THREE ESSAYS ON THE FACTOR CONTENT OF TRADE

A Dissertation

presented to

the Faculty of the Graduate School

University of Missouri-Columbia

In Partial Fulfillment

Of the Requirement for the Degree

Doctor of Philosophy

By

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MAY 2009

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THREE ESSAYS ON THE FACTOR CONTENT OF TRADE

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ACKNOWLEDGEMENTS

I really appreciate Dr. Vitor Trindade, my dissertation advisor, for his guidance through this dissertation and for his intellectual and precious guidance. I learned many academic, professional, and personal things from him. Many thanks to my wonderful committee members; Dr. Shawn Ni, Dr. Xinghe Wang, Dr. Gunjan Sharma, and Dr. Cooper Drury gave me valuable discussions and encouragements. I appreciate Ms. Lynne Riddell the graduate administrative assistant for her precious helps. I also appreciate Dr. Inbong Kang, Steven Pleydle, Patty Buxton, Kyle Bosh, Dan Kowalski, and my best friend Dr. Inkyu Kim, and all the members in the Ways and Means Committee, New York State Assembly and all the members in the Legislative Research and Legislative Budget Office, State of Missouri. I also appreciate the writing center of University of Missouri.

My wholehearted appreciation should go to my family for their endless love and support. More than anyone else, I would like to express my deepest and wholehearted thanks to my wife, Yun Hee Kim for her love, sacrifice, and encouragements. I am also thankful to my daughter Seo Yeon and son, Joel for their being with me. I dedicate this dissertation to God.

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THREE ESSAYS ON THE FACTOR CONTENT OF TRADE

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ABSTRACT

This dissertation investigates the factor content of trade. This dissertation consists of three chapters that explain the factor content of trade with different methodologies.

The first chapter is Demand Effects in International Trade. We supplement prevalent international trade theory based on supply-side and extend the Heckscher-Ohlin-Vanek model in a new direction by incorporating demand-side consideration. These have been important in the "lore" of economics but not in economics research practice. We focus on aggregate demand differences across different countries that are induced by inequality in the presence of nonhomothetic preferences. We have constructed a new rich dataset that has information on consumption, trade, and factor usage for 32 countries across 45 industries that span the whole economy, for a year circa 2000. We fit the data for different types of preference assumptions, which allows us estimate preference parameters. We then use these results, plus our new demand-side methodology, to compare the relative importance of the supply-side and the demand-side in accounting for global factor trade.

The second chapter, has the title the Relevance of Trade Costs for the Factor Content of Trade: A Comparison of the Trans-Atlantic and the Intra-European Trade, extends the original Heckscher-Ohlin-Vanek (HOV) model in a modified direction, with a consideration of the pair-wise HOV model. Moreover, the original HOV model and the pair-wise HOV model both assume that there are no trade costs. This chapter studies the

relevance of trade costs by comparing the fit of the factor content methodology for the trans-Atlantic trade (that is, trade between the United States and several European countries), and the purely intra-European trade (that is, trade among the largest five European economies). This chapter also examines trade data that includes Australia and Canada. Note by using the trans-Atlantic countries with Australia and Canada, this chapter argues that the trans-Atlantic trade with Australia and Canada has higher trade costs than the intra-European trade. The sign test performs well without major amendments, but simply by restricting trade to the intra-European trade. The evidence presented in this chapter is at least suggestive that trade costs may play a very significant role in trade, and therefore in the calculation of the factor content of trade.

The third chapter is the Factor Content of Trade with Trade Costs. This chapter expands upon the original HOV model by considering trade costs. It deduces the original HOV model with trade costs and compares the importance of the original HOV model with and without trade costs. It does so by including trade costs directly in the technology matrix, where the working assumption is that the trade costs are located in the original country. Additionally, this chapter includes trade costs directly in the vector of the net exports. This chapter concludes that the original HOV model with trade costs achieves better results than the model without trade costs using the data constructed for the purpose of this chapter. These test results show that trade costs play an important role in explaining the factor content of trade.

Chapter 1

Demand Effects in International Trade

I. Introduction

In a line of research that extends back to Vassily Leontieff's (1953) seminal study of United States trade in factor services, economists have long been interested in using the "factor content" methodology to test the factor proportions model of international trade. This methodology requires calculating the amounts of each factor that are embodied in a country's trade and then comparing them to theoretically-derived predictions, which will be based on the difference between the country's endowments of each factor and the average world endowment of the same factor. In the decades since Leontieff's work, this line of research has threaded through many twists and turns, with spectacular failures followed by no less spectacular successes. Starting with Leontieff's surprising failure to demonstrate that the United States is a net exporter of capital services, the story runs through Edward Leamer's (1980) proof that the test proposed by Leontieff was the wrong one and Leamer's derivation of the theoretically correct test. However, even after Leamer's path breaking research, both Bowen, Leamer and Sveikauskas (1987) and Daniel Trefler (1993) essentially confirmed Leontieff's findings. Importantly, Trefler (1995) concluded that technological differences across different countries can add predictive success to the empirics. Donald Davis and David Weinstein (2001a) amend the standard multi-good factor proportions model of international trade model in various ways, and argue that such an amended model can largely account for the observed factor content of trade in a sample of developed countries.

Crucially, these recent successes all rely on "supply-side" models for the reasons why countries trade. To see what we mean, and what a "demand-side" approach would look like, note that a country's aggregate exports of a good are trivially equal to its aggregate supply minus its aggregate demand for that good. Therefore the casual observer of the theory might expect to see some explanations for the structure of trade that are based on the demand side, just as she observes some explanations that are based on the supply side. This casual observer would be well-justified in forming her expectations. She would also be remarkably wrong! In fact, there is a clear and strong bias in classical trade theory towards supply-side explanations,[1] a bias that naturally propagates into most empirical application of trade theory.

There are at least three reasons to take demand considerations seriously, especially in accounting for the structure of foreign trade in factor services. First, while the theoretical preference for supply-side explanations may in fact reflect how the world works, we shall never find out it unless if we test that explanation against appropriate alternatives. In other words, even the *negative* result that the demand side does not matter (or does not matter much) for international trade would be a useful result to have.

Second, even within the narrow confines of the factor proportions model, the only way to sweep demand effects away is by assuming that tastes are homothetic, which (with the added assumption that they are identical across different countries and different people) is the only way to neutralize all demand-side determinants of trade. But the assumption of homotheticity is empirically untenable. Even if we restrict ourselves to the evidence provided by international trade studies, the list is already long: see, among others, Thursby and Thursby (1987), Hunter and Markusen (1988), Hunter (1991), Francois and Kaplan (1996) and Dalgin, Trindade and Mitra (2007), in all of which

[1] It is important to mention the single most important exception: the work of Markusen (1986), who explicitly allows demand considerations as part of his "eclectic" explanations for the volume of trade. The adjective itself is revelatory of how much demand-side considerations have been absent from mainstream explanations of trade. A more recent contribution is Mitra and Trindade (2005).

homotheticity is rejected. For example, Hunter and Markusen (1988) show that income-expansion paths intercept the axis for at least one of the goods (in consumption space) significantly away from zero. This shows that people consume some goods before consumption of other goods even starts, a violation of homotheticity. Furthermore, both Francois and Kaplan (1996) and Dalgin et al. (2007) find that income distribution is a strong indicator of trade flows, which would not happen if tastes were homothetic. Hunter (1991) builds on Hunter and Markusen (1988) and concludes that "non-homothetic preferences significantly contribute to trade flows. Approximately one quarter of the volume of inter-industry trade flows is caused by non-homothetic preferences."

The assumption of homotheticity is also rejected in by the consumption literature. In the words of Deaton (1992, p. 9), "the supposition that there are neither luxuries nor necessities contradicts both common sense and more than a hundred years of empirical research." Okubo (2008) uses the data in Ogaki and Reinhart (1998), and finds that the latter's assumption of homotheticity over durable and non-durable goods is strongly rejected. Moving from consumption to financial literature, Aït-Sahalia, Parker and Yogo (2004) find that using nonhomothetic preferences is useful in explaining the equity risk premium puzzle. In particular, they take into account that stock holders are on average richer than the general population and therefore their consumption patterns of luxuries are much more responsive than those of necessities, as returns change.

Third, casual observation suggests that tastes may be quite different across different cultures. It certainly does not seem the case, for example, that the Japanese have similar consumption patterns as West Europeans of the same approximate income level. This might for example explain why rice and tea may play a major role in Japan's trade (including the need to protect it), with coffee and wine playing that role in Europe's trade. In this way, then, differences in tastes as an explanation of trade flows are an example of those stories that we tell to our undergraduates but that we fail to take seriously as researchers.

In this chapter, we accept from the outset that consumer preferences may be non-homothetic, and we rederive the factor content of trade under that assumption. In doing so, we allow the data to actually dictate the best fit for preferences, and in particular we allow for preferences to be homothetic. The methodology consists, in its essence, of assuming a shape for consumers' income-expansion paths, and deriving the theoretical predictions for the factor content of trade based on that shape. This therefore imposes a structure on the estimation. However, instead of simply assuming an income-expansion path that is a straight line from the origin, as previous research assumes, we allow that assumption to be relaxed.[2] As a first step we begin by reproducing Davis and Weinstein's (2001a) first set of results under homothetic assumptions.[3] In our second step, we assume that tastes are non-homothetic, while keeping the assumption that they are identical across countries.[4] We estimate a system of equations similar to Hunter and Markusen's (1988) linear expenditure system for 32 countries and 45 industries around the year 2000, after which we have enough information to calculate the predicted factor content of trade and compare it with the actual factor content of trade of each country.

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[2] We point out that this is a simple (and in our opinion elegant) procedure. One common misperception is that since some demand-side theories are very simple, then no further work is needed. But that would be confusing simplicity with irrelevance! If the demand side is a major driving force of trade flows, surely we would like to measure its relative impact.

[3] Differences in sample and methodolgy will prevent an exact replication of their results.

[4] In this dissertation we restrict ourselves to quasi-homothetic tastes, which are defined by income-expansion paths that start on one of the axes at a point significantly different from zero, but that are straight lines thereafter. These are the same preferences assumed by Markusen (1986) and Hunter and Markusen (1988).

Our research is related to some recent work. Chung (2005) uses the factor content methodology, and an assumption of nonhomothetic preferences, to address the specific issue of what Trefler (1995) calls the missing trade. He uses country and factor-specific factor consumption shares to estimate equations similar to Davis and Weinstein's (2001a) different specifications, and finds that nonhomothetic preferences do not contribute to an explanation of the missing trade for total trade. However, he also tests hypotheses for tradables only, and there he finds a large contribution of nonhomotheticity. A recent important contribution is by Reimer and Hertel (2007), whose main interest is in an explanation for the apparent missing trade. They adapt one test from Davis and Weinstein (2001a) to the case of nonhomothetic tastes. However, they find that nonhomothetic preferences do not contribute a major explanation for the missing trade. Contrasting with our current approach, neither Chung (2007) nor Reimer and Hertel (2007) deduce the testing equations directly. Rather they adopt testing equations from Davis and Weinstein (2001a), changing them to reflect the nonhomothetic nature of preferences. We use a different approach in this chapter, in that we deduce testing equations from first principles. In a theoretical approach, Dinopoulos, Fujiwara and Shimomura (2007) argue for the introduction of quasi-linear preferences in the study of international trade, and find that the predicted factor content of trade with quasi-linear preferences is smaller than the predicted factor content of trade with homothetic preferences if and only if the numeraire good is capital intensive.

This chapter offers three main contributions. The first is largely methodological, in that it provides a procedure to calculate correctly the factor content of trade in the presence of more generalized preferences than previously assumed. The second contribution consists of using the methodology for an assessment of the importance of demand in trade. One last important contribution was the construction of a detailed data set that we hope will be useful to other researchers. Based on data provided by the Organization for Economic Cooperation and Development (OECD), the data set contains 32 countries, 45 industries, and two factors (labor and capital). For each country and industry we have information about factor usage, production, value-added, and trade.

II. Theory and Empirical Methodology

Our discussion suggests that theoretically predicted factor content flows will vary according to the assumptions made on preferences. To verify how much impact the assumptions from the demand side matter, we follow a two step procedure. In the first step, we create a benchmark by rederiving a model of the factor content that ignores all demand-side effects. That is, we retread the basic model of Trefler (1995) and Davis and Weinstein (2001a), based on Vanek's (1968) model. The second step will relax successive layers of assumptions on preferences, while in order to control for the supply side we stay within the most simplistic version of the factor proportions model. Thus, we assume throughout that preferences are identical across countries, all countries share identical technologies, markets are competitive, there are no trade costs, all factors are fully employed and all countries lie within the same "cone if diversification."[5] These

[5] We emphasize that we do this to simplify the supply side of the analysis, and in order to isolate the possible demand-side effects. For example, see Schott (2003) for evidence that different countries may lie on multiple cones.

assumptions imply that techniques of production are identical and ensure factor price equalization.

II.1. *Homothetic Preferences*

Let us assume that there are C countries, G goods and H factors of production.[6] With the standard assumptions of the factor proportions model as stated above, and with homothetic preferences, each country's consumption is proportional to world consumption, with the proportion given by $s^c = (I^c - TB^c)/I^w$, where I^c is country c's Gross Domestic Product (GDP), $I^w = \sum_c I^c$ is the world's GDP, and TB^c is country c's trade balance. In words, s^c is country c's share of world income, corrected by the trade balance to obtain its share of the world's consumption. Writing the vectors of final demand for country c and for the world as $\mathbf{D^c}$ and $\mathbf{D^w}$, respectively, homotheticity implies $\mathbf{D^c} = s^c\mathbf{D^w}$. Because world demand equals world supply, we can write equivalently:

$$\mathbf{D^c} = s^c\mathbf{Y^w}, \tag{1-1}$$

where $\mathbf{Y^w}$ is the world vector of final world output. We write country c's final goods export vector as $\mathbf{T^c} = \mathbf{Y^c} - \mathbf{D^c}$, where $\mathbf{Y^c}$ is country c's final output vector (implying that $\mathbf{Y^w} \equiv \sum_c \mathbf{Y^c}$). We shall also use country c's total factor input matrix, denoted by $\mathbf{B^c}$. This is distinguished from the direct factor input matrix (which we call $\mathbf{F^c}$), in that $\mathbf{B^c}$ accounts for all of the factors embodied in the production of a good, including those that are embodied indirectly through intermediate inputs, through the intermediate inputs of the intermediate inputs, and so on. We describe in the data section and in the data appendix how we use input-output tables to construct a matrix $\mathbf{B^c}$ for *each* country c.

[6] The letter F will be reserved for the factor content of trade.

We will then deduce a testing hypothesis that will be very similar to Trefler's (1995) test with Hicks-neutral productivity differences, and to Davis and Weinstein's (2001a) third hypothesis. Specifically, we assume that the matrices $\mathbf{B^c}$ for the several countries differ in two ways only: all factors in country *c* are shifted by an "efficiency" factor δ_c; and matrix $\mathbf{B^c}$ may be measured with error. Thus, suppose that we have the elements B_{fi}^c of matrix $\mathbf{B^c}$, where the index *c* denotes the country, *f* denotes the factor, and *i* denotes the industry. We then estimate the following equation:

$$\ln B_{fi}^c = \theta^c + \beta_{fi} + \varepsilon_{fi}^c \,, \tag{1-2}$$

Equation (1-2) implies that $B_{fi}^c = e^{\theta^c} e^{\beta_{fi}} e^{\varepsilon_{fi}^c}$, where θ^c and β_{fi} are parameters to be estimated, and ε_{fi}^c is the measurement error. This allows us to define $\exp(\theta^c) \equiv \delta_c$ as the Hicks-neutral technology shift for country *c*. We choose the omitted dummy to be the US's, that is, we normalize the technology shift of the United States to be one. The larger δ_c is, the higher the unit total factor requirements of the country are, and therefore the lower the productivity of the country is. We interpret $\exp(\beta_{fi}) \equiv b_{fi}$ as the element of the international reference matrix, denoted as **B**. The fitted elements for country *c* are $\tilde{B}_{fi}^c \equiv \delta_c b_{fi}$, and they form a matrix that we denote by $\tilde{\mathbf{B}}^c (\equiv \delta_c \mathbf{B})$. It has two parts: the country's technology factor δ_c, and the estimated international total factor input matrix **B** (which is of course also the United States' total factor input matrix).

We can also define the vector $\mathbf{V}^c$ whose element V_f^c is country *c*'s endowment of factor *f*. Given full employment of factors, this is also the total *usage* of factor *f* in country *c*, and in particular $\mathbf{V}^c \equiv \tilde{\mathbf{B}}^c \mathbf{Y}^c$, where the right-hand side represents the total factor usage to produce final output $\mathbf{Y}^c$.

Premultiplying the trade vector $\mathbf{T}^{\mathrm{c}}$ by **B,** and using equation (1-1), we obtain: $\mathrm{BT^c} = \mathrm{BY^c} - s^c\mathrm{BY^w} = \widetilde{\mathrm{B}}^{\mathrm{c}}\mathrm{Y^c}/\delta_c - s^c \sum_{\mathrm{c}'} \widetilde{\mathrm{B}}^{\mathrm{c}'}\mathrm{Y}^{\mathrm{c}'}/\delta_{\mathrm{c}'} = \mathrm{V^c}/\delta_c - s^c \sum_{\mathrm{c}'} \mathrm{V}^{\mathrm{c}'}/\delta_{\mathrm{c}'}$, which yields our first testing hypothesis:

$$\mathrm{BT^c} = \mathrm{V^{cE}} - s^c\mathrm{V^{wE}}\,, \qquad \text{(H1)}$$

where $\mathbf{V}^{cE}$ ($\equiv \widetilde{\mathrm{B}}^{\mathrm{c}}\mathrm{Y^c}/\delta_c = \mathrm{V^c}/\delta_c$) is country *c*'s endowment vector adjusted by its efficiency factor δ_{c}, and therefore can be interpreted as the endowment vector measured in efficiency units. Also, $\mathbf{V}^{wE}$ ($\equiv \sum_{c'=1}^{C} \mathrm{V}^{\mathrm{c}'\mathrm{E}} = \sum_{c'=1}^{C} \mathrm{V}^{\mathrm{c}'}/\delta_{c'}$) is the world's endowment vector in efficiency units.[7] Equation (H1) is equivalent to Trefler's (1995) equation (4) and to Davis and Weinstein's (2001a) (T3) specification, and it will serve as our benchmark for comparison with the nonhomothetic preferences model. In equation (H1), the left-hand side is the *measured* factor content of trade, while the right-hand side is the *predicted* factor content of trade, as yielded by the theory. We think of the theoretical prediction as the "misalignment" between a country's factor endowments and what its share of the world's factor endowments would be if it were an average country. Suppose for example that country *c* is capital-abundant relative to the rest of the world, which is reflected with a plus sign on the row for capital on the right-hand side. To obtain a plus sign on the same row on the left-hand side, the country must be a net exporter of goods that utilize capital intensively: such goods have relatively large numbers on the capital row in matrix **B**, which when combined with the plus signs for the same goods in vector $\mathbf{T}^{\mathrm{c}}$ tend to yield a positive sign overall in the row for capital.

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[7] Thus, factor endowments in less efficient (high δ_c) countries are smaller when expressed in efficiency units. Trefler (1995) explains how this helps in solving the "endowments paradox," that is, the fact that less developed countries seem to be abundant in all factors, while developed countries seem to be scarce in all factors. The key is that less developed countries are not so abundant in the efficiency-adjusted factors.

The model above is the simplest version of the Heckscher-Ohlin-Vanek theory. It tends to perform badly, and both Trefler and Davis and Weinstein introduce a series of modifications before they get hypotheses that perform relatively well. However, we shall not pursue such modifications here. Rather, we maintain throughout the most basic supply-side assumptions, and instead relax the demand-side assumptions, checking how much of a contribution the demand side provides to fit the model. We do this in order not to confuse the demand-side explanations and the supply-side explanations. In particular, we maintain throughout the hypothesis that production techniques are the same across all countries. When there are different production techniques, the problem is complicated by the fact that when there are traded inputs, the researcher must trace each input back to its country of origin. See the pioneer studies by Reimer (2006) and Trefler and Zhu (2007), who work out the correct specification in that case.

II.2. *Non-homothetic Preferences*

So far this has been a supply story: a country's inelastic supply of factors is compared with the world's supply, which determines how much of each good the country produces and therefore, since all consumers choose consumption bundles proportional to each other, how much of each good the country trades. This intuition has been quite beneficial to previous studies, as neutralizing any demand differences accomplishes a radical simplification in the testing equation. The key neutralization step can be seen in equation (1-1), which "translates" demand into supply. But such a translation requires homothetic and identical tastes, a hypothesis that lacks support in the data, as we argued before.

