technology matrix in international economics. Since IO analysis is the core in deriving my new measure of bilateral factor exports, I adopt the terminologies of IO literature in my equations.

4. For simplicity in the expression, this paper uses "consumption" and "final use by a country" interchangeably, i.e. "consumption" in this paper refers to the summation of a country's household use, government consumption and investment in the national account.

i's factors. It is an extension to Johnson and Noguera's (2016) measure of bilateral value-added export, and is also related with Johnson and Noguera (2012) and Timmer *et al.* (2014) who measure total value-added from each country to the rest of world. But as I will show in this and the next sections, the derivation and the empirical estimates of the new measure of bilateral factor exports are very different from the conventional measure in the current literature.

To calculate my new measure of bilateral factor export, the following three sets of data are required: the so-called global input-output technical matrix, denoted by $\boldsymbol{A}$; the final consumption by each importing country j, denoted by $\boldsymbol{d}_j$; and direct factor intensity vectors $\boldsymbol{v}_f$ which measure the *direct* value-added contribution[5] by each factor f in producing unit value of product from each country industry. The structure of data will be explained in detail alongside the discussion of the derivation of the new measure. The first two sets of data are obtained from the World Input-Output Database (WIOD), and the last one is from WIOD's accompanied Social Economic Account dataset (SEA); more details on data source will follow in the next subsection.

The derivation of the new measure can be considered as a "backward-tracing" strategy. Its starting point is *not* trade flows between countries, but instead the bundle of all final consumption by the importing country j, $\boldsymbol{d}_j$, and then input-output analysis is used to identify the origins of value-added embodied in j's consumption. Assume there are N countries in the world and each country has G industries, $\boldsymbol{d}_j$ is a column vector with NG elements, each of which captures the value of final goods (or services) consumed by j that are finalized by a certain country-industry in the world. To put it clearer, in calculating the bilateral factor export from country i to j, one needs to investigate not only country j's imports of final products from i, but also j's consumption of all final goods from *all* countries, including the consumption of products that are finalized by j itself. This is because the products made by any country in the world may directly or indirectly use the intermediate inputs that contain the value added by country i's factors.

The next step is to calculate the gross output in the world that is directly and indirectly linked with the final demand of j. This requires the global technical matrix $\boldsymbol{A}$, which provides the information on the use of intermediate goods in the production of each country industry. In table 2.2 I show the structure of the global input-output technical matrix. It has the size of $(NG \times NG)$, with each element $A^{(j,y)}_{(i,x)}$ representing the value of intermediate goods from country i's industry x that is directly used in producing \$1 gross output in j's industry y. If someone demands \$1 of final product made by country 1, industry 1, the required direct intermediate inputs is given by the first column of the global technical matrix $\boldsymbol{A}$. Namely, one needs intermediate inputs worth $A^{(1,1)}_{(1,1)}$ made by country 1 industry 1, $A^{(1,1)}_{(1,2)}$ by country 1, industry 2, ..., and $A^{(1,1)}_{(N,G)}$ by country N, industry G. In matrix form, the vector of required direct intermediate inputs is therefore $\boldsymbol{A}[1, 0, \cdots, 0]'$. Similarly, the direct intermediate inputs in producing \$1 final goods in country 1 industry 2 is given by the second column of $\boldsymbol{A}$, i.e. $\boldsymbol{A}[0, 1, 0, \cdots, 0]'$, etc. Therefore, it is not difficult to see that in order to produce the final demand $\boldsymbol{d}_j$, the required amount of direct intermediate inputs is given by $\boldsymbol{A}\boldsymbol{d}_j$.

5. i.e. the value that is directly added by a factor in a given stage of production, which does not include any upstream factor embodied in intermediate goods.

Table 2.2: The structure of Global Technical Matrix $\boldsymbol{A}$

			Direct intermediate goods used in producing \$1 output in								
			Country 1				$\cdots$	Country N			
			Ind 1	Ind 2	$\cdots$	Ind G	$\cdots$	Ind 1	Ind 2	$\cdots$	Ind G
Intermediate Goods Supplied by	Country 1	Ind 1	$A^{(1,1)}_{(1,1)}$	$A^{(1,2)}_{(1,1)}$	$\cdots$	$A^{(1,G)}_{(1,1)}$		$A^{(N,1)}_{(1,1)}$	$A^{(N,2)}_{(1,1)}$	$\cdots$	$A^{(N,G)}_{(1,1)}$
		Ind 2	$A^{(1,1)}_{(1,2)}$	$A^{(1,2)}_{(1,2)}$	$\cdots$	$A^{(1,G)}_{(1,2)}$		$A^{(N,1)}_{(1,2)}$	$A^{(N,2)}_{(1,2)}$	$\cdots$	$A^{(N,G)}_{(1,2)}$
		$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
		Ind G	$A^{(1,1)}_{(1,G)}$	$A^{(1,2)}_{(1,G)}$	$\cdots$	$A^{(1,G)}_{(1,G)}$		$A^{(N,1)}_{(1,G)}$	$A^{(N,2)}_{(1,G)}$	$\cdots$	$A^{(N,G)}_{(1,G)}$
	$\vdots$	$\vdots$			$\vdots$		$\ddots$			$\vdots$	
	Country N	Ind 1	$A^{(1,1)}_{(N,1)}$	$A^{(1,2)}_{(N,1)}$	$\cdots$	$A^{(1,G)}_{(N,1)}$		$A^{(N,1)}_{(N,1)}$	$A^{(N,2)}_{(N,1)}$	$\cdots$	$A^{(N,G)}_{(N,1)}$
		Ind 2	$A^{(1,1)}_{(N,2)}$	$A^{(1,2)}_{(N,2)}$	$\cdots$	$A^{(1,G)}_{(N,2)}$		$A^{(N,1)}_{(N,2)}$	$A^{(N,2)}_{(N,2)}$	$\cdots$	$A^{(N,G)}_{(N,2)}$
		$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
		Ind G	$A^{(1,1)}_{(N,G)}$	$A^{(1,2)}_{(N,G)}$	$\cdots$	$A^{(1,G)}_{(N,G)}$		$A^{(N,1)}_{(N,G)}$	$A^{(N,2)}_{(N,G)}$	$\cdots$	$A^{(N,G)}_{(N,G)}$

In order to produce these intermediates, one further demands other direct intermediate inputs, which is given by $\boldsymbol{A}\left(\boldsymbol{A}\boldsymbol{d}_j\right) = \boldsymbol{A}^2\boldsymbol{d}_j$. This process continues and a total gross production of $\boldsymbol{d}_j + \boldsymbol{A}\boldsymbol{d}_j + \boldsymbol{A}^2\boldsymbol{d}_j + \boldsymbol{A}^3\boldsymbol{d}_j + \cdots + \boldsymbol{A}^\infty\boldsymbol{d}_j$ is required to deliver the final goods $\boldsymbol{d}_j$ to satisfy country j's final demand. For well-behaving input-output tables, it can be shown that this infinity summation converges to:

$$\boldsymbol{y}(\boldsymbol{d}_j) = \sum_{k=0}^{\infty} \boldsymbol{A}^k\boldsymbol{d}_j = \left(\boldsymbol{I} - \boldsymbol{A}\right)^{-1}\boldsymbol{d}_j. \tag{2.1}$$

The term $\left(\boldsymbol{I} - \boldsymbol{A}\right)^{-1}$ is the famous "Leontief Inverse" (Leontief 1953), in which $\boldsymbol{I}$ is the identity matrix with the size $(NG \times NG)$.

For the sake of clarity, two things are worth mentioning at this point. Firstly, the *global* technical matrix $\boldsymbol{A}$ used in my measure is different from the *domestic* technical matrix that is used by Davis and Weinstein (2001) and Krishna and Choi (2004). The domestic technical matrix of a country i, $\boldsymbol{A}_i^D$, only contains the information on i's domestic industries' usage of intermediate inputs that are produced by other domestic industries. It has the size of $(G \times G)$, and is a sub-matrix on the main diagonal of the global technical matrix. For instance, the upper-left $(G \times G)$ block in $\boldsymbol{A}$ is the domestic technical matrix for country 1, et cetera. Domestic technical matrices do not provide information on traded intermediates. Assume that the production in Chinese metal industry makes use of imported Russian minerals. This is recorded by a positive $A^{(CN,Met)}_{(RU,Min)}$ which is an element from the off-diagonal blocks of $\boldsymbol{A}$ and is absent from both Chinese and Russian domestic technical matrices. As I will show later, the neglection of traded intermediates in the conventional measure may lead to confusing pattern of factor trade. Secondly, although the global technical matrix $\boldsymbol{A}$ is one single matrix, it does allow different production technologies across countries. This is because domestic technical matrices $\boldsymbol{A}_i^D$ of each country is represented by *different* $(G \times G)$ sub-matrices in $\boldsymbol{A}$, such that the input-output coefficients differ across countries. I do not make prior assumptions about production technology in each country; the methodology here should be distinguished from Bowen *et al.* (1987) and Trefler (1993, 1995) who assume all countries' production technologies are the same as that in the U.S.

The vector of total gross output $\boldsymbol{y}(.)$ can be linked with the value added by each factor, using the NG-element vector $\boldsymbol{v}^f$ that captures direct contribution by factor f in producing \$1 of gross output in each country industry. $\text{Diag}(\boldsymbol{v}^f)$ is an $(NG\times NG)$ matrix with elements of $\boldsymbol{v}^f$ on its diagonal line, and all off-diagonal elements are zero. It can be shown that $\text{Diag}(\boldsymbol{v}^f)\boldsymbol{y}(\boldsymbol{d}_j)$ represents the usage of factor f in each country industry that are required in producing the final goods for country j. To obtain the new measure of factor export from country i to j, one takes the summation of all factor contributions in $\text{Diag}(\boldsymbol{v}^f)\boldsymbol{y}(\boldsymbol{d}_j)$ that belong to country i. This is done by the pre-multiplication by a summation vector $\boldsymbol{\iota}_i' = [0, 0, \cdots, 1, 1, \cdots, 1, 0, \cdots, 0]$, which has NG elements; the elements equal 1 for industries in country i, and zero otherwise. Therefore, the full equation I use to obtain export of factor f from country i to j is:

$$\begin{aligned} E_{ij}^f &= \boldsymbol{\iota}_i'\text{Diag}(\boldsymbol{v}^f)\boldsymbol{y}(\boldsymbol{d}_j) \\ &= \left[\boldsymbol{\iota}_i'\text{Diag}(\boldsymbol{v}^f)\,(\boldsymbol{I}-\boldsymbol{A})^{-1}\right]\boldsymbol{d}_j. \end{aligned} \tag{2.2}$$

Empirically, direct factor intensity in each country industry, say $v_{(i,x)}^f$, is calculated by the factor payment to f in country i industry x, divided by its gross output. Relevant statistics are available in the SEA dataset of the WIOD project.

The derivation of the new measure of bilateral factor export, as shown in equation 2.2, can be viewed as a "conversion" from the consumption bundle of country j to the factor content of i; the term inside the square bracket captures the cost share of country i's factor f in the whole value chain of products finalized in each country industry. From a first sight, this may look similar as the conventional measure, so before moving on to the data and empirics, it is worthwhile to first compare the difference in two measures' mathematical derivations.

The conventional measure can also be derived using input-output algebra, for example Wahl (1961) and Choi and Krishna (2004)[6] calculate their bilateral factor trade indicator using similar equations as:

$$\text{DiX}_{ij}^f = \left[\boldsymbol{\iota}'\text{Diag}(\boldsymbol{v}_i^f)\left(\boldsymbol{I}-\boldsymbol{A}_i^D\right)^{-1}\right]\boldsymbol{X}_{ij}. \tag{2.3}$$

I use DiX to denote the conventional measure, which is the abbreviation for its definition: *d*omestic factor *i*n gross e*x*port. In equation 2.3, $\boldsymbol{v}_i^f$ is a G-element subset of $\boldsymbol{v}^f$ that is associated with direct factor intensity in country i's industries. Identity matrix $\boldsymbol{I}$ now

6. See equation (3) in Choi and Krishna (2004). The symbol of their equation have been re-written to make it comparable with other equations in this paper. And also note that they calculate the quantity of bilateral factor export, so in their equation the term $\boldsymbol{v}_i^f$ is replaced by $\boldsymbol{q}_i^f$ which stands for the quantity of factor f that is directly used in producing \$1 gross output in each industry of country i.

has the dimension of $(G \times G)$, and $\boldsymbol{\iota}'$ is a row vector with G elements and all elements equal one. It is a conversion of bilateral gross export flow; denoting the terms inside the square bracket as $\boldsymbol{\Psi}_i$ and one obtains the familiar equation $\text{DiX}^f_{ij} = \boldsymbol{\Psi}_i \boldsymbol{X}_{ij}$ in the international economics literature.

Regardless of the similar outlook, the two measures are intrinsically different, and the matrices in equations 2.2 and 2.3 have different dimensions. In the new measure, the "target" to be decomposed is all final consumption of the importing country j, including the products that are not finalized in i. As discussed above, this is because other countries may produce and export final goods to j that direct or indirect use imported intermediate inputs from country i. In addition, the "conversion matrix" (i.e. the square bracket of equation 2.2) used the information about production technologies in all countries, which is necessary in tracing country i's factor content that reach j indirectly via the processing of third countries. As a comparison, the "target" in the conventional measure is gross exports between i and j, which is a mixture of both exported intermediate and final goods. The "conversion" is based on the domestic production technology of the exporting country only; it does not use any information on the supply and use of traded intermediates. This makes the conventional measure unsuitable to deal with globalized production and offshoring. Section 2.3 will provide a non-technical illustration about how bias of the conventional measure arises in global value chains, and will show that the disparity of two measures based on real world data.

2.2.2 Data

To build my bilateral factor export indices, I use the newly available World Input Output Database (Timmer *et al.* 2015, 2013 release) as the primary data source. WIOD covers 40 countries in the world including most of the developed countries and major emerging economies (Brazil, China, India, Indonesia, Turkey, Russia, and all Eastern European countries in the European Union), as well as a Rest-of-World estimate such that the production structure of the whole world is documented. It provides multi-regional input-output tables annually from 1995 to 2011. The multi-regional IO tables contain the information on final use of each country, international trade in both final goods and intermediate inputs, and the usage of domestic as well as imported intermediate inputs in the production of each country/industry. The supplementary Socio Economics Account (SEA) dataset in WIOD contains the factor usage data in each country/industry from 1995 to 2009, which allows me to further decompose traded value-added into factor contributions in this time period.

The registry of imported intermediates is crucial for the derivation of my new measure of bilateral factor exports. Past research on factor trade relied on domestic IO tables in which all imported intermediates are either ignored, or merged to a single entity such that the country/industry of origin of the intermediates cannot be identified. The identification is possible in multi-regional IO tables like WIOD. In its construction, WIOD uses various official data sources like the detailed bilateral WTO trade data in goods and services at 6-digit level that allow the distinction between trade in final goods (services) and intermediates. In combination with the existing domestic IO tables for each country and other country-industry level statistics, WIOD provides a mapping that links the domestic industries that use imported intermediates with the foreign countries/industries in which the relevant intermediates are made. Therefore, the indirectly exported factors that are embedded in traded intermediates can be correctly accounted for.

