More on Missing Trade

(Building on our paper “Per Capita Income and the Mystery of Missing Trade”)

James Cassing* and Shuichiro Nishioka**

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Abstract

In the context of the HOV model, systematic income dependent differences in demand patterns could explain the large volume of “missing trade” between richer and poorer countries (Markusen, 1986; Riemer and Hertel, 2006). In particular, with identical but non-homothetic preferences across countries, if labor-intensive goods are in fact low income elasticity goods, and if low income countries are labor abundant and so export labor-intensive goods, then North-South trade will be reduced as the low income countries consume relatively more of their labor-intensive export goods whereas high income capital abundant countries consume relatively more of their capital-intensive export goods. In this paper, we pursue empirically this seemingly plausible explanation of “missing trade” using a data set of 29 countries including both developed and developing countries. Of note, we incorporate considerations of traded intermediate inputs as in Trefler and Zhu (2010). In this framework, knowing the bilateral details of each country’s input-output structure is key to the correct calculation of the factor content of trade. By using Hakura’s (2001) pair-wise HOV framework combined with Davis and Weinstein’s (2001) specifications, modified to account for trade in intermediates, we develop an empirical method to estimate the amount of missing factor trade caused by nonhomothetic tastes in conjunction with per capita income differences and compare it with that caused by assuming identical techniques. We find systematic preference differences to be quite important.

F11: Neoclassical Model of Trade
Keywords: Heckscher-Ohlin; Technology; North-South Bias in Development; Factor Abundance; Nonhomothetic Tastes; Per Capita Income

*Department of Economics, 4908 WW Posvar Hall, University of Pittsburgh, Pittsburgh, PA 15216, Tel: +1(412) 648-8746, Fax: +1(412) 648-1793, E-mail: jcassing@pitt.edu.
**Department of Economics, PO Box 6025, West Virginia University, Morgantown, WV 26506-6025, Tel: +1(304) 293-7875, Fax: +1(304) 293-5652, E-mail: shuichiro.nishioka@mail.wvu.edu.
1. Introduction

Recent advances in empirical international trade have increased our understanding of how the Heckscher-Ohlin-Vanek (HOV) model fails to predict the direction and volume of global factor trade. Most of the literature (e.g., Davis and Weinstein, 2001; Hakura, 2001; Schott, 2003; Choi and Krishna, 2004; Lai and Zhu, 2007) has demonstrated that the unrealistic assumptions of identical techniques and factor price equalization are responsible for previous empirical failures. In particular, since developed countries employ more capital-intensive techniques than developing countries do, we cannot measure accurately the direction and volume of factor trade under the assumption of identical techniques everywhere. So repairing the supply side of the general equilibrium HOV model has credibly restored its ability to predict the direction of trade.

However, these supply side repairs, while successfully accounting for the direction of trade, have been less successful in explaining why the volume of trade is still substantially over-predicted by the modified HOV model. That is, there is “missing trade.” And this is particularly true of trade between richer and poorer countries. This predictive deficiency of “missing trade” was first noted empirically by Trefler (1995) and a potential explanation involving the demand side was explored theoretically by Markusen (1986).

Markusen’s work focuses on the role of systematic differences in consumption owing to per capita income differences across countries. In earlier (and Nobel prize recognized) work, Krugman (1979) and others had formalized Linder’s (1961) monopolistic competition theory of international trade, but incorporated the conventional assumption of identical and homothetic preferences, neglecting Linder’s emphasis on the role of per capita income and nonhomothetic preferences. Consequently, such models were good at explaining the large volume of trade among the developed countries – North-North trade – but were inadequate for explaining why there is so little North-South trade. Markusen provided a theoretical synthesis of Linder and