In our departure from the established literature of the factor content of trade, we now turn to a consideration of the special case of nonhomothetic preferences in which preferences are actually quasi-homothetic. If there were only two goods, *X* and *Y*, individual consumers' income-expansion paths with quasi-homothetic preferences would look as in Figure 1.1.[8]

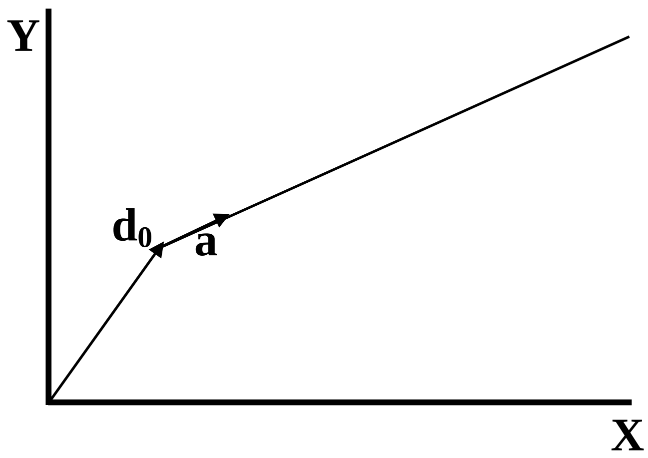

Figure 1.1: Income-expansion Path with Quasi-homothetic Preferences

Such an income expansion path can be rationalized by assuming that consumers have a "subsistence consumption bundle," the vector $\mathbf{d_0}$, beyond which consumption is steered towards more luxurious goods, in the direction of vector **a**. Thus, $\mathbf{d_0}$ could be weighted toward food and other necessities for survival, and **a** toward nonessential goods such as air transport, entertainment, or education. Thus, with quasi-homothetic preferences, preferences become essentially homothetic beyond the subsistence point, in that all additional consumption is proportional to vector **a**. Assuming that all consumers can afford the subsistence consumption $\mathbf{d_0}$, the demand by a consumer with income *w* is:

[8] The income-expansion path is the locus of successive consumption bundles chosen by consumers as their incomes rise. The one presented in the figure is slightly more general than, but otherwise similar to, Hunter and Markusen's (1988).

$$\mathbf{d} = \mathbf{d}_0 + (w - \mathbf{p}\cdot\mathbf{d}_0)\mathbf{a}\,, \tag{1-3}$$

where $\mathbf{p}$ is the vector of goods prices and a dot denotes the inner product. We will call $\mathbf{p.d_0}$ the "subsistence income" and w-$\mathbf{p.d_0}$ the "excess income," just as we call $\mathbf{d_0}$ the subsistence consumption and will call (w-$\mathbf{p.d_0}$)$\mathbf{a}$ the "excess consumption." [9]

Let us denote the population in country c by n^c, and country c's aggregate excess consumption by $\widetilde{\mathrm{D}}^{\mathrm{c}} \equiv \mathrm{D}^{\mathrm{c}} - n^c\mathbf{d}_0$.[10] We can add $\mathrm{D}^{\mathrm{c}} = n^c\mathbf{d}_0 + \widetilde{\mathrm{D}}^{\mathrm{c}}$, to obtain the world aggregate demand: $\mathrm{D}^{\mathrm{w}} = \sum_{c=1}^{C}\left(n^c\mathbf{d}_0 + \widetilde{\mathrm{D}}^{\mathrm{c}}\right) = n^w\mathbf{d}_0 + \widetilde{\mathrm{D}}^{\mathrm{w}}$, where $\widetilde{\mathrm{D}}^{\mathrm{w}} \equiv \sum_{c=1}^{C}\widetilde{\mathrm{D}}^{\mathrm{c}}$ is the world's excess consumption and n^w is world population. Let us also define $\tilde{I}^c \equiv I^c - TB^c - n^c\mathbf{p}\cdot\mathbf{d}_0$ and $\tilde{I}^w = \sum_{c=1}^{C}\tilde{I}^c$, which can be thought of as country c's and the world's excess income adjusted for trade balances, respectively. Then, country c's share of the world's excess consumption can be written as $\tilde{s}^c \equiv \tilde{I}^c/\tilde{I}^w$. Since all consumption beyond $\mathbf{d}_0$ can be thought of as homothetic, any variables with tildes (the excess variables) are proportional to each other, and in particular $\widetilde{\mathrm{D}}^{\mathrm{c}} = \tilde{s}^c\widetilde{\mathrm{D}}^{\mathrm{w}}$.[11] We can now premultiply the trade vector by the matrix of total factor inputs of the reference country, as in the previous sub-section, obtaining: $\mathrm{BT}^{\mathrm{c}} = \mathrm{B}(\mathrm{Y}^{\mathrm{c}} - \mathrm{D}^{\mathrm{c}}) = \mathrm{B}(\mathrm{Y}^{\mathrm{c}} - n^c\mathbf{d}_0 - \widetilde{\mathrm{D}}^{\mathrm{c}})$, where we have separated the consumption vector into the subsistence part and the excess part. Substituting from above and noting that the production side will yield the same as in the previous sub-section (that is, $\mathrm{BY}^{\mathrm{c}} = \mathrm{V}^{\mathrm{cE}}$), we get $\mathrm{BT}^{\mathrm{c}} = \mathrm{V}^{\mathrm{cE}} - n^c\mathrm{B}\mathbf{d}_0 - \tilde{s}^c\mathrm{B}\widetilde{\mathrm{D}}^{\mathrm{w}}$.

[9] Hunter and Markusen (1988) rationalize the income expansion path of equation (1-3) with the aid of Stone-Geary preferences, that is: $U(c_1 \ldots c_g \ldots c_G) = \prod_{g=1}^{G}(c_g - d_{0g})^{\beta_g}$, where c_g is consumption of good g and the β_g are taste parameters that add to one. It is easy to see that consumption of good g is then given by $c_g = d_{0g} + \beta_g(w - \sum p_j d_{0j})/p_g$, which is similar to equation (1-3). The income-expansion path of figure 1 is more general in that it only requires two things: that there is a subsistence consumption requirement $\mathbf{d_0}$; and that preferences beyond the subsistence consumption requirement are homothetic.

[10] We shall use lower-case for individual variables, and upper-case for aggregate variables. Any variables on the demand-side with a tilde always refer to excess consumption, excess income, etc.

[11] Again, this can be shown directly from the underlying preference primitives. However, it is also clear from the income-expansion path (see Figure 1.1).

Importantly, because of the separation of demand into two components, $n^c\mathbf{d}_0$ and $\tilde{s}^c\widetilde{\mathbf{D}}^{\mathrm{w}}$, we can no longer make either component of demand equal to some trivial expression of the world's supply. Instead, the world's subsistence consumption (and hence the world's excess consumption) will have to be *estimated*. We can further transform the last expression as follows: $\mathbf{BT}^{\mathrm{c}} = \mathbf{V}^{\mathrm{cE}} - n^c\mathbf{Bd}_0 - \tilde{s}^c\mathbf{B}(\mathbf{D}^{\mathrm{w}} - n^w\mathbf{d}_0)$. Using as before $\mathbf{BD}^{\mathrm{w}} = \mathbf{BY}^{\mathrm{w}} = \sum_{c'} \widetilde{\mathbf{B}}^{c'}\mathbf{Y}^{c'}/\delta_{c'} = \sum_{c'} \mathbf{V}^{c'}/\delta_{c'} = \mathbf{V}^{\mathrm{wE}}$, we obtain our second testing equation:

$$\mathbf{BT}^{\mathrm{c}} = \mathbf{V}^{\mathrm{cE}} - \tilde{s}^c\mathbf{V}^{\mathrm{wE}} + \mathbf{Bd}_0 n^w(\tilde{s}^c - n^c/n^w). \qquad \text{(H2)}$$

The left-hand side is the measured factor content of trade, and it is the same as in hypothesis (H1). The right-hand side is the predicted factor content of trade, the first half of which ($\mathbf{V}^{\mathrm{cE}} - \tilde{s}^c\mathbf{V}^{\mathrm{wE}}$) looks almost identical to (H1), except that it uses the country's share of the world's *excess* consumption, not total consumption. This part is due to the homothetic nature of quasi-homothetic preferences beyond subsistence consumption. The second half of the predicted factor content of trade is the correction introduced by the subsistence consumption vector $\mathbf{d}_0$. We argued intuitively in the previous subsection that the predicted factor content of trade is the result of the mismatch between a country's factor endowments and the world's factor endowments. When preferences are quasi-homothetic, we see an additional type of mismatch. Note that the term $\mathbf{Bd}_0 n^w(\tilde{s}^c - n^c/n^w)$ measures the factor utilization to produce the world's aggregate subsistence consumption, multiplied by $(\tilde{s}^c - n^c/n^w)$. We can think of this as representing the difference between country *c*'s subsistence consumption level and what it would be if the country fit exactly with the world's average. Suppose that country *c* is an "average" country of the world (i.e., in income per capita), in that its share of the world's excess consumption is proportional to population, that is, $\tilde{s}^c = n^c/n^w$. Then the second half on the right-side of equation (H2) would vanish. By contrast, a country with a very high income per capita will have a low proportion of aggregate subsistence consumption, resulting in $\tilde{s}^c > n^c/n^W$. If for example the subsistence consumption vector $\mathbf{d}_0$ is labor-intensive, then this country's exports of labor services should be higher than what the standard model would otherwise predict, the difference being explained by the fact that it needs relatively little subsistence consumption, in proportion to its income. Note that in this case $\mathbf{Bd}_0$ in (H2) would be multiplied by a positive number. Since we just assumed that $\mathbf{d}_0$ is more labor-intensive than the average consumption vector, the predicted factor content of trade is corrected upwards for labor services. Thus, the predicted content of trade must be corrected in order to take into account that poorer people consume relatively labor-intensive goods, and richer people consume relatively capital-intensive goods. For the correction to be significant, therefore, two things need to be in place: persons with high incomes and persons with low incomes have very different consumption patterns; *and* that the factor intensities of their consumption bundles are very different.

To test (H2) we need the vector $\mathbf{d_0}$ besides all the data used for (H1). Fortunately the data allow us to estimate $\mathbf{d_0}$. Writing equation (1-3) for good i, and multiplying it by the price of that good p_i, yields:

$$p_i d_i^c = p_i d_{0i} + p_i a_i \left(w^c - \sum_{g=1}^{G} p_g d_{0g} \right). \tag{1-4}$$

where d_i^c, d_{0i}, and a_i denote the i^{th} elements of vectors $\mathbf{d}^c$, $\mathbf{d}_0$, and $\mathbf{a}$, respectively. We can estimate the parameters $p_i d_{0i}$ and $p_i a_i$ above with the aid of the regressions:

$$p_i d_i^c = \alpha_i + \beta_i w^c + \varepsilon_i^c, \tag{1-5}$$

where d_i^c and w^c are reinterpreted to be per capita variables.[12] These regressions are run separately for each good i, across all countries. The disturbance term ε_i^c represents further deviations from homotheticity that are not related to income per capita, or are simply measurement error. Comparison between estimation (1-5) and the theoretical equation (1-4) allows the identification $\beta_i = p_i a_i$, which then allows the identification of $p_i d_{0i}$ from:

$$\alpha_i = p_i d_{0i} - \beta_i \sum_{g=1}^{G} p_g d_{0g}. \tag{1-6}$$

These equations constitute a system of G linear equations in the G unknowns $p_g d_{0g}$.[13] They are easily solved as:

$$p_i d_{0i} = \alpha_i + \beta_i \left(\sum_{g=1}^{G} \alpha_g \right) \Bigg/ \left(1 - \sum_{g=1}^{G} \beta_g \right), \tag{1-7}$$

yielding the $\mathbf{d_0}$ that we need for our test (H2). Note that formally what we get is the vector with elements $p_i d_{0i}$. This is not a problem, and in fact is preferred, because all of the data used in testing (H2) are already in dollar units, not physical units.

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[12] In order to identify regression (1-5) with equation (1-4), it may seem that we are imposing the restriction that all consumers have the same income, so that each consumer's income equals income per capita. But it can be easily seen that that is not the case. All that we are imposing is that all consumers can afford the subsistence consumption bundle. Writing equation (1-4) for each consumer (indexed by m), and then adding over all consumers, yields: $\sum_{m=1}^{n^c} p_i d_{im}^c = n^c p_i d_{0i} + p_i a_i (I^c - n^c \sum_{g=1}^{G} p_g d_{0g})$. Dividing by n^c we get $p_i \sum_{m=1}^{n^c} d_{im}^c / n^c = p_i d_{0i} + p_i a_i (I^c / n^c - \sum_j p_j d_{0j})$, which is the same as equation (1-4), as long as we interpret the variables of equation (1-4) to be per capita. Crucial to this derivation is that d_{0i} does not to be indexed by m, since all consumers can afford the full subsistence bundle.

[13] Note that if preferences were homothetic, in the sense that $d_{og} = 0$ for all goods, then all the intercepts of regressions (1-5) would be zero. Hunter and Markusen (1988) use this fact for one of their tests. They estimate a linear expenditure system for demand in thirty four countries across eleven industries, and in one of their models estimate a system such as (1-5), as well as a similar system but with the restriction that $\alpha_i = 0$. A chi-squared test between the two models rejects the most restrictive model (and thus homotheticity) at the 1% significance level. We shall perform a similar test.

In order to test hypothesis (H2) we will additionally use data on each country's populations and incomes. Finally we will need to calculate $\tilde{s}^c$ which can be readily done by definition once we have the $p_i d_{0i}$, since:

$$\tilde{s}^c \equiv (I^c - n^c \mathbf{p}{\cdot}\mathbf{d}_0) \Big/ \sum_{c=1}^{C} (I^c - n^c \mathbf{p}{\cdot}\mathbf{d}_0)\,. \tag{1-8}$$

III. Data

As further explained in the appendix, constructing this data set was a major undertaking, in that many problems were found in the data, especially those related to countries aggregating industries in different manners. As a result of all the procedures implemented, we can state with high degree of confidence that we possess as reliable a data set as it is possible under the constraints. The main data sources are the OECD's Input-Output Tables and Structural Analysis database. IO provides data on inter-industry flows for each country for a year around 2000. STAN has data, by country, year and industry, on production, labor and investment. There are 32 countries in IO, which accounted for about 90% of world GDP in 2000. We exclude the Russian Federation and Mexico, both of which represent less than 2% of World GDP.[14]

As mentioned, the main data problems were that for some country-industry pairs the data are all seemingly zero, which is due to the country aggregating the industry into

[14] In this, we are forced by the data. Input-Output data for Russia have not been harmonized with the ISIC classification used in IO. An IO table for Mexico is promised soon but not yet available.

another industry. We have used several information sources to impute disaggregates in those cases. See the data appendix for more details on the mechanics of data construction, and for all other problems that we addressed. One obvious choice would be to use the data constructed by Davis and Weinstein (2001a), who graciously made it available to us. We chose to construct our own dataset, for two reasons. First, we can now use data for 2000, instead of 1985. Importantly, the newer data provides industries at a more disaggregated level (45 industries versus 34 in Davis and Weinstein). It also includes many more countries (32 versus 10), including a number of important economies such as China, Brazil, and India, that were not available in Davis and Weinstein's sample.

IV. Empirical Analysis of Demand Effects

We now proceed to the empirical analysis, following the procedures described in section II. Table 1.1 shows the results of estimating equation (1-5).

Table 1.1: Regression of Demand per capita on Income per capita

IO Industry	Constant	Slope	R^2	Observations
1	142.9742***	0.0038051***	0.2097139	32
2	-15.28328	0.0023045**	0.1521457	32
3	-4.031032	0.0009563*	0.1212782	32
4	193.0664***	0.0339476***	0.8369803	32
5	80.65165**	0.0116133***	0.5446284	32
6	-1.757658	0.0013287***	0.3534426	32
7	11.96834	0.0070038***	0.6988382	32
8	9.4712	0.0065073***	0.7351128	32
9	39.12439**	0.0051365***	0.5059953	32

IO Industry	Constant	Slope	R^2	Observations
10	13.72378	0.0031796***	0.2890346	32
11	14.88692**	0.0015037***	0.4527326	32
12	6.898497	0.0012931***	0.3414043	32
13	.718209	0.000307**	0.1318374	32
14	1.374558	0.0001946*	0.0879436	32
15	14.74915	0.0047128***	0.5061247	32
16	58.66057	0.0200428***	0.7819555	32
17	-11.68477	0.0093417***	0.6270361	32
18	22.63568	0.0040878***	0.5239604	32
19	17.25413	0.0107642***	0.5853083	32
20	1.346999	0.0062071***	0.8228002	32
21	52.01612	0.0238611***	0.5941956	32
22	-42.61408	0.0059848***	0.2138726	32
23	.9135898	0.002275***	0.3768318	32
24	3.87524	0.0011259***	0.5054429	32
25	16.2567	0.0107825***	0.6851407	32
26+27+28+29	29.82466	0.011787***	0.7923978	32
30	193.5111	0.0796442***	0.773784	32
31	8.244092	0.099351***	0.8430198	32
32	43.54092	0.0335992***	0.6100405	32
33	23.24115	0.0120991***	0.6016405	32
34	-6.505804	0.0015168***	0.2356678	32
35	-.4175622	0.0041357***	0.4567848	32
36	-5.510763	0.0082493***	0.3516936	32
37	4.718791	0.013241***	0.7912711	32
38	-46.10209	0.0276621***	0.4807185	32
39	-98.49873	0.0955897***	0.915278	32
40	-1.720086	0.002692***	0.2685539	32
41	-46.44816	0.0111419***	0.5531402	32
42	1.198311	0.0019003***	0.3030404	32
43	-25.87239	0.0135057***	0.6473367	32
44	102.0238	0.074419***	0.8486514	32
45	-36.73636	0.0541422***	0.9125933	32
46	-286.0382*	0.0946093***	0.8378031	32
47	-120.487	0.0460885***	0.7546713	32
48	31.06501*	0.0007384	0.0280843	32

Note: For each industry the dependent variable is demand per capita, the independent variable is income per capita. See equation (1-5). *, **, and *** denote significant at the 10%, 5%, and 1% precision level, respectively.

Not surprisingly, income per capita is a strong determinant in most cases of consumption per capita. It also noteworthy that seven of the intercepts are significantly different from zero (and a few others are close to statistic significance), indicating non-homotheticity.

We can use equation (1-7) to calculate the imputed subsistence consumptions, which are reported on Table 1.2.[15]

Table 1.2: Subsistence Consumptions

IO Industry	Subsistence Consumption
1	153.9228
2	-8.652487
3	-1.279493
4	290.7445
5	114.0668
6	2.065433
7	32.12053
8	28.19477
9	53.90382
10	22.87238
11	19.2135
12	10.61922
13	1.601451
14	1.934494
15	28.3093
16	116.3301
17	15.19437
18	34.39753
19	48.22609
20	19.20674
21	120.6721
22	-25.39377
23	7.4596
24	7.114781
25	47.28151
26+27+28+29	63.73967

[15] A word of caution should be useful. Since many of the intercepts are estimated imprecisely, and each subsistence consumption requires *all* intercepts (see equation 1-7), these are perforce imprecisely estimated as well.

IO Industry	Subsistence Consumption
30	422.6732
31	294.109
32	140.2167
33	58.05404
34	-2.141475
35	11.48207
36	18.22506
37	42.81748
38	33.49058
39	176.5437
40	6.025698
41	-14.38934
42	6.666004
43	12.98774
44	316.1513
45	119.0482
46	-13.8166
47	12.1244
48	33.18968

Table 1.3 lists several tests that are based on hypotheses (H1) and (H2). For each hypothesis, we have preformed the same tests as Davis and Weinstein (2001a). For example, for hypothesis (H1), the slope test is the result of running equation (H1) above as a regression, and comparing the slope of that regression to the theoretical slope of one. The sign test compares the sign of the measured factor content of trade (left-hand side) with the sign of the predicted factor content of trade (right-hand side). Finally the variance ratio test is the ratio between the variance of the measured and the predicted factor contents of trade. For comparison we also list the corresponding results from Davis and Weinstein (2001a), that is, their hypothesis (T3). For (H2) we have also listed the result obtained by excluding three less developed countries: China, Indonesia and India.

Table 1.3: Results based on hypotheses (H1) and (H2)

	H1	H2	H2	Davis and Weinstein (T3)
Slope Test	0.0101***	-0.0000213***	-0.0000476***	-0.05
Standard Error	0.0022	0.00000407	0.00000496	0.02
R^2	0.25	0.302	0.617	0.31
Sign Test	0.56	0.625	0.655	0.50
Variance Ratio Test	0.021	0.0000384	0.0000625	0.07
Observations	64	64	58	22

Note: *** denotes significant at the 1% precision level.

As can be seen from the table the results of assuming non-homothetic preferences do change the outcomes of the various tests. We note that none of the hypotheses delivers the expected result of one for the slope test, which of course was already true for Davis and Weinstein (2001a). But we get a different conclusion if we turn our attention to the sign test. Davis and Weinstein (2001a) obtained a sign test of 0.50, which is no better than a coin toss! Our results, by assuming non-homotheticity in the simplest possible way, provide a better sign test, in one sample in which the signs align 65% of the time. We should also point out that the simple regression (H2) evidences a better fit, with an R2 of 0.617, versus Davis and Weinstein's (2001a) 0.31. However, the variance ratio test seems to perform *worse* than Davis and Weinstein (2001a). Overall, these results represent some weak evidence that the demand side may matter for trade. We further discuss these results in the concluding section.

V. Conclusions

This chapter has undertaken the research agenda of trying to assess the importance of the demand side on international trade. We began by asserting that the assumption of homothetic preferences is not empirically tenable. We derived the predicted factor content of trade under the assumption that preferences may be non-homothetic, and then compared it with the measured factor content of trade. We concluded that several tests yield different messages about the impact of the demand side on trade.

The best support that we could find for the notion that the demand side matters substantially is that the signs of the predicted factor content and the measured factor content align themselves better (62% or 66%, instead of 58% of the time) if we calculate a subsistence consumption pattern for all countries of the world and use it to define non-homothetic preferences. However, the other tests that we have used hardly perform any better than if we assume homothetic preferences, which may be excellent news for the current state of research in trade, in that they would imply that the demand side matters relatively little and therefore two hundred years of empirical research in international trade is still allowed to stand! Evidently more research is needed in this important topic.

Chapter 2

The Relevance of Trade Costs for the Factor Content of Trade: A Comparison of the Trans-Atlantic and the Intra-European Trade

I. Introduction

In this chapter, the hypothesis concerns how the consideration of the existence of trade costs will help to explain the factor content of trade better than a model that ignores trade costs. In other words, without trade costs, the factor content of trade cannot fully be explained. This chapter uses the pair-wise Heckscher-Ohlin-Vanek (HOV) model, a modified model of the strict HOV model. This chapter selects three types of trade to explain the bilateral trade by regions. The three types considered are as follows: the trans-Atlantic trade (between the United States and European countries); the intra-European trade (among European countries only); and the trans-Atlantic trade that also includes Australia and Canada. We argue that, compared with the trans-Atlantic trade, the intra-European trade will have lower trade costs, but the trans-Atlantic trade with Australia and Canada will have higher trade costs. This chapter draws on research from Davis and Weinstein (2001a)'s study of 1985 trade data. This chapter makes the argument that trade costs are an important consideration for the factor content of trade methodology.

II. Literature Review

The original Heckscher-Ohlin (HO) model is a two-country, two-factor, and two-good model. Vanek (1968) introduces multi-factors and multi-goods into the original HO model, which became the Heckscher–Ohlin–Vanek (HOV) model. To begin with, we need to comprehend the HOV model to know what the pair-wise HOV model is. The

Heckscher-Ohlin model argues that two countries' different ratios of their endowment in factors are the force that creates trade. If two countries have different endowment ratios, they will trade with each other. Let us assume there are two countries (home and foreign), two goods (good one and good two), and two factors (capital and labor). We assume that producers and consumers behave under perfect competition. In addition, the two countries' technologies are the same and all firms produce under constant returns to scale. It is important to note that the factor content of trade methodology originally assumes that there are no trade costs.

Many trade economists attempted to verify empirically whether the HOV model works in the real world (Feenstra (2003), p.31). Leamer (1980) argues that Leontief's (1953) objects of comparison are not valid. Leontief (1953) compares the factor content of exports with the factor content of imports, and arrives at the apparent "Leontieff paradox" that the United States seemed to be a labor-abundant country. By contrast, Leamer (1980) compares the factor content of consumption with the factor content of net exports. In his paper, Leamer tests the factor content of trade, defined as $F \equiv BT$, where F is the vector of net factor (capital and labor) exports, B is the total factor usage matrix, and T is the net export vector. He uses the same 1947 data from the United States that Leontief used, trying to replicate Leontief's findings, but with a different methodology. With the new methodology, Leamer (1980) finds that the United States is, in fact, a capital-abundant country.