I am aware of other alternative data sources that are currently available, among others the Eora MRIO database, the Global Trade Analysis Project (GTAP), and OECD's Trade in Value Added (TiVA) project. Eora MRIO (Lenzen, Moran, Kanemoto, and Geschke 2013) has the most detailed industrial classifications, and it covers virtually all countries in the world. However it does not have a coupled supplementary dataset that allows the decomposition of industrial value-added to the contribution by different factors. Moreover, a large share of estimates in the Eora input-output tables are not based on statistical registry, but are extrapolated from optimization algorithms in order to maximizing the fitness of international trade flows; this extrapolation procedure may not be consistent with the actual input-output structure of each country. GTAP includes around 100 countries and covers a longer time period than WIOD. The GTAP project itself only consists of the domestic IO tables of each country. Recent research, like Johnson and Noguera (2012), merges these national IO tables with bilateral gross export data to construct multi-regional input-output tables that can be used in estimating bilateral factor trade. The problem with GTAP is that for many countries the input-output coefficients are extrapolated based on one benchmark national IO table, and it assumes that the intermediates usage structure of these countries stays unchanged for all years. The exact benchmark years are not the same across countries which vary between somewhere in the 1990s to 2000s. Problems may arise if, for example, the offshoring from country i to j takes place since 2000, but the benchmark domestic IO tables are based on the year 1995 for i and 2005 for j. The IO tables in WIOD, on the other hand, are constructed using the national IO tables of multiple benchmark years for most of the countries, which is expected to provide a more consistent estimate for the global production structure over a long time period. An additional advantage of WIOD is that its supplementary dataset allows the decomposition of labour content into the contribution by low-, medium- and high-skilled labour according to the workers' educational attainment, while GTAP only decomposes industrial value-added into capital, and labour income.

WIOD input-output tables also have two notable limitations. Firstly, WIOD does not have separated entries for processing exporters and regular firms. Firms in processing trade usually have very different technology and input-output structures when compared with other firms (Koopman *et al.* 2012). This issue has been addressed in the Inter-Country Input-Output (ICIO) tables in OECD's TiVA project. ICIO is constructed using a comparable methodology as WIOD, but for China and Mexico ICIO tables provides also a decomposition between domestic-selling firms, regular exporters, processing exporters, and service exporters. Specifically, ICIO treat different types of firms within an industry as if they were different industries, such that each type of firms has its own input-output coefficients. In this paper I use WIOD database, since the ICIO dataset is still preliminary; a major update is expected around 2018.[7] In addition, the ICIO dataset does not have a coupled dataset on factor usage, therefore the decomposition of value-added export into factor content is not possible.

7. See `http://www.oecd.org/sti/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm` for details. Accessed on 2017-MAR-02.

The second concern on WIOD is the so-called "proportionality" assumption that is used in matching import flows of intermediate goods with the use by each domestic industry. Under proportionality assumption, imported intermediates from different countries are evenly assigned to industries according to the share of imported intermediates that each industry uses. For instance, assume the trade statistics show that China imports \$1 billion of steel from Germany and \$2 billion from Japan, and industrial statistics show that Chinese automobile uses \$1 billion imported steel while machinery uses \$2 billion. Since automobile uses one third of of the imported steel, under proportionality it is presumed that that Chinese automobile sector uses \$1/3 billion of imported steel from Germany and $1/3 \times 2 = \$2/3$ billion from Japan. However, it might be the case that all \$1 billion German steel is used by Chinese automobile industry, and all \$2 billion from Japan in machinery. To the best of my knowledge, the Asian Input-Output Table by IDE-Jetro – covering 9 East- and Southeast-Asian countries and the U.S. – is the only multi-regional IO table that is constructed without proportionality assumption. Instead, it assigns imported intermediates to different domestic industries based on firm survey data. Using IDE-Jetro data, Puzzello (2012) shows that proportionality assumption affects the accuracy of factor exports by each industry, but the estimating error is limited in the factor exports by each country (i.e. factor export by all industries from a country).

Before moving on to the next section, it is worthwhile to mention that in this paper I study the *value* of factor export, therefore my tests in the following sections are different from Helpman (1984), Choi and Krishna (2004), and Lai and Zhu (2007) that focus on the quantity of factors exported. These papers explicitly assume that factor price equalization does not hold, and aim to test whether the bundle of tasks that a country purchases from its trade partner will be more expensive when the country performs these tasks on its own. I focus on a different research question which is about the role of endowment structure in determining the pattern of bilateral factor trade. Although it is also possible to derive the quantity of bilateral factor export using WIOD database, there is no suitable measure for the efficiency of each factor in each country. Choi and Krishna (2004) uses 8 OECD countries and assume efficiency to be identical; this assumption is not feasible for the WIOD database which includes countries at very different stages of development, and the estimation of factor efficiency is beyond the scope of this paper. Lai and Zhu (2007) focus only on the last stage of production. They estimate the productivity of each country industry based on the assumption that there is only one single, identical, and free traded intermediate input; this is contradictory to the story of globalized production, however.

2.3 The Comparison with the Conventional Measure of Bilateral Factor Exports

As discussed in the previous section, the conventional measure of bilateral factor export ignores the structure of globalized production. When offshoring is pervasive, it is less capable to capture the underlying economic activities that has been exchanged between countries behind the trade in products. In general, within a particular GVC, depending on the positions of two countries in the production process the conventional measure may systemically over- or underestimate the bilateral factor export between them, and the estimating error is expected to increase when the GVC becomes more complex. This will be illustrated using a simple and non-technical example based on a fictional value chain. In the aggregation, the difference between the conventional and new measure is dependent on the overall positions of countries in globalized production. I compare the two measures using real world data, and I will show that the disparity is large and widely observed.

Consider a Japanese firm that produces a machine which is sold to U.S. customers. Three tasks are needed in production. The metal parts are produced by capital goods, an electrical circuit board is developed by high-skilled labour, and low-skilled labour assembles the machine. For simplicity I assume that each task requires 1 unit of a factor. Initially all tasks are performed in Japan. Unambiguously, both the conventional measure and new measure will register the export of all the relevant factors from Japan to the U.S. But if the Japanese firm re-allocates assembly to China, the two measures of bilateral factor export will differ. Recall that my new measure relies on the identification of the origin and the final destination of consumption of the values added by each factor. It will therefore record the export of 1 unit of high-skilled labour and 1 unit of capital from Japan to the U.S., and 1 unit of low-skilled labour from China to the U.S.; Japanese low-skilled labour in the assembly line is replaced by the Chinese, so the same substitution will happen in the factor export. However, the conventional measure will yield a very different picture of factor trade, and the result is sensitive to the exact organization of the production.

Assume the firm first produces and ships both metal parts and the circuit to China for assembly, and the assembled final products are directly exported from China to the U.S. Table 2.3.A summarizes the gross export flows, and the conventional measure of bilateral factor export, i.e. the domestic factor content embedded in gross export. By deducting the values of imported intermediate inputs from the exported machines, the conventional measure correctly captures the Chinese factor export to the U.S. However, there is no export of Japanese factor to the U.S., since there is no direct export flow between these two countries. Instead, Japanese high-skilled worker and capital appear as the export to China which is the country of further processing but not the ultimate destination of consumption. What is more, the outcome of the conventional measure changes when the

Table 2.3.A: Bilateral Export Flows of Products and Factors

Country Pair	Gross Export Flows	Embedded Domestic Factor (Conventional Measure)
Japan → China	Metal parts, Circuit	1 High-skilled Labour, 1 Capital
China → U.S.	Machine (fully finished)	1 Low-skilled Labour

production chain is organized in an alternative way, even when all countries are still doing the same tasks. Consider that the Japanese company now worries about its technology inside the circuit; it ships only the metal parts to China for assembly, and the assembled machine is shipped back to Japan for the installation of circuit board before exporting to the U.S. In principle, the change in the sequence of production should not affect the estimates for factor export. But as shown in table 2.3.B, the picture from the conventional measure changes considerably. Since circuit becomes the last stage of production, the

Japanese high-skilled labour is registered as the export to the U.S. However, the export of Japanese capital is still wrongly assigned to China. And in the new situation there is no longer a direct trade link between China and the U.S., as a result the Chinese low-skilled labour is recorded as the export to Japan. In a strict sense, the disparity between two

Table 2.3.B: Bilateral Export Flows of Products and Factors

Country Pair	Gross Export Flows	Embedded Domestic Factor (Conventional Measure)
Japan $\rightarrow$ China	Metal parts	1 Capital
China $\rightarrow$ Japan	Machine without circuit	1 Low-skilled Labour
Japan $\rightarrow$ U.S.	Machine (fully finished)	1 High-skilled Labour

measures may not be viewed as an "error" since they are defined in different ways. But it is doubtful whether the conventional definition of bilateral factor export, being widely used in the literature, is the most suitable option for economic research under globalized production. In general, the conventional measure only correctly registers the factor export that is related with the final country of completion. The export of factors that are deployed in upstream countries are potentially biased in the conventional measure due to its lack of capacity in tracing offshoring and traded intermediates. Some factor exports reach the final destinations *indirectly* in the sense that they are first embedded in exported intermediates to a third country for further processing. Such indirect export cannot be captured in the conventional measure; therefore it underestimates the factor exports between upstream countries and the final destination of consumption. On the other hand factor exports into the countries that processes intermediate inputs are systematically over-estimated. The factors embedded in imported intermediates will leave the countries of processing for their final destinations (or to other countries for further processing), but this "departure" will not be recorded by the conventional measure.

When there are only two instead of multiple countries in the world (or when one analyses the domestic country and rest-of-world), it seems that the problem of indirect factor export does not exist – if one country exports anything, it must directly be the import of another due to the construction of a two-country world: one cannot find a "third" country who performs processing trade in between. Being seemingly plausible, this argument is, however, incorrect. When the production process is fragmented across the two countries, the conventional measure still suffers from a problem of "returning exported factors", which is in analogy to the indirect factor export discussed above. Effectively, if the domestic country outsource some processing stages to the foreign country, the foreign country becomes the "man in the middle" between domestic factors in upstream industries and domestic final consumption. In the appendix I provide a non-technical and highly realistic example with two countries. The developed country outsources low-skilled tasks to developing country, but the conventional measure mistakenly suggests that the developed country is the largest exporter of low-skilled labour.

It is also expected that the disparity between two measures might be more serious in the future due to the rise of large multinational firms and trade in services which frequently use revenue centers in specific countries with a taxation advantage. As an extreme case, consider that all firms use a tax haven as the intermediating country when they do cross-border businesses. The conventional measure will appear to be "laundered" such that all exported factors go to the tax haven and all imports are from the tax haven; there will be no factor export between two regular countries (i.e. the countries where actual production and consumption are taking place).

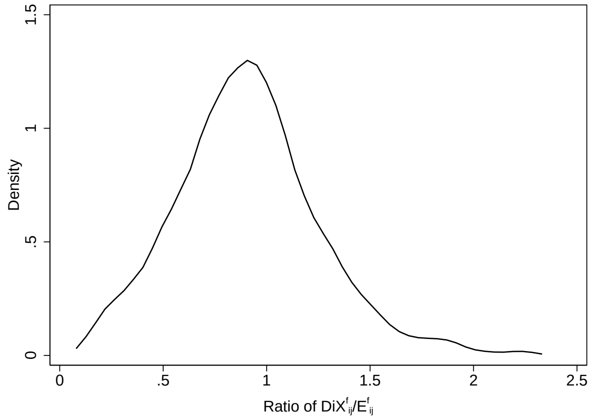
How large is the difference between the conventional and new measures in the real world data? Using WIOD database, the two measures of bilateral factor exports can be computed using equations 2.2 and 2.3, respectively. I find their disparity is large in many country pairs. In figure 2.1 I plot the density distribution between the ratio of the conventional and new measures in 2007. The ratio of $\text{DiX}^f_{ij}/E^f_{ij}$ is distributed with a mean of 0.935 and medium of 0.893, so "on average" it seems that these two measures are close to each other. However, for each single observation the probability is high that the two measures differ largely from each, as revealed by the large variation in the density plot. About half (48%) of the observations have a $\text{DiX}^f_{ij}/E^f_{ij}$ ratio below 0.75 or above 1.25, and about one fifth (18%) if the observations have the ratio below 0.5 or above 1.5. To put it otherwise, if one randomly picks a pair of trading partners, in half of the cases the mismatch between the new and the conventional measure is larger than 25%, and there is a probability of almost 1/5 that the difference exceeds 50%.

Large mismatches between two measures are also widely found in the trade between pairs of large countries, for example between Russia and the U.S., and in some circumstances the difference can be enormous. The largest disparity throughout the period covered by this research is observed in the export of low-skilled labour from Turkey to Cyprus in 1995. The ratio of $\text{DiX}^f_{ij}/E^f_{ij}$ was only 0.002, which implies that the indirect factor export from Turkey to Cyprus is 500 times bigger than the Turkish low-skilled labour embedded in the direct export flows to Cyprus. It is most probably due to the trade embargo between Turkey and Cyprus due to the Cypriot war such that most of the Turkish value had to reach Cyprus indirectly via a third country. The ratio of $\text{DiX}^f_{ij}/E^f_{ij}$ suddenly increased to around 0.4 during 2003 to 2004, which coincides with the timing that Cyprus joined the EU and new regulations were applied. This story is an exceptional case which is mainly driven by politics. Nevertheless it provides an example how indirect exports affect the misestimation of the conventional measure, and a similar outcome will arise in global value chains and entrepôt trade.

To see how the location of a country in the global value chain will affect the estimating bias of the conventional measure, I consider the export of low-skilled labour from Russia and China. Russia's export is dominated by natural resources which are located upstream of GVCs.[8] It is expected that factor exports from Russia might travel through one or multiple countries of processing before reaching its final destination, which implies a large overestimation of conventional factor exports to processing countries, and a large underestimation to the countries of final consumption. On the other hand, Chinese low-skilled workers that are related to trade are largely deployed in textile, machinery and electronics value chains that make or assemble final products. These are mostly the final tasks in the GVCs that can be correctly captured by the conventional measure of factor exports, so the disparity between the two measures is expected to be small. In Table 2.4.A and 2.4.B I report the ratio of $\text{DiX}^f_{ij}/E^f_{ij}$ for the Russian and Chinese exports of low-skilled labour to different countries. The result in Table 2.4-A confirms that the conventional measure underestimates factor export by a large margin between

8. Minerals and oil have a share of 43.3% in Russia's gross exports in 2011 (Soruce: WIOD).

Figure 2.1: Density Distribution of the Ratio between the Conventional and New Measures of Bilateral Factor Export ($\mathrm{DiX}^f_{ij}/E^f_{ij}$)



Notes: Based on author's own calculations using the WIOD dataset for the year 2007. DiX^f_{ij} is the conventional measure calculated based on equation (2.3), and E^f_{ij} is the new measure calculated using equation (2.2). The observations for different factors are pooled since the distribution patterns are highly similar across factors. There are some observations with extreme discrepancies in the two measures, therefore only the observations within the 1st to 99th percentiles are shown in the density plot.