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1 The history of the empirical HOV that concentrated on modifications of the assumptions started with Maskus (1985) followed by Bowen, Leamer, and Sveikauskas (1987).
2 The HOV errors represent Trefler’s (1995) “missing trade.” Factor services embodied in net exports are usually smaller than those predicted from the standard HOV model. The HOV errors in this paper are factor services embodied in net exports, measured factor contents of trade, minus those predicted from factor abundance, or predicted factor contents of trade.
3 Linder’s important idea also related to the role of product quality as a determinant of the volume and direction of trade. Hallak (2006) introduced a quality index into the Dixit-Stiglitz demand system and found evidence for nonhomothetic preferences within a product by keeping the identical and homothetic preferences across industries.
Dixit-Stiglitz (1977) monopolistic competition by using a Stone-Geary utility approach that proved simple and tractable. Preferences were taken to be identical but not homothetic. By adding the assumption that labor-intensive goods are also low income-elasticity goods, Markusen was able to better explain both North-North and North-South trade volumes.\(^4\,\,5\)

In the context of the HOV model, such systematic income dependent differences in demand patterns could explain the large volume of “missing trade” between richer and poorer countries (Trefler and Zhu, 2010; Reimer and Hertel, 2010). In particular, with identical but nonhomothetic preferences across countries, if labor-intensive goods are in fact low income elasticity goods, low income countries export labor-intensive goods. Then, North-South trade will be reduced as the low income countries consume relatively more of their labor-intensive export goods whereas high income capital abundant countries consume relatively more of their capital-intensive export goods.

In this paper, we pursue empirically this seemingly plausible explanation of “missing trade” using a data set of 29 countries including both developed and developing countries.\(^6\) By using Hakura’s (2001) pair-wise HOV framework combined with Trefler and Zhu’s (2010) specifications, we develop an empirical method to estimate the amount of missing factor trade caused by nonhomothetic tastes in conjunction with per capita income differences and compare it with that caused by assuming identical techniques. Specifically, we first divide country pairs into North-North pairs, South-South pairs, and North-South pairs according to real GDP per capita. Next, we evaluate the standard HOV model performance by imposing all HOV assumptions. Then, we relax the assumption of identical techniques by introducing each country’s actual production techniques. The improvement in the HOV prediction from the standard model to the relaxed model is the volume of missing trade explained by identical techniques. Second, we develop an HOV specification that imposes only the assumption of identical and homothetic preferences.\(^7\) Then, we drop this assumption by introducing a vector of


\(^5\) Hunter (1991) empirically addressed the statistical significance of the preference-driven trade by extending Hunter and Markusen (1988). She obtained the demand data for a group of 34 countries and developed the counterfactual consumption bundles under the assumption of identical and homothetic preferences to estimate inter-industry trade caused from differences in preferences. Her results provided strong evidence that nonhomothetic preferences play an important role in determining the direction and volume of global trade. In particular, the preference-driven trade accounts for as much as 25 percent of global net-trade flows.

\(^6\) The data set consists of actual techniques, Input-Output tables, and bilateral imports for 29 countries.

\(^7\) Indeed, this specification is Hakura’s (2001) modified HOV model. Even though Hakura argued that her specification is evidence for technical differences across countries, it really imposes only the one assumption of
deviations between one country’s actual consumption vector and its counterfactual one under the assumption of identical and homothetic preferences. Now the improvement in the HOV prediction from the former to the latter is the volume of missing trade explained by cross-country differences in per capita income and nonhomothetic preferences. By comparing these deviations, we study the contributions of technique versus income differences and nonhomothetic preferences for Trefler’s missing trade in the HOV model.

The findings in this paper are both compelling and somewhat surprising. While consumption patterns are similar among the countries with similar per capita incomes, and so there is not so much “missing trade,” the HOV errors generated by assuming identical and homothetic preferences become significant as income gaps of two countries increase. In fact, the preference-related missing trade for labor services is quantitatively more significant than the technology-related missing trade in North-South trade. Moreover, the direction of the income-difference/preference driven HOV deviations is consistent with the prediction from Markusen’s (1986) model. Thus, developed countries apparently consume relatively less of labor-intensive goods (e.g., agriculture products and food) and relatively more of capital-intensive goods (e.g., automobiles and office machinery) compared to developing countries and so the volume of factor trade decreases as the difference in per capita income increases.