Markusen's (1986) important theoretical study investigates how the per capita income differences between the North, the rich portion of the world, and the South, the poor portion of the world, can affect trade flows. Both Markusen's (1986) and Deardorff's

(1998) theoretical articles provide many insights and assume non-homothetic tastes as well. However, they do not provide additional developments about the factor content of trade.

Bowen et al. (1987) premises that the methodology that measured factor content of trade should be the same as the predicted factor content of trade. Their empirical results could be interpreted as being able to explain the factor content of trade, because they explain the factor content of trade by more than 50% in their sign test.

Trefler's (1993) paper, another important study, tries to test the factor content of trade with strict factor price equalization. However, for the most part, he is not able to fit the model to the data. While Trefler's paper concentrates on supply side considerations, he also extends his theory with demand side considerations, which this dissertation addressed in chapter 1. Trefler does many tests on the factor content of trade as well as the bias in consumption. By putting consumption in his model, he diminishes the value of predicted factor content of trade. Two of Trefler's other attempts, however, are more successful in fitting the predicted and the measured factor content of trade. His model with the Hicks-neutral technological differences has a better result than the standard HOV model that assumes identical technologies across countries. Furthermore, when he used a so-called Armington assumption in his model (that is, when he assumed a home-bias in consumption), he achieves better results than with the standard HOV model that assumes that preferences are the same everywhere. More specifically, the Armington assumption is the premise that there is an imperfect substitution between home country goods and foreign country goods in consumption. The Armington assumption can be explained with the simple example that people in one country like to consume their country's products, while people in a different country prefer products from their own country. Then, one country's consumption of domestic products will be higher than predicted in the theory, which helps to explain Trefler's (1995) "missing trade," the fact that predicted factor trade is much larger than observed factor trade. Developing Bowen, Leamer, and Svikauskas's (1987) methodology and using industry data, Trefler (1995) constructs a factor requirement matrix for the United States. He identifies three factors: capital stock, labor, and land. Again, he uses 33 countries, and his test results using the standard HOV model are not good. For example, the sign test result is less than 50%.[16] To get better results, he studies modified versions of the HOV model and tries to modify the assumption of strict factor price equalization. A modified form of the factor price equalization is used when he uses the Hicks-neutral technological differences, and this modified factor price equalization explains factor trade better than the HOV model with strict factor price equalization.

Gabaix (1997) also uses a modified factor content of trade model, just as Trefler (1995) does. Using the same data as Trefler (1995), he tries to find out if one country's endowment could be an appropriate predictor in measured factor content of trade. He uses the strict HOV model and he also uses the methodology of allowing for the Hicks-neutral technological differences. His results could not explain the factor content of trade well. However, when he includes demand considerations in his methodology, he observes slightly better results.

[16] As explained in more detail in section IV of this chapter, the sign test is a test that counts the number of observations that have the same sign between the measured factor content of trade and the predicted factor content of trade. It is reported as a percentage of the observations that pass the test.

Let us examine in more detail the study by Davis and Weinstein (2001a), who also use the Heckscher-Ohlin-Vanek model to fit trade data. They use trade data with 10 OECD countries, plus a "Rest of the World" aggregate country. The 10 OECD countries are Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, the United Kingdom, and the United States. The Rest of the World is an aggregate of Argentina, Austria, Belgium, Finland, India, Indonesia, Ireland, Israel, R.O. Korea, Mexico, New Zealand, Norway, Philippines, Portugal, Singapore, South Africa, Spain, Sweden, Thailand, and Turkey. They amend the model in several ways to explain the factor content of trade. They use two factors: capital and labor. Among the many amendments to the traditional HOV model, they have introduced non-traded goods and trade costs using the gravity model of international trade. In their final specification (the model with most amendments), Davis and Weinstein (2001a) assume a gravity-based demand determination of demand,[17] and thus generate the factor content of consumption incorporating derived fitted values for import demand and complementary measures of one country's own demand. More specifically, they derive the factor content of trade as follows:

$$\hat{B}^{cH}Y^{cT} - \left[\hat{B}^{cH}D^{cc} + \sum_{c'\neq c}\hat{B}^{c'H}M^{cc'}\right] = V^{c} - \left[\hat{B}^{cH}\hat{D}^{cc} + \sum_{c\prime\neq c}\hat{B}^{c'H}\hat{M}^{cc'}\right].$$

Here, $\hat{B}^{cH}$ is the technology matrix of country c with the Helpman no-Factor Price Equalization (FPE) model. Because of no-FPE, each country's capital to labor ratio (*K/L*) will affect all input coefficients in the technology matrix. Note that country c and country c' are different. Y^{cT} is the net output vector for country *c* and tradable goods. V^{c} stands for the endowment vector for country *c*. D^{cc} denotes the absorption by country c

[17] The gravity model studies bilateral trade flows with size of economy and distance between two countries.

produced in country *c,* and $\widehat{D}^{cc}$ means the predicted absorption by country c produced in country c. $M^{cc'}$ stands for the imports from country c to c'. $\widehat{M}^{cc'}$ denotes the predicted imports from country c to c' by fitting from a gravity-model estimation. Davis and Weinstein generate factor content of consumption incorporating derived fitted values for import demand and complementary measures of own demand.

Table 2.1 shows key specifications of Davis and Weinstein's (2001a) paper, in which production specifications are associated with different models of technology. The Hicks-neutral technical differences are shown by the equation: $B^c = \lambda^c B^\lambda$, where λ stands for country specific technology shifts. For example, if we assume that factors of the United States are two times more productive than those of Italy, we can write that: $B^{US} = 2B^{Italy}$, and therefore λ^{Italy} is 2.

Table 2.1: Key Specification of Davis and Weinstein (2001a)

Key assumption	Production Specifications	Trade specifications	
Conventional HOV with U.S. technology	$B^{US}Y^c = V^c$	T1	$B^{US}T^c = B^{US}(Y^c - D^c) = V^c - s^cV^W$
Hicks-neutral efficiency adjustment	$\hat{B}^\lambda Y^c = V^{cE}$	T3	$\hat{B}^\lambda T^c = V^{cE} - s^cV^{WE}$
Helpman no-Factor Price Equalization (FPE) model, different input ratios in all, H-NE Forces ROW production model to work	$\hat{B}^{cH}Y^c = V^c$	T5	$\hat{B}^{cH}Y^{cT} - \left[\hat{B}^{cH}D^{cc} + \sum_{c' \neq c} \hat{B}^{c'H}M^{cc'}\right] = V^c - \left[\hat{B}^{cH}\widehat{D}^{cc} + \sum_{c' \neq c} \hat{B}^{c'H}\widehat{M}^{cc'}\right]$
Add gravity-based demand determination	$\hat{B}^{cH}Y^c = V^c$	T7	$B^{cH}Y^c - \left[\hat{B}^{cH}D^{cc} + \sum_{c' \neq c} \hat{B}^{c'H}M^{cc'}\right] = [V^c - s^cV^W]^c - [V^{cN} - s^cV^{WN}]$

Notes: Hats (^) indicate fitted values from estimation of technology and absorption.
Davis and Weinstein (2001a), p. 1437.

Davis and Weinstein's (2001a) test results of above trade specifications are as follows:[18]

Table 2.2: Trade Tests from Davis and Weinstein (2001a)

	T1	T3	T5	T7
Predicted (Slope test)	-0.002	-0.05	0.43	0.82
Standard error	0.005	0.02	0.02	0.03
R^2	0.01	0.31	0.96	0.98
Sign test	0.32	0.50	0.86	0.91
Variance ratio	0.0005	0.008	0.19	0.69
Observations	22	22	22	22

Notes: Dependent variable is Measured Factor Content of Trade (MFCT). Theoretical coefficient on Predicted (the slope test), the sign test, and the variance ratio test is unity (Davis and Weinstein (2001a), p.1438).

Table 2.2 above shows that equation T7 explains the factor content of trade better than the other equations (T1, T3, and T5). This means that with all modifications in place, the HOV model explains the factor content of trade quite well.

We will now turn to the case of the pair-wise HOV model. Here, a test done by country pair is proposed by Staiger, Deardorff, and Stern (1987). Hakura (2001) studies the technological differences in production in the context of this pair-wise test, and tries to fit the data using these technological differences. Recall that in the strict HOV model, all international countries' technologies are the same. Hakura (2001) uses the Input-Output data to try to get better results with different technologies between countries. Therefore, this is a modified pair-wise HOV model, from which she obtains good results.

[18] As explained in more detail in the methodology section (section IV), the three tests that were performed were: 1) the sign test: compares the sign of the measured factor content of trade (left-hand side) with the sign of the predicted factor content of trade (right-hand side); 2) the slope test: the result of running the specification as a regression, whose theoretical slope is one; 3) the variance ratio test: the ratio between the variance of the measured and the predicted factor contents of trade.

In particular, Hakura (2001) studies European Community (EC) data[19] from the years 1970 and 1980, and shows that it is important to know from where the actual production came; the history of inputs (intermediate goods) used in making the final goods should be taken into account. Consider the example of an automobile. Its engine may have come from country *A*, the seats from country *B*, the windows from country *C*, etc. This vehicle is assembled in the United States, but its parts came from different countries.

Reimer (2006) also emphasizes the importance of intermediate goods' trade. He keeps track of final goods and intermediate goods by country to measure the factor content of trade in a more efficient way. He concludes that by failing to incorporate imported intermediate goods correctly, the predicted factor content of trade is overstated. Both Hakura (2001) and Reimer (2006) argue that the correct measure of the factor content of trade would take into account the actual factor content of each of these intermediate goods as they are produced in their own countries.

Staiger et al. (1987) study factor content of trade using data from the United States and Japan by comparing the measured factor content of trade (left-hand side of the trade specification) and the predicted factor content of trade (right-hand side of the trade specification). Relevant to this chapter, they attempt to introduce trade costs. Using protection in their model caused measured and predicted factor content of trade to be different. They point out that differences in natural resources and types of workers should be taken into account when doing research on the factor content of trade. The first concern is natural resources and their differences across countries. For example, the amount of arable land in the United States is greater than that in Japan. Staiger et al. (1987) argue that these differences in natural resources could be a possible reason why

[19] She uses four European Community countries: Belgium, France, Germany, and the Netherlands.

the sign tests are wrong. The second concern is that there exist many different types of workers. These workers are comprised of professional workers, technical workers, managerial workers, administrative workers and so on. Staiger et al. believe that the United States has more professional and administrative workers who can contribute to the multinational firms than Japan. The problem with these more diversified types of workers is that these workers' incomes are not measured perfectly, which will ultimately reflect on our ability to measure the factor content of trade. This may be the second reason why the sign tests of the factor content of trade do not perform well. Staiger et al. argue that if those two concerns can be solved, the results of sign tests would better explain the factor content of trade.

Debaere (2003) explains the factor content of trade in the context of the HOV model using bilateral data. He compares North-South factor content for countries with very different endowments. He studies the relationship between comparative factor abundance and bilateral trade between countries. His results explain the factor content of trade, especially in sign tests. Countries with different endowment ratios (*K/L*) have different factor content of trade.

Helpman (1987) predicts that countries with similar size will trade more and proves this prediction using the OECD countries. Hummels and Levinsohn (1995) revisit Helpman's tests using Helpman's data set comprised of the OECD countries and prove empirically Helpman's finding. Hummels and Levinsohn repeat their tests using non-OECD countries and again empirically prove Helpman's prediction. According to Debaere (2005), "intra-industry trade is thought not to matter" with regards to non-OECD countries (p.250). Debaere (2005) shows that bilateral trade to GDP ratios increases as a results of similarity in GDPs among the OECD country pairs. Debaere also tests Helpman's prediction with non-OECD countries and rejects the prediction. Thus, his result contradicts Hummels and Levinsohn's findings.

Finally, the paper by Choi and Krishna (2004) argues that when we assume that there are Ricardian technological differences, theoretical restrictions need to be imposed on the model. To this purpose, Choi and Krishna (2004) have used Helpman's (1994) methodology. Both Helpman (1994) and Choi and Krishna (2004) assume that all countries have the same technology.

Having described all of the different methodologies, this chapter will use the methodology that is common to Hakura (2001) and Staiger et al. (1987), along with Davis and Weinstein's 1985 data set, in order to perform three tests of the HOV model: the trans-Atlantic countries' analysis, the intra-European countries' analysis, and the trans-Atlantic countries' analysis with Australia and Canada. As discussed in the first chapter of this dissertation, the study of international trade can be divided into a production side and a consumption side, where the production side has been trade economists' main research topic. Therefore, unlike the first chapter, this chapter concentrates on the production side.

This chapter argues that the trans-Atlantic trade has higher trade costs and therefore, the factor content of trans-Atlantic trade should not be as well explained as the intra-European trade. However, many different issues (that are not studied in this chapter) may complicate that simple prediction. In particular, there is the issue of intra-industry trade, trade that exists between two countries in the same industry, and that goes both directions (imports and exports). Such trade is difficult to conform with the Heckscher-Ohlin theory and is more properly the object of the “New Trade Theory” devised by Elhanan Helpman, Paul Krugman, and others. Note that the European countries have developed rapidly since 1945, and these economic developments encourage them to trade more, including intra-industry trade. Their close proximity gives rise to a pattern where these nations trade mostly amongst themselves, and less with outside trading partners.

First, this chapter tests, the trans-Atlantic analysis using seven countries: the United States, France, Germany, Italy, the Netherlands, the UK, and Denmark. Second, this chapter tests the intra-European countries’ trade using six European countries: France, Germany, Italy, the Netherlands, the UK, and Denmark. Third, this chapter tests the trans-Atlantic trade with Australia and Canada, the United States, France, Germany, Italy, the Netherlands, the UK, Denmark, Australia, and Canada.

III. Methodology and Models

This chapter assumes that preferences are identical and homothetic across all countries; there is perfect competition; for the most part, identical technologies are shared by all countries; and there are constant returns to scale. It also assumes that factors of production are perfectly mobile in the long run across sectors, but are perfectly immobile across countries. Countries have different factor endowments, which cause them to trade. With the free and costless trade assumption, the price of traded goods will be the same. We shall assume that there is no measurement error. Davis and Weinstein’s (2001a) paper deduces a factor trade equation as follows:

$$B^{c'}T^c = B^{c'}(Y^c - D^c) = V^c - s^c V^W. \quad (2\text{-}1)$$

Here, c means country c, c' means country c' (country other than country c), and W means world. $B^{c'}$ is the total factor input matrix of country c'. To explain what the total factor input matrix is, consider the example of two factors (labor and capital) and three industries. Then, $B = \begin{bmatrix} b_{1K} & b_{2K} & b_{3K} \\ b_{1L} & b_{2L} & b_{3L} \end{bmatrix}$, where b_{ij} denotes the total quantity of input j (capital or labor, measured in dollars) to produce one dollar of good i. Note that this total factor requirement includes any factor requirement that is used in producing the intermediates that are used in the production of good i, including the intermediates that are used in producing those intermediates, and so on. To obtain equation 2-1, the following equation 2-2 is needed:

$$B^c Y^c = V^c. \quad (2\text{-}2)$$

Here, Y^c denotes the net output vector, while V^c is the endowment vector for country c. Equation 2-2 could be called full employment condition or factor market equilibrium condition. Again, let us suppose, for example, that there are three goods and two factors. Then, $Y = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix}$, where y_j is the country's output of good j, and $V = \begin{bmatrix} K \\ L \end{bmatrix}$, where K is the country's endowment of capital and L is the country's endowment of labor. Thus, in this example, and using the form of the matrix B above, equation 2-2 can be fully written out as:

$$\begin{bmatrix} b_{1K} & b_{2K} & b_{3K} \\ b_{1L} & b_{2L} & b_{3L} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} b_{1K}y_1 + b_{2K}y_2 + b_{3K}y_3 \\ b_{1L}y_1 + b_{2L}y_2 + b_{3L}y_3 \end{bmatrix} = \begin{bmatrix} K \\ L \end{bmatrix}.$$

If all countries share the same technology, all goods are produced by all countries, and there is factor price equalization, this will immediately imply that $B^{c'} = B^c$ for all c and

c'. This is because factor price equalization (along with the other assumptions) implies that all countries share the same techniques of production. The net exports vector can be written:

$$\mathrm{T^c} = \mathrm{Y^c} - \mathrm{D^c}, \tag{2-3}$$

where the consumption vector of country *c* is denoted by $\mathrm{D^c}$, assuming that consumption in country *c* is proportional to $\mathrm{Y^W}$, which would be the case under homothetic tastes. Define country *c*'s consumption share by the notation:

$$\mathrm{s^c} = \frac{\mathrm{GDP^c}}{\mathrm{GDP^W}}. \tag{2-4}$$

Then, with the assumption of homothetic tastes, the country's consumption vector will be equal to:

$$\mathrm{D^c} = \mathrm{s^c Y^W}. \tag{2-5}$$

The original HOV model is $\mathrm{F^c} \equiv \mathrm{BT^c} = \mathrm{V^c} - \mathrm{s^c V^W}$. In other words, the individual factor content of net trade (exports minus imports) in the original HOV model is denoted by $F_K^c \equiv (BT^c)_K = V_K^c - s^c V_K^W$ and $F_L^c \equiv (BT^c)_L = V_L^c - s^c V_L^W$. In this example, there are two factors: capital and labor. Country *c* is relatively abundant in factor *L* if $V_L^c / V_L^W > s^c$, and it is abundant in factor *K* if $V_K^c / V_K^W > s^c$. In this case, both F_K^c and F_L^c have positive signs. Positive signs on both F_K^c and F_L^c mean that capital and labor should both be exported. Conversely, if the signs of F_K^c and F_L^c are negative, then those two factors should be imported. In sum, the formula above gives us F_K^c, which is country *c*'s capital content of net trade and F_L^c, which is country *c*'s labor content of net trade. We will call $\mathrm{BT^c}$ the measured factor content of trade (MFCT) and $\mathrm{V^c} - \mathrm{s^c V^W}$ the predicted factor content of trade (PFCT) for the sake of convenience. The various tests of trade (explained in section IV below) consist of checking how close MFCT and PFCT are to each other. Obviously, if they are the same, the factor content of trade could be fully explained by the HOV model per Leamer's (1980) study. Leamer argues that the set of equation 2-1 "serves as a logically sound foundation for a study of trade-revealed factor abundance" (p.497).

Hakura (2001) analyzes the pair-wise HOV model like Staiger et al.'s (2001) model. Hakura studies European Community (EC) data from 1970 and 1980 respectively. With her methodology, aggregate world data does not need to be estimated for the strict HOV model. As already mentioned, this chapter will use Hakura's and Staiger et al.'s fundamental methodology.

This chapter compares the results of the pair-wise HOV model with different country groups to show that the existing trade costs fit the factor content of trade better than a model that ignores trade costs. In other words, without trade costs, factor content of trade cannot fully be explained.

Let *c* and *m* stand for two different countries and introduce the notation:

$$\mathrm{s^{cm}} = \frac{\mathrm{s^c}}{\mathrm{s^m}} = \frac{\mathrm{GDP^c}/\mathrm{GDP^W}}{\mathrm{GDP^m}/\mathrm{GDP^W}}. \qquad (2\text{-}6)$$

Why do we use s^{cm} instead of s^c in the pair-wise HOV model? We can think of two possible reasons. First reason is that the strict HOV model includes world aggregates when calculating world GDP: GDP^W . GDP^W is one component of s^c , $s^c = GDP^c/_{GDP^W}$. In total, this chapter uses nine countries;[20] there is some question about data sums representing world aggregates. In particular, the data for less developed but very large (hence important in this context) economies is either non-existent or very bad.

[20] Refer to Table 2.3.

For all of these reasons, calculation of the world aggregates is quite problematic. It is a major benefit to have a model, the pair-wise HOV model, in which world aggregates are not included. Second reason is that $s^{cm}B^cT^c$ and $s^{cm}B^mT^m$ will have about the same size, which should help with 'heteroskedasticity' issues. To explain this effect of using s^{cm}, let us assume that there are two countries, the United States and Japan, and that those two countries' expenditure levels are identical. Then, s^{cm} would be equal to one. In this case, net exports of the United States' abundant (scarce) factor to the world of services ought to be greater (less) than Japan's exports of the same abundant (scarce) factor. When expenditure levels are different, s^{cm} will not be one. In this case, "s^{cm} simply controls for the difference in country size and the same interpretations apply" (Staiger, Deardorff, and Stern (1987), p.453).

Deduction of the pair-wise HOV model is as follows:

To derive the pair-wise HOV model, apply equation 2-1 and 2-6 to two randomly chosen countries, country c and m:

$$B^cT^c - s^{cm}B^mT^m. \tag{2-7}$$

With equation 2-3, we deduce:

$$B^cT^c - s^{cm}B^mT^m = B^c(Y^c - D^c) - s^{cm}B^m(Y^m - D^m).$$

When we apply full employment condition (equation 2-2), we get:

$$= V^c - B^cD^c - s^{cm}V^m + s^{cm}B^mD^m.$$

By using equation 2-6, we get:

$$= V^c - B^cD^c - s^{cm}V^m + {}^{s^c}\!/_{s^m}\, B^mD^m.$$

When we use the assumption that preferences are identical and homothetic, we can write one country's consumption as a proportion of the world, and therefore, with equation 2-5 for country *m*, we get:

$$= V^c - B^c D^c - s^{cm} V^m + {s^c}/{s^m} \, B^m s^m Y^W.$$

With canceling out s^m, we get:

$$= V^c - B^c D^c - s^{cm} V^m + s^c B^m Y^W.$$

By equation 2-5, we know that $Y^W = {D^c}/{s^c}$:

$$= V^c - B^c D^c - s^{cm} V^m + s^c B^m \, {D^c}/{s^c}.$$

Here, s^c cancels out and we get:

$$= V^c - B^c D^c - s^{cm} V^m + B^m D^c.$$

Finally, substituting for the factor content from equation 2-7, we get our testable equation:

$$B^c T^c - s^{cm} B^m T^m = V^c - s^{cm} V^m - (B^c - B^m) D^c. \qquad (2\text{-}8)$$

Note that with the assumption of homothetic preferences, all countries' consumption vectors are proportional to each other, which allows us to write $\mathrm{s^{cm} D^m = D^c}$.