Russia and many of its trade partners; for example the conventional measure of Russia's low-skilled labour exports to the U.S. is just 42% compared with the new measure. On the other hand, Russian factor exports to Finland, the Netherlands, and Slovakia are largely overestimated; these countries seem to play the role as an "entry point" for Russian natural resources as well as other products to other Western countries. As a comparison, Table 2.4-B shows that there are indeed much smaller differences between the two measures in Chinese exports of low-skilled labour; the variation in $\mathrm{DiX}^f_{ij}/E^f_{ij}$ is about half compared with the case of Russia.

On the other hand, the conventional measure will overestimate factor export to the country which processes imported intermediates. To see this, I look at the factor export from several developed economies into China. Many firms in the developed world have outsourced assembly or other low-skilled tasks to China. It brings a large import flow of intermediate inputs, but many of the final products are sold back to western countries. When the scale of offshoring increases the mismatch ratio of $\mathrm{DiX}^f_{i,\mathrm{CN}}/E^f_{i,\mathrm{CN}}$ is expected to rise. To show this type of misestimation in a clearer way, in figure 2.2 I investigate the changes in $\mathrm{DiX}^f_{i,\mathrm{CN}}/E^f_{i,\mathrm{CN}}$ over time for the export of high-skilled labour by Korea, Taiwan, the U.S., and the Netherlands. The figure shows that the ratio between the two measures was stable until 2000, but has increased rapidly afterwards. This finding is important since its timing coincides with China joining the WTO in 2001 after which the offshoring to China has increased tremendously (Xu and Lu 2009).

Table 2.4: The Ratio of the Conventional and New Measures of Factor Export (%, 2007)

A - The Export of Low-skilled Labour from Russia

Country	$\text{DiX}_{ij}^L/E_{ij}^L$	Country	$\text{DiX}_{ij}^L/E_{ij}^L$	Country	$\text{DiX}_{ij}^L/E_{ij}^L$	Country	$\text{DiX}_{ij}^L/E_{ij}^L$
Australia	4.9	India	50.0	Latvia	90.0	Hungary	126.2
Mexico	15.6	Ireland	58.1	France	92.6	Poland	129.1
Portugal	18.5	Cyprus	58.3	Taiwan	99.9	Sweden	129.2
Indonesia	22.1	Denmark	58.9	Romania	102.8	Lithuania	132.3
Canada	23.6	Slovenia	73.1	China	103.0	Czech	133.4
Luxembourg	32.9	Austria	73.6	Greece	103.3	Estonia	138.0
Malta	38.8	Belgium	74.2	Italy	103.9	Finland	185.8
Brazil	40.9	Japan	81.0	Korea	111.1	Slovakia	186.8
U.S.	42.2	Bulgaria	86.0	Turkey	121.1	Netherlands	239.5
U.K.	45.0	Spain	90.5	Germany	123.7	Std. Dev	51.2

B - The Export of Low-skilled Labour from China

Country	$\text{DiX}_{ij}^L/E_{ij}^L$	Country	$\text{DiX}_{ij}^L/E_{ij}^L$	Country	$\text{DiX}_{ij}^L/E_{ij}^L$	Country	$\text{DiX}_{ij}^L/E_{ij}^L$
Slovenia	61.2	Brazil	87.8	Denmark	99.5	Netherlands	118.4
Latvia	61.3	Spain	89.7	Germany	101.5	Mexico	120.0
Portugal	67.7	U.S.	90.0	Japan	102.1	Malta	120.1
Romania	71.5	Russia	90.1	Poland	104.5	Korea	130.4
Lithuania	71.6	Austria	90.5	Indonesia	105.1	Ireland	133.7
Greece	71.8	Italy	91.9	Slovakia	106.0	Czech	152.6
Cyprus	81.7	Australia	95.2	India	107.9	Hungary	171.3
U.K.	86.5	Sweden	96.1	Finland	110.8	Taiwan	175.6
France	86.8	Turkey	96.9	Estonia	111.8	Luxembourg	182.6
Bulgaria	87.8	Canada	99.4	Belgium	111.6	Std. Dev	28.9

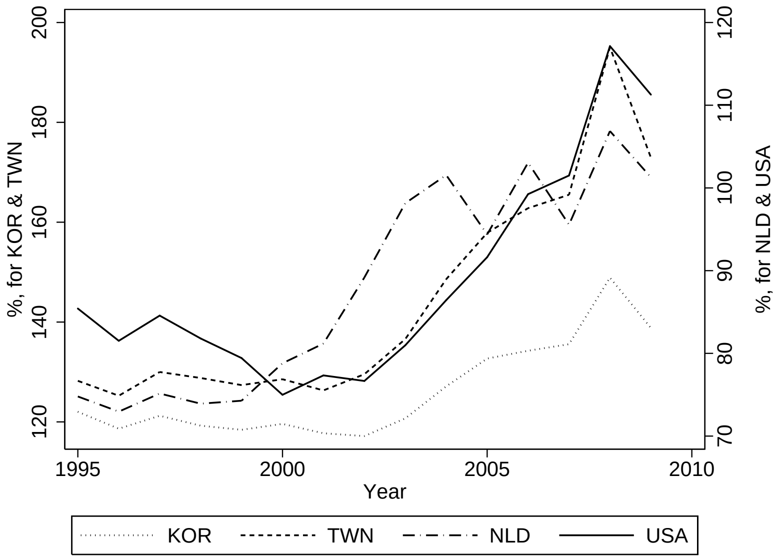
Note: Panels A and B report the ratio of $\text{DiX}_{ij}^L/E_{ij}^L$ for the factor export of low-skilled labour from Russia and China. The conventional measure, i.e. the domestic factor content embedded in the bilateral export flows, denoted by DiX_{ij}^f, is derived using equation 2.3, and E_{ij}^f is the new measure introduced in this paper and is calculated using equation (2.2). The cell "Std. Err" reports the unweighted standard deviation in $\text{DiX}_{ij}^L/E_{ij}^L$ between Russia (China) and all its 39 trading partners. All the results are based on WIOD dataset and the year of 2007.

2.4 Testing the Role of Factor Endowments in the Direction of Net Bilateral Factor Trade

2.4.1 A Simple Testing Framework

Does the pattern of bilateral factor trade align with the endowment structures of country pairs? In this section I perform a test on the direction of net factor export bilaterally between countries. Consider a pair of countries, standard theories predict that the one with a higher relative endowment of a factor f should be the net exporter of this factor. How strong is the predictive power of this simple hypothesis? To have a systematic analysis, the theoretical background of my test makes use of the so-called *consumption similarity condition* posed in Trefler and Zhu (2010). Let Q_i^x denote the total final products or services that are finalized in sector x of country i, and Q_{ij}^x the respective

Figure 2.2: Mismatch of the Conventional Measure in the Factor Export of High-skilled Labour into China ($\text{DiX}^H_{i,\text{CN}}/E^H_{i,\text{CN}} \times 100\%$)



Notes: Based on author's own calculation using the WIOD dataset. The graph shows the mismatch of two measures (i.e. $\text{DiX}^f_{i,\text{ij}}/E^f_{i,\text{ij}} \times 100\%$) from 1995 to 2009 for the factor export of high-skilled labour from Korea (KOR), Taiwan (TWN), the U.S. (USA), and the Netherlands (NLD) into China, in the period from 1995 to 2009. The y-axis on the left-hand side is for Korea and Taiwan, while the y-axis on the right-hand side is for the U.S. and the Netherlands.

consumption by country j, then the consumption similarity condition is given by:

$$Q^x_{ij} = c_j Q^x_i \quad \forall i, j, \qquad \text{with } c_j = C_j/Y_W. \tag{2.4}$$

The condition states that each country j consumes a fixed share c_j of all kinds of final products that are available in the world, and c_j is the share of country j's consumption in world GDP. Equation 2.4 may arise under standard assumptions that are frequently being made in the international economics literature. Consider, for instance, the love-for-variety model in Krugman (1980). Consumers are assumed to have a homothetic preference that is identical across countries, and firms produce differentiated products in a monopolistic competition. When trade is frictionless, consumer will evenly spread the expenditure on all final products that are available in the world market. The export of sector x from i to j therefore is related with the share of country j's consumption expenditure in world consumption (equivalent to world GDP) and the final goods country i's sector x is able to offer, so one obtains the consumption similarity condition in equation (2.4).

The factor export from country i to j, as defined in this paper, is the summation of the factor content contributed by country i that is embedded in all final products

9. It is assumed that ρ^{if}_{kx} is fixed for each product x finalized in k, and is independent of the consuming country. To put it another way, the production structure and value-added composition is the same for all final products of an industry in a country, regardless of whether the products are for export of domestic consumption.

consumed by j, namely:

$$E_{ij}^{f}=\sum_{k}\sum_{x}\rho_{kx}^{if}Q_{kj}^{x}. \tag{2.5}$$

In the equation ρ_{kx}^{if} denotes the value generated by country i's factor f that is embedded in one unit of product x finalized in country k.[9] Note that the summation is over any country k which includes the consuming country j itself, since any country may directly or indirectly use the intermediate inputs from country i. When consumption similarity holds, the predicted bilateral factor export from i to j can be obtained by plugging equation (2.4) into (2.5):

$$\begin{aligned}E_{ij}^{f}&=\sum_{k}\sum_{x}\rho_{kx}^{if}Q_{kj}^{x}=\sum_{k}\sum_{x}\rho_{kx}^{if}c_jQ_{k}^{x}\\&=c_j\left[\sum_{k}\sum_{x}\rho_{kx}^{if}Q_{k}^{x}\right]=c_jV_i^f.\end{aligned} \tag{2.6}$$

The term inside the square bracket is the summation of value added by country i's factor f that is used in all final products in the world, which by construction of the data equals the total value of factor endowment f in country i (denoted by V_i^f). Therefore, equation (2.6) states that when consumption similarity holds, the predicted factor export from i to j equals the share of country j's consumption in the world, times country i's factor endowment.

In the rest of my paper I will base my tests on the simple factor export prediction in equation (2.6). There might be some other alternative models giving rise to consumption similarity. In some models the consumption similarity in products (i.e. equation 2.4) is violated but one still obtains factor consumption similarity of equation (2.6), for example in a love-for-intermediates-variety model similar to Ethier (1982). Due to the aim of my research and its limited scope, I am not proposing new trade theories, nor do I try to distinguish different theoretical models that give rise to the same factor consumption similarity prediction. My study tries to contribute mainly on the empirical side. The message I would like to address is that bilateral exports between countries, when viewed from the angle of factor content and measured properly, are still consistent with the endowment-driven view in standard neo-classical trade theories in the recent decades with pervasive global production fragmentation and offshoring.

Equation (2.6) yields a simple testable equation on the direction of net factor trade bilaterally between countries. Following the definition of bilateral factor export in this paper (i.e. equation 2.5), the net factor trade between i and j is defined as the difference between E_{ij}^f and E_{ji}^f. Using equation (2.6), it can be re-written as:

$$\begin{aligned}NE_{ij}^{f}&=E_{ij}^{f}-E_{ji}^{f}=c_jV_i^f-c_iV_j^f=(C_j/Y_W)(s_i^fY_i)-(C_i/Y_W)(s_j^fY_j)\\&=\left(\frac{C_j}{Y_j}s_i^f-\frac{C_i}{Y_i}s_j^f\right)\frac{Y_iY_j}{Y_W}=\left(\tau_js_i^f-\tau_is_j^f\right)\frac{Y_iY_j}{Y_W}.\end{aligned} \tag{2.7}$$

I use s_i^f to denote the income share of factor f in country i's GDP, i.e. $s_i^f=V_i^f/Y_i$, and τ_i to denote the consumption to GDP ratio C_i/Y_i which reflects the trade balance of each country.[10] When τ_i is larger than unity, it indicates that the value consumed by country i is larger than the value it generates, therefore the country is running a trade deficit; vise versa $\tau_i < 1$ indicates a trade surplus.[11] The sign of the net factor export between two countries is then determined by the term in the bracket of (2.7). When both countries are running a balanced trade (or having a same level of trade deficit/surplus), the country with a higher relative endowment of a factor f is predicted to be the net exporter of f in their bilateral trade. A larger τ_i, i.e. a larger trade deficit, is negatively associated with the probability that country i is the net exporter in the bilateral trade of any factor with any trade partner.

The moderating role of trade balance in predicting net factor export is intuitive, since a higher trade deficit implies that the country may systematically import more from any country for any factor. The sign test here should not be confused with Leamer (1980) who identifies whether a country is labour or capital abundant based on the factor composition of its basket of production and consumption; information on trade balance is not necessary. Namely, if the K/L ratio in production is larger than in consumption, the country is considered as abundant in capital. My test has a very different aim; in predicting the direction of net factor export between countries the adjustment of trade balance is also *necessary.* To see that, consider a country which consumes much more than its production and runs a huge trade deficit. In the extreme case, the country may be a net importer of all factors from all its trade partners, including its most endowed factor.[12]

The sign of (2.7) is equivalent to the normalized term of $\left(\ln \tilde{s}_i^f - \ln \tau_i\right) - \left(\ln \tilde{s}_j^f - \ln \tau_j\right) = \theta_i^f - \theta_j^f$, with $\tilde{s}_i^f = s_i^f / s_W^f$ representing country i's endowment structure of factor f relative to the world average level.[13] A sign test can be built by comparing the predicted direction of bilateral factor export with the actual sign of NE_{ij}^f that is observed from the data:

$$\text{Sig}(NE_{ij}^f) = \text{Sig}(\theta_i^f - \theta_j^f). \tag{2.8}$$

This predicting equation can be viewed as an analogy with the standard Heckscher-Ohlin-Vanek (HOV) prediction, but in a bilateral setup. Henceforth I refer to equation (2.8) as the *bilateral HOV sign test.* My test investigates whether the factor endowment structure successful predicts the direction of net factor trade between country pairs. Although the underlying idea is similar as HOV, equation (2.8) is a new test. The testing equation is

10. Recall that "consumption" refers to all final uses by a country (see footnote 4).

11. Note that τ is the *overall* trade balance of each country and is not the bilateral trade balance with a particular trade partner.

12. Strictly speaking, the method by Leamer (1980) is an identification for relative abundance and is *not* a test for HOV. The main aim of Leamer is to show that the Leontief paradox might be the outcome of an incorrect method used by Leontief. He compares the K/L ratios in U.S. production and consumption and finds that U.S. is indeed capital abundant. But if one views Leamer's comparison of two K/L ratios as a test, from a logical point of view this "test" requires an *ex ante* determined premise on each country's abundance (in this case: "U.S. should be capital abundant, otherwise there is a paradox"). It is not possible to construct similar tests on *how well* the actual factor trade data fits trade theory, unless one is able to make similar *ex ante* arguments for all countries without looking into the data.