As in Davis and Weinstein (2001), the modification in identical techniques remains central in order to obtain the right direction of factor trade relative to the HOV prediction. By relaxing the restriction of identical techniques and using each country’s actual techniques according to Trefler and Zhu (2010), the sign tests for North-South pairs improve from 39.9 to 89.9 percent for labor and from 75.8 to 88.9 percent for capital. The HOV model with technical adjustment precisely predicts that a developed country is an exporter of capital services and an importer of labor services relative to a developing country.8 The relaxation in techniques is important even for the North-North or the South-South country pairs since measured factor content of trade involves all trade-partners’ techniques through bilateral imports of intermediate inputs. The difference in consumption patterns, on the other hand, does not change the direction of factor trade but matters for the volume of factor trade between developed and developing

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8 See Leontief’s original paradox (1953) and Leamer’s (1980) and Davis and Weinstein’s (2001) solutions. Nishioka (2010) argues that Davis and Weinstein’s (2001) solutions do not stem from the composition of exports and imports but from the technical difference across countries.
countries. There is no noticeable change for the North-North country pairs when the assumption of identical and homothetic tastes is relaxed, indicating preferences as well as per capita incomes are similar among developed countries.

One way to view our results is that we should expect the development stage of a country to affect various aspects of the country’s economic activity. Countries accumulate capital stocks and skills, increase their productivity levels, employ more capital-intensive techniques, and specialize in capital- or skill-intensive subsets of goods as they develop (e.g., Fitzgerald and Hallak, 2004; Maskus and Nishioka, 2009). Nonhomotheticity in preferences and rising per capita income is one such systematic mechanism on the demand side.

The remainder of this paper is organized into three sections. In Section 2, we develop the four HOV specifications developed from Hakura (2001) and Trefler and Zhu (2010), and provide the empirical strategy to measure the volume of missing trade attributable to technique and taste/income differences. Section 3 provides some insight into how consumption bundles differ across countries and studies empirical regularities by sorting country pairs according to the differences in two countries’ per capita incomes. We present concluding remarks in the last section.

2. Theoretical Framework

We begin by deriving the standard HOV model in a world with \( F \) factors, \( C \) countries, and \( N \) products. For each country \( c \), the net export vector is the difference between net production (\( Y^c \)) and final consumption (\( D^c \)):

\[
T^c = X^c - \left[ \sum_{c^\prime} M^{c^\prime c} \right] = Y^c - D^c
\]

where \( T^c \) is an \( N \times 1 \) vector of net exports, \( X^c \) is an \( N \times 1 \) vector of total exports for country \( c \), and \( M^{c^\prime c} \) is an \( N \times 1 \) vector of imports from country \( c^\prime \) to country \( c \).

\( B^c \) is the \( F \times N \) technical matrix and each element \( (B^c_{fi}) \), representing the unit factor requirement, corresponds to the amount of a factor \( f \) required to produce one unit of net output for sector \( i \). Equation (1) is multiplied by the technical matrix \( B^c \), and using the factor-exhaustion assumption \( B^c Y^c = V^c \) where \( V^c \) is an \( F \times 1 \) vector of factor endowments, we obtain:

\[
B^c T^c = V^c - B^c D^c
\]

That is, a country’s factor content of trade is the difference between a country’s factor endowments (\( B^c Y^c = V^c \)) and factors absorbed in final consumption (\( B^c D^c \)).
Here, equation (2) is an *identity equation* for each country since \( \mathbf{B}^c \mathbf{Y}^c = \mathbf{V}^c \) and \( \mathbf{T}^c = \mathbf{Y}^c - \mathbf{D}^c \) always hold by data construction.

Assuming identical and homothetic tastes, along with identical prices of goods and services, the final consumption vector is proportional to the world output vector (\( \mathbf{Y}^w \)):

\[
\mathbf{D}^c = s^c \mathbf{Y}^w
\]

where \( s^c \) is a scalar representing the share of country \( c \) in world expenditure.