By calling the left-hand side of the previous equation the measured bilateral factor content of trade, it can be written as:

$$\mathrm{B^c T^c - s^{cm} B^m T^m = F^c - s^{cm} F^m}.$$

F^c is the measured factor content of net exports from country *c*; and F^m is the measured factor content of net exports from country *m*. Therefore, we can get following equation:

$$\mathrm{F^c - s^{cm} F^m = V^c - s^{cm} V^m - (B^c - B^m) D^c}.$$

The left-hand side of equation 2-8 is the Measured Relative Factor Content of Trade (MRFCT) of the pair-wise HOV model and the right-hand side of the same equation is the Predicted Relative Factor Content of Trade (PRFCT) of the pair-wise HOV model.

Let us define $(\mathrm{B^c} - \mathrm{B^m})\mathrm{D^c} = \mathrm{Q}$ as country *c* and country *m*'s technological differences derived from the general HOV model. If it is assumed that there are only two factors, capital and labor, then it follows that there are two elements in Q, Q^K and Q^L. This chapter conducts empirical tests with the last equation 2-8. If it is assumed that all countries' technology is the same (although this does not happen in the real world) with factor price equalization, then it can be concluded that $\mathrm{B^c}$ and $\mathrm{B^m}$ are the same, and Q is zero, and we can derive the following equation 2-9:

$$\mathrm{F^c} - \mathrm{s^{cm}F^m} = \mathrm{V^c} - \mathrm{s^{cm}V^m}. \tag{2-9}$$

By using Davis and Weinstein's (2001a) data, this chapter will show whether there is support for the pair-wise HOV model for different groups of countries.

IV. Empirical Tests

This chapter conducts three kinds of tests: the sign test, the slope test, and the variance ratio test. In Davis and Weinstein (2001a), the sign test compares the sign of the measured factor content of trade (MFCT) with the sign of the predicted factor content of trade (PFCT) in the case of equation 2-1: $\mathrm{B^{c'}T^c} = \mathrm{B^{c'}(Y^c - D^c)} = \mathrm{V^c} - \mathrm{s^cV^W}$. In particular, this test counts the proportion of the same signs between MFCT and PFCT. In the case of the pair-wise HOV model, the sign test compares the sign of the measured relative factor content of trade (MRFCT) with the sign of the predicted relative factor content of trade (PRFCT). Here, for example, the measured relative factor content of trade (MRFCT) refers to the left-hand side of equation 2-8: $B^cT^c - s^{cm}B^mT^m$, and the predicted relative factor content of trade (PRFCT) is on the right-hand side of equation 2-8: $V^c - s^{cm}V^m - (B^c - B^m)D^c$.

The slope test is the result of using a regression analysis. For this analysis, we regress the MFCT (or MRFCT) on the PFCT (or PRFCT). For example, in the case of equation 2-8, this test regresses $B^cT^c - s^{cm}B^mT^m$ on $V^c - s^{cm}V^m - (B^c - B^m)D^c$, and we can obtain the coefficient. We can then compare the estimated coefficient with the theoretical slope. Since the theoretical slope is one, we can simply check whether the estimated slope is significantly different from one.

The variance ratio test is used to compare the variances of the measured and the predicted factor content of trade; that is, we calculate Var (MFCT)/Var (PFCT). In the case of the pair-wise HOV model, the variance ratio test calculates Var (MRFCT)/Var (PRFCT). When the test result is close to one, this model explains the trade theory well. If the result is one, the trade model fits completely. Table 2.3 lists three different country groups that this chapter uses.

Table 2.3: Country Groups for Test Equations 2-8 and 2-9

Type of Trade	Number of Countries	Name of Countries
Trans-Atlantic analysis	Seven	France, Germany, Italy, the Netherlands, the UK, Denmark, and the US
Intra-European analysis	Six	France, Germany, Italy, the Netherlands, the UK, and

		Denmark
Trans-Atlantic analysis with Australia and Canada	Nine	France, Germany, Italy, the Netherlands, the UK, Denmark, the US, Canada, and Australia

Note: Data came from Davis and Weinstein (2001a).

For the trans-Atlantic trade analysis, this chapter examines all bilateral trade flows between the United States and European countries. For the intra-European trade analysis, this chapter chooses six European countries and examines all bilateral trade flows between these countries. This chapter will argue that the intra-European trade flows have lower trade costs. Finally, for the trans-Atlantic trade analysis with Australia and Canada, this chapter uses nine countries, and examines bilateral trade flows between the countries. We will argue that the trans-Atlantic countries with Australia and Canada have higher trade costs.

This chapter uses different assumptions to see which one explains trade theory better. First, this chapter uses equation 2-1, the original HOV model, to test the factor content of trade. Second, this chapter assumes that each country uses different technology, which is the main assumption of the Ricardian model. Third, this chapter assumes that all countries have the same technology. With this assumption, the trans-Atlantic trade and the trans-Atlantic trade with Australia and Canada assume that all countries have the same technology. With this assumption, the United States' technology is used for all the other countries:

$$B^{US}T^{c} - s^{cm}B^{US}T^{m} = V^{c} - s^{cm}V^{m}.$$

B^c is replaced by B^{US}, because we are using the United States technology matrix for all countries.

With this same technology assumption, the intra-European trade assumes that all six European countries have the same technology. With this assumption, Germany's technology is used for the other five countries:

$$B^{Germany}T^c - s^{cm}B^{Germany}T^m = V^c - s^{cm}V^m.$$

Table 2.4 shows the summary of different models that this chapter examines.

Table 2.4: Specification of Models

	Model	Main assumption
2-1	$B^{US}T^c = B^{US}(Y^c - D^c)$ $= V^c - s^c V^W$	The original HOV model with the United States' technology
2-8	$B^c T^c - s^{cm} B^m T^m$ $= V^c - s^{cm} V^m - (B^c - B^m) D^c$	The pair-wise HOV model with different technologies
2-9	$B^c T^c - s^{cm} B^m T^m$ $= V^c - s^{cm} V^m$	The pair-wise HOV model with same technology

Note : Equation 2-1 is the same as Davis and Weinstein (2001a) paper's T1 (p.1437).

V. Importance of Trade Costs and Comparison of Trade Costs for Intra-European Trade versus Other Trade

Anderson and van Wincoop (2004) classify the trade costs under three categories: border costs, transportation costs, and distribution costs. They determine that border barriers and (international) transportation costs are the main source of trade costs. Table 2.5 shows that total border related barriers are equivalent to a 44% tax on imported goods, total transportation costs are a 21% tax-equivalent, and total trade costs are 74% of the factory price. Table 2.5 presents the various trade costs, with sub-totals and the final total. Note that non-tariff barriers (NTBs) consist of all import restrictions that are not tariff-based such as quotas or regulatory requirements.

Table 2.5: Trade Costs

A Breakdown of Trade Costs	
Description	Percent Markup over the Price of the Good
Time costs	9
+ shipping costs	11
Total Transport Costs	21
Tariffs and NTBs	8
Language costs	7
Currency costs	14
Information costs	6
+security costs	3
Total Border-Related Barriers	44%
Total	74%

Note: Ostapik and Yi (2007, p.23).

For the detailed formulas used in Table 2.5, refer to Ostapik and Yi (2007, p.25) and Anderson and van Wincoop (2004). Anderson and van Wincoop find that costs of different languages are 7% of the value of the goods traded and costs of different currencies are 14%. Costs for information are 6% and costs for security are 3%. Government policy barriers such as tariffs and non-tariff barriers are 7.7% of the tax on industrial goods. They also estimate that "tariffs and non-tariff barriers can be translated into a 7.7% "tax" on industrial goods for the EU in 1999" (Ostapik and Yi (2007), p.25). Note that they use a multiplicative formula because each border cost is applied to the total value of trade including other border costs. By the multiplicative formula, they find that border related trade costs without government policy barriers are 33%. In other words, they calculate 1.07*1.14*1.06*1.03 – 1= 0.33. When Anderson and van Wincoop add government policy barriers to these barriers, they find that total border related trade costs are 44%, that is, 1.33*1.077 – 1 = 0.44 (44%). Hummels (2001) finds that freight transport costs are 10.7%. Hummels estimates that time costs of the United States are 9% of the price of goods at the factory. Time costs are the willingness to pay for saving time. For example, if we use air transportation we can save time. Anderson and van Wincoop report Hummels' freight transport cost and time costs. Total transport costs are 21% of the price of the good. Non-tariff barriers are loosely defined as all other trade barriers, besides tariffs, imposed by a national government. The most familiar of these are quotas, which are restrictions on the quantity of a good that can be imported from a country"(Ostapik and Yi (2007), p.21).

In this section, we compare the trade costs for the intra-European trade and those for the trans-Atlantic trade. Why does the intra-European trade have lower trade costs than the trans-Atlantic trade or the trans-Atlantic trade with Australia and Canada? One possible important reason may be the European Union (EU). Free trade among the EU members was the original purpose, when the Union was founded 50 years ago. There are no tariffs in trading between the European Union membership countries.

When we think about transportation perspective, it is safe to assume that the trade costs of the intra-European trade are less than that of the trans-Atlantic trade. Transportation costs are one of the examples of trade costs. The intra-European trade has lower transportation costs than the trans-Atlantic trade because the intra-European trade has shorter trade distance than its trans-Atlantic counterpart. This finding is related to the gravity model. The gravity model analyzes bilateral trade flows with economic sizes and distance between two countries. This result shows that shorter distances mean lower trade costs.

Table 2.6 below shows each country's tariff rates, NTBs *Ratio,*[21] and Imports' Duties. The European Union has lower tariff rates and NTBs *Ratio* than the other countries. Australia has higher tariff rates and Canada has higher NTBs *Ratio* than the other countries. Summary statistics show that the European Union has lower Imports Duties than the other countries.

Table 2.6: Tariff Rates, NTBs *Ratio*, and Imports Duties

Country	Weighted Average Tariff Rates	NTBs *Ratio*	Imports Duties		
			1970s	1980s	1990s
United States	3%	0.015	4.37	3.44	2.78
European Union	1%	0.008	0.53	0.06	0.038
Canada	3%	0.151	5.65	3.94	2.44

[21] "These NTB ratios are arithmetic and trade weighted NTB coverage ratios, and these ratios are the percentage of tariff lines subject to NTBs" (Anderson and van Wincoop (2004), p.699).

Australia	8%	0.014	10.62	8.54	5.10

Note: World Development Indicators, 2007.

The column labeled Tariff Rates is the summary of tariff rate statistics for the year 1992. It shows each country's or region's weighted average tariff rate with import shares as weights (effective tariff rates). The tariff rates that the European Union imposes against third countries are 1%, except the U.K., which imposes 2%. Lai and Zhu (2004) calculated tariff rates as the ratio of import duties to total imports. There is no industry dimension (Lai and Zhu (2004), p.480).

The column labeled NTBs *Ratio* is for the year 1999. The data are from the United Nations Conference on Trade and Development's (UNCTAD) Trade Analysis and Information System (TRAINS) database. They include quantity, price, quality, and advanced payment NTBs (advanced payment means that no allowance is made for interest to be accrued), but do not include threat measures such as antidumping investigations and duties. This NTBs *Ratios* are arithmetic and trade-weighted NTBs coverage ratios, and these ratios are the percentage of tariff lines subject to NTBs (Anderson and van Wincoop (2004), p.700).

The columns labeled Imports Duties are averages of various years. The European Union data is the average of European countries: Denmark, France, Germany, Italy, the Netherlands, and the U.K. This data came from Yanikkaya (2003, p.85-87). In order to make the case that intra-European trade has lower trade costs than other trade, we have collected data from Jacks et al.'s (2008) paper. This chapter analyzes 1985 and 2000 data. Table 2.7 below shows the trade costs for several country pairs (columns labeled TC).

Jack et al.'s (2008) paper uses an 'iceberg' for bilateral trade costs. They calculated this 'iceberg' (bilateral trade costs) as follow:

$$\tau_{ij} = \left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{1/[2(\sigma-1)]} - 1.$$

τ_{ij} means bilateral trade costs from country i to country j. x_{ij} means exports from country i to j, in other words bilateral trade flows. σ denotes the elasticity of substitution.

Table 2.7: Bilateral Trade Costs (TC)

Year	From country1	To country2	TC	Year	From country1	To country2	TC
1985	France	Australia	0.46	2000	UK	Germany	0.28
2000	France	Australia	0.47	1985	UK	Italy	0.36
1985	France	Canada	0.45	2000	UK	Italy	0.35
2000	France	Canada	0.44	1985	UK	Netherlands	0.28
1985	France	Denmark	0.41	2000	UK	Netherlands	0.27
2000	France	Denmark	0.39	1985	UK	Norway	0.31
1985	France	Germany	0.29	2000	UK	Norway	0.34
2000	France	Germany	0.27	1985	UK	USA	0.36
1985	France	Italy	0.31	2000	UK	USA	0.34
2000	France	Italy	0.30	1985	USA	Australia	0.40
1985	France	Netherlands	0.30	2000	USA	Australia	0.41
2000	France	Netherlands	0.31	1985	USA	Canada	0.24
1985	France	Norway	0.39	2000	USA	Canada	0.20
2000	France	Norway	0.37	1985	USA	Denmark	0.44
1985	France	UK	0.33	2000	USA	Denmark	0.45
2000	France	UK	0.31	1985	USA	France	0.40
1985	France	USA	0.39	2000	USA	France	0.38
2000	France	USA	0.37	1985	USA	Germany	0.37
1985	UK	Australia	0.41	2000	USA	Germany	0.35
2000	UK	Australia	0.41	1985	USA	Italy	0.40
1985	UK	Canada	0.39	2000	USA	Italy	0.40
2000	UK	Canada	0.37	1985	USA	Netherlands	0.36
1985	UK	Denmark	0.35	2000	USA	Netherlands	0.36
2000	UK	Denmark	0.35	1985	USA	Norway	0.45
1985	UK	France	0.33	2000	USA	Norway	0.43
2000	UK	France	0.31	1985	USA	UK	0.36
1985	UK	Germany	0.30	2000	USA	UK	0.34

Note: TC means bilateral trade costs. Data came from Jacks et al. (2008).

Table 2.8 summarizes the information from Table 2.7 by aggregating European countries together. Table 2.8 shows that the intra-European trade costs are low.

Table 2.8: Bilateral Trade Costs

Year	From country 1	To country 2	TC	Year	From country 1	To country 2	TC
1985	France	Europe[22]	0.34	2000	UK	USA	0.34
2000	France	Europe	0.33	1985	UK	Australia	0.41
1985	France	USA	0.39	2000	UK	Australia	0.41
2000	France	USA	0.37	1985	UK	Canada	0.39
1985	France	Australia	0.46	2000	UK	Canada	0.37
2000	France	Australia	0.47	1985	USA	Europe[23]	0.40
1985	France	Canada	0.45	2000	USA	Europe	0.39
2000	France	Canada	0.44	1985	USA	Australia	0.40
1985	UK	Europe[24]	0.32	2000	USA	Australia	0.41
2000	UK	Europe	0.32	1985	USA	Canada	0.24
1985	UK	USA	0.36	2000	USA	Canada	0.20

Note: TC means bilateral trade costs. Data came from Jacks et al. (2008).

VI. Test Results

This chapter examines the factor content of trade model with some assumptions. Equation 2-1 reproduces the test in Davis and Weinstein (2001a). It tests the original

[22] Here, Europe means average of the European countries: Denmark, Germany, Italy, Norway, the Netherlands, and the U.K.

[23] Europe means average of the European countries: Denmark, France, Germany, Italy, Norway, the Netherlands, and the U.K.

[24] Europe means average of the European countries: Denmark, France, Germany, Italy, Norway, and the Netherlands.

HOV model using the United States' technology to construct the matrix of total factor inputs: $B^{US}T^c = B^{US}(Y^c - D^c) = V^c - s^cV^W$. Equation 2-8 tests the pair-wise HOV model with different technologies: $B^cT^c - s^{cm}B^mT^m = V^c - s^{cm}V^m - (B^c - B^m)D^c$. Because technologies are different, $-(B^c - B^m)D^c$ will not be zero. Equation 2-9 tests the pair-wise HOV model with the same technology, $B^cT^c - s^{cm}B^mT^m = V^c - s^{cm}V^m$. Because technologies are the same, $-(B^c - B^m)D^c$ will be zero.

Table 2.9 shows the test results using Davis and Weinstein's (2001a) data. Rows 3-5 report the slope test (where "predicted" denotes the slope of the measured factor trade on the predicted factor trade, as explained above); the "standard error" refers to the standard error of that slope; and R^2 is the results of running that regression. Row 6 reports the sign test and row 7 reports the variance ratio test. Table 2.9 shows that equation 2-8 using the trans-Atlantic countries' data model fits the model best in the case of the slope test. However, the difference of the slope test result between the trans-Atlantic trade and the intra-European trade is very small and probably not very significant. Row 6 reports the sign test's results. We recall that this test counts the number of same signs between the measured factor content of trade (or measured relative factor content of trade, the left-hand side of the testing equations) and the predicted factor content of trade (or predicted relative factor content of trade, the right-hand side of the testing equation). The sign test shows, at least when we use Davis and Weinstein's (2001a) data, that the factor content of trade using the intra-European countries' data fits the model better than the factor content of trade using the trans-Atlantic countries' data and the trans-Atlantic countries with Australia and Canada' data. Note that a sign test close to 50%, as in the case of both the trans-Atlantic trade and the trans-Atlantic trade with Australia and Canada, is almost no better than a coin toss, and it is close to stating that the model has almost no explanatory power at all! By contrast, in the intra-European trade, the signs are as predicted about 80% of the time, which is a major improvement on the predictive power of the factor content model, when applied to European countries. The result of this sign test is close to Davis and Weinstein's of 86% for their model T5 (see Table 2.2), which is a model that incorporates major amendments of the HOV model, while here it is obtained *without* major amendments at all, but simply by restricting trade to the intra-European trade. Therefore, we see here *some* evidence suggestive that trade costs are quite important for the factor content of trade.

We should mention that the variance ratio test, while performing horribly in all cases (which in the context of Davis and Weinstein's results is not surprising), does perform marginally better for the trans-Atlantic trade than for the intra-European trade. However, given that all such ratios are very small and far from the theoretically-predicted value of one, we simply state that this may mean that other causes for trade (such as intra-industry trade, as mentioned in the literature review to this chapter) may be at the root cause for this. Note that the European economies are arguably more similar to each other than to the United States and Canada, which would probably cause for a larger proportion of trade to be intra-industry trade, and therefore less well explained by the Heckscher-Ohlin model and perhaps better explained by the "New Trade Theory," which is outside the scope of this chapter.

Finally, it is worthwhile to compare the R^2 from the three different samples. Note that the regression model restricted to European countries fits much better, at least judging from the goodness of fit.

The evidence presented in this section at least suggests the possibility of significant role of trade costs in trade, and therefore significant role in the calculation of the factor content of trade.

Table 2.9: Trade Test with Davis and Weinstein's (2001a) Data, 1985

All Factors							
	Davis and Weinstein (2001a)	1. Trans-Atlantic trade		2. Intra-European trade		3. Trans-Atlantic trade with Australia and Canada	
Assumption	2-1	2-8	2-9	2-8	2-9	2-8	2-9
Dependent Variables	MFCT	MRFCT	MRFCT	MRFCT	MRFCT	MRFCT	MRFCT
Predicted	-0.002	0.19	0.012	0.17	0.138	0.106	0.035
Standard error	0.005	0.08	0.0998	0.05	0.053	0.076	0.075
R^2	0.01	0.37	0.001	0.55	0.45	0.12	0.0153
Sign Test	0.32	0.58	0.58	0.8	0.8	0.56	0.69
Variance Ratio Test	0.0005	0.107	0.0998	0.057	0.0425	0.0931	0.080
Observations	22	12	12	10	10	16	16

Notes: GDP data came from World Development Indicator (WDI) from the World Bank. WDI data uses current (1985) $US. D&W means Davis and Weinstein (2001a). MFCT means Measured Factor Content of Trade, and MRFCT denotes Measured Relative Factor Content of Trade.

VII. Concluding Remarks

Many trade economists adapt the original HOV model to get better explanations for trade flows. This chapter extends the original HOV model in a modified direction with the pair-wise HOV model. The original HOV model and the pair-wise HOV model assume that there are no trade costs in trade. This chapter introduces the idea of trade costs. While chapter two does not figure out the factor content of trade with trade costs, it does test the possibility that by fitting the HOV model with trade between countries that have arguably small trade costs, the intra-European countries group, it compares the results with trade flows between country pairs that have arguably higher trade costs, the trans-Atlantic countries with Australia and Canada.

This chapter selects three country groups to explain the bilateral trade by regions. The three regional groups are as follows: the trans-Atlantic countries; the intra-European countries; and the trans-Atlantic countries with Australia and Canada. The intra-European countries' trade will have lower trade costs, however the trans-Atlantic with Australia and Canada will have higher trade costs.

This chapter compares the importance of the pair-wise HOV models regarding countries with different technologies and countries with same technology. Equation 2-1 tests the original HOV model with the United States' technology; Equation 2-8 tests the pair-wise HOV model with different technology; Equation 2-9 tests the pair-wise HOV model with the same technology.

By restricting trade to the intra-European trade without major amendments, the sign test makes substantial progress in this chapter. Therefore, we see here some evidence suggestive that trade costs are quite important for the factor content of trade.

The pair-wise HOV model explains the intra-European countries' trade data better than the trans-Atlantic countries' trade data with Australia and Canada. This is because the intra-European trade has smaller trade costs than the trans-Atlantic countries' trade with Australia and Canada. This empirical result also shows intuitively that countries with similar size will trade more like Helpman (1987), Hummels and Levinsohn (1995), and Debaere (2005) argue, however, this is outside the scope of this chapter.

In conclusion, the evidence presented in this chapter is suggestive that trade costs may play a very significant role in trade, and therefore in the calculation of the factor content of trade.

Chapter 3

Factor Content of Trade with Trade Costs

I. Introduction and Brief Overview of Existing Literature

"Trade costs are large, even in the absence of formal barriers to trade and even between apparently highly integrated economies" (Anderson and van Wincoop (2004), p.1).

The original Heckscher-Ohlin (HO) model assumes two countries, two factors, and two goods. Paul Samuelson transformed the HO model into a mathematical model, thus becoming the Heckscher–Ohlin–Samuelson (HOS) model. Vanek (1968) introduces multi-factors and multi-goods into this model, which becomes the Heckscher–Ohlin–Vanek (HOV) model. Many trade economists have used the HOV model to verify empirically whether and how well the HOV model explains the trade data. Davis and Weinstein (2001a) also use the HOV model to develop their theory.

The original HOV, also known as the strict HOV model, assumes the following: free trade (no trade costs), perfect competition, identical technologies across countries, constant returns to scale, different factor endowments across different countries, identical and homothetic preferences across all consumers in all countries, factors that are perfectly mobile in the long run across sectors, but perfectly immobile across countries, and finally no measurement error.