13. Note that τ_i equals C_i/Y_i which is always positive, we have $\text{Sig}(\tau_j s_i^f - \tau_i s_j^f) = \text{Sig}((s_i^f/\tau_i - s_j^f/\tau_j)\tau_i\tau_j)$ $=\text{Sig}(s_i^f/\tau_i - s_j^f/\tau_j)$, which is equivalent as the sign of $(\ln s_i^f - \ln \tau_i) - (\ln s_j^f - \ln \tau_j)$. The normalization of $\ln \tilde{s}_i^f = \ln s_i^f - \ln s_w^f$ is the same for both $\ln s_i^f$ and $\ln s_j^f$; it will not alter the sign.

very different compared to Vanek (1968) (see also equation 1 in Trefler and Zhu 2010), and recall that standard HOV focus on the aggregated net factor export from domestic economy to all other countries in the world, but not bilateral factor trade. Same as many standard HOV tests, my sign test also uses actual observed data for trade, endowment, and production technology, therefore it is a so-called "complete test" according to the criteria in Feenstra (2011).[14] And as discussed above, my sign test is based on different foundations compared to the sign test in Krishna and Choi (2003) who test whether trade and offshoring saves costs.

To perform the sign test, one may also compare the actual direction of bilateral factor trade directly with the term inside the bracket of equation (2.7). But the normalization in (2.8) is useful since the term θ_i^f is only dependent on the property of a single country i, and it can be interpreted as the factor export propensity. θ_i^f equals zero if the country i runs a balanced trade and has the same structure of endowment in factor f as the world average (i.e. $s_i^f = s_W^f$); a larger θ_i^f is associated with a higher probability that country i is the net exporter of f in bilateral factor trade. The score θ_i^f is also comparable across factors while one cannot directly compare $\tau_j s_i^f$ for different factors.

2.4.2 The Fitness of the Bilateral HOV Sign Test

I report the results of the sign test in table 2.5 for each factor and for each year from 1995 to 2009. The left panel reports the unweighted sign test. The numbers represent the percentage of country pairs whose actual direction of net factor export is the same as predicted.[15] It shows that the predicted direction of bilateral export in labour factors is correct for around 80% of the observations, and the performance of the sign test is quite stable over the years. For the bilateral export in capital content, the fitness is around 70%. The fitness is considered as quite high in the view that in the literature of standard HOV sign tests the predictive power is frequently not better than tossing a coin (i.e. 50%, see Trefler 1995), and high fitness is achieved only after complex adjustments (Davis and Weinstein 2001).

Note that when the net bilateral factor export is close to zero, whether a country is a net exporter or importer is more sensitive to measurement errors in the bilateral factor trade indicators, since in such cases a small change in the value of factor export (or import) may alter the direction of net trade. To deal with this problem, in the standard HOV literature a *weighted* sign test is frequently performed such that each country gets an importance weight based on the absolute value of its net factor export; in this way those observations that are sensitive to measurement errors are discounted (see e.g. Trefler 1995). Following the same idea, I also perform a weighted sign test for

14. Feenstra argues that a HOV test is "complete" if one uses independent data for trade, endowment and technology; the test is not complete if one kind of data is inferred and calculated based on the other two sets. For my study, endowment data are taken from the SEA dataset. Although both production technology and trade data are from WIOD input-output tables, they are constructed based on independent sources. Trade related statistics are from UN Comtrade dataset, and the production technologies are based on national IO tables supplied by each country's relevant statistical agencies.

15. Since the net factor export (actual and predicted) from i to j and from j to i is exactly the same in magnitude but opposite in sign, only one direction is counted for each country pair.

Table 2.5: Bilateral HOV Sign Test, Baseline Specification

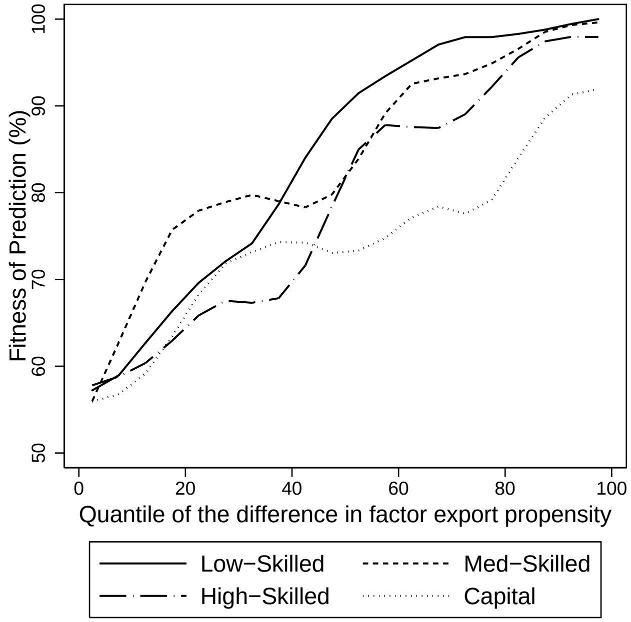
	Unweighted				Weighted by Net Factor Trade Flows				Weighted by Diff. Fac. Exp. Propensity			
Year	L	M	H	K	L	M	H	K	L	M	H	K
1995	82.8	83.4	79.3	70.1	92.3	96.9	94.2	75.9	93.7	93.4	90.1	78.7
1996	82.9	83.2	79.4	66.7	93.8	97.0	95.5	76.8	93.3	92.5	90.1	77.0
1997	83.8	81.0	78.5	64.8	91.6	95.7	93.4	70.5	93.5	90.5	88.7	72.5
1998	82.6	82.3	79.6	65.9	92.6	94.2	92.4	71.1	92.9	92.3	90.0	71.7
1999	82.6	83.0	79.5	67.8	94.2	94.2	91.8	83.0	92.8	92.1	89.5	76.6
2000	83.5	82.6	78.9	68.9	95.5	93.1	91.2	85.1	93.0	92.9	89.8	78.4
2001	84.0	83.4	79.1	70.0	95.7	93.5	91.7	85.6	93.5	92.2	89.4	79.2
2002	82.9	81.8	77.8	68.5	95.6	93.0	92.0	83.6	93.2	91.6	89.1	78.8
2003	83.3	83.2	79.1	70.4	95.1	92.0	92.3	83.3	92.9	92.9	89.9	79.8
2004	83.5	82.1	78.4	68.5	95.2	91.1	92.2	83.2	93.5	91.4	89.1	77.1
2005	82.9	82.0	80.0	72.1	96.3	92.7	92.3	87.2	93.5	91.3	89.5	79.5
2006	84.0	82.4	78.5	74.3	96.6	94.1	92.7	88.6	94.4	91.1	89.0	81.6
2007	84.0	83.8	78.8	74.3	95.5	94.3	93.8	88.9	93.8	92.3	89.1	81.6
2008	83.8	85.1	79.3	74.1	96.7	95.3	94.1	90.8	93.8	93.7	89.4	81.1
2009	83.5	83.2	80.6	72.1	94.6	95.4	95.8	87.6	93.9	92.2	89.3	80.9
Mean	83.3	82.8	79.1	69.9	94.8	94.2	93.0	82.7	93.4	92.2	89.5	78.3
Range	1.5	4.1	2.8	9.5	5.0	5.9	4.6	20.3	1.6	3.2	1.4	9.9

Note: The test is build upon equation 2.8 by comparing the actual direction of net factor export between two countries, and the predicted sign based on the difference in two countries factor export propensity θ_i^f. The first panel is the unweighted sign test, and the numbers correspond to percentage of observations whose actual direction of net bilateral factor export is same as predicted. In the second panel, each observation is attached with an importance weight of $|NE_{ij}^f|$ which is the absolute value of the actual net factor export between two countries. The third panel uses the importance weight based on the absolute value of their differences in factor export propensity, i.e. $|\theta_i^f - \theta_j^f|$. In the table, L, M, H, and K represent low-, medium-, and high-skilled labour and capital. The row "range" reports the difference between the highest and lowest fitness over the 15 years.

my bilateral HOV test, in which each country pair gets an importance weight based on $|NE_{ij}^f|$. I report the result of this weighted test in the middle panel of table 2.5. The use of weights improves the fitness of the bilateral HOV test. The predictive power is around 94% for the three labour factors. The fitness on capital remains at 70% for the years between 1995 and 1998, but increases to around 85% afterwards, and remains stable at this high level over the period from 1999 to 2009.

A concern may arise when each observation is weighted by $|NE_{ij}^f|$ that the pairs of large countries get an overwhelmingly large weight, such that the fitness of the test is largely determined by a few number of observations. As a result, I also use an alternative weight based on $|\theta_i^f - \theta_j^f|$. The intuition is that the factor trade predictor also suffers from the observational error problem, therefore the sign prediction should hold with a higher probability when two countries have very different factor export propensities θ_i^f. This weight is isolated from country size, such that large country pairs like China and the U.S. will get a similar weight as Belgium and Bulgaria. But this weighting method also have its drawbacks since it is more vulnerable to the measurement errors in factor trade between small countries, since the direction of net factor export is more likely to be

Figure 2.3: Fitness Curves of the Bilateral HOV Sign Predictions for Each Factor



Notes: Based author's own calculation using WIOD dataset for the year 2007. The graph illustrate the (unweighted) fitness of the bilateral HOV sign prediction for country pairs with different quantiles of the factor export propensity differences (i.e. $|\theta_i^f - \theta_j^f|$, see also equation 2.8). Country pairs with a large $|\theta_i^f - \theta_j^f|$ means that their export propensity in factor f is very different from each other such that the HOV sign prediction should, in principle, holds with a higher probability; this has been confirmed in the graph.

overturned by observation errors if the factor trade between two countries is small. The result of this method is reported in the right-hand-side panel of table 2.5. The export propensity weighted sign test also yields a higher fitness compared with the unweighted specification, although the improvement is smaller when compared with the net factor trade weighted one. But it is important to notice that the export propensity weighted specification shows a stronger consistency over time and the fitness has less than half of the cross-year variation compared to the middle panel. This is especially the case for the three labour factors; when weighted by $|\theta_i^f - \theta_j^f|$ the difference between maximum and minimum fitness across the 15 year period is merely 3.2 percentage points.

As an alternative to the weighted sign-test, in figure 2.3 I plot the (unweighted) fitness of bilateral HOV sign predictions for country pairs with different quantiles of $|\theta_i^f - \theta_j^f|$, for four factors respectively. Figure 2.3 confirms that the fitness of the predicted direction of net factor export increases if a country pair has a larger difference in their factor export propensities. The fitness starts low at around 55% for country pairs with the smallest $|\theta_i^f - \theta_j^f|$, but rises quickly as $|\theta_i^f - \theta_j^f|$ increases. For the three labour factors, the fitness is above 80% for country pairs with an above-medium difference in their factor export propensity, and approaches 100% for pairs with $|\theta_i^f - \theta_j^f|$ in the top 25% quantile. The fitness of capital is somewhat lower, and stays stable around 70% for the observations with $|\theta_i^K - \theta_j^K|$ in the 20% to 80% percentile, and the fitness increases to around 90% for the country pairs with the largest differences in capital export propensities.

Table 2.6: Bilateral HOV Sign Test for Subsets of Countries

Sample Coverage		(1) Low-income countries	(2) High-income countries	(3) Low/high-income pairs
Unweighted	L	81.0	83.0	86.1
	M	82.7	82.5	84.9
	H	71.4	75.4	84.2
	K	75.3	72.5	74.4
Weighted by Net Fac. Exp.	L	94.9	95.9	95.7
	M	92.0	95.5	95.5
	H	84.6	83.3	98.4
	K	84.4	80.0	92.6
Weighted by Exp. Propensity	L	91.8	95.6	93.7
	M	91.5	90.3	93.5
	H	80.6	85.9	92.4
	K	82.6	83.2	80.4

Note: Based on the year 2007. The methodology is the same as in Table 2.5 but using different subsets of country pairs. High income countries are those with a real GDP per capita above $25,000 in 2007, according to the Penn World Table version 8.0.

Zhu and Lai (2007) find that the theoretical prediction on the direction of factor trade holds more robustly between countries with very different structures of factor endowment. To test this, I divide the countries into two sets according to their GDP per capita; a country is considered as high-income if its real GDP per capita is above $25,000 in the year 2007, and using this criteria I split the 40 countries and the RoW region in WIOD into two sets with 22 high-income countries and 19 low-income ones. In table 2.6 I report the sign test results using the subsamples for the year 2007,[16] and the three columns are for high-income country pairs, low-income pairs, and the pairs between high- and low-income countries. The most notable result is that the fitness in high-skilled labour shows a big improvement of around 10 percentage points in the subsample with high- & low-income pairs and this improvement holds in all specifications. The fitness of factor trade in low- and medium-skilled labour is similar across all three subsets. The fitness of capital increases in the high- & low-income pairs subsample when weighted by $|NE_{ij}^K|$, but not in other specifications.

2.4.3 Alternative Specifications

All the tests above are based on the consumption similarity assumption that each country j consumes a fixed share of c_j of all available goods in the world. In the literature, it is

16. Much analysis in this paper focuses on the year of 2007, which is the latest year before the breakout of the subprime crisis that has generated a significant fluctuation in international trade (see e.g. Timmer *et al.* 2016). There is no other particular reason for the choice of the year; all results after 1998 are highly comparable and are available upon request.

frequently argued that the preference is non-homogeneous across countries. For example Engel's law states that the share of food in national consumption decreases as income per capita grows, and Baumol (1967) argues that the share of expenditure on services increases as a country develops. To account for heterogeneous demand across countries, I assume an alternative consumption similarity that each country consumes a share of c_j^f of all available factor f in the world (i.e. $c_j^f = \left(\sum_i E_{ij}^f / V_W^f\right)$), and c_j^f can differ across factors. Under this assumption, the factor export from i to j is predicted by $E_{ij}^f = c_j^f V_i^f$. As I will show in the appendix, heterogeneous preferences can be introduced into the sign test if the export propensity θ_i^f is replaced by $\ln \tilde{s}_i^f - \ln \tau_i - \ln \tilde{\alpha}_i^f$, in which $\tilde{\alpha}_i^f = \alpha_i^f / \alpha_W^f$ is the country i's expenditure share of factor f in its total consumption, relative to the world average level. Say, if a country i has a stronger love for low-skilled labour intensive products, it leads to a larger $\tilde{\alpha}_i^L$ which lowers the probability that i is the net exporter of low-skilled labour in its factor trade with other countries. The results of the preference adjusted bilateral HOV sign test are reported in the second column of Table 2.7; the first column is a replication of the baseline specification. It shows that the model fitness has increased after allowing for heterogeneous preferences, and the improvement is most visible in high-skilled labour.

Furthermore, the inclusion or exclusion of $\ln \tau_i$ in the propensity θ_i^f can also be used to evaluate the influence of unbalanced trade in predicting the direction of net bilateral factor trade. While Vanek (1968) originally accounted for unbalanced trade in the HOV test he proposed, many studies in the standard HOV test assume trade is balanced for all countries. The third column in Table 2.7 reports the result of a sign test in which I ignore the trade imbalance and predict the direction of net bilateral factor trade solely based on two countries' differences in their relative endowments (i.e. $\ln \tilde{s}_i^f - \ln \tilde{s}_j^f$). Comparing column (3) with (1), it is evident that ignoring unbalanced trade leads to a much lower predictive power, especially in high-skilled labour and capital. When weighted by NE_{ij}^f the fitness of this endowment-only specification increases to 83%, but it is not robust to alternative weighting since when the export propensity based weights are used the fitness is still low at 69% only. In column (4) I report the result of the sign test that adjusts for heterogeneous preferences but keeps the assumption of balanced trade (i.e. $\theta_i^f = \ln \tilde{s}_i^f - \ln \tilde{\alpha}_i^f$). Interestingly, there is virtually no improvement in the fitness compared to the endowment-only specification in column (3), and for some factors the fitness actually *decreases*. Therefore, although theoretically speaking the adjustment for heterogeneous preferences should improve the fitness of the sign-test prediction, the empirical result shows the effect is limited, while the adaptation for unbalanced trade plays a more important role. It seems to suggest that ignoring unbalanced trade may be responsible for the poor performance of standard HOV tests in some of the previous literature.