Since the standard HOV assumption is identical techniques worldwide (\( \mathbf{B}^c = \mathbf{B}^{c''} \)), the techniques matrix of country \( c \) is arbitrarily chosen to derive \( \mathbf{B}^c \mathbf{D}^c = s^c \mathbf{B}^c \mathbf{Y}^w = s^c \mathbf{V}^w \). Then, the standard HOV model follows:

\[
\mathbf{B}^c \mathbf{T}^c = \mathbf{V}^c - s^c \mathbf{V}^w
\]

where \( \mathbf{B}^c \mathbf{T}^c = \mathbf{B}^c \mathbf{X}^c \cdot [\Sigma_{c \neq c'} \mathbf{B}^c \mathbf{M}^{cc'}] \) is the *measured factor content* of trade and \( \mathbf{V}^c - s^c \mathbf{V}^w \) is the *predicted factor content* of trade. The HOV theorem predicts that the measured factor content of trade for any country must equal the difference between the country’s factor endowments and the product of that country’s consumption share and world factor endowments (Leamer, 1980).

The standard HOV model is further modified to develop the pair-wise model (e.g., Staiger, Deardorff, and Stern 1987; Hakura 2001). Although the pair-wise model tests the HOV equation bilaterally, it does not test bilateral factor content of trade (e.g., Choi and Krishna, 2004). That is, while the pair-wise HOV equation is a bilateral relationship, it is derived from the worldwide general equilibrium system. For any two arbitrarily chosen countries \( c \) and \( c'' \), take the ratio of consumption shares so that the world output (\( \mathbf{Y}^w \)) in equation (3) can be eliminated to yield:

\[
\mathbf{D}^c = s^c / s^{c''} \mathbf{D}^{c''} = s^{cc} \mathbf{D}^{c''}
\]

Then, by combining equation (4) for these two countries with equation (5), the pair-wise version of the HOV model follows:

\[
\mathbf{B}^c \mathbf{T}^c - s^{cc} \mathbf{B}^{c''} \mathbf{T}^{c''} = \mathbf{V}^c - s^{cc} \mathbf{V}^{c''}
\]

where \( \mathbf{B}^c \mathbf{T}^c - s^{cc} \mathbf{B}^{c''} \mathbf{T}^{c''} \) is the measured *relative factor content* of trade with country \( c \)’s techniques and \( \mathbf{V}^c - s^{cc} \mathbf{V}^{c''} \) is the predicted *relative factor content* of trade.

Equation (6) reveals that the measured relative factor content of trade can be predicted from the relative factor abundance between any two countries. The primary advantage of the two-country HOV model is that the testing equation does not include any world aggregate. In
addition, since our data set consists of 29 countries, we have 406 observations for each factor, which can be organized into combinations of country pairs with various stages of development.

**Deviations from Identical Techniques**

Davis and Weinstein (2001) found substantial improvements in the predictive power of the HOV model when national techniques are relaxed according to technical differences and a breakdown in factor price equalization. The Dornbusch-Fischer-Samuelson (1980) model is the first specification that relaxes the unrealistic assumption of identical techniques. Since the DFS model predicts that a capital abundant country exports capital-intensive goods and imports labor-intensive goods,9 exports from a capital abundant country in a given industry are more capital-intensive than world production in that industry. These insights are introduced into the following specification wherein the factor content of exports is measured with the exporter’s actual techniques and that of imports is measured bilaterally with the producer countries’ techniques.10 Rather than following Davis and Weinstein (2001) directly, we employ the factor content of trade as proposed by Trefler and Zhu (2010) who improve on Davis and Weinstein’s insight by taking account of foreign intermediates:

\[
\tilde{B}^e X^c - \left[ \sum_{c' \geq c} \tilde{B}^{c'} M^{cc'} \right] = V^c - s^c V^w
\]

where \( \tilde{B}^c \) is Trefler and Zhu’s (2010) factor requirement matrix.11

By combining equation (7) for two countries with equation (5), the pair-wise HOV model that allows for technical differences follows:

\[
\tilde{B}^e X^c - \left[ \sum_{c' \geq c} \tilde{B}^{c'} M^{cc'} \right] - s^c X^c - \left[ \sum_{c' \geq c} \tilde{B}^{c'} X^{cc'} \right] = V^c - s^{cc'} V^e
\]

Thus, a comparison of equation (8) with equation (6) will allow an assessment of the role of technology differences in explaining errors in the HOV prediction.