Strictly speaking, the free trade assumption is not realistic in our world. When two countries trade with each other, trade costs exist. What are these trade costs? With the assumption that there are consumers and producers, all costs except production costs are trade costs. Transportation costs, travel costs, and transaction costs are trade costs with distance effects: greater distance equals greater costs. Transportation costs are needed to relocate the goods.

Currently, many trade agreements, such as the European Union (EU)[25] and the North American Free Trade Agreement (NAFTA),[26] make taxes and tariffs much smaller when accounting for trade costs. This means that transportation costs, travel costs, and transaction costs are the main components of trade costs. Let us look at the previous literature regarding the factor content of trade and trade costs.

Samuelson (1952), who studies transportation costs, uses the 'iceberg' form to model transportation costs in his paper in which he studies "transfer problems." He argues that firms engaging in international trade try to minimize their trade costs to reap more benefits. Anderson and van Wincoop's (2002) paper argues that trade costs are related to the international trade policy and represent about one-tenth of a country's gross national income. Obstfeld and Rogoff (2000) investigate how trade costs are difficult to analyze and are mixed with many issues in an international economy. Davis' (1998) paper argues that developed countries produce more goods and diversified products than underdeveloped countries, that by contrast, produce simpler products. Also, according to Davis, developed countries have a more scaled economy than undeveloped countries. One contribution of Davis' paper is his demonstration that, depending on the relative size of trade costs in differentiated and homogeneous industries, market size matters for the national industrial structure (p.1274). Of course there is an exception to the rule; Davis

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[25] The EU was established in 1993 and has developed into a single market with 27 membership countries: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

[26] The NAFTA was established in 1994 between Canada, Mexico, and the United States.

points out the home market effect,[27] and therefore market size is not a factor when trade costs are equal (p.1294).

Edward Ray is one author who has studied the Heckscher-Ohlin model with trade costs. In particular, Ray's (1981a) paper deduces trade equations in the presence of protection. Using data from the United States and some other countries,[28] he finds that tariffs and non-trade barriers are complementary. He also finds that trade protection does not significantly affect the imports in the United States; this is a result that we should keep in mind in the context of the results in this chapter (note that Ray's methodology was not a factor content methodology). Ray's (1981b) paper researches imports and trade barriers. He estimates the equation for trade as a function of trade barriers, and finds that trade and trade barriers affect each other simultaneously. He derives trade equations, specifically the import equation, with the Hecksher-Ohlin model. He also derives the trade barriers equation and considers characteristics of every industry. These industrial characteristics are the measure of capital intensity and the ratio of skilled labor, indicating that factor endowments are not only important in the aggregate sense, but also at the industry level.

Radelet and Sachs (1998) construct a model of trade costs using the CIF/FOB ratio[29] as transportation costs. They argue that transportation costs go down as technology develops. Because government policy affects these transportation costs, they argue that transportation costs are endogenous variables. They argue that the CIF/FOB ratio

[27] The home market effect means that, ceteris paribus, producers prefer to produce within larger countries because producers would face transportation costs on a smaller share of their output (p.1281).
[28] The other countries are Canada, the United Kingdom, Germany, Belgium, Italy, France, and Japan.
[29] CIF means Cost, Insurance, and Freight and FOB means Free On Board. The CIF price estimates imported items' cost when they arrive at the importing country. The FOB price estimates imported items' cost when they are shipped by the exporter.

decreases as technology develops and telecommunications become more important. Radelet and Sachs (1998) argue that countries far apart from each other have more transportation costs than countries close to each other when they trade. Geographic isolation and higher shipping costs make it hard to promote exports. When firms sell their high value-added products, they pay high transportation costs; and they compensate for these high transportation costs with low wages and low capital incomes. Manufacturing firms strategize to strengthen their competitiveness in world markets. Radelet and Sachs (1998) argue that countries with high shipping cost, such as Mongolia, Rwanda, Burundi, and Bolivia cannot grow according to the export-led growth theory, although these countries try to reduce tariff rates, and remove quantitative restrictions. This is yet one more way to see that transportation costs tend to have economically significant impacts.

Davis and Weinstein (2001a) argue that trade costs exist in international trade, but in very small amounts. When Davis and Weinstein research the volume of trade, they use distance as a measure of trade costs in the same way that it is used in the gravity model. They use the following equation to add distance in their import equation:

$$d(M^{cc'}) = \alpha_0 + \alpha_1 \ln\left(sX^{c'}\right) + \delta \ln\left(\mathrm{d}^{cc'}\right) + \ln\left(\varepsilon^{cc'}\right).$$[30]

$M^{cc'}$ denotes predicted imports to country c from country c'. s means total domestic absorption. $\mathrm{X}^{c'}$ denotes gross output in country c'. $\mathrm{d}^{cc'}$ means distance between countries c and c'. ε means error term. α_0, α_1, and δ are parameters. When α and δ are zero, there are no trade costs. Davis and Weinstein (2001a) add the effect of trade costs in their accounting, and conclude that trade costs can improve the explanatory power of the factor content of trade. However, it is very important to note, as they write in their paper, that

[30] Davis and Weinstein (2001a), p.1429.

the use of the gravity model[31] is a major theoretical departure from the factor content methodology, and it is not clear that mixing the two methodologies allows for a clean model. In this chapter, we do not attempt to mix the two methodologies, rather we attempt to incorporate the trade costs directly into the factor content methodology.

Deardorff (2004) argues that if there are trade costs, the pattern of trade may not be well described by the usual measures of comparative advantage. Usual measures of comparative advantage mean comparing a country's costs or autarky price to those of the world (p.3). He explains his theory using comparative advantage methodology and researches the Ricardian model with trade costs. Deardorff also uses his previous research (1980) as well as Dixit and Norman's (1980) book to extend his research and to construct his model with trade costs. He researches the relationship between differentiation in the products and trade to uncover a previously unnoticed role of trade costs. He explains that a country's net trade depends upon production costs and trade costs. His conclusion is that factoring in trade costs works in real world trade.

Hummels and Lugovskyy's (2006) paper nicely explains how to choose and use trade cost data. They argue that trade costs, specifically transportation costs, are not easy to collect. Their paper explains that many trade economists use indirect measures for gathering transportation costs. These indirect measures of transportation costs use matched partner CIF/FOB ratios. These ratios can be collected from the International Monetary Fund (IMF) and the United Nations (UN) databases. Hummels and Lugovskyy also acquire directly measured transportation costs for the United States and the Netherlands. Hummels and Lugovskyy (2006) compare the following transportation

[31] The gravity model studies bilateral trade flows as dependent of the size of economy and distance between two countries.

costs: direct measured transportation costs and indirectly measured transportation costs. They conclude that the IMF CIF/FOB ratios have some errors. These ratios came from the IMF Direction of Trade Statistics (DOTS). Hummels and Lugovskyy (2006) argue that the IMF CIF/FOB ratios are quite error-ridden and do not have useful information for time series or cross-commodity variation, but that these IMF CIF/FOB ratios have some significant cross-exporter variation (p.1).

Bernard, Jensen and Schott (2006) show that trade costs affect the manufacturing activities of the United States. They use ad valorem trade costs with a heterogeneous firm model. If the trade costs decrease, high productivity firms redistribute their economic activities. Firms with low productivity cannot survive when trade costs decrease. Firms with high productivity will increase their exports as trade costs are decreased. Bernard et al.'s contribution was to construct trade costs by industry (p.917). They calculate the following (p.922):

$$Trade\ Costs_{it} = d_{it} + f_{it},$$

where the left side represents the trade costs for industry *i* and year *t*. Thus, trade costs are the sum of any tariffs[32] and freight costs. In the expression above, d_{it} means ad valorem duty on industry i and year *t*; and f_{it} means freight and insurance costs of industry i and year *t*. Bernard, Jensen and Schott (2006) obtained d_{it} and f_{it} from Feenstra's (1996) paper and database. This database is made up from the United States' import data. They construct the ad valorem duty (*d*) and ad valorem freight and insurance (*f*) according to the following formula (p.922):

$$d_{it} = \frac{duties_{it}}{fob_{it}}.$$

[32] Here, tariff means ad valorem tariff.

Thus, tariff costs (d_{it}) are the sum of duties collected in industry i in year t divided by fob_{it}. In the expression above, fob_{it} is the free on board value of imports. Furthermore, Bernard, Jensen and Schott (2006) construct the freight and insurance of industry i and year t according to the following formula:

$$f_{it} = \frac{cif_{it}}{fob_{it}} - 1.$$

Freight costs[33] are the sum of freight and insurance charges in industry i in year t (i.e. the markup of the cost insurance freight value (cif_{it})) divided by fob_{it} (i.e. custom value of imports). They construct their trade costs as follows (see Table 3.1):

Table 3.1: Ad valorem Trade Costs by Two Digits SIC[34] Industry and Year

Two digit SIC industry	Tariff rate (d_{it}) (%)			Freight rate (f_{it}) (%)			Total rate ($d_{it} + f_{it}$) (%)		
	1982	1987	1992	1982	1987	1992	1982	1987	1992
20 Food	5.7	5.1	4.4	10.2	9.7	8.9	15.9	14.8	13.4
21 Tobacco	10.4	14.1	16.7	5.9	5.2	2.9	16.3	19.3	19.5
22 Textile	17.0	13.2	11.2	6.0	6.4	5.4	23.1	19.6	16.6
23 Apparel	23.3	20.7	16.9	8.6	7.6	6.3	31.8	28.3	23.2
24 Lumber	3.2	2.3	1.7	11.1	6.5	7.5	14.2	8.8	9.2
25 Furniture	5.9	4.1	4.1	9.4	8.6	8.5	15.3	12.8	12.6
26 Paper	0.9	0.8	0.6	3.9	3.1	4.4	4.7	4.0	4.9
27 Printing	1.7	1.2	1.1	5.9	5.5	5.1	7.5	6.6	6.2
28 Chemicals	3.8	4.3	4.4	6.4	4.8	4.5	10.1	9.1	9.0
29 Petroleum	0.4	0.5	0.9	5.2	5.1	8.3	5.6	5.5	9.3
30 Rubber	7.4	7.9	11.3	7.5	6.8	6.9	14.9	14.7	18.2
31 Leather	9.0	10.7	11.2	8.3	7.2	5.5	17.3	17.8	16.7
32 Stone	8.9	6.4	6.5	12.0	11.1	9.6	20.9	17.5	16.1
33 Primary Metal	4.6	3.8	3.4	6.9	6.3	6.0	11.5	10.1	9.4
34 Fabricated	6.6	5.1	4.3	6.8	5.9	5.0	13.4	11.0	9.3

[33] Freight costs are ad valorem freight rates.
[34] SIC stands for Standard Industrial Classification.

Metal									
35 Industrial Machinery	4.2	3.9	2.4	4.0	4.0	2.9	8.2	7.9	5.3
36 Electronic	5.0	4.6	3.3	3.4	3.1	2.4	8.3	7.6	5.6
37 Transportation	1.9	1.6	2.3	4.5	2.5	3.1	6.4	4.1	5.4
38 Instruments	6.8	5.2	4.3	2.7	2.8	2.5	9.5	8.0	6.8
39 Miscellaneous	9.6	5.7	5.2	5.0	4.9	3.6	14.6	10.6	8.8
Average	4.8	4.4	4.2	5.6	4.4	4.1	10.4	8.8	8.3

"*Notes:* This table summarizes ad valorem tariff, freight, and total trade costs across two-digit SIC industries. Costs for each two-digit industry are weighted averages of the underlying four digit industries employed in our empirical analysis, using U.S. import values as weights. Figures for each year are the average for the five years preceding the year noted (e.g., the costs for 1982 are the average of costs from 1977 to 1981). The final row is the weighted average of all manufacturing industries" (Bernard et al. (2006), p.923).

Bernard et al.'s (2006) paper concludes that when trade costs decrease by a large amount, then productivity growth increases by a large amount. When trade costs are decreased, low-productivity firms are met with destruction and high-productivity firms are met with prosperity. Bernard et al. find the relationship between free trade and an increase in productivity in the case of developed countries (p.934). This chapter uses the trade cost data shown above in Table 3.1 ($Trade\ costs_{it} = d_{it} + f_{it}$) along with Peter Schott's (2002) data.[35]

Bergstrand and Egger (2006) research intra-industry trade with trade costs. They use the bilateral OECD Grubel-Lloyd index[36] with cross-sectional data. Their idea came from Anderson and van Wincoop's (2004) paper, which studies the trade costs and trade.

[35] www.som.yale.edu/faculty/pks4/sub_international.htm.

[36] The Grubel-Lloyd index is used to measure the degree of trade overlap. It is defined as Grubel-Lloyd index = $\frac{\text{Trade Overlap}_{\text{if}}}{\text{X}_{\text{if}}+\text{M}_{\text{if}}} \times 100$, where Trade $\text{overlap}_{\text{if}} = (\text{X}_{\text{if}} + \text{M}_{\text{if}}) - |\text{X}_{\text{if}} - \text{M}_{\text{if}}|$. Here, "$X_{if}$ and M_{if} are the value of country *i*'s exports and imports, respectively, of commodity *j* either to the world or on a bilateral basis" (Bowen et al. (1998), p.24).

Bergstrand and Egger (2006) ask the question: Is there a non-linear relationship between trade costs and the Grubel-Lloyd index? Bergstrand and Egger make the following four assumptions: first, if trade costs of goods are increased, the volume of intra-industry trade decreases (here, goods are differentiated goods); second, if the share of intra-industry trade decreases, trade costs increase; third, if trade costs are increased, the Grubel-Lloyd index will decrease; fourth, trade costs are nonlinear (p.434-435).

Bergstrand and Egger (2004) assume that there are two countries, two sectors, and two factors to show trade costs' role for intra-industry trade, and their paper uses the following equations in their research on trade costs and intra-industry trade (p.5):

$$\mathrm{L_i = a_{LX} n_i (x_{ii} + x_{ij}) + a_{LY} (Y_{ii} + t_Y Y_{ij}) + a_{Ln} n_i,}$$

$$\mathrm{K_i = a_{KX} n_i (x_{ii} + x_{ij}) + a_{KY} (Y_{ii} + t_Y Y_{ij}) + a_{Kn} n_i.}$$

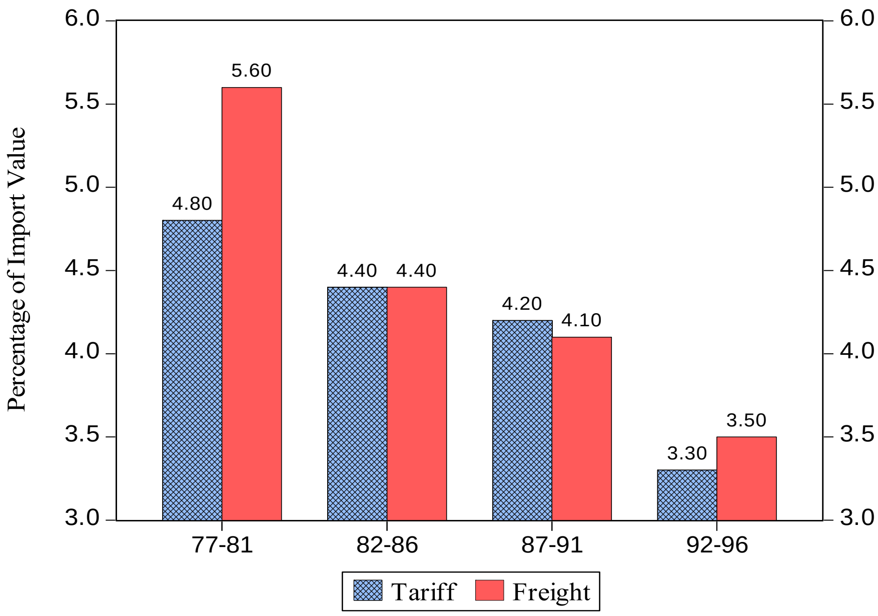
Here, a_{LX} means how much labor is needed to produce one unit of good *X*. a_{KX} stands for how much capital is needed to produce one unit of good *X*. a_{LY} means how much labor is needed to produce one unit of good *Y*. $\mathrm{a_{KY}}$ means how much capital is needed to produce one unit of good *Y*. Note that these 'a's are the same as the component of the 'technology matrix' in the Davis and Weinstein (2001a) paper and technology matrix that this dissertation uses; therefore this methodology is closely related to the one in this chapter. x_{ii} is the demand from the domestic market, while x_{ij} is the demand from the foreign market. t_X and t_Y mean transportation costs for goods *X* and *Y* respectively. Bergstrand and Egger's (2006) paper uses the following equations (p.436):

$$\mathrm{L_i = a_{LX} n_i (x_{ii} + x_{ij}) + a_{LY} (Y_{ii} + t_Y Y_{ij}) + a_{Ln} n_i,}$$

$$\mathrm{K_i = a_{KX} n_i (x_{ii} + x_{ij}) + a_{Kn} n_i.}$$

Figure 3.1 shows the average manufacturing industry's trade costs over time. It demonstrates that tariff and freight were decreased from 1977 to 1996. Figure 3.1 shows an outright decline in freight during 1982-1986. This is a sign that the trade costs (here, tariff and freight) are decreasing as time goes on. However, they have certainly not disappeared, and as we have also argued above, trade costs in general are still quite important.

Figure 3.1: Average Manufacturing Industry Trade Costs over Time



Notes: P. Schott, Trade Costs Indexes by SIC4 (1987 Revision) Manufacturing Industry, 1972 to 1999, Falling Trade Costs, Heterogeneous Firms and Industry Dynamics, Yale School of Management, Mimeo.

II. Methodology and Models

II.1. Method 1

This chapter uses the original HOV model. The original HOV model assumes the following: 1) that preferences are homothetic and identical across countries; 2) that all countries share identical technologies; 3) that there is perfect competition; and 4) that there are no trade costs.

We will expand upon the original HOV model in this chapter by considering trade costs. This chapter deduces the original HOV model with trade costs and compares the importance of the original HOV model with and without trade costs. It does so by including trade costs directly in the technology matrix, where the working assumption is that the trade costs are located in the original country. Trade costs are increased by the exporter. Exporters need to spend more trade costs as they export more.

To calculate the factor content of trade in the presence of trade costs, this chapter explains how to derive computable expressions for the technology matrix, which includes the trade costs. This is inspired by the work of Deardorff (2004), who considers trade costs explicitly and includes them in the technology matrix.

Let us use the symbol *B* as previously mentioned to represent the factor input matrix. For goods that are traded, we shall define *C* as the matrix of trade costs measured in factor services. For example, if there are two factors and three industries, the trade cost matrix is defined by the equation:

$$C = \begin{bmatrix} tc_{1K}, tc_{2k}, tc_{3K} \\ tc_{1L}, tc_{2L}, tc_{3L} \end{bmatrix}. \qquad (3\text{-}1)$$

Here, tc_{ij} denotes the trade cost in factor *j* to deliver one unit of good *i* abroad. Let us take each country *c*'s vector of net exports $\mathrm{T^c}$ and divide it into two vectors, one which contains all rows of $\mathrm{T^c}$ that are positive and zeros (called $\mathrm{T^{c+}}$), and one which contains all rows of $\mathrm{T^c}$ that are negative and zeros (called $\mathrm{T^{c-}}$). Note that $\mathrm{T^c} = \mathrm{T^{c+}} + \mathrm{T^{c-}}$. In other words, $\mathrm{T^{c+}}$ and $\mathrm{T^{c-}}$ are the vectors of net exports and net imports, respectively.[37] Then, with the assumption that all trade costs are in the exporter country, country *c*'s factor content of trade exports is:

$$\mathrm{F^c} = (B + C)\mathrm{T^{c+}} + \mathrm{BT^{c-}}. \tag{3-2}$$

Furthermore, country *c*'s factor endowments are used for production and for exports, and therefore the country's endowments are given by:

$$\mathrm{V^c} = \mathrm{B(D^c + T^{c-})} + (B + C)\mathrm{T^{c+}}, \tag{3-3}$$

where $\mathrm{V^c}$ is country *c*'s vector of endowments. The first term on the right is the factor used in producing goods consumed domestically (where $\mathrm{D^c}$ is consumption and therefore $\mathrm{D^c + T^{c-}}$ is the total consumption produced domestically), and the second term is total factor services used in the production and trade of the exported goods. This can also be written as:

$$\mathrm{V^c} = \mathrm{B(D^c + T^c)} + \mathrm{CT^{c+}} = \mathrm{BY^c} + \mathrm{CT^{c+}}. \tag{3-4}$$

Here, Y^c is the net output vector for country *c*.

If we add equation 3-4 for all countries of the world, we have:

$$\mathrm{V^W} = \mathrm{BY^W} + \mathrm{CT^{W+}}, \tag{3-5}$$

[37] In this theory, we are ignoring the role of intra-industry trade.

where V^W, Y^W, and T^{W+} are world endowments of factors, world net output, and world net exports, respectively (i.e., $T^{W+} = \sum_c T^{c+}$). Comparison between equations 3-2 and 3-3 shows that:

$$F^c = V^c - BD^c. \quad (3\text{-}6)$$

The assumption of identical and homothetic preferences allows us to write one country's consumption as a proportion of the world, and therefore $D^c = s^c D^W = s^c Y^W$. When we add D^c for all countries, we get D^W. We define country *c*'s portion of the consumption by the notation: $s^c = GDP^c / GDP^W$.

Subsequently, using equation 3-6 first and then equation 3-5, we can write the factor content of trade:

$$F^c = V^c + s^c BY^W = V^c - s^c(V^W - CT^{W+}).$$

Finally, substituting for the factor content of trade from equation 3-2, we get our testable equation:

$$(B + C)T^{c+} + BT^{c-} = V^c - s^c(V^W - CT^{W+}). \quad (3\text{-}7)$$

This amends the basic Davis and Weinstein (2001a) equation by taking into account the trade cost in factor services (matrix *C*). [38]

All of the variables in equation 3-7 are given by the data of Davis and Weinstein, except the matrix of trade costs in factor services (*C*). We have discussed Deardorff (2004), who also employs a similar matrix. However, in the Ricardian methodology, Deardorff only considers one factor of production, labor, and therefore he does not have to model the separation of the cost of trade in labor and the cost of trade in capital. Here,

[38] Recall that the basic factor content equation was $BT^c = V^c - s^c V^W$.

we want this separation of the cost of trade in labor services and capital services. The data appendix of this chapter shows how to calculate the trade costs matrix *C*.