Lastly, it is also interesting to investigate the fitness of the bilateral HOV sign test when the conventional measure is used. In appendix table A.1 I replicate the baseline sign test of table 2.5, but the net factor export between two countries is measured by $NE_{i,j}^{f,\text{Conv}} = \text{DiX}_{ij}^f - \text{DiX}_{ji}^f$, in which DiX_{ij}^f is the conventional bilateral factor export defined as country i's factor f that is embedded in the gross export from i to j (see equation 2.3 for the derivation). I find that when the conventional measure is used, the average fitness of bilateral HOV sign tests decline for all factors and under all weighting

Table 2.7: Bilateral HOV Sign Test Using Different Export Propensity Scores

Specifications		(1) Baseline	(2) Adjust for Heter. Pref.	(3) Endowment Only	(4) Endowment + Heter. Pref.
Unweighted	L	84.0	87.2	82.1	80.9
	M	83.8	85.0	78.5	77.7
	H	78.8	84.4	71.2	68.3
	K	74.3	79.5	62.2	63.2
Weighted by Net Fac. Exp.	L	95.5	97.5	94.1	91.3
	M	94.3	96.3	93.2	92.6
	H	93.8	97.2	86.7	92.1
	K	88.9	92.6	83.0	82.6
Weighted by Exp. Propensity	L	93.8	95.9	91.7	92.3
	M	92.3	94.6	88.5	87.6
	H	89.1	92.7	84.0	79.8
	K	81.6	87.6	68.7	72.4

Note: Based on the year 2007. The first column is the replication of the baseline specification in table 2.5. Column (2) to (4) are also based on equation (2.8) but use alternative factor export propensities. The derivations of the fitnesses of unweighted and weighted sign tests are the same as table 2.5. Column (2) adjusts for heterogeneity in the consumption preferences across countries and the factor export propensity is modified to $\theta_i^f = \ln \tilde{s}_i^f - \ln \tau_i - \ln \tilde{\alpha}_i^f$ in which the $\tilde{\alpha}_i^f$ term represents the (logarithm of) country i's share of expenditure in its final consumption that are ultimately paid to factor f. Column (3) predicts the direction of net factor trade purely based on two countries' relative factor endowment (i.e. $\theta_i^f = \ln \tilde{s}_i^f$). Column (4) adjusts for heterogeneity in consumption, but trade is assumed to be balanced (i.e. $\tau_i = 1$ such that $\theta_i^f = \ln \tilde{s}_i^f - \ln \tilde{\alpha}_i^f$).

methods. The decrease is small when each observation is weighted by the net factor export flow (i.e. in the middle panel). However, in the unweighted sign test and in the specification weighted by export propensities, the fitness for medium- and high-skilled labour and capital has decreased by around 8 percentage points, which is quite large in magnitude. It shows that factor endowments of each country are less capable in predicting the direction of net factor trade as defined by the conventional measure. Or to put it otherwise, the factor endowment of each country is more closely related to the new measure of factor trade that identifies the origin and final destination of values that are added by different factors.

To summarize, in this section I use my bilateral factor trade indicator to perform a simple sign-test on the direction of net factor trade bilaterally between countries. I find strong support for the hypothesis that the country with a higher relative endowment in a factor is the net factor exporter in the country pair after adjusting for unbalanced trade. The predictive power is particularly high for the three labour factors and a bit lower for capital, which I think might be related to two potential reasons. Firstly, the capital income share in a country may not correctly reflect its actual relative endowment in capital, and this adds noise to the analysis. The mobility of capital is much higher than labour and the capital return is frequently registered in tax-friendly locations which differs from the origin where the values are truly added. Secondly, the lower fitness for capital might be associated with the construction of socio-economic accounts in the WIOD database. Capital income in each industry is not directly measured, but is constructed as the industrial value-added minus labour compensation. Effectively the observational error in capital is the summation of errors in labour income and total industrial value-added; therefore the measure of capital has a larger observational error.

2.5 Gravity Equation in Factor Exports: Home Bias and the Role of Distance

In the previous section, I showed that relative factor endowment has strong predictive power on the direction of net factor trade between countries when properly measured. Does factor endowment also predict the volume of trade? How do national borders and distance affect factor exports and how do these effects change over time? To answer these questions, in this section I estimate a gravity-like equation on the new measure of factor exports.

The gravity model, formally introduced in Anderson (1979), has become one of the workhorses in the international economics literature and yielded a large number of important empirical studies (see, e.g. Bergstrand 1985, 1989, Feenstra, Markusen and Rose 2001, Anderson and Wincoop 2003). However, the research is mostly conducted on gross export flows, and to the best of my knowledge there is yet no study that estimates gravity equation for bilateral factor export. I contribute to the literature by showing that factor export flows also fit well in the gravity model. Factor export elasticity to the exporter's factor endowments is found to be close to unity in all specifications, which suggests the important role of endowments in determining bilateral factor exports.

Besides the predictive power of endowments on factor trade, I am particularly interested in the so-called "home bias", which refers to the phenomenon that a country consumes a much higher amount of her own goods and factors than the volume implied by frictionless trade. Trefler and Zhu (2010) argue that home bias is the most important reason for the failure of standard HOV predictions. Under free trade in which the consumption similarity condition holds, the share of domestic factor in consumption should equal the share of domestic endowment in the world. However, in any country a substantially higher share of factor consumption is domestic. Even in small countries like Luxembourg, domestic factors have a share around 50% in consumption, and the share is much higher in larger countries. Trefler and Zhu (2010) suggest that home bias arises due to little-traded products (services) that are finalized in four sectors, namely agriculture, food manufacturing, construction, and government services. They illustrate that the fitness of standard HOV sign test is close to 100% in a counterfactual dataset in which one impose consumption similarity on these products (services). However, the test they perform is on the implication of consumption similarity, but not on the hypothesis of consumption similarity itself, and their analysis remains silent on the magnitude of home bias in the economy with or without these little-traded products.

Home bias is related with trade costs; distance plays an important role and has been studied in numerous papers. And besides the observable trade barriers, there is also a large unexplained home bias due to the existence of national borders. Several studies used gravity model to estimate the magnitude of unexplained home bias, using gross export data. Wei (1996) uses OECD trade and industrial statistics from 1984 to 1992 and shows that a country's trade with itself is around 2.5 times of the trade with a foreign country that is otherwise identical. Chen (2004) analyses the Eurostat data for seven European countries in 1996. She confirms the existence of home bias, but finds that the estimates for home bias are sensitive to the measurement of distance; home bias varies between 1.3 to 3 log scales[17] across different specifications. Wolf (2000) and Hillberry and Hummels (2003) use a similar set of gravity equations to investigate the home bias in intra- and inter-states trade in the U.S., based on the Commodity Flow Surveys. Both of them find that home bias also exists in sub-national level as the trade within a state is much higher than between states.

However, till now there is no break-down analysis that investigates whether the role of distance varies in the trade of different factors. My analysis is related to the recent seminal work by Johnson and Noguera (2016) who find that the volume of bilateral value-added exports is much smaller than gross exports, and the ratio of value-added export to gross export is decreasing rapidly in recent decades. They also find that the changes in this ratio are heterogeneous across trade pairs. Largest decreases have been observed in the pairs of emerging economies, nearby countries, and those with regional trade agreements. By decomposing value-added trade to factors, I find that distance also matters in factor trade. Similar as Johnson and Noguera (2016), the effect of distance has declined from 1995 to 2007. Trade elasticity to distance is lowest in high-skilled labour and capital; over the 13 year period it also had the largest decline for these two factors. Home bias is found to be largest in the trade of high-skilled labour and smallest in low-skilled labour. In contradiction to Trefler and Zhu (2010), I find that home bias is widely existing in the economy and is not restricted to the four above mentioned sectors.

Estimating gravity equations using factor export data has some measurement and statistical advantages over the studies on gross export. Note that in order to estimate home bias, one needs to measure the volumes of trade both between and *within each country*. It is hard to find a suitable measure for within-country trade that is comparable with gross export flows. Current literature mostly follows Wei (1996) who defines within-country trade as total gross output of a country (*not* its GDP) minus gross export. This measure is sensitive to domestic production structures and accounting standards. Consider a certain product that is produced in two stages, each of which generates value-added of $10. When both stages are performed by production units within a single firm, only the value of final output, i.e. $20, is registered. However, when one stage of production is domestically outsourced, or simply the firm splits the production units into two individual taxation accounting entities, the total output in the economy increases to $10+$20=$30, in which the upper-stream value-added is counted twice. Yi (2010) shows that offshoring and the shipping of intermediates back and forth between countries will magnify the gross export flows in a similar manner, but to a less extent compared to the multiple counting problem in the statistics on domestic trade. He finds that the estimated home bias is sensitive to the organization of multi-stage production. This

17. Or equivalently, internal trade of a country is estimated to be 3.7 to 20 times (i.e. exponential of the log score) compared to the trade with an "otherwise-identical" foreign country.

problem does not occur in the new measure of factor export. It identifies the origin and final destination of value added by each factor, such that both exported and domestically used factors share a unified definition. The measure of factor export is also robust to the alternative organization of production process, and does not suffer from multiple counting (because each unit of value can only have one origin and one final destination).

The gravity equation system I am going to estimate is derived from equation (2.6), i.e. $E_{ij}^f = c_j V_i^f$, which is the consumption similarity in factors under frictionless trade. Taking logarithms it gives $\ln E_{ij}^f = \ln V_i^f + \ln c_j$, so I estimate the following equation:

$$\ln E_{ij}^f = \beta_0^f + \beta_1^f \ln V_i^f + \beta_2^f \ln c_j + \varepsilon_{ij}^f. \tag{2.9}$$

The gravity equation in factor trade is very similar as the Anderson's (1979) gravity equation in gross exports, but the "masses of gravity" are no longer the GDP of each country. To see that, by substituting C_j/Y_W for c_j equation (2.9) is transformed into $\ln E_{ij}^f = (\beta_0^f - \beta_2^f \ln Y_W) + \beta_1^f \ln V_i^f + \beta_2^f \ln C_j + \varepsilon_{ij}^f$. It shows that the volume of factor export is determined the endowment of f of the exporter (V_i^f), and the total consumption of the importer (C_j).[18] If equation (2.6) holds, the estimated β_0 should be close to zero, while β_1 and β_2 should be close to unity. Under frictionless trade, the factor consumption similarity condition of equation (2.6) also applies to country's domestic factor consumption, such that a country i's use of its own factors, E_{ii}^f, should equal $c_i V_i^f$. So in the benchmark regression I include the observations regarding domestic factor uses. Offshorability may differ across the tasks performed by different factors, so I allow coefficients to vary across factors.

Equation (2.9) can be estimated independently for each factor. However, in order to improve the consistency of the regression I estimate the equations of all four factors simultaneously using iterated seemingly unrelated regression (iSUR). The estimates from SUR should be more consistent, because for a pair of countries the error terms ε_{ij}^f are potentially positively inter-correlated across factors. To see this, consider that two countries have some non-observed ties making them more willing to trade with each other. This force may affect the trade in all factors, such that the actual export of all factors between these two countries are larger than predicted. Similar SUR regressions are also used in Wei (1996) who estimate the gravity equations of different years simultaneously, and in Egger (2004) who estimates an equation system of gross exports and FDI to control for the potential inter-correlation between trade and investment.

I estimate the gravity model of factors using the data of year 2007, and the results for baseline regression on equation (2.9) are reported in panel (1) of table 2.8. The fitness of the gravity equation system is quite high; only two variables are able to explain almost 70% of the variation in the world bilateral trade in factor content (note that there are no fixed effect dummies). Result shows that $\widehat{\beta_1^f}$, i.e. the elasticity of factor trade to the endowment in the exporting country, is close to unity which fits the prediction by consumption similarity, while $\widehat{\beta_2^f}$, i.e. the elasticity to total consumption of the importing

18. The transformation only affects the constant term since $\ln Y_W$ is common for all countries. In this paper I estimate equation (2.9), because the divergence of β_0 from zero can be directly interpreted as the existence of a home bias.

Table 2.8: Estimating Gravity Equation and Home Bias (without control variables)

	(1) Baseline				(2) Excl. Domestic Usage				(3) Home Dummy			
	L	M	H	K	L	M	H	K	L	M	H	K
β_1	0.977	0.980	0.994	0.984	0.976	0.977	0.987	0.979	0.976	0.977	0.987	0.978
	[0.002]	[0.002]	[0.004]	[0.004]	[0.002]	[0.002]	[0.004]	[0.004]	[0.002]	[0.002]	[0.004]	[0.004]
β_2	0.763	0.764	0.761	0.768	0.780	0.780	0.779	0.785	0.763	0.764	0.761	0.768
	[0.019]	[0.019]	[0.020]	[0.019]	[0.015]	[0.015]	[0.015]	[0.014]	[0.015]	[0.014]	[0.014]	[0.014]
Home									5.82	5.87	6.19	5.75
									[0.16]	[0.16]	[0.16]	[0.15]
Cons. (β_0)	-2.02	-2.06	-2.47	-2.00	-2.06	-2.08	-2.46	-1.99	-2.15	-2.17	-2.53	-2.07
	[0.10]	[0.10]	[0.11]	[0.11]	[0.08]	[0.08]	[0.09]	[0.09]	[0.08]	[0.08]	[0.09]	[0.09]
Obs.	1681	1681	1681	1681	1640	1640	1640	1640	1681	1681	1681	1681
Adj-R^2	0.694	0.693	0.668	0.684	0.802	0.806	0.796	0.802	0.826	0.829	0.824	0.827