We will use several different assumptions to do this. This chapter's basic intention is to update the factor content of trade model by employing a trade costs matrix. We use Deardorff's (2004) basic idea to add the trade costs in the factor content of trade model. Deardorff (2004) argues that there are two kinds of theories, the law of Ricardian comparative advantage with no trade costs, and the law of Ricardian local comparative advantage with trade costs (p.15-17). In the case with no trade costs, he assumes that there are two countries, country *c* and ĉ, and two goods, good *q1* and *q2*. The unit factor input $\mathrm{a}_{\mathrm{q}1}^{\mathrm{c}}$ denotes how many units of labor are needed to produce one unit of *q1* in the country *c*. $\mathrm{a}_{\mathrm{q}2}^{\mathrm{c}}$ denotes how many units of labor are needed to produce one unit of *q2* in the country *c*. With no trade costs, country *c* has a comparative advantage in producing *q1*[39] if the following condition is satisfied:

$$a_{q1}^{c} / a_{q2}^{c} < a_{q1}^{\hat{c}} / a_{q2}^{\hat{c}}. \tag{3-8}$$

In the second case, Deardorff (2004) includes the trade costs, and the result is:

$$(a_{q1}^{c} + tc_{q1}^{cc'}) / (a_{q2}^{c} + tc_{q2}^{cc''}) < (a_{q1}^{\hat{c}} + tc_{q1}^{\hat{c}c'}) / (a_{q2}^{\hat{c}} + tc_{q2}^{\hat{c}c''}). \tag{3-9}$$

Country *c* produces *q1* and delivers it to country c' with additional trade costs, $tc_{q1}^{cc'}$. $tc_{q}^{cc'}$ means how many units of country *c*'s labor are needed to deliver one unit of *q* from country *c* to country c'. Country *c* does not produce *q2* and deliver it to country c''. Then there is a country $\hat{c}$ that satisfies equation 3-9. "The countries c' and c'' could be the

[39] Country *c* strictly does not produce good *q2* per Deardorff's study.

same, and either or both could be the same as c or $\hat{c}$, in which case the associated trade cost would be zero. Likewise, good $q2$ could be the same as $q1$, although this would be meaningful only if it were delivered to a different country" (Deardorff (2004), p.15-17).

Let us consider why one country makes steel but not wheat. One reason is that when trade costs are small, there is a comparative advantage in making steel compared to making wheat. However, when trade costs are large, there are bigger relative costs in producing steel than wheat, because there are costs in delivering steel. Why does Mexico export cement to the United States instead of exporting clothes to Europe? The reason is that Mexico has a comparative advantage in exporting cement to the United States when compared with exporting clothes to European countries. Mexico has a comparative advantage in distance, not the costs in producing goods. When we think about the two cases discussed above −steel and wheat, and cement and cloth− trade costs matter in trade. When we think that trade costs matter, relatively low trade costs will be a comparative advantage.

II.2. Method 2

Method 1 is inspired by the work of Deardorff (2004), and method 2 is inspired by the idea that trade costs are applied to the net exports (T^{c+}) and not directly to the technology matrix (B). We know that T^{c+} is the vector of net exports and T^{c-} is the vector of net imports. This method 2 also ignores the role of intra-industry trade. With the assumption that all trade costs are located in the exporting country, we define country c's trade cost vector by the equation:

$$C^c = \begin{bmatrix} T_1^{c+} tc_1 \\ T_2^{c+} tc_2 \\ \vdots \\ \vdots \\ T_n^{c+} tc_n \end{bmatrix}, \tag{3-10}$$

where $T^{c+} = \begin{bmatrix} T_1^{c+} \\ T_2^{c+} \\ \vdots \\ \vdots \\ T_n^{c+} \end{bmatrix}$, *n* is the number of industries, and tc_i are the ad valorem trade costs for industry *i*.

With the above equation 3-10, country *c*'s factor content of trade is:

$$F^c = BT^c + BC^c. \tag{3-11}$$

Moreover, country *c*'s factor endowments are given by:

$$V^c = BY^c + BC^c, \tag{3-12}$$

where V^c is country *c*'s vector of endowments. That is, the factor endowments are all the factors used in production, plus all the factors used in trade.

If we add equation 3-12 for all countries of the world, we have the world endowment vector:

$$V^W = BY^W + BC^W, \tag{3-13}$$

where V^W, Y^W, and C^W are the world endowment of factors, world net output, and world trade costs, respectively.

Note that from equation 3-11, we get:

$$F^c = B(Y^c - D^c) + BC^c$$

$$= BY^c + BC^c - s^c BY^W$$

$$= V^c - s^c(V^W - BC^W), \tag{3-14}$$

where use was made of equation (3-13).

Finally, substituting for the factor content of trade from equation 3-11, we get our testable equation:

$$BT^c + BC^c = V^c - s^c(V^W - BC^W). \tag{3-15}$$

III. Empirical Analysis

We will now proceed to the empirical analysis of the factor content of trade model, following two procedures in section II. Table 3.2 lists the test results that are based on method 1 and method 2. We have performed the same tests as Davis and Weinstein (2001a). The slope test is the result of running the trade specification as a regression, whose theoretical slope on the predicted factor content of trade is one. The sign test compares the sign of the measured factor content of trade (left-hand side of the trade specification) with the sign of the predicted factor content of trade (right-hand side of the trade specification); and theoretical value of the sign test is one, which means one hundred percent correct match between the measured and the predicted factor content of trade. Finally, the variance ratio test is the ratio between the variance of the measured and the predicted factor contents of trade, and has a theoretical value of one. For comparison, we also list the corresponding results from Davis and Weinstein's paper in Table 3.2.

For the original HOV model's specification with the trade costs in the technology matrix, method 1, the sign test fits and improves to 65 percent, as shown in Table 3.2. This is better than relying on a coin toss, and the slope coefficient measured on the predicted factor content of trade is 0.12, which shows that it is still short of the theoretical prediction of unity, but is greater than that of Davis and Weinstein's test result (T1) and it is an impressive statistic, because the slope coefficient is positive, where Davis and Weinstein's trade slope was negative. The variance ratio increases to 0.02, indicating that the variance of the predicted factor content of trade is about 50 times of that which was measured. The R^2 of 0.83 allows us to conclude that the predicted factor content of trade helps to explain 83 percent of the variation in the measured factor content of trade. When we compare the R^2 of method 1 with the R^2 of Davis and Weinstein's study (T1), method 1's result is greater than that of Davis and Weinstein. Therefore, method 1 has a better fit than Davis and Weinstein's result. This high R^2 is a result of the important size effects present when comparing measured and actual factor usage across countries. Standard error means standard error of that slope. Note that these results were obtained without relying on any major departure from the HOV model, which is what Davis and Weinstein do in their theoretically dubious use of the gravity model. We emphasize that the last column of Table 3.2 was obtained not only by using the gravity model but also by amending the HOV model in several ways. We get comparable results by simply taking trade costs directly into account!

Table 3.2: Test Results of Trade Test

	Method 1	Method 2	Davis and Weinstein (2001a)	
			(T1)	(T7)
Slope Test	0.12	0.0023	-0.002	0.82
Standard Error	0.01	0.0022	0.005	0.03
R^2	0.83	0.052	0.01	0.98
Sign Test	0.65	0.60	0.32	0.91
Variance ratio Test	0.02	0.00017	0.0005	0.69
Observations	20	20	22	22

Notes: Dependent variable is the Measured Factor Content of Trade (MFCT). Theoretical value for the sign test, and the slope test, and the variance ratio test is unity.

As we can see from the test results with method 2 in Table 3.2, the fit of the sign test improves to 60 percent and the slope coefficient increases to 0.0023, relative to Davis and Weinstein's results (T1), which shows that it is still short of the theoretical prediction of unity. The difference of the slope test result between method 2 and Davis and Weinstein (T1) is very small and not very significant. However, it is an impressive statistic, because the slope coefficient is positive where Davis and Weinstein's trade slope was negative. The variance ratio decreases to the insignificant amount of 0.00017, indicating that the variance of the predicted factor content of trade still exceeds that of the measured factor content of trade by a factor of over 5,800. The R^2 of 0.052 implies that the regression equation explains 5.2 percent of the variation in the measured factor content of trade. The R^2 of method 2 is greater than Davis and Weinstein (T1)'s. We conclude therefore that method 1 seems to be the best method to account for trade costs.

IV. Concluding Remarks

"Trade costs are large on average" (Anderson and van Wincoop (2004), p.86).

Departing from the Davis and Weinstein procedure, we expand upon the original HOV model by considering trade costs. This chapter deduces the original HOV model with trade costs, and compares the importance of the original HOV model with and without trade costs. This first model, method 1, includes the trade costs directly in the technology matrix, where our assumption is that the trade costs are located in the original country. To calculate the factor content of trade in the presence of trade costs, this chapter explains how to derive computable expressions for the technology matrix, which includes the trade costs.

This approach permits us to use the standard evaluations of the original HOV model: the sign test, the slope test, and the variance ratio test. Using the dataset of 10 countries, we find evidence supporting the fundamental idea of trade costs inside of the technology matrix, method 1, with a result of 65 percent for the sign concordance, of 0.12 for the slope coefficient, and 0.02 for the variance ratio. Our results indicate that the trade costs inside of the technology matrix are an appropriate modification of the HOV model.

Additionally, this chapter includes trade costs directly in the vector of the net exports, method 2, and also finds evidence supporting the theory with the same data as method 1. However, the evidence is weak. With method 2, the sign fit of the sign test improves to 60 percent and the slope coefficient increases to 0.0023; however, the variance ratio test does not show better results than Davis and Weinstein. Our test results also indicate that the trade costs in the vector of the net exports are an appropriate modification of the HOV model, but not as much as the case that the trade costs inside of the technology matrix.

The contribution of this chapter is to show that modifying the HOV model by including trade costs inside of the technology matrix and trade costs in the vector of the net exports can establish considerable gains in the predictive performance of the HOV model.

DATA APPENDIX

A. For Chapter One

A contribution of this project was the construction of a new and rich dataset. We hope that making this new dataset widely available to researchers interested in international trade and production becomes an important contribution of the chapter. In order to facilitate the dissemination of the data, we provide in this appendix a full documentation of the data construction.

The main data sources are the OECD's Input-Output Tables (henceforth "IO") and Structural Analysis database (henceforth "STAN"). See Yamano and Ahmad (2006) and OECD (2005) for data documentation, respectively. IO provides data on inter-industry flows for each country for a year around 2000. STAN has data, by country, year and industry, on production, labor and investment. There are 36 countries in IO, including 28 OECD members (all except Iceland and Mexico), plus 8 nonmember countries (Argentina, Brazil, China, Chinese Taipei, India, Indonesia, Israel, and South Africa). Together, these countries accounted for about 90% of world GDP in 2000. In this version of the chapter we exclude the Russian Federation, Mexico, Estonia and Slovenia, which represent less than 2% of World GDP.[40] Because of data problem, we also exclude four countries: Luxembourg, Switzerland, Taiwan, and South Africa. The 32 countries are listed in Table A1. We use the version of the IO files provided by the OECD in February 2009, because the most recent files (November 2007) seem to be somewhat incomplete. We have STAN data for 27 of those countries. We define two country groups: developed

[40] Input-Output tables for Russia are available but they have not been harmonized with the ISIC classification used in IO. IO tables for Mexico, Estonia and Slovenia are not yet available.

countries (DC) are those for which GDP per capita is above $15,000, while all other countries are classified as less developed countries (LDC).[41]

Table A1: Countries with IO Tables

Country	Year	STAN available	DC/LDC
Argentina	1997	no	LDC
Australia	1998	yes	DC
Austria	2000	yes	DC
Belgium	2000	yes	DC
Brazil	2000	no	LDC
Canada	2000	yes	DC
China	2000	no	LDC
Czech Republic	2000	yes	LDC
Denmark	2000	yes	DC
Finland	2000	yes	DC
France	2000	yes	DC
Germany	2000	yes	DC
Greece	1999	yes	LDC
Hungary	2000	yes	LDC
India	1998	no	LDC
Indonesia	2000	no	LDC

[41] We chose this cut-off both because it seemed to lay at a natural break in our sample, and for the very practical reason that we needed to keep a substantial number of LDCs. We used the rgdpl series from the World Penn Tables, which contain real GDP per capita in international dollars (Laspeyres index).

Ireland	2000	yes	DC
Israel	1995	no	DC
Italy	2000	yes	DC
Japan	2000	yes	DC
Korea	2000	yes	DC
Netherlands	2000	yes	DC
New Zealand	2002	yes	DC
Norway	2000	yes	DC
Poland	2000	yes	LDC
Portugal	2000	yes	DC
Slovak Republic	2000	yes	LDC
Spain	2000	yes	DC
Sweden	2000	yes	DC
Turkey	1998	no	LDC
United Kingdom	2000	yes	DC
United States	2000	yes	DC

The data in IO cover 48 industries, at a level of aggregation that roughly tracks 2-digit ISIC. We aggregated industries 26, 27, 28 into just one industry, because it was not possible to disaggregate the data from STAN. Thus we end up with 45 industries, listed below.

Table A2: List of Industries

IO Industry	Description	ISIC Rev.3
1	Agriculture, hunting, forestry and fishing	01+02+05
2	Mining and quarrying (energy)	10-12
3	Mining and quarrying (non-energy)	13-14
4	Food products, beverages and tobacco	15-16
5	Textiles, textile products, leather and footwear	17-19
6	Wood and products of wood and cork	20
7	Pulp, paper, paper products, printing and publishing	21-22
8	Coke, refined petroleum products and nuclear fuel	23
9	Chemicals excluding pharmaceuticals	24, ex. 2423
10	Pharmaceuticals	2423
11	Rubber & plastics products	25
12	Other non-metallic mineral products	26
13	Iron & steel	271+2731
14	Non-ferrous metals	272+2732
15	Fabricated metal products, except machinery & equipment	28
16	Machinery & equipment, n.e.c.	29
17	Office, accounting & computing machinery	30
18	Electrical machinery & apparatus, n.e.c.	31
19	Radio, television & communication equipment	32
20	Medical, precision & optical instruments	33
21	Motor vehicles, trailers & semi-trailers	34
22	Building & repairing of ships & boats	351
23	Aircraft & spacecraft	353
24	Railroad equipment & transport equip. n.e.c.	352+359
25	Manufacturing n.e.c.; recycling (including furniture)	36-37
26+27+28	Electricity, gas, steam and hot water supply	40

29	Collection, purification and distribution of water	41
30	Construction	45
31	Wholesale & retail trade; repairs	50-52
32	Hotels & restaurants	55
33	Land transport; transport via pipelines	60
34	Water transport	61
35	Air transport	62
36	Supporting and auxiliary transport activities; travel agencies	63
37	Post & telecommunications	64
38	Finance & insurance	65-67
39	Real estate activities	70
40	Renting of machinery & equipment	71
41	Computer & related activities	72
42	Research & development	73
43	Other Business Activities	74
44	Public admin. & defense; compulsory social security	75
45	Education	80
46	Health & social work	85
47	Other community, social & personal services	90-93
48	Private households with employed persons & extra-territorial organizations & bodies	95+99

The ultimate origins of the data are the national accounts of the source countries, supplemented by questionnaires drawn up by the OECD. Even though most countries have by now adopted the United Nations Standard for the Systems of National Accounts, published in 1993 (SNA93), some inconsistencies remain. One important reason to use the OECD data is that the OECD's statistical group has evened out many of these inconsistencies. We detail below how we deal with data problems that do remain.

We need to construct four vectors and one matrix for each of the 32 countries: total final demand ($\mathbf{Y}^c$), domestic final demand ($\mathbf{D}^c$), trade ($\mathbf{T}^c$), the total factor requirements matrix ($\mathbf{B}^c$), and the factor endowment vector ($\mathbf{V}^c$), where "*c*" will henceforth index a generic country. In constructing these variables we follow many of the approaches in Trefler (1995, henceforth T), Davis and Weinstein (2001a, henceforth DW), and Trefler and Zhu (2006, henceforth TZ), while in some cases departing significantly from them. We use the footnotes to contrast among the different approaches.

To see the main data problems, consider a simple example with four industries. With no data problems, IO for country *c* would look as in Table A3 (superscript omitted).

Table A3: Format of the IO Data for Country *c*: No Data Incompleteness

	Ind. 1	**Ind. 2**	**Ind. 3**	**Ind. 4**	**D**	**E**	***M***
Ind. 1	Z_{11}	Z_{12}	Z_{13}	Z_{14}	D_1	E_1	M_1
Ind. 2	Z_{21}	Z_{22}	Z_{23}	Z_{24}	D_2	E_2	M_2
Ind. 3	Z_{31}	Z_{32}	Z_{33}	Z_{34}	D_3	E_3	M_3
Ind. 4	Z_{41}	Z_{42}	Z_{43}	Z_{44}	D_4	E_4	M_4
Tax on intermediates	TI_1	TI_2	TI_3	TI_4			
Value added	VA_1	VA_2	VA_3	VA_4			
Output	X_1	X_2	X_3	X_4			

Each shaded column lists inputs that go into a single industry, while each row describes how the outputs from a single industry are distributed. That is, Z_{ij} is the total value of industry *i*'s output that goes into industry *j*. The Z_{ij}'s form a matrix *Z* of input-output flows. For each industry i, IO also has a row for taxes on intermediates, which we represent by TI_i. The data also contains three rows for value added, represented in aggregate form as VA_i in Table A3. The three rows are: employee compensation, gross operating surplus, and taxes on production. They can be interpreted as payment for three types of input: labor, capital, and government services, respectively. Finally, the last row in Table A3 shows total (gross) output for each industry i (denoted X_i). Following along column i, total output can be calculated as the sum of inputs:

$$X_i^c \equiv \sum_k Z_{ki}^c + TI_i^c + VA_i^c. \qquad \text{(A1)}$$

Considering now the rows, the data also provides information on D_i, E_i and M_i for each industry i, which denote domestic final demand, exports and imports, respectively. In the actual data D_i is the sum of a number of columns: household consumption, government consumption, investment goods, and so on. Considering all possible destinations of the output from industry i, that is, following along row i, total output is given by:

$$X_i^c \equiv \sum_j Z_{ij}^c + D_i^c + E_i^c - M_i^c\,. \qquad \text{(A2)}$$

However, IO rarely has the perfect data described in Table A3. The major difficulty is that some countries aggregate two or more industries, reporting only the aggregate. When industries i and j are both reported as industry j, then $Z_{ik}^c = 0$ and $Z_{ki}^c = 0$ for all k. For example, Canada includes all of industry 14 (non-ferrous metals) in industry 13 (iron and steel), and consequently all data in row 14 and column 14 are reported as zero. Continuing with our four-industry example, suppose that country c reports industry 1 and industry 2 as an aggregate under industry 1. Excluding the rows that are irrelevant for this discussion, the reported data looks as in Table A4.

Table A4: Format of the IO Data for Country *c*: Some Incomplete Data

	Ind. 1	**Ind. 2**	**Ind. 3**	**Ind. 4**	**D**	**E**	***M***
Ind. 1	$Z^*_{11}+Z^*_{12}+Z^*_{21}+Z^*_{22}$	0	$Z^*_{13}+Z^*_{23}$	$Z^*_{14}+Z^*_{24}$	$D^*_1+D^*_2$	$E^*_1+E^*_2$	$M^*_1+M^*_2$
Ind. 2	0	0	0	0	0	0	*0*
Ind. 3	$Z^*_{31}+Z^*_{32}$	0	Z_{33}	Z_{34}	D_3	E_3	M_3
Ind. 4	$Z^*_{41}+Z^*_{42}$	0	Z_{43}	Z_{44}	D_4	E_4	M_4
Output	$X^*_1+X^*_2$	*0*	X_3	X_4			

Here, the starred variables represent the latent "true" data. In the event, we do not possess such data, and it must be imputed. Note that the unstarred variables in Table A4 stand for all non problematic entries.[42] Without risk of confusion, we shall also use unstarred variables to denote reported *aggregate* data. Thus, for example, the reported element (1,1) of matrix Z is $Z_{11}^{c}=Z_{11}^{c^*}+Z_{12}^{c^*}+Z_{21}^{c^*}+Z_{22}^{c^*}$.

We are now ready to explain the process of data construction.

[42] In reality, such non-problematic industries constitute the large majority of cases.

A1. Output:

Output vector $\mathbf{X}^c$ for each country is obtained directly from the data (last row of Table A3). For years other than 2000, all values were deflated to 2000. We used the production volume index (variable PRODK) to deflate when it is available from STAN. When PRODK was not available, we used the value added volume index, VALUK. In all cases in which either volume index was not available at the corresponding industry aggregation, we used the next available level of aggregation. Thus the data were deflated according to the equation:

$$X_{i,deflated}^{c} = X_i^c \left[\frac{PROD_{I,2000}^{c}}{PRODK_{I,2000}^{c}}\right] \Big/ \left[\frac{PROD_{I,t}^{c}}{PRODK_{I,t}^{c}}\right],$$

where X_i^c is output (in year *t*) and $X_{i,deflated}^{c}$ is the output deflated for 2000. In the formula above, $PROD_{I,t}^{c}$ is STAN's variable PROD (gross output) for country *c* for industry *I* in year *t*, where industry *I* is the most disaggregated industry that contains industry *i* and for which there is data available. An analogous definition applies for $PRODK_{I,t}^{c}$.

For countries for which STAN is not available at all (see Table A1), and for Ireland, which has neither PRODK nor VALUK in STAN, we used the consumer price index to deflate gross output values. This was done for: Argentina, Brazil, China, India, Indonesia, Ireland, Israel, Taiwan, and Turkey. All values were converted to U.S. dollars, using the nominal exchange rate for 2000.[43]

[43] Data for the CPI come from the World Development Indicators (WDI). We used Penn World Tables, version 6.2, for the nominal exchange rate.

Data problems

As explained above, in some cases sector *j* is reported under sector *k*, resulting in a row and in a column of zeros for sector *j* and in aggregate data under sector *k*. Therefore, prior to deflating the outputs, we calculate the share of each sector in the aggregate. We do so with the aid of STAN, which for the majority of cases provides production data separately for the two sectors. Formally, we reassign production from the IO aggregate for sector *j* and *k* ($X_k^{c,IO}$) to sector *j* in the following manner:

$$\tilde{X}_j^c = X_k^{c,IO} \frac{X_j^{c,STAN}}{X_j^{c,STAN} + X_k^{c,STAN}} \quad \text{(A3)}$$

with an analogous formula for $\tilde{X}_k^c$.[44] Procedure (A3) was used for the following countries and sectors (we list only the sector with zero data, see the IO documentation for corresponding sectors into which they were aggregated): Australia (19), Austria and Portugal (10,14), Belgium, Finland, France, Germany, Hungary, Italy, Netherlands, Spain, Sweden, and the United Kingdom (10,14,23,24), Greece and Ireland (10), New Zealand (36), Norway (14,23,24), and Poland (10,23,24). In one case STAN did not provide data for the same year as IO, and we used data from one year apart: Netherlands (14).