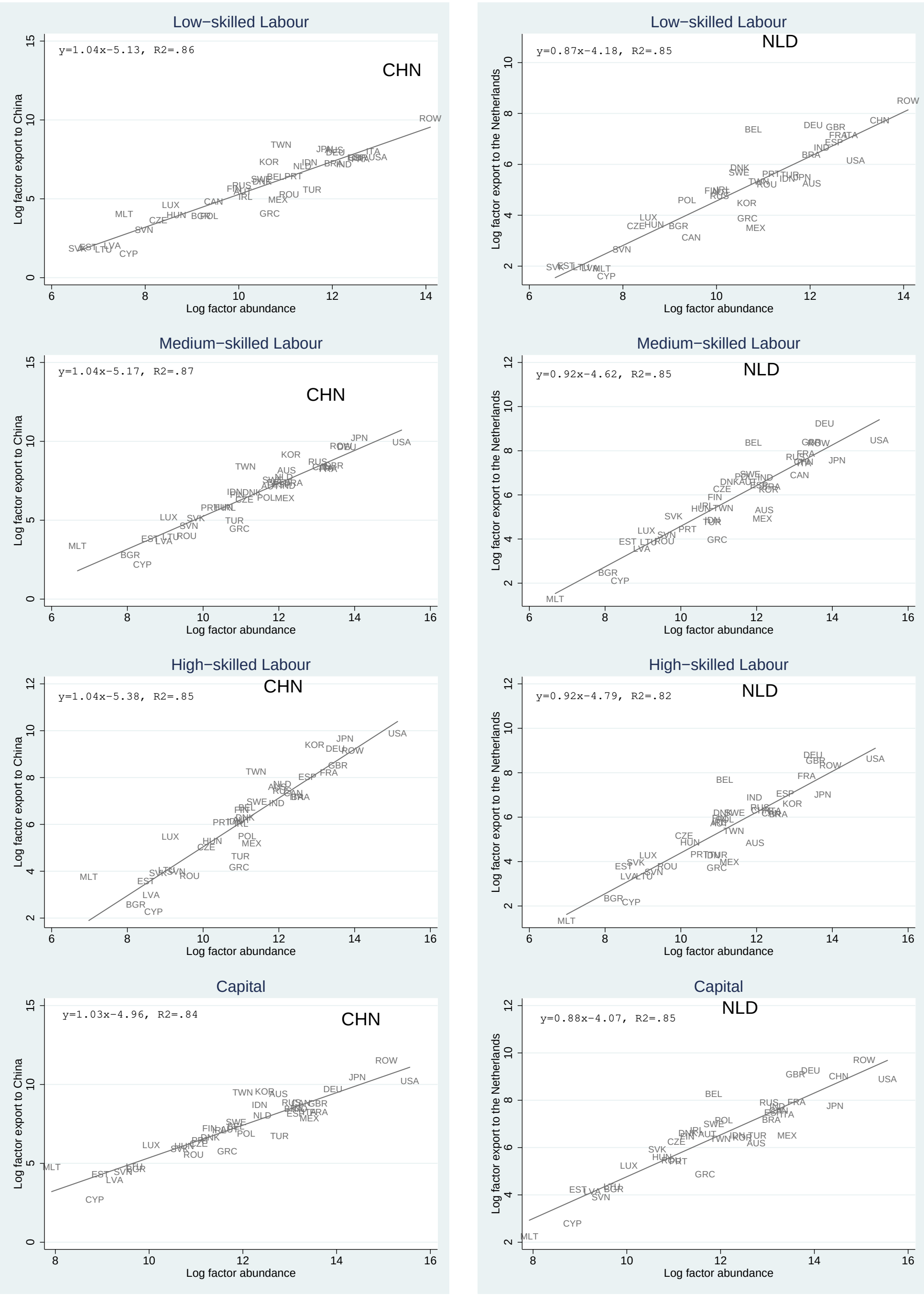
Note: Based on the data of year 2007. The tests in panel (1) and (2) are based on equation (2.9), and panel (3) on equation (2.10). Panel (1) and (3) include the observations regarding the use of domestic factors (i.e. E_{ii}), while panel (2) only considers traded factors. The exports of all four factors between each country pair is estimated in an equation system using iterated seemingly unrelated regression (iSUR). β_1 represents the factor trade elasticities to the total value of factor endowment in the exporting country (V_i^f), and β_2 is the elasticity to the importing country's consumption share in world GDP (c_j). Standard errors are reported in square brackets.

country is high and above 0.75 although not very close to 1. Importantly, the intercept terms (i.e. β_0^f) are significantly negative and have a large magnitude around -2, meaning that the actual volume of factor trade is much smaller than predicted under consumption similarity and frictionless trade.

The results suggest that factor endowments can explain the volume of factor exports, while a considerable amount of factors remain non-traded. To see this more intuitively, in figure 2.4 I plot the factor exports from different countries to China and to the Netherlands (representing the factor exports to a big and a small economy). The vertical axis is the logarithm of factor export to these two countries ($\ln E_{ij}^f$), and the horizontal axis indicates the logarithm of total factor endowment in each exporting country ($\ln V_i^f$). The domestic factor uses of China and the Netherlands are also indicated on the plots by larger labels (not included in the regression of each plot). When we focus on the export to one particular country, the regression equation (2.9) collapses to $\ln E_{ij}^f = \beta_{0j}^f + \beta_1^f \ln V_i^f + \varepsilon_i^f$, and when consumption similarity holds, the slope β_1 is predicted to be unity. Figure 2.4 shows a close linear trend between $\ln E_{ij}^f$ and $\ln V_i^f$ for traded factors, and importantly the slopes of the fitted lines are indeed close to one. But the use of domestic factors is substantially above the fitted line, suggesting a home bias where a large share of tasks that are needed in the production for domestic final consumption must be fulfilled by domestic factors.

How do the estimates of gravity equation change if one excludes the "outliers" of domestic factor use? In the second panel of table 2.8 I estimate equation (2.9) only for traded factors. I find that in panel (2) all the estimated coefficients remain largely similar as in panel (1). But importantly, the R-square has increased by around 10 percentage points, suggesting that a major part of prediction error by (2.9) occurs in the observations regarding the use of domestic factors.

Figure 2.4: Factor Export by Each Country to China and the Netherlands



Note: Based on author's own calculation using the WIOD dataset for year 2007. The vertical axis captures the (log) factor export to China and the Netherlands. The horizontal axis is the (log) total value of factor endowments of each exporting country. The domestic factor usage is highlighted by a bigger label. The fitted line is based on OLS estimates of traded factors (exclude the observations of domestic factor usages); the coefficients of the fitted line are reported in each plot.

To provide more insights on the magnitude of home bias, I follow Wei (1996) and Wolf (2000) and estimate the following gravity equation that contains a home country dummy:

$$\ln E_{ij}^f = \beta_0^f + \beta_1^f \ln V_i^f + \beta_2^f \ln c_j + \gamma \text{Home}_{ij} + \boldsymbol{X\beta} + \varepsilon_{ij}^f, \tag{2.10}$$

in which $\text{Home}_{ij} = 1$ if $i = j$, and zero otherwise; $\boldsymbol{X}$ is a list of other control variables. A positive significant γ indicates the existence of home bias, and its magnitude represents the "overuse" of domestic factors (in log scale) compared to the factor import from an otherwise identical foreign country. In panel (3) of table 2.8 I estimate equation (2.10) with the home dummy but without control variables. I find that the estimates for β_1 and β_2 are largely the same as in panel (1) and (2), while the coefficients on home dummies are large in magnitude and highly significant.

Home bias is due to trade costs and other kinds of trade barriers. For example, international shipment of intermediate inputs incurs longer travel distance than domestic, and language differences lead to higher coordinating costs and may prevent some kinds of offshoring from happening (e.g. costumer services). It is therefore necessary to include trade costs related control variables to investigate whether the national border, i.e. being "home" *per se*, leads to an "overuse" of domestic factors. Panel (4) and (5) in table 2.9 replicate the specifications (2) and (3) of table 2.8, but include a standard set of four control variables that are frequently used in gravity regressions of gross exports, i.e. the log distance between two countries, and three dummies indicating whether two countries share a land border, use a common language, and have colonial ties.[19] All four control variables are obtained from CEPII GeoDist Database (Mayer and Zignago 2011, accessible from `www.cepii.fr`). The distance between two countries is measured by the weighted distance between their cities in kilometers, accounting for the distribution of their populations. The internal distance of a country is constructed in a same way as the population weighted distance between cities inside the country.

After the inclusion of control variables, the magnitude of remaining home bias decreases compared to table 2.8, but is still significant and large in magnitude. Similar as Wolf (2000), the remaining home bias is found to be a bit above 3 in log scale; meaning that the use of home factor is on average more than 20 times (i.e. exp(3)) compared to the factor imports from an otherwise identical foreign country. The bias is found largest in high-skilled labour (3.55, compared with the average of 3.2 for other factors), and the difference is statistically significant at 1% level. It should be better viewed as an upper-bound for the border effect on trade, because I only include a limited set of control variables. Some important controls (like regional trade agreements) are missed out due the limited scope of this research, and in addition there is no exhaustive list for the control variables. It is expected that a higher proportion of domestic trade can be explained by adding more controls into the regression. However, given the large magnitude, it is unlikely that the home bias can be fully explained by control variables. In regression (4) and (5), all control variables have the expected sign, and are all significant except the dummy regarding common language. The parameters β_1^f and β_2^f are, strictly speaking, no longer testing the consumption similarity assumption, but can still be interpreted as the factor trade elasticity to the exporter's factor endowment and the

19. To be specific, this dummy equals one if (a) one country was colonized by another, or (b) both countries were colonized by a third country.

Table 2.9: Estimating Gravity Equation and Home Bias (with standard controls)

	(4) Excl. Domestic Use				(5) Home Dummy				(6) Unitary Elasticities			
	L	M	H	K	L	M	H	K	L	M	H	K
β_1	0.979	0.979	0.992	0.975	0.979	0.979	0.990	0.975	1	1	1	1
	[0.002]	[0.002]	[0.004]	[0.004]	[0.002]	[0.002]	[0.004]	[0.004]	-	-	-	-
β_2	0.912	0.906	0.908	0.901	0.902	0.899	0.897	0.890	1	1	1	1
	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	-	-	-	-
ln(Dist)	-0.740	-0.722	-0.730	-0.647	-0.740	-0.722	-0.730	-0.649	-0.808	-0.791	-0.794	-0.728
	[0.017]	[0.017]	[0.017]	[0.018]	[0.017]	[0.017]	[0.017]	[0.018]	[0.016]	[0.017]	[0.017]	[0.017]
Border Contiguity	0.391	0.383	0.332	0.389	0.392	0.383	0.332	0.386	0.278	0.259	0.221	0.248
	[0.081]	[0.081]	[0.082]	[0.084]	[0.083]	[0.820]	[0.083]	[0.085]	[0.085]	[0.084]	[0.085]	[0.088]
Common Language	0.072	0.077	0.175	0.137	0.077	0.082	0.181	0.144	0.044	0.050	0.150	0.108
	[0.068]	[0.068]	[0.082]	[0.071]	[0.069]	[0.069]	[0.070]	[0.072]	[0.072]	[0.071]	[0.072]	[0.074]
Colonial History	0.354	0.309	0.272	0.321	0.349	0.304	0.266	0.314	0.372	0.324	0.285	0.336
	[0.077]	[0.076]	[0.077]	[0.079]	[0.078]	[0.077]	[0.078]	[0.080]	[0.081]	[0.080]	[0.081]	[0.083]
Home					3.12	3.25	3.55	3.26	3.06	3.20	3.50	3.20
					[0.13]	[0.13]	[0.13]	[0.14]	[0.14]	[0.14]	[0.14]	[0.14]
Cons.	4.53	4.35	4.02	3.83	4.47	4.31	3.98	3.80	5.30	5.13	4.91	4.69
	[0.16]	[0.16]	[0.17]	[0.17]	[0.16]	[0.16]	[0.17]	[0.17]	[0.14]	[0.14]	[0.14]	[0.15]
Obs.	1640	1640	1640	1640	1681	1681	1681	1681	1681	1681	1681	1681
Adj-R^2	0.952	0.924	0.92	0.911	0.933	0.932	0.929	0.921	0.928	0.927	0.925	0.915

Note: Based on the data of year 2007. All panels uses the iSUR method. Panel (4) and (6) include the observations regarding the use of domestic factors (i.e. E_{ii}), while panel (5) only considers traded factors. The tests in panel (4) and (5) are based on equation (2.9). Panel (6) assumes that the elasticity of factor export is unity in respect with exporters endowment and importer's consumption, such that β_1 and β_2 are constrained to one; the regression is otherwise the same as in (5). All control variables are obtained from CEPII GeoDist Database (`www.cepii.fr`). The distance measure is the weighted distance between two countries which accounts for within-country geographical distribution of their population (i.e. the `distw` variable). Border contiguity, common language and the colonial history variables are dummy variables and they equals one if two countries share a land border, have a common language, and have a colonial history. Common language is defined as the language that is spoken by more than 9% of the population in both countries. Two countries are considered to have a colonial history if one country has colonized another, or both countries are/were in a same commonwealth. All three dummy variables equal one for a country's internal trade.

importer's total consumption. There is no major change in $\widehat{\beta_1^f}$, while $\widehat{\beta_2^f}$ has increased from 0.75 to around 0.9. In panel (6), I use an alternative regression by imposing the unitary elasticity constraint that sets β_1 and β_2 to be one (See Haveman and Hummels 2004, also table 1 in Anderson and Wincoop 2001); the regression is otherwise the same as panel (5). There are some changes in the estimates for control variables, but home bias and the effects of distance on factor trade remain large.

For a more consistent estimation of the magnitude of home bias and the role of distance in factor trade, as well as their changes over time, I use an alternative specification of gravity equation that accounts for the so-called "multilateral resistance to trade" (MRT). Anderson and Wincoop (2003) and Redding and Venables (2004) argue that the standard gravity equation, i.e. the one that regress export by two countries' "economic masses", is potentially inconsistent in a world with trade costs where effective factor price equalization is not satisfied. Anderson and Wincoop (2003) show that the following specification[20] should be used in order to make the gravity regression closer to

20. Equation 2.11 is taken from the equations (9) to (11) in Anderson and Wincoop (2003).

the theoretical gravity model in Anderson (1979):

$$\text{Export}_{ij} = \frac{Y_i Y_j}{Y_W} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma}, \tag{2.11}$$

where P_j and Π_i are the solutions to

$$P_j \equiv \left(\sum_i (t_{ij}/\Pi_i)^{1-\sigma} \theta_i \right)^{1/(1-\sigma)},$$

$$\Pi_i \equiv \left(\sum_j (t_{ij}/P_j)^{1-\sigma} \theta_j \right)^{1/(1-\sigma)}.$$

In the equation, σ is the substitution elasticity between goods in the CES utility function that Anderson and Wincoop have used, and $\theta_i = Y_i/Y_W$ which is country i's income share in world GDP. t_{ij} is the iceberg-type bilateral trade cost of the exports from country i to j. It can be interpreted as the "resistance" of country j in importing from i. Similarly, since a high t_{ij} makes the export from country i to j more costly, it can also be interpreted as the resistance of country i in exporting to j. The parameters P_j are named as "multilateral resistance" to import of country j, since it is a combination of all bilateral resistance that j faces in importing (i.e. trade costs t_{ij}). Vise versa, Π_i can be called as country i's multilateral resistance to export. Π_i and P_i are the same when trade costs are symmetric, but are different in general cases.

Empirically, P_j and Π_i cannot be easily solved or estimated, but since they are country specific it is not difficult to control for MRT using a fixed effect model. By taking logarithm on equation (2.11), one obtains:

$$\ln\left(\text{Export}_{ij}\right) = [\ln Y_i - (1-\sigma)\Pi_i] + [\ln Y_j - (1-\sigma)P_j] - \ln Y_W + (1-\sigma)d_{ij}.$$

The terms in the square brackets are country specific to the exporter i and importer j, and are represented by country dummies in the regression. It should be noticed that "economic masses" Y_i and Y_j are *not* included in the MTR adjusted fixed effect regression, since they are country specific. As a result, it is not possible to identify the parameters regarding trade elasticities to income (i.e. the β_1 and β_2) and separate them from MTR terms, or make any inference about unitary trade elasticity on income. But the fixed effect regression gives consistent estimates for the variables regarding trade costs and other barriers (Hummels 1999 and Anderson and Wincoop 2001).

In analogy to Anderson and Wincoop (2001), the factor trade gravity specification can be modified as follows to adjust for multilateral resistance:

$$\ln E_{ij}^f = \beta_0^f + \left[\beta_1^f \ln V_i^f - (1-\sigma)\Pi_i^f\right] + \left[\beta_2^f \ln c_j + (1-\sigma)P_j^f\right] + \text{Control Variables}.$$

By replacing the term inside square brackets by country fixed dummies, the regression I perform is the following:

$$\ln E_{ij}^f = \beta_0^f + \zeta_i^f + \eta_j^f + \gamma \text{Home}_{ij} + \boldsymbol{X\beta} + \varepsilon_{ij}^f, \tag{2.12}$$

Table 2.10: Gravity Specification with Multilateral Resistance Effect

	(7) MR Baseline				(8) Excl. Domestic Use				(9) MR - 1995			
	L	M	H	K	L	M	H	K	L	M	H	K
ln(Dist)	-0.843	-0.813	-0.765	-0.786	-0.847	-0.812	-0.762	-0.790	-0.894	-0.870	-0.833	-0.855
	[0.022]	[0.022]	[0.023]	[0.022]	[0.022]	[0.022]	[0.023]	[0.022]	[0.028]	[0.028]	[0.028]	[0.028]
Border Contiguity	0.299	0.280	0.288	0.281	0.295	0.279	0.287	0.281	0.400	0.382	0.361	0.348
	[0.063]	[0.063]	[0.066]	[0.064]	[0.061]	[0.061]	[0.063]	[0.061]	[0.079]	[0.080]	[0.080]	[0.081]
Common Language	0.170	0.151	0.151	0.146	0.151	0.131	0.124	0.117	0.082	0.075	0.078	0.090
	[0.056]	[0.056]	[0.058]	[0.056]	[0.054]	[0.054]	[0.056]	[0.054]	[0.070]	[0.070]	[0.071]	[0.071]
Colonial History	0.311	0.296	0.298	0.298	0.320	0.311	0.315	0.312	0.390	0.396	0.394	0.412
	[0.059]	[0.059]	[0.062]	[0.059]	[0.057]	[0.057]	[0.059]	[0.057]	[0.074]	[0.074]	[0.075]	[0.075]
Home	2.89	3.06	3.50	3.02					3.08	3.26	3.73	3.24
	[0.10]	[0.10]	[0.10]	[0.10]					[0.13]	[0.13]	[0.13]	[0.13]
Obs.	1681	1681	1681	1681	1640	1640	1640	1640	1679#	1679	1679	1679
Adj-R2	0.965	0.964	0.960	0.960	0.963	0.962	0.958	0.959	0.956	0.955	0.952	0.949

Note: Panel (7) and (8) are based on the data of year 2007 and panel (9) on 1995. Panel (7) and (9) include the observations regarding the use of domestic factors (i.e. E_{ii}), while panel (8) only considers traded factors. All three regressions use the iSUR method, and include importer and exporter fixed effect in accordance to the gravity equation specification with multilateral resistance to trade. Note that it is *not* possible to estimate the factor trade elasticity to exporter's endowment and importer's consumption (i.e. β_1 and β_2). #: The number of observation in 1995 is lower than in 2007, this is because in 1995 two country pairs has negative export of capital and these observations are excluded. "Negative export of capital" is possible in the dataset when the firms in the exporting country incur a large capital loss in the goods or services exported. If I focus on the same sample across the whole time period and exclude the respective observations in 2007, the coefficients in (7) and (8) has virtually no change; results are available upon request.

Note that the MTR terms of ζ_i^f and η_j^f are country *and* factor specific. Panel (7) in table 2.10 reports the outcome for regression equation (2.12). The distance elasticity to factor trade is estimated to be around -0.8. Distance elasticity is the smallest in magnitude in high-skilled labour and largest in low-skilled labour, and their difference (7.8 log points) is statistically significant. This difference is also economically significant. Consider the factor trade between Spain and Germany with the distance of around 1627 km. The distance-related barrier is around 57 log points lower in high-skilled labour compared with low-skilled (or 43% lower). The magnitude of remaining home bias is found to be similar with table 2.9. Interestingly, remaining home bias is the largest in high-skilled labour. There is no conflict with high-skilled labour's smallest trade elasticity to distance. The results show that high-skilled labour is the least traded among the four factors, but within traded factors it is relatively the easiest for high-skilled to overcome distance barriers. The other three control variables, namely border contingency, common language, and colonial ties all have positive significant effect on the trade in all four factors. In panel (8) I exclude the observations about use of domestic factors. The magnitude of home bias cannot be estimated due to the exclusion of home country, but otherwise there is no significant difference from (7).

How does the distance elasticity of trade and the remaining home bias change over time? In panel (9) I replicate the same specification as in (7) but for the data of 1995. I find that the home bias has declined for about 20 log points in all factors over this period. Distance elasticity has declined the most in the trade of high-skilled labour and capital contents, and to a lesser extent for low- and medium-skilled labour. It implies that all factors are becoming increasingly traded, and the trade barrier due to distance has declined especially in the tasks performed by high-skilled labour and capital. Similar as distance, the effect of border contiguity has also declined. Interestingly, the coefficients for common language were insignificant in 1995, but have *increased* from 1995 to 2007. Sharing a language is estimated to increase factor trade by on average 7% in this time period; the effect is the largest for low-skilled labour and the least for capital. This might relate with the increasing offshoring of some low-skilled service tasks that require language skills, for instance call operators.

Trefler and Zhu (2010) argue that consumption similarity is violated in some little-traded final products made by four sectors that serve mainly domestic consumers, but this argument has not been formally tested. Is home bias absent in rest of the economy? In appendix table A.2 and A.3 I estimate the same specifications as in table 2.9 and 2.10, but for a counter-factual dataset that excludes all factors that are deployed in producing the output of the four potentially home-biased sectors.[21] If home bias is much lower in other sectors, the coefficient of the home dummy should be much smaller in the specification using conterfactual data. However, I find home bias remains large, which does not support the argument in Trefler and Zhu (2010). In fact, statistically significant decrease in home bias is only found in low-skilled labour, and the change is significant only at around 10% level.

2.6 Concluding Remarks

This paper argues that the analysis of bilateral trade in products is no longer suitable due to the rise of offshoring and globalized production. Instead, the focus should be on the underlying factor trade which is directly linked with the actual tasks that a country performs for export.

The current literature lacks a properly defined and precisely measured indicator for bilateral exports. The conventional measure defines bilateral factor exports as the domestic factor content of the exporting country that is embedded in its bilateral gross export flows. Under this definition, the conventional measure cannot identify the indirect factor exports that are embedded in traded intermediates, which are becoming increasingly important when offshoring is pervasive. I introduce a new measure of bilateral factor exports based on the identification of origin country and the ultimate destination of value that is added by each factor, which is robust to the complex structure of globalized production. I find large differences between my measure and the conventional measure. I argue that the latter is sensitive to the organization of GVCs, and I show that the differences between the two measures can be attributed to the position of countries in global production chains.

I find that bilateral trade in factors, when measured properly, can be largely explained by the relative endowment of each country, which is in line with neo-classical trade theo-

21. I exclude the factors that are directly used in the production of these final products, as well as the factors used in producing their upper-stream inputs. One may argue that these intermediate inputs are tradable (for example the buildings cannot be traded, but cement and steel can), therefore the factors used in making intermediates should not be excluded. So I have also tested another counter-factual dataset that only excludes the factors directly used by these four sectors. The results remain very similar.

ries. I perform a simple sign test on the direction of net factor trade bilaterally between countries. I find strong support that in a pair of countries the one with a larger relative endowment in a factor will be the net exporter of this factor, after adjusting for imbalanced trade. I also use the factor export indicators to estimate a gravity-like equation in factor trade. The volume of bilateral factor exports can be also closely approximated by a simple gravity equation based on the factor endowment of the exporting country and the total consumption of the importer. But in contrast to Trefler and Zhu (2010), home bias is found to be large even after excluding factors used in producing little-traded final products. Similar as trade in products, distance negatively affects trade in factors. The role played by distance becomes significantly smaller from 1995 to 2007, especially in the trade of high-skilled labour and capital. The remaining home bias also declines in this time period, and the decreases are similar across factors.

The main message of this paper is that standard theories still provide important insights for our view of trade. Gross exports are not well aligned with the actual activities that a country performs for exporting, but if we break trade down to ultimate factors that have been exchanged across countries, trade patterns are back in line with theoretical predictions. It is related with Baldwin and Robert-Nicoud (2014) who also aim to highlight the relevance of standard trade theories in recent patterns of trade, but from a different perspective. They introduce the concept of *shadow migration* which argues that the economic boundary of a country differs from its physical national border. Effectively, the endowment of a country is not the amount of workers (and capital) who physically reside domestically, but all factors, domestic and foreign, that are used in producing the goods finalized by the domestic country. In this view the Chinese workers who are employed to perform offshored tasks for U.S. products should be considered as economic residents of the U.S.; offshoring thus has the same impact as a factor inflow. They further argue that the predictions from the original neo-classical models like the HO and Rybczynski theorems are perfectly restored, once the actual endowment of each country is replaced by the shadow migrants adjusted one.

I think that the factor trade approach provides more direct implications for policy making, since it takes endowment in the domestic country as the starting point of analysis. The shadow migration approach instead focuses on the economic boundary which encloses a mix of domestic and foreign labour. It is unclear how the benefits in the production and export are distributed among domestic and foreign workers, and among different domestic workers which policy makers are usually interested in. To give an example, assume that a certain technology greatly increased Dutch firms' capability in using cheap foreign low-skilled labour via offshoring. Taking the shadow migration perspective and applying the Rybczynski theorem, it suggests that the Netherlands is going to produce and export more low-skilled intensive products which seems to be good news for low-skilled labour within the Dutch economic boundary. However, if one considers only low- and high-skilled workers who live in the Netherlands, offshoring possibly leads to unemployment of the domestic low-skilled workers and an increasing inequality between the rich and the poor.

On the other hand, the shadow migration approach excels in analysing global trade flows. When the shadow migrant adjusted endowment of each country is properly documented, this approach is well equipped to explain trade in products which is also of great interest for economic research and is an important advantage over my factor trade approach. But it should be noticed that neither approach is suitable to *predict* the future pattern of trade in products. My approach can be used to predict the future trend of factor trade if future endowment structures can be extrapolated, but it remains silent on trade of products. And the shadow-migrant adjusted endowment is known only *ex post*, i.e. after firms have made their offshoring decisions. According to Baldwin (2006), the decisions of offshoring are sensitive to the development of particular technologies. It frequently takes a discrete pattern (either no offshoring, or a whole range of consecutive stages offshored) rather than being smooth, and is *ex ante* largely unpredictable.

Appendix

The conventional and new measures of factor exports in a two-country world

This appendix illustrates the potential mismatch between the conventional and new measures of bilateral factor exports in a two-country world.

Recall that the conventional measure is defined as the domestic factor contents that are embodied in the gross export flows from between two countries. In a world with multiple countries, it has an evident drawback in tracing the factor contents embodied in traded intermediates that are first exported to a third country for processing (or just entrepôt trade) before reaching its final destination of consumption. In such case, the conventional measure registers the intermediating country as the importer, leaving the ultimated destination invisible. In a world with only two countries (or more realistically, the domestic country and the "rest of world"), the above type of mismatch is seemingly impossible: at a first sight anything exported by one country must, by construction, end up as the import by another. This is, however, *not* true for factor exports and value-added exports under globalized production. The problem arises due to *returning factor contents* embodied in the intermediate inputs to be processed abroad, which later return home for final consumption. This is in analogy with the story in a multi-country world: effectively the foreign country is the "man-in-the-middle" between domestic final consumption and domestic factors producing upstream intermediates.

This appendix aims to illustrate this possibility more clearly using a reasonable example. Consider a world with two countries, a small developed country *North*, and a big developing country *South* that is initially unknown. North has an endowment of 200 low-skilled workers, and 300 high-skilled workers. The low-skilled wage in North is normalized to $w_L = \$1$, and its high-skilled wage w_H is \$2. There are three sectors, producing two final products: machine and peeled shrimp. Each unit of machines is produced by one high-skilled worker in the machine industry. In the aquaculture industry, four low-skilled workers are needed to raise and catch one unit of unpeeled shrimps. Shrimps are peeled in the food manufacturing industry; one unit of machine and one low-skilled worker are required to peel each unit of shrimp.

The unit price of machine is given by $P^M = w_H = \$2$, and for unpeeled shrimp $P^{\text{UPS}} = 4w_L = \$4$. Each unit of peeled shrimp costs $P^{\text{PS}} = P^{\text{UPS}} + P^M + w_L = \$7$. It can be validated that in total North produces and consumes 40 units of peeled shrimp with a total worth of \$280; its value chain involves all 200 low-skilled workers (160 fishermen and 40 peeling workers), and 40 high-skilled workers (producing the required 40 units of machine). In addition, 260 high-skilled workers produce 260 units of machines for final use that worth \$520.

Later, the country South is discovered. South has a much larger population than the North, most of which are low-skilled. The wage ratio between high and low-skilled is 6. Two goods are produced: each unit of pottery artwork is produced by one high-skilled worker, and each unit of grain by one low-skilled worker. People in both North and South strongly prefer eating their own food. But South finds machines highly useful, and people in North have some interests in the traditional pottery artworks. The international price of machine is twice than pottery artwork. This implicitly determines the wage of South workers denominated by North's currency (denoted by an asterisk), i.e. $w_H^* = 1/2P^M =$ \$1, and $w_L^* = 1/6 w_H^* =$ \$1/6.

South would like to buy more machines, but North's demand for artworks is limited. A merchant from South discovered that the production of shrimps is rather costly in North. Shrimp farming is impossible in South due to the high temperature, but its low-skilled workers can be easily trained to peel the shrimps manually. Through some experiment he finds that each unit of shrimp can be peeled by three low-skilled workers in the South, so unit cost of peeling decreases from \$3 to merely $3 \times 1/6 =$ \$1/2.

Offshoring in shrimp-peeling happens after he announces the finding. Now there is no need to produce machines for shrimp peeling, such that all 300 high-skilled workers are engaged in producing 300 machines for final consumption, worth \$600. Food manufacturing industry disappears in the North and all workers lose their jobs. But due to their close tie with the aquaculture sector they soon start to work as fishermen. As a result, in total $200/4 = 50$ units of unpeeled shrimps are now produced by the North. The food manufacturing industry appears in South but a different technology is used. In total 3*50=150 low-skilled workers are hired, with a costs of, in principle, $50 \times 1/2 =$ \$25. Being criticized by North's humanitarians, companies in North decide to pay \$30 to South's low-skilled workers to improve their working conditions and to make sure the food safety requirements are met. In addition, North buys 10 units of pottery artwork which worth \$10. The peeling service and the import of artworks are financed by the export of 20 units of machines which worth \$40.