In a few cases STAN itself has missing output data, while for some countries STAN data is missing altogether. We then use a formula similar to (A3), but where the proportionality factor on the right is replaced by the average ratios among countries in the same group (developed or less developed). Thus, for the less developed group, we use:

[44] DW use a somewhat different procedure for missing manufacturing sectors (see their second equation on page 1449, which we translate into our notation): they write $\tilde{X}_j^c / \sum_m X_m^{c,IO} = X_j^{c,STAN} / \sum_m X_m^{c,STAN}$, where *m* runs over *all* manufacturing sectors. Compared to our procedure, their assumption is that each missing sector *j*'s share of total manufacturing output is the same in STAN and in IO. We adopt the weaker assumption that the share across only the two relevant industries, *j* and *k*, is the same in STAN and in IO.

$$\tilde{X}^{c}_{j,LDC} = X^{c,IO}_{k,LDC} \underset{c' \in LDC}{AVG} \left[\frac{X^{c,IO}_{j,LDC}}{X^{c,IO}_{j,LDC} + X^{c,IO}_{k,LDC}} \right], \qquad \text{(A3')}$$

where the average runs over all countries c' that are in the group of less developed countries and for which data on industries *j* and *k* do exist after step (A3). (The subscript *LDC* is added for readability purposes only, since the superscript *c* completely describes the country.) This was done for the following country-sector pairs with zero data: Argentina (40,41,42,23), Australia (40,42,48), Brazil (42), China (23,34,35,36,40,41,47,42), Denmark and Canada (42), Czech Republic and Slovak Republic (10, 14, 23, 24), Greece (14, 23, 24), India (20,23,40,42,48), Ireland (8,14), New Zealand (14,17,19,23), Norway (10), Poland (14,35), Israel (23,24,42,3).[45] Austria and Portugal posed a different problem, which required a two-step procedure: although they aggregate industries 22, 23 and 24 under industry 22, their STAN reports 22 separately, while still aggregating 23 and 24. In order to maximize the use of information, we used equation (A3) first to separate 22 from the aggregate 23+24, and then used equation (A3') to separate the latter two industries. An additional problem is that Australia splits industry 48 (ISIC 95 + ISIC 99) into industry 44 (where it reports ISIC 75 + ISIC 99) and 47 (where it reports ISIC 90-93 + ISIC 95).[46] We dealt with this in an approximate fashion. First, we note from the variable EMPE in Australia's STAN that ISIC 99 is a very small industry, both compared with ISIC 75 (800 employees versus 483,796, respectively) and compared with ISIC 95 (800 employees versus 8,425, respectively). Therefore it is a very small error to ignore ISIC 99's inclusion in industry

[45] Similarly to equation (A3), the implicit assumption is that the output *split* between industries *j* and *k* be similar between country *c* and the rest of the group. For some non-manufacturing sectors DW require that each industry's share of *total* output be similar to the other countries in the sample (see their first equation on page 1449).

[46] It is not possible to deduce this from the IO documentation. However, STAN documentation makes clear that these are the assignments made by the OECD.

44, which allows us to split industry 47 into industries 47 and 48 according to procedure (A3') above.

A2. Construction of the Matrix of Technical Coefficients:

Next, we construct a matrix of technical coefficients (henceforth denoted by $\mathbf{A}^c$), whose elements are defined as ratios between usage of each input and industry output. That is, element a^c_{ij} of the matrix for country c is defined as:

$$a_{ij}^c \equiv \frac{Z_{ij}^c}{X_j^c}. \qquad \text{(A4)}$$

Data problems

Regarding the missing values of matrix Z in Table A4, consider an accounting identity mandated by the aggregation itself. If country c aggregates industry j into industry k, the following identity holds for all i:

$$Z_{ik}^c = Z_{ik}^{*c} + Z_{ij}^{*c} = \tilde{Z}_{ik}^c + \tilde{Z}_{ij}^c\,, \qquad \text{(A5)}$$

where the left hand side is the reported value, the starred variables are the latent unknown values, and tildes denote imputed values. Furthermore, consider the following equation, which assumes the same techniques of production across countries in the same development group:[47]

$$\frac{\tilde{Z}_{ik}^c / \tilde{X}_k^c}{\tilde{Z}_{ik}^c / \tilde{X}_k^c + \tilde{Z}_{ij}^c / \tilde{X}_j^c} = \underset{c'}{Avg}\left[\frac{Z_{ik}^{c'} / X_k^{c'}}{Z_{ik}^{c'} / X_k^{c'} + Z_{ij}^{c'} / X_j^{c'}}\right], \qquad \textbf{(A6)}$$

[47] Indeed this and similar assumptions is the reason to restrict averages to the same development group.

where the average is performed over all countries c' that do not aggregate industries i and k, and that are in the same development group (DC or LDC) as country c. Furthermore, the $\widetilde{X}$'s in the equation above are the values obtained from part A. The solutions to equations (A5) and (A6) supply the required imputed values for $\tilde{Z}_{ik}^{c}$ and $\tilde{Z}_{ij}^{c}$, which allows us to disaggregate the columns. This procedure comes with the usual caveats, but here perhaps in a less dramatic fashion because generally the two industries are similar to each other. Let us for example suppose that industry k is "Iron and steel," industry j is "Non-ferrous metals," and industry i is "Computers." Equation (A6) estimates country c's proportion of computer usage in iron production, as compared to computer usage in non-ferrous metals, as similar to the same development group. This is a weaker condition than assuming that all production techniques are similar across the world.[48]

Consider now the rows, for which we can write, analogously to equations (A5) and (A6):

$$Z_{ki}^{c} = Z_{ki}^{*c} + Z_{ji}^{*c} = \tilde{Z}_{ki}^{c} + \tilde{Z}_{ji}^{c}\,, \tag{A7}$$

And

$$\frac{\tilde{Z}_{ki}^{c}}{\tilde{Z}_{ki}^{c} + \tilde{Z}_{ji}^{c}} = \underset{c'}{Avg}\left[\frac{Z_{ki}^{c'}}{Z_{ki}^{c'} + Z_{ji}^{c'}}\right], \tag{A8}$$

where again the average is performed over the countries country c's development group. The first equation provides an accounting identity that must necessarily hold.[49] Equation

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[48] That would be assuming $\tilde{a}_{ik}^{c} = Avg(Z_{ik}^{c'}/X_{k}^{c'})$, which is what DW do (see also footnote 26). Note that an alternative to the methodology in equations (A5) and (A6) is to separate the columns in the same proportions as outputs. However, that would not use any information about techniques of production from other countries. Suppose for example that computers are 2% of the input in iron on average, but are 4% of the input in non-ferrous metals. If we split the columns according to the proportion of the outputs, we will obtain two identical technical coefficients, ignoring the expectation that one should be double of the other.

[49] The reader familiar with input-output methodology will recognize a resemblance between our methodology and the well-known RAS method for updating input-output matrices with limited information (see Miller and Blair 1985).

(A8) would compare, for example, the proportion of ferrous versus non-ferrous metals that are used in computers with that of other countries in the same group. Equations (A7) and (A8) provide estimates to disaggregate the rows, which completes our construction of matrix *Z*.[50] These procedures were done for the same country-industry pairs reported at the end of part A. Note that in one case the reported zeros were actual zeros, and we defined $\tilde{a}_{ij}^{c} = Avg\left(\tilde{a}_{ij}^{c'}\right)$, where the average covers non-problematic countries in the same group. This was done for: Belgium (2).

A3. Matrix of Direct Factor Inputs and Matrix of Total Factor Inputs:

Next, we construct matrix $\mathbf{F}^c$, whose element F_{fl}^{c} is defined as the amount of factor *f* used directly in industry *l* in country *c*, per dollar of output.

Data on Gross Fixed Capital Formation for each country and industry, and for all available years starting in 1980, is taken from STAN (series GFCF). The data for each year *t* were deflated using STAN's investment volume index (series GFCFK). Formally we calculate:

$$GFCF_{i,t,deflated}^{c} \equiv GFCFK_{i,t}^{c} GFCF_{i,2000}^{c} / GFCFK_{i,2000}^{c},$$

where $GFCF_{i,t}^{c}$ $\left(GFCFK_{i,t}^{c}\right)$ is the value of the STAN data series GFCF (GFCFK) for country *c*, industry *i*, and year *t*. All data are converted to US dollars as in Part A. We get

[50] As mentioned, our procedure is similar to DW, with an important distinction. They also use averages from other countries, but they use them to calculate the input coefficient directly (see the first equation on page 1451): they use $\tilde{a}_{ki}^{c,DW} = Avg(Z_{ki}^{c\prime}/X_i^{c\prime})$, while we use $\tilde{a}_{ki}^{c} = Avg\left[Z_{ki}^{c\prime}/(Z_{ki}^{c'} + Z_{ji}^{c'})\right] Z_{ki}^{c}/\tilde{X}_i^{c}$. The main difference is that DW's procedure does not use any information on either Z_{ki}^{c} or X_i^{c} from country *c*. Since we do have that information, we prefer to use it. In particular our procedure will automatically enforce the accounting identities (A5) and (A7), which is generally *not* the case with DW. Furthermore, suppose that the price of industries *k* and *j* in country *c* is higher than in most other countries. Then the true coefficients $a_{ki}^{c^*}$and $a_{ji}^{c^*}$ are likely to be smaller than the rest of the world. In our procedure, that information is incorporated through the factor $Z_{ki}^{c}/\tilde{X}_i^{c}$.

an estimate of the initial capital by multiplying data series KAPW (capital per worker) from PWT by series LF (labor force) from WDI for the initial year. This yields aggregate capital K_0^c for country *c* and year t_0. We deflate it according to the formula:

$$K_{0,deflated}^c = K_0^c GFCFK_{Agg,t}^c GFCF_{Agg,2000}^c / (GFCFK_{Agg,2000}^c GFCF_{Agg,t}^c),$$

where $GFCF_{Agg,t}^c$ $(GFCFK_{Agg,t}^c)$ is the value of the STAN data series GFCF (GFCFK) for country *c*, and year *t* for the aggregate economy. Finally $K_{0,deflated}^c$ is distributed across the different industries according to the proportion of the Gross Surplus data from IO, yielding $K_{i,0,deflated}^c$.

We then use the perpetual inventory method to construct a stock of capital for each country and industry in the year of interest. Thus the capital stock in country *c* and industry *i* at the beginning of year 2000 is defined as:

$$K_i^c \equiv K_{i,0,deflated}^c (1-\delta)^{1999-t_0} + \sum_{t=t_0}^{1999} (1-\delta)^{1999-t} GFCF_{i,t,deflated}^c, \qquad \text{(A9)}$$

where t_0 =1980, the depreciation rate is δ=0.133, and K_{0i}^c is the initial capital stock in country *c* and industry *i*. To estimate K_{0i}^c we first obtain aggregate capital stock from the Penn World Tables, version 5.6 (the last for which there is capital stock available) which is in 2000 US dollars. [51] Then we distribute it among the different industries according to each industry's Gross Operating Surplus (which for country *c* and industry *i* we denote by S_i^c), available from IO. Note that in some cases (precisely the same as listed at the end of part A) we first need to impute values for S_i^c when aggregation wrongly implies that they would be zero. Formally, if sectors *j* and *k* are both reported under sector *k*, we calculate:

[51] We calculated it with the approximation KAPW*POP, where KAPW is Nonresidential Capital Stock per Worker and POP is population.

$$\tilde{S}_j^c = S_k^c \frac{\tilde{X}_j^c}{\tilde{X}_j^c + \tilde{X}_k^c}, \quad \text{(A10)}$$

with an analogous formula for sector *k*. This all that is needed for the calculation of the capital stock (equation A9).

Labor compensation data by country and industry are also taken from STAN (variable LABR).[52]

We then divide both the factor data by the corresponding output to obtain the elements of matrix $\mathbf{F}^c$. Finally, for each country we construct the matrix of total (direct plus indirect) factor input requirements as:

$$\mathbf{B}^c = \mathbf{F}^c(\mathbf{I} - \mathbf{A}^c)^{-1}\,. \quad \text{(A11)}$$

The interpretation of equation (A11) is straightforward. Post-multiplying it by ($\mathbf{I}$-$\mathbf{A}^c$) and rearranging, we obtain: $b_{fi}^c = f_{fi}^c + \sum_j b_{fj}^c a_{ji}^c$, where b_{fi}^c is element (*fi*) of matrix $\mathbf{B}^c$. It is given by the *direct* factor input (f_{fi}^c) plus the sum for each industry *j* of the indirect factor input ($b_{fj}^c a_{ji}^c$), where the latter in turn takes into account all intermediate inputs to industry i.

Data problems

In some instances investment data in STAN are at a more aggregated level than the 45 IO industries. In those instances we use equation (A9) to calculate the capital stocks at the most disaggregated levels available, and then distribute the capital stocks for each

[52] DW use the actual number of employees. If wages were equalized within each country (though not necessarily across countries), then the two are approximately equivalent (although ours would take into account part-time and over-time labor). However, with differences in wages across industries, using the currency as the unit of labor is equivalent to using "efficiency units," with some advantage.

industry according to the proportions of each industry's Gross Operating Surplus (variable S_i^c in IO).

For Japan, and for the eight countries without STAN, there was no investment data available from STAN, so we used a different approach. We obtained the aggregate gross fixed capital formation series (GFCF) from the World Bank's World Development Indicators, in constant 2000 US dollars. After using the perpetual inventory method to construct the aggregate capital stock at the beginning of 2000 (where the initial capital stock is still given by the Penn World Tables), we distributed it among the different IO industries according to the proportions of each industry's Gross Operating Surplus. Since Gross Operating Surplus is not available for Argentina and India and we use Value Added instead.

In some cases the variable S_i^c in IO turns out to be negative, rendering it useless for the proportions described in the previous two paragraphs. We then use output as the proportions to distribute the capital stocks across industries.

For some country-industry pairs we could also not obtain investment information from STAN at any but the most aggregate level. In those cases we used the same methodology as for Japan, but restricted to the problematic industries. This was done for: France (2, 3, 6), New Zealand (6, 7, 16-24), Norway (8, 9) and Portugal (2, 3).

For six countries there was no aggregate capital stock from the Penn World Tables, which affects our calculation of K_{0i}^c. We estimated K_{0i}^c using the proportion between initial capital and capital accumulation from the remaining countries in the LDC group (of which all the problematic countries were part). Specifically we calculated:

$$\widetilde{K}_i^c \equiv \left[1 + \underset{c' \in LDC}{Avg}\left[\frac{K_{0i}^{c'}(1-\delta)^{1999-t_0^{c'}}}{\sum_{t=t_0^{c'}}^{1999}(1-\delta)^{1999-t} GFCF_{i,t,deflated}^{c'}}\right]\right] \sum_{t=t_0}^{1999}(1 - \delta)^{1999-t}\, GFCF_{i,t,deflated}^{c}\,,$$

where the average runs over all LDC countries with initial capital data from the Penn World tables, and $t_0^{c'}$ is country *c*'s initial year in equation (A9). This was done for: Czech Republic, Hungary, Slovak republic, Brazil, China, and Indonesia.

For labor compensation, in some cases the data in STAN were also more aggregated than the 45 IO industries. In those instances we distributed aggregate employment across the different industries according to the proportions of the Compensation of Employees variable for country *c* and industry *i* (which we denote by C_i^c), available in IO. In the case of Argentina and India, Compensation of Employees is also not available, and we use Value Added instead.

A4. Final Demand, Trade, and Endowments:

The vector of total final demand is constructed as:

$$Y_i^c \equiv X_i^c - \sum_j Z_{ij}^c\,. \qquad \text{(A12)}$$

Using equation (A4) it can be easily seen that this is equivalent to: $\mathbf{Y}^c = (\mathbf{I} - \mathbf{A}^c)\mathbf{X}^c$. The vector of factor endowments for country *c*, denoted by $\mathbf{V}^c$, is constructed as:

$$\mathbf{V}^c \equiv \mathbf{B}^c\mathbf{Y}^c\,.$$

This is tantamount to assuming full employment of factors. Note that $\boldsymbol{V}^c = \boldsymbol{B}^c\boldsymbol{Y}^c = \boldsymbol{F}^c(\boldsymbol{I} - \boldsymbol{A}^c)^{-1}\boldsymbol{Y}^c = \boldsymbol{F}^c\boldsymbol{X}^c$, as it should.

The net trade vector is given by:

$$\mathbf{T}^{c} = \mathbf{E}^{c} - \mathbf{M}^{c} \,,$$

where we recall that $\mathbf{E}^c$ and $\mathbf{M}^c$ are the export and import vectors for country c, respectively. $\mathbf{T}^c$ is deflated to 2000 with the same deflators used for output, that is:

$$T_{i,deflated}^{c} = T_{i,t}^{c} X_{i,deflated}^{c} / X_{i,t}^{c} \,,$$

where $T_{i,t}^{c}$ and $X_{i,t}^{c}$ are the elements of the trade and output vectors given in year t. Finally, $\mathbf{T}^c$ is converted to dollars in the same way as before.

The vector of final domestic demand $\mathbf{D}^c$ is constructed by adding the columns in the IO tables for household final consumption (HHFC), final consumption by non-profit institutions serving households (NPISH), final consumption expenditures by government (GGFC), gross fixed capital formation (GFCF), changes in inventories, and valuables. For ease of presentation those columns were combined into one in Tables A3 and A4.

Data problems

Again we need to address the cases where IO collapses sector j into sector k, and therefore we have zero exports and zero imports reported for industry j. Fortunately, for the majority of cases STAN provides export and import information by industry and we disaggregate exports and imports in a way similar to equation (A3). For example, for exports in industry j, we calculate:

$$\tilde{E}_{j}^{c} = E_{k}^{c,IO} \frac{E_{j}^{c,STAN}}{E_{j}^{c,STAN} + E_{k}^{c,STAN}} \,,$$

where $E_{j}^{c,STAN}$ denotes exports in industry j in country c, available from STAN. Analogous procedures were used for exports in industry k and for imports in both industries. This was done for: Australia (17, 19), Austria, Ireland, Portugal (9, 10, 13, 14, 22, 24), Belgium, Czech Republic, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Slovak Republic, Spain, Sweden and United Kingdom (9, 10, 13, 14, 22, 23, 24), New Zealand (13, 14, 17, 18, 19, 23, 24), Poland (2, 3, 9, 10, 13, 14, 22, 23, 24).

In some cases where STAN does not have trade data but has production data. For the case where industry j is collapsed into industry k, we use the following expression directly for the trade vector element j:

$$\tilde{T}_j^c = (E_k^{c,IO} - M_k^{c,IO}) \frac{X_j^{c,STAN}}{X_j^{c,STAN} + X_k^{c,STAN}}, \tag{A13}$$

with an analogous expression for sector k. This is tantamount to assuming that the country's share of exports in industry j (compared to the total exports in industries j and k) is given by the share in production. For example, if we only know the aggregate exports in pharmaceuticals and in chemicals, but we know that the chemical industry is nine times larger than the pharmaceutical industry, we attribute 10% of the exports to pharmaceuticals, and the remainder to chemicals.[53] This procedure was done for: Australia (48), Canada (42, 43), Denmark (23, 24), New Zealand (35, 36), Poland (34, 35).

Note that we adjusted $\mathbf{X}^c$, $\mathbf{E}^c$, and $\mathbf{M}^c$, for the most part, based on each country's STAN proportions, while matrix $\mathbf{Z}^c$ was adjusted based partly on averages of other

[53] As before, we point out the limitations of this procedure. The imputation in equation (A13) will be less exact to the extent, for example, that country c has comparative advantage in chemicals and comparative *dis*advantage in pharmaceuticals. The working assumption is that the two industries in question are similar enough for comparative advantage to be similar. This is the best (weakest) assumption that we can adopt, given the data limitations.

countries.[54] One problem with this is that it is then difficult to separate the final domestic demand for the aggregate industries. Here, for such problematic industries, we simply use the definition:

$$\mathbf{D}^{c} \equiv \mathbf{Y}^{c} - (\mathbf{E}^{c} - \mathbf{M}^{c}).$$

This equation is true by definition, after having solved all the problems with the exports and imports.

A5. Generalization with Intermediate Inputs and Different Techniques:

In two recent important papers, both Reimer (2006) and Trefler and Zhu (TZ, 2006) show that when there are traded intermediate inputs and different countries have different choices of techniques of production, the definition of the factor content of trade needs to be generalized so that we keep track of where each intermediate input is produced. We will follow TZ's procedure, whose mechanics we describe next, followed by a brief discussion.[55] For any country *c* let us calculate the share of absorption in good *j* that is sourced from country c', defined as $\theta_j^{c'c}$:

$$\theta_j^{c'c} = \frac{E_j^{c'c}}{X_j^c + M_j^c - E_j^c}. \qquad \text{(A14)}$$

In equation (A14), $E_j^{c'c}$ denotes exports from c' to c of good *j*, (note that M_j^c, as previously defined is also given by $M_j^c \equiv \sum_{c' \neq c} E_j^{c'c}$, and $E_j^c \equiv \sum_{c' \neq c} E_j^{cc'}$). The denominator of equation (A14) is total absorption of good *j* in country *c*. We must also

[54] As already noted, this is mandated by theory. In the null hypothesis of identical techniques across countries, we know that other countries' technical coefficients are a good guide for one country's technical coefficients, essentially forcing us to take that information into account. By contrast, STAN does provide abundant information regarding relative sizes of industries, exports and imports, which correlate directly with their counterparts in IO, again forcing the issue in the direction we took.

[55] We became aware of their paper only after a rough draft of this chapter had been written, preventing better harmonization of notation.

define $\theta_j^{cc} \equiv 1 - \sum_{c' \neq c} \theta_j^{c'c}$. Let us now construct a CG x CG matrix $\hat{\mathbf{A}}$ with typical element:

$$\hat{A}_{ji}^{c'c} \equiv A_{ji}^{c} \theta_j^{c'c} . \quad \text{(A15)}$$

$\hat{A}_{ji}^{c'c}$ is interpreted as the amount of good *j* produced in country c' that is used in the production of one unit of good *i* in country *c*.