What are the factor exports between two countries under the new and conventional measures? The new measure identifies the location where value are added by factors and are consumed. North exports high-skilled labour content of \$40 to South, which is related to the exported machines. Effectively, no low-skilled labour is exported from North to South, because all shrimps are peeled and then finally shipped back to North for final consumption. South exports low-skilled content of \$30 and high-skilled content of \$10 to North, which are related with the peeling service and pottery artworks, respectively. Note also that the factor trade between two countries, in monetary value, is balanced.

The conventional measure traces the domestic content embedded in gross export flows. In the story above, the gross export flows between the two countries are given by:

Direction of Trade	North → South		South → North	
Items and Value	Unpeeled Shrimps	\$200	Peeled Shrimps	\$230
	Machines	\$40	Pottery Artworks	\$10
Total		\$240		\$240

Note that trade, as measured by the value of gross export, is also balanced. The domestic factor content embodied in gross export flows are therefore ("*Imp. Int*" in the table is short for "imported intermediates"):

Direction of Trade	North → South		South → North	
Items and Value	Unpeeled Shrimps	$200	Peeled Shrimps	$230
	Domestic	L: $200	*Domestic*	L: $30
	Imp. Int.	$0	*Imp. Int.*	$200
	Machines	$40	Pottery Artworks	$10
	Domestic	H: $40	*Domestic*	H: $10
	Imp. Int.	$0	*Imp. Int.*	$0
Factor Exports	Low-skilled	$200		$30
	High-skilled	$40		$10
	Total	$240		$40

Under the conventional measure, the pattern of factor exports is confusing. North not only exports much higher value of low-skilled labour content to the South ($200 versus $40), but has also a higher L/H ratio in its factor export (5 versus 3). It looks as if North, instead of South, is the developing country. Another noteworthy observation is that the factor trade turns out to be *unbalanced*: The value of factors exported from North to South amounts to $240, in comparison with $40 from South to North. This confusing pattern arises because the conventional measure lacks the ability in tracing traded intermediates and the embodied factors. The export of $200 low-skilled labour content is registered when unpeeled shrimps crossed the border from North to South. But when the peeled shrimps are shipped back, this value is not captured by the conventional measure, since the $200 is *not* the domestic content of the exporting country (i.e. South).

More generally, in a multi-country world, the conventional measure systematically overstates the factors exported from a country to the rest of world (i.e. all other countries). The reason is the same that the factor content embodied in exported intermediates may return home after being processed abroad. It is expected that offshoring is more possible in the tasks that are performed by the relative scarce factors, however the exact bias in the conventional measure depends on the types of intermediates that the country ships abroad for processing, which is not necessarily linked to the factor endowment structure of the home country. Consider that if the production of machines requires two steps, high-skilled workers make components and low-skilled workers do the assembly. When North exports the components to be assembled in South and part or all of these machines are shipped back for home consumption, then the factor export of high-skilled labour is overstated. It should also be noticed that the overestimation of factor exports is a different problem than the double counting of value-added in Koopman *et al.* (2014). Under the conventional measure, factor export is counted only once, which occurs at the first time when the factor content leaves its home country. The overestimation arises because the conventional measure fail to subtract the returning factor content embodied in intermediates that were exported earlier.

Alternative assumption that accommodates heterogeneous demand

The consumption similarity condition in Trefler and Zhu (2010) assumes that each country j consumes a fixed share c_j of all available products in the world. As shown by equations (2.5) and (2.6), consumption similarity predicts that effectively country j consumes a fixed share c_j of all available factors in the world, and the factor export from country i to j is predicted to be $E_{ij}^f = c_j V_i^f$. Note that the country specific share of c_j is the same across all factors.

The consumption similarity condition presumes that the preference is identical for all countries (i.e. every country consumes the same basket of final products), which might not be true. For instance, some countries may have a stronger preference for low-skill than high-skilled intensive products. I accommodates for heterogeneous preference by allowing the c_j parameter to vary across factors, such that the predicted factor export from country i to j is given by $E_{ij}^f = c_j^f V_i^f$, in which c_j^f equals $C_j^f / V_W^f = \left(\sum_k E_{kj}^f\right) / V_W^f$. The value of c_j^f can be calculated by the data on C_j^f which is country j's total expenditure on factor f, and the world total endowment of factor f (i.e. V_W^f).[A.1]

Under this alternative assumption, net factor export from i to j is predicted to be $NE_{ij}^f = c_j^f V_i^f - c_i^f V_j^f$. The prediction on the right-hand side is observed from the data, and the test in the second panel of table 2.7 can be built directly upon this prediction. But in order to provide a more informative explanation for the sign test that adjusts for heterogeneous preferences, NE_{ij}^f can be re-written in a similar way as equation (2.7) into the following:

$$\begin{aligned} NE_{ij}^f &= c_j^f V_i^f - c_i^f V_j^f = \frac{C_j^f}{V_W^f} s_i^f Y_i - \frac{C_i^f}{V_W^f} s_j^f Y_j \\ &= \frac{C_j^f}{C_j} \frac{C_j}{Y_j} \frac{Y_j}{Y_W} \frac{Y_W}{V_W^f} s_i^f Y_i - \frac{C_i^f}{C_i} \frac{C_i}{Y_i} \frac{Y_i}{Y_W} \frac{Y_W}{V_W^f} s_j^f Y_j \\ &= \left(\frac{\alpha_j^f s_i^f \tau_j}{\alpha_W^f} - \frac{\alpha_i^f s_j^f \tau_i}{\alpha_W^f} \right) \frac{Y_i Y_j}{Y_W} = \left(s_i^f \tilde{\alpha}_j^f \tau_j - s_j^f \tilde{\alpha}_i^f \tau_i \right) \frac{Y_i Y_j}{Y_W}. \end{aligned}$$

In the equation, $\alpha_i^f = C_i^f / C_i$ which denotes country i's share of expenditure on factor f, and $\alpha_W^f = V_W^f / Y_W$ is the world expenditure share on factor f. Note that α_W^f is equivalent to s_W^f, i.e. the world income share of f since the world income of a factor must equal the world expenditure. $\tilde{\alpha}_i^f$ equals α_i^f / α_W^f which represent the preference of country i on factor f relative to the world average level. The direction of net factor export is dependent on the term inside the bracket.

Following similar steps as in footnote 13, it can be shown that the sign of the term

A.1. There are many reasons why preferences differ across countries, see, for example, Engel's law. However, it should be emphasized that in this paper I do not intend to explain the exact reasons of inside the bracket is equivalent to $\mathrm{Sig}((\ln s_i^f - \ln \tau_i - \ln \tilde{\alpha}_i^f) - (\ln s_j^f - \ln \tau_j - \ln \tilde{\alpha}_j^f))$. Note that s_i^f can be further normalized to $\ln \tilde{s}_i^f = s_i^f - s_W^f$, and s_j^f to $\ln \tilde{s}_j^f = \ln s_j^f - \ln s_W^f$. The direction of net factor export is predicted by comparing the differences between the modified factor export propensity θ_i^f and θ_j^f, with $\theta_i^f = \ln \tilde{s}_i^f - \ln \tau_i - \ln \tilde{\alpha}_i^f$.

Table A.1: Bilateral HOV Sign Test (using conventional factor export data)

	Unweighted				Weighted by Net Factor Trade Flows				Weighted by Diff. Fac. Exp. Propensity			
Year	L	M	H	K	L	M	H	K	L	M	H	K
1995	81.2	78.2	74.4	65.2	91.6	96.1	92.8	72.5	92.1	87.2	84.4	73.4
1996	82.2	78.8	76.3	64.4	93.5	95.4	94.3	73.2	92.0	87.7	85.4	71.8
1997	82.2	74.8	74.5	61.3	91.8	94.0	92.2	69.8	91.9	84.4	82.3	68.7
1998	82.8	77.9	77.1	62.4	92.2	93.1	92.7	68.4	92.0	86.6	84.7	68.5
1999	82.3	76.2	75.1	63.3	93.5	93.1	91.6	80.0	91.0	85.2	84.1	70.4
2000	82.4	75.1	73.5	65.6	94.3	92.5	91.7	84.4	91.1	84.7	81.8	73.4
2001	82.7	75.7	74.8	64.4	94.5	92.3	92.9	83.8	91.6	85.0	82.2	72.2
2002	82.4	75.1	73.2	64.9	94.1	92.4	93.3	81.2	91.5	84.6	81.7	71.3
2003	79.8	74.5	74.4	64.3	93.6	91.3	91.4	80.4	89.7	85.2	83.3	71.3
2004	82.4	73.7	70.6	62.2	93.3	90.7	91.0	79.8	92.7	83.5	80.3	67.5
2005	82.6	73.2	71.0	65.4	94.7	92.6	90.4	83.8	92.7	83.6	79.2	70.4
2006	82.1	73.8	70.4	68.0	95.2	93.2	90.1	82.8	92.4	83.1	79.5	71.7
2007	83.9	74.0	71.7	67.6	94.3	92.8	89.8	83.8	92.7	84.4	81.3	71.1
2008	82.8	75.5	71.1	67.6	94.8	94.0	88.9	85.0	92.4	84.1	79.9	71.0
2009	83.3	73.9	71.3	66.2	93.2	93.9	89.1	80.7	92.5	83.9	78.7	70.9
Mean	82.3	75.4	73.3	64.9	93.6	93.2	91.5	79.3	91.9	84.9	81.9	70.9
Range	4.1	5.6	6.7	6.7	3.6	5.4	5.3	16.5	3.0	4.6	6.6	5.9

Note: This table replicates the same tests in table 2.5, using the conventional measure of bilateral factor export calculated from equation 2.3.

heterogeneous preferences. The value of c_j^f can be *observed* from the data and I use it as a *revealed* measure for preference.

Table A.2: Estimating Gravity Equation and Home Bias (Counterfactual)

	(4') Excl. Domestic Use				(5') Home Dummy				(6') Unitary Elasticities			
	L	M	H	K	L	M	H	K	L	M	H	K
β_1	0.989	0.996	1.016	0.993	0.989	0.995	1.014	0.992	1	1	1	1
	[0.002]	[0.002]	[0.004]	[0.004]	[0.002]	[0.002]	[0.004]	[0.004]	-	-	-	-
β_2	0.913	0.911	0.908	0.899	0.902	0.900	0.896	0.888	1	1	1	1
	[0.009]	[0.009]	[0.010]	[0.010]	[0.009]	[0.010]	[0.010]	[0.010]	-	-	-	-
ln(Dist)	-0.682	-0.683	-0.680	-0.618	-0.683	-0.684	-0.682	-0.621	-0.742	-0.741	-0.731	-0.687
	[0.017]	[0.017]	[0.018]	[0.019]	[0.017]	[0.017]	[0.018]	[0.019]	[0.016]	[0.017]	[0.017]	[0.018]
Border Contiguity	0.368	0.350	0.320	0.375	0.367	0.349	0.318	0.370	0.262	0.246	0.228	0.250
	[0.080]	[0.081]	[0.083]	[0.088]	[0.081]	[0.082]	[0.084]	[0.089]	[0.083]	[0.084]	[0.086]	[0.091]
Common Language	0.044	0.068	0.132	0.087	0.049	0.074	0.140	0.094	0.018	0.045	0.117	0.060
	[0.067]	[0.068]	[0.069]	[0.074]	[0.068]	[0.069]	[0.071]	[0.075]	[0.071]	[0.071]	[0.073]	[0.077]
Colonial History	0.352	0.316	0.304	0.332	0.346	0.309	0.296	0.323	0.368	0.329	0.313	0.346
	[0.075]	[0.076]	[0.078]	[0.083]	[0.077]	[0.078]	[0.079]	[0.084]	[0.079]	[0.080]	[0.082]	[0.087]
Home					2.98	3.17	3.61	3.36	2.93	3.13	3.57	3.31
					[0.13]	[0.13]	[0.14]	[0.14]	[0.14]	[0.14]	[0.14]	[0.15]
Cons.	4.17	4.01	3.43	3.39	4.13	3.97	3.40	3.38	5.00	4.88	4.48	4.37
	[0.16]	[0.16]	[0.17]	[0.18]	[0.16]	[0.16]	[0.17]	[0.18]	[0.14]	[0.14]	[0.14]	[0.15]
Obs.	1640	1640	1640	1640	1681	1681	1681	1681	1681	1681	1681	1681
Adj-R^2	0.930	0.926	0.919	0.905	0.935	0.933	0.928	0.915	0.930	0.928	0.924	0.909

Note: This table replicates all specifications in table 2.9 but uses a counterfactual dataset that discards all factors that are used directly or indirectly in producing the final products from the following four potentially home-biased sectors as argued in Trefler and Zhu (2010): Agriculture, Food Manufacturing, Construction, and Government Services.

Table A.3: Gravity Specification with Multilateral Resistance Effect (Counterfactual)

	(7') MR Baseline				(8') Excl. Domestic Use				(9') MR - 1995			
	L	M	H	K	L	M	H	K	L	M	H	K
ln(Dist)	-0.790	-0.777	-0.739	-0.760	-0.791	-0.775	-0.735	-0.761	-0.860	-0.850	-0.815	-0.835
	[0.022]	[0.022]	[0.023]	[0.022]	[0.022]	[0.022]	[0.023]	[0.022]	[0.028]	[0.028]	[0.029]	[0.029]
Border Contiguity	0.242	0.237	0.249	0.246	0.238	0.235	0.250	0.247	0.337	0.332	0.326	0.329
	[0.063]	[0.064]	[0.066]	[0.064]	[0.060]	[0.061]	[0.062]	[0.061]	[0.079]	[0.081]	[0.082]	[0.082]
Common Language	0.162	0.141	0.143	0.130	0.145	0.120	0.117	0.103	0.084	0.068	0.073	0.065
	[0.055]	[0.056]	[0.058]	[0.057]	[0.053]	[0.054]	[0.055]	[0.054]	[0.070]	[0.071]	[0.073]	[0.072]
Colonial History	0.307	0.292	0.293	0.292	0.319	0.308	0.311	0.308	0.378	0.384	0.378	0.410
	[0.059]	[0.059]	[0.061]	[0.060]	[0.056]	[0.057]	[0.058]	[0.057]	[0.074]	[0.075]	[0.077]	[0.076]
Home	2.75	2.99	3.52	3.11					2.95	3.19	3.77	3.38
	[0.10]	[0.10]	[0.10]	[0.10]					[0.13]	[0.13]	[0.13]	[0.13]
Obs.	1681	1681	1681	1681	1640	1640	1640	1640	1679	1679	1679	1679
Adj-R2	0.966	0.964	0.961	0.960	0.965	0.963	0.959	0.959	0.958	0.955	0.951	0.949

Note: This table replicates all specifications in table 2.10 but uses a counterfactual dataset that discards all factors that are used directly or indirectly in producing the final products from the following four potentially home-biased sectors as argued in Trefler and Zhu (2010): Agriculture, Food Manufacturing, Construction, and Government Services.