Let us also define $\hat{\mathbf{F}} \equiv (\mathbf{F}^1, \mathbf{F}^2, \ldots, \mathbf{F}^C)$ and let us call $\hat{\mathbf{I}}$ the CG x CG identity matrix. Assuming that ($\hat{\mathbf{I}}$-$\hat{\mathbf{A}}$) is invertible, we can construct the following matrix:

$$\widehat{\boldsymbol{B}} \equiv \widehat{\boldsymbol{F}} (\widehat{\boldsymbol{I}} - \widehat{\boldsymbol{A}})^{-1} . \quad \text{(A16)}$$

Then TZ show that $\widehat{\mathbf{B}}$ thus constructed provides the correct measure of the factor content of trade which for country *c* can be defined as:

$$\mathbf{F}^{c} = \widehat{\mathbf{B}} \widehat{\mathbf{T}}^{c} , \quad \text{(A17)}$$

where $\widehat{\mathbf{T}}^{c}$is a detailed trade vector for country *c*, specifically:

$$\widehat{\mathbf{T}}^{c} \equiv \begin{bmatrix} -\mathbf{E}^{1c} \\ -\mathbf{E}^{2c} \\ \cdot \\ \cdot \\ \mathbf{E}^{c} \\ -\mathbf{E}^{(c+1)c} \\ \cdot \\ -\mathbf{E}^{Cc} \end{bmatrix} \quad \text{(A18)}$$

In equation (A18), $\boldsymbol{E}^{c'c}$ is the vector of exports from country c' to country *c* (with general element $E_j^{c'c}$) and $\boldsymbol{E}^{c}$denotes as before the vector of total exports from country *c* to the world.

The interpretation of this procedure is as follows.[56] As already suggested by Deardorff (1982) and calculated in a somewhat more restricted sense by Reimer (2006), this procedure keeps track of not only where each intermediate input is produced, but also where *its* intermediate inputs are produced, and so on. It then correctly calculates the factor content of production by using the techniques of production where each input was produced. Note that the element $\hat{A}_{ji}^{c'c}$ (equation A15) generalizes A_{ji}^{c}, which is the relevant measure when we do *not* need to keep track where each intermediate input is produced. When is that the case? Either when there are no traded inputs (a dubious hypothesis) or when all countries produce with the same techniques of production (our null hypothesis along the demand dimension). One difficulty is that $\hat{A}_{ji}^{c'c}$ is not provided by the available data sets, and only A_{ji}^{c} is. To get around this problem, TZ use a proportionality argument, namely they assume that if, say, 1% of good *j*'s absorption in country *c* is due to imports from country c' (that is, $\theta_j^{c'c} = 0.01$), then all industries will use 1% of good *j* from country c', in whatever their needs are for good *j*. This is in essence what underlies equation (A15). Accepting this construction of matrix $\mathbf{\hat{A}}$, equation (A16) provides the total factor input in a global way, in the same sense that equation (A11) provided the total factor input for each country separately. This is what finally allows the calculation of the factor content of trade (equation A17), keeping track of imports from each individual country, and the exports of country *c* (definition A18).

[56] We are quite terse in this paragraph, as we are essentially repeating TZ, to which the reader is directed for an ampler discussion.

B. For Chapter Three

The data in this chapter came from the Input-Output (IO) tables and Structural Analysis (STAN) database of the OECD in 1985. All of the data in this chapter are given by Davis and Weinstein (2001a), except the matrix of trade costs in factor services. This data section explains briefly where Davis and Weinstein got their original data, and how we obtain trade costs.

B1. Data Sources:

The data for the total factor requirement matrix (B) used the 1985 OECD IO tables. The data for capital (K) and labor (L) used the 1997 OECD STAN database for manufacturing sectors and the 1996 International Sectoral Database (ISDB) for other sectors. Capital stock was calculated by the perpetual inventory method.[57] Sectoral labor inputs and total employment for the year 1985 were derived from the OECD STAN databases and the ISDB. Labor for manufacturing sectors data were taken from the STAN Numbered Engaged (NE) and, for non-manufacturing sectors of labor, the ISDB Total Employment was used.

The data for production (Y^c), demand (D^c), and trade (T^c, T^{c+}, T^{c-}) used the 1995 OECD IO database. The vector of factor endowments (V^c) for country c was calculated as: $V^c \equiv B^c Y^c$. The data for trade costs (tc_i) were taken from Bernard, Jensen, and Schott's (2006) data and were modified for this chapter.

[57] "The Perpetual Inventory Method (PIM) generates an estimate of the capital stock by accumulating past purchases of assets over their estimated service lives" (Measuring Capital, OECD Manual (2001), p.43).

B2. Countries:

We used 10 OECD countries for a year circa 1985: Australia (1986), Canada (1986), Denmark (1985), France (1985), Germany (1986), Italy (1985), Japan (1985), the Netherlands (1986), the United Kingdom (1984), and the United States (1985).

B3. Industries:

Data for each of the 10 OECD countries are organized by their 16 industries. Table B1 shows classification of 16 industrial activities. These are the industries that can be matched between Bernard, Jensen, and Schott's (2006) and Davis and Weinstein's (2001a) papers. Table B1 shows IO sectors, IO sectors' description, and International Standard Industrial Classification (ISIC) Revision 2 codes that match with IO sectors.

Table B1: Classification of Industrial Activities

IO Sector	Description	ISIC Rev. 2 codes
3	Food, beverages, and tobacco	31
4	Textiles, apparel, and leather	32
5	Wood products and furniture	33
6	Paper, paper products and printing	34
7	Industrial chemicals	351+352-3522
9	Petroleum and coal products	353+354
10	Rubbers and plastic products	355+356
11	Non-metallic mineral products	36
14	Metal products	381
15	Non electrical machinery	382-3825
16	Office and computing machinery	3825
20	Other transports	3842+3844+3849
21	Motor vehicles	3843
22	Aircraft	3845
25	Electricity, gas, and water	4
35	Other producers	

Note: Davis and Weinstein (2001a), p.1446.

B4. Trade Costs:

Along with Davis and Weinstein's (2001a) data, this chapter also uses trade costs data from 1987. Because we cannot get data for trade costs from 1985, we assume that trade costs in 1987 were approximately similar to the trade costs in 1985.

We explained Bernard et al.'s (2006) paper in the section I of this chapter, and explained how they calculated the trade costs. With their explanation, we are going to expand our explanation here to show how we use and calculate our trade costs data for the purpose of this chapter.

Bernard et al. (2006) create a dataset of industry level trade costs for years, 1982, 1987, and 1992. They calculate industry-level data and construct ad valorem trade costs. These ad valorem trade costs data are changed by time and across industries. Bernard et al. (2006) define the trade costs variable for industry i and year t as, $Trade\ costs_{it}$. $Trade\ costs_{it}$ are the sum of the ad valorem duty(d_{it}) and the ad valorem freight and insurance (f_{it}). Bernard et al. calculate d_{it} and f_{it} from Feenstra (2006). They define the trade costs rate for industry *i* as the weighted average of trade cost rates across all products in industry *i*. Bernard et al. (2006) explain tariff, freight, and total trade costs.

We now explain how to calculate trade costs, C for this chapter. To calculate trade costs for industry i for the United States, we used Bernard et al.'s (2006) data. First, we harmonized the two-digit SIC industry in Bernard et al.'s trade cost rates and the ISIC Rev.2 codes in Davis and Weinstein's paper.

When two or more industries (i, j) in Bernard et al.'s data correspond to only one of Davis and Weinstein's IO industries, we used the following equation:

$$Trade\ Costs_{IO\ industry} = \frac{US\ trade\ in\ i \times Trade\ Costs_i + US\ trade\ in\ j \times Trade\ Costs_j}{US\ trade\ in\ i + US\ trade\ in\ j}. \qquad \text{(B1)}$$

The United States' trade data for the above equation B1 came from Davis and Weinstein. Finally, we can get the following trade cost rates with 16 concordant IO sectors.

Table B2: Trade Costs Rate (%)

IO Sector	Trade costs rate (%)
3	16.3
4	22.4
5	9.7
6	6.4
7	9.1
9	5.5
10	14.7
11	17.5
14	10.2
15	7.9
16	7.9
20	4.1
21	4.1
22	4.1
25	7.6
35	10.6

Next, we need to model the separation of the cost of trade in capital and the cost of labor. Therefore, we want this separation of the cost of trade in capital services and labor services. We divided trade costs for industry i (tc_i) into labor and capital; to calculate trade costs for capital, we used the following equation:

$$tc_{iK} = \frac{b_{iK} \times tc_i}{b_{iK} + b_{iL}}. \qquad \text{(B2)}$$

To calculate trade costs for labor, we used the following equation:

$$tc_{iL} = \frac{b_{iL} \times tc_i}{b_{iK} + b_{iL}}. \qquad \text{(B3)}$$

The sum of trade costs for industry i in capital services (tc_{iK}), and trade costs for industry i in labor services (tc_{iL}), is therefore equal the total trade costs for industry i:

$$tc_{iK} + tc_{iL} = tc_i. \qquad \text{(B4)}$$

Furthermore, we have assumed that the division of trade costs into labor and capital services has followed the same proportion as production in the same industry. This is obviously a very strong assumption, but it is one that is dictated by the data.

REFERENCES

Aït-Sahalia, Yacine, Jonathan A. Parker, and Motohiro Yogo (2004) “Luxury Goods and the Equity Premium,” *Journal of Finance*, 59(6), 2959-3004.

Anderson, James E. and Eric van Wincoop (2002) “Borders, Trade and Welfare,” in Brookings Trade Forum 2001. Susan Collins and Dani Rodrik, eds. Washington: Brookings Institution, 207-244.

Anderson, James E. and Eric van Wincoop (2004) “Trade Costs,” *Journal of Economic Literature*, 42(3), 691-751.

Andrews, Donald W.K. (1993) “Tests for Parameter Instability and Structural Change with Unknown Change Point,” *Econometrica*, 61 (4), 821-856.

Andrews, Donald W.K. (2003) “Tests for Parameter Instability and Structural Change with Unknown Change Point: a Corrigendum,” *Econometrica*, 71 (1), 395-397.

Barroso, José Manuel (2007) “Hands across the ocean,” The International Herald Tribune Wednesday, April 25.

Bergstrand, Jeffery and Peter Egger (2004) "Trade Costs and Intra-Industry Trade," University of Notre Dame, 1-19.

Bergstrand Jeffery and Peter Egger (2006) "Trade Costs and Intra-Industry Trade," Review of World Economics/Blackwell, 142, July (3rd Quarter/Summer), 433-458.

Bernard, Andrew, Bradford Jensen, and Peter Schott (2006) “Trade Costs, firms and productivity,” *Journal of Monetary Economics*, 53, 917-937.

Bowen, Harry, Abraham Hollander, and Jean-Marie Viaene (1998) “Applied International Trade Analysis,” Ann Arbor, The University of Michigan Press.

Bowen, Harry P., Edward E. Leamer, and Leo Svikauskas (1987) “Multi-country,Multi-factor Tests of the Factor Abundance Theory,” *The American Economic Review*, 77(5), 791-809.

Brecher, R.A. and E.U. Choudri (1986) “The factor content of consumption in Canada and the United States: A two country test of the Heckscher-Ohlin-Vanek model,” Paper presented at the NBER Conference on Empirical Methods for International Trade, Cambridge, MA.

Choi, Yong-Seok and Pravin Krishna (2004) "The Factor Content of Bilateral Trade: An Empirical Test," *Journal of Political Economy*, University of Chicago Press, 112(4), 887-914.

Chung, Chul (2005) "Factor Content of Trade: Nonhomothetic Preferences and 'Missing Trade'" Georgia Institute of Technology manuscript.

Dalgin, Muhammed, Vitor Trindade, and Devashish Mitra (2008) "Inequality, Nonhomothetic Preferences and Trade: a Gravity Approach," *Southern Economic Journal*, 74(3), 747-774.

Davis, D.R. (1997) Critical Evidence on Comparative Advantage? North-North Trade in a Multilateral World, *Journal of Political Economy*, 105(5), 1051-1060.

Davis, Donald (1998) "The Home Market Effect, Trade and Industrial Structure," *The American Economic Reviews*, 88(5), 1264-1276.

Davis, D. R. and D.E. Weinstein (2001a) "An Account of Global Factor Trade," *The American Economic Review*, 91(5), 1423-1453.

Davis, D. R. and D.E. Weinstein (2001b) "The Factor Content of Trade," NBER working paper 8637.

Deardorff, Alan V. (1982) "The General Validity of the Heckscher-Ohlin Theorem," *The American Economic Review*, 72 (4), 683-694.

Deardorff, A. V. (1998) Determinants of Bilateral Trade: Does Gravity work in a Neoclassical World? in: Frankel, J.A.(Ed.), The Regionalization of the World Economy, University of Chicago Press.

Deardorff, Alan V. (2004) "Local Comparative Advantage: Trade Costs and the Pattern of Trade," University of Michigan Research Seminar in International Economics Working paper No. 500.

Deaton, Angus (1992) *Understanding Consumption*. New York: Oxford University Press.

Debaere, Peter (2005) "Monopolistic Competition and Trade, revisited: Testing the Model without Testing for Gravity," *Journal of International Economics*, 66, 249-266.

Debaere, Peter (2003) "Relative Factor Abundance and Trade," *Journal of Political Economy*, 111(3), 589-610.

Dinopoulos, Elias, Kenji Fujiwara, and Koji Shimomura (2007) "International Trade and Volume Pattern under Quasi-Linear Preferences," University of Florida manuscript.

Dixit, A.K. and V. Norman (1980) *Theory of International Trade*, Cambridge, Nisbet/Cambridge University Press, Cambridge.

Dollar, D. (1993) "Technology Differences as a Source of Comparative Advantage," *The American Economic Review*, 83, 431-435.

Ethier, Wilfred J. (1982) “National and International Returns to Scale in the Modern Theory of International Trade,” *The American Economic Review*, 72, 950-959.

Feenstra, Robert C. (1996) “U.S. Imports, 1972-1994. Data and Concordances,” NBER Working paper 5515.

Feenstra, Robert C. (2003) *Advanced International Trade*, Princeton University Press.

Feenstra, Robert C., et al. (2002) “U.S. Imports, Exports and Tariff data, 1989-2001,” NBER working paper 9387, December.

Feenstra, Robert C., website available at http://cid.econ.ucdavis.edu/.

Francois, Joseph F. and Seth Kaplan (1996) “Aggregate Demand Shifts, Income Distribution, and the Linder Hypothesis,” *Review of Economics and Statistics*, 78 (2), 244-250.

Gabaix, Xaiver (1997) “The Factor Content of Trade: A Rejection of the Heckscher-Ohlin Leontief Hypothesis,” Working paper, Harvard University, May.

Hakura, Dalia (1995) “A Test of the General Validity of the Heckscher-Ohlin Theorem for Trade in the European Community,” Three Essays on the Effects of International Trade, Unpublished dissertation, University of Michigan.

Hakura, D. (2001) “hy does HOV fail? The role of technological differences within the EC,” *Journal of International Economics*, 54, 361-382.

Hamiton, D. S. and Quinlan, J. P. (2004) “Partners in Prosperity: The changing Geography of the Transatlantic Economy,” Center for Transatlantic Relations.

Harrigan, J (1997) “Technology, Factor Supplies, and International Specialization: Estimating the Neoclassical Model,” *The American Economic Review*, 87(4), 475-494.

Helpman, Elhanan (1987) “Imperfect Competition and International Trade: Evidence from Fourteen Industrial Countries,” *Journal of the Japanese and International Economies*, I, 62-81.

Helpman, Elhanan (1984) “The Factor Content of Foreign Trade,” *Economic Journal*, 94 (373), 84-94.

Hunter, Linda C. (1991) “The Contribution of Nonhomothetic Preferences to Trade,” *Journal of International Economics* 30, 345-358.

Hunter, Linda C. and James R. Markusen (1988) “Per-Capita Income as a Determinant of Trade,” in Robert C. Feenstra, ed., Empirical Methods for International Trade, Cambridge, MA: MIT Press.

Hummels, David and J. Levinsohn (1995) "Monopolistic Competition and International Trade: Reconsidering the Evidence," *The Quarterly Journal of Economics*, 110, 799-836.

Hummels, David and Volodymyr Lugovskyy (2006) "Are Matched Partner Trade Statistics a Usable Measure of Transportation Costs?" *Review of International Economics*, 14(1), February.

Hummels, David (2001a) "Time as a Trade Barriers," manuscript, Purdue University.

Hummels, David (2001b) "Toward a Geography of Trade Costs," manuscript, Purdue University.

Jacks, David, Christopher Meissner, and Dennis Novy (2008) "Trade Costs, 1870-2000," *The American Economic Review*, 98(2), 529-534.

Johnson, Harry G. (1959) "International Trade, Income Distribution, and the Offer Curve," *Manchester School of Economic and Social Studies*, 27, 241-260.

Korth, Christopher (1987) "International Counter Trade," Quorum Books.

Lai, Huiwen and Susan Chun Zhu (2007) "Technology, Endowments, and the Factor Content of Bilateral Trade," *Journal of International Economics*, 71, 389-409.

Leamer, Edward E. (1980) "The Leontief Paradox, Reconsidered," *Journal of Political Economy*, 88(3), 495-503.

Leamer, Edward E. and James Levinsohn (1995) "International Trade Theory: The Evidence," Handbook of International Economics, Vol.3, Ch.26, 1339–1394, Edited by G. Grossman and K. Rogoff, Elsevier Science B.V.

Leontief, Wassily W. (1953) "Domestic Production and Foreign Trade: The American Capital Position Re-Examined," *Proceedings of the American Philosophical Society*, 97 (4), 332-349.

Lai H. and S.C. Zhu (2004) "The determinant of bilateral trade," *Canadian Journal of Economics*, 37(2), 459-483.

Linder, Staffan (1961) *An Essay on Trade and Transformation*, Stokholm: Almqvist and Wicksell.

Markusen, James R. (1986) "Explaining the Volume of Trade: an Eclectic Approach," *The American Economic Review*, 76(5), 1002-1011.

Matsuyama, Kiminori (2000) "A Ricardian Model with a Continuum of Goods under

Nonhomothetic Preferences: Demand Complementarities, Income Distribution, and North-South Trade," *Journal of Political Economy*, 108, 1093-1120.

Miller, Ronald E. and Peter D. Blair (1985) *Input-Output Analysis: Foundations and Extensions*, Englewood Cliffs, New Jersey: Prentice-Hall.

Mitra, D. and Trindade, V. (2005) "Inequality and Trade," *Canadian Journal of Economics*, 38(4), 1253-1271.

Muhammed, Dalgin, Devashish Mitra, Vitor Trindade (2008) "Inequality, Non-homothetic Preferences, and Trade: A Gravity Approach," *Southern Economic Journal*, 74(3), 747-774.

Obstfeld, Maurice and Kenneth Rogoff. (2000) "The Six Major Puzzles in International Macroeconomics. Is There a Common Cause?" in NBER Macroeconomics Annual 2000, B.S. Bernanke and K. Rogoff, eds. Cambridge, MA: MIT Press, 339-390.

OECD (Organization of Economic Cooperation and Development) (2002) "The OECD Input–Output Database, International Sectoral Data Base, and The OECD Structural Analysis (STAN) Data Base," OECD Economic and Statistic Division.

OECD (2005) "The OECD STAN database for Industrial Analysis," available at http://www.oecd.org/dataoecd/53/21/34464010.doc.

Ogaki, Masao and Carmen M. Reinhart (1998) "Measuring Intertemporal Substitution: The Role of Durable Goods," *Journal of Political Economy*, 106(5), 1078-1098.

Okubo, Masakatsu (2008) "Intertemporal Substitution and Nonhomothetic Preferences," *Economics Letters*, 98, 41-47.

Ostapik E. and Kei-Mu Yi (2007) "International Trade: Why we don't have more of it," *Business Review*, Q3.

Penn World Table 6.2, University of Pennsylvania.

Prebisch, R. (1964) "Towards a new trade policy for development," Report by the Secretary General of UNCTAD, United Nations, New York.

Radelet, Steven and Jeffrey Sachs (1998) "Shipping Costs, Manufactured Exports, and Economic Growth," January.

Ramezzana, Paolo (2002) "Per Capita Income and Industrial Demand in Economic Development and International Trade," University of Virginia manuscript.

Ray, Edward (1981a) "Tariff and Non-tariff Barriers to Trade in the United States and Abroad," *The Review of Economics and Statistics*, 63(2), 161-168.

Ray, Edward (1981b) “The determinants of Tariffs and Nontariff Trade Restrictions in the U.S.,” *Journal of Political Economy*, 89, 105-121.

Reimer, Jeffrey J. (2006) “Global Production Sharing and Trade in Services of Factors,” *Journal of International Economics*, 68, 384-408.

Reimer, Jeffrey J. and Thomas W. Hertel (2007) “Non-homothetic Preferences and International Trade,” Oregon State University manuscript.

Samuelson, Paul A. (1952) “The Transfer problem and Transport Costs,” *Economic Journal*, 62(246), 278-304.

Schott, Peter K. (2003) “One Size Fits All? Heckscher-Ohlin Specialization in Global Production,” *The American Economic Review*, 93(3), 686-708.

Schott, P., website available at www.som.yale.edu/faculty/pks4/sub_international.htm.

Schott, P., “Falling Trade Costs, Heterogeneous Firms and Industry Dynamics,” Yale School of Management, Mimeo.

Singer, H. (1950) “The distributions of gains between investing and borrowing countries,” *The American Economic Review*, Vol.40.

Staiger, R. W., Alan V. Deardorff, and Robert M. Stern (1987) “An Evaluation of Factor Endowments and Protection as Determinants of Japanese and American Foreign Trade,” *The Canadian Journal of Economics*, 20(3), 449-463.

Tchamourliyski, Yuriy (2002) “Distance and Bilateral Trade: the Role of Nonhomothetic Preferences,” Boston College manuscript.

Thursby, Jerry G. and Marie C. Thursby (1987) “Bilateral Trade Flows, the Linder Hypothesis, and Exchange Risk,” *The Review of Economics and Statistics*, 69, 488-495.

Trefler, Daniel (1993) “International Factor Price Differences: Leontief was Right!” *Journal of Political Economy*, 101 (6), 961-987.

Trefler, Daniel (1995) “The Case of the Missing Trade and Other Mysteries,” *The American Economic Review*, 85, 1029-1046.

Trefler, Daniel and Susan Chun Zhu (2000) “Beyond the Algebra of Explanation: HOV for the Technology Age,” *The American Economic Review*, 90(2), 145-149.

Trefler, Daniel and Susan C. Zhu (2006) “The Structure of Factor Content Predictions,” University of Toronto manuscript.

United Nations (1968) *Statistical Papers*, Series M, No. 4, rev. 2, New York.

Vanek, Jaroslav (1968) "The Factor Proportions Theory: The N-Factor Case," *Kyklos*, 21(4), 749-754.

World Development Indicators (2007) World Bank.

Yamano, Norihiko and Nadim Ahmad (2006) *The OECD Input-Output Database: 2006 Edition*, STI Working paper no. 2006/8, OECD.

Yanikkaya, Halit (2003) "Trade openness and economic growth: a cross-country empirical investigation," *Journal of Development Economics*, 72, 57-89.

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