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9 The specifications, such as Helpman’s (1999) multiple-cone production model, assume a similar idea. A capital abundant country employs more capital-intensive techniques across all industries. Instead of estimating techniques and employing the fitted values from estimation as in Davis and Weinstein (2001), we take advantage of using actual techniques as in Hakura (2001).

10 Although the 29 countries in the data set cover more than 70 percent of world trade, there are still many countries outside the data coverage. In particular, we need to measure the factor content of imports for each of 29 countries from the rest of the world for equation (8). Since the rest of the world consists mostly of developing countries, we employ production techniques of China to measure factor content of bilateral imports.

11 Our corresponds to Trefler and Zhu’s (2010) \( A_c \) matrix.
Deviations from Identical and Homothetic Tastes

Hakura (2001) developed the modified version of the HOV model by combining equation (2) for two countries with the corresponding countries’ relative consumption shares, equation (5), under the assumption of identical and homothetic preferences:

\[
B^c T^c - s^{cc'} B^{c'} T^{c'} - (B^{c'} - B^c) D^c = V^c - s^{cc'} V^{c'}
\]

Equation (9) represents the standard HOV relationship in equation (6) adjusted by the difference in the techniques multiplied by country c’s consumption vector. Hakura (2001) argued that the assumptions of identical and homothetic preferences, no barriers to trade, zero transport cost, and perfect competition in product and factor markets are imposed to obtain equation (9) and that the vector \((B^{c'} - B^c)D^c\) captures how differences in techniques across two countries modify the standard HOV prediction.\(^{12}\) However, equation (9) is developed from the identity equations of national accounts, equation (2) for two countries, and the assumption of identical and homothetic preferences between countries \(c\) and \(c''\), equation (5). Therefore, good performance of equation (9) provides evidence solely for identical and homothetic tastes. In particular, Hakura’s evidence is based on four European countries: Belgium, France, Germany, and the Netherlands. It is then not surprising to find strong support for equation (9) since consumers’ preferences and per capita income across these four European countries might be similar.

As discussed previously however (e.g., Linder, 1961; Markusen, 1986; Hunter, 1991; Matsuyama, 2002; Trefler and Zhu, 2010; Reimer and Hertel, 2010; Fieler, 2011), low-income countries might spend more on labor-intensive goods, suggesting a violation of identical and homothetic preferences. To study preference-driven errors in the HOV prediction, we introduce a vector \(E^{cc'}\) in order to construct the following identity equation:

\[
D^c + E^{cc'} \equiv s^{cc'} D^{c'}
\]

\(^{12}\) Even though Davis and Weinstein (2001) and Hakura (2001) both argued that their favored models depend on the modification in identical techniques and factor price equalization, the successes of the two equations (9) and (8) are fundamentally different. While Davis and Weinstein (2001) employed all trade partners’ techniques to measure factor content of trade, Hakura (2001) used only two countries’ techniques. Therefore, Hakura’s technology adjustment term, \((B^{c'} - B^c)D^c\), is not consistent with Davis and Weinstein’s technology modification. In particular, Hakura’s specification generates systematic technology biases such that net factor trade of a developed country, \(B^c T^c\), overstates capital services and understates labor services imported from developing countries.
If two countries’ preferences are identical and homothetic, \(E^{cc^*}\) must be a zero-vector. \(E^{cc^*}\) captures the deviation in the consumption bundle relative to the other country. By using equation (2) for two countries and equation (10), equation (11) follows:

\[
E^{cc^*} = \mathbf{B}^c \mathbf{T}^c - s^{cc^*} \mathbf{B}^{c^*} \mathbf{T}^{c^*} - (\mathbf{B}^{c^*} - \mathbf{B}^c) \mathbf{D}^c - \mathbf{B}^c \mathbf{E}^{cc^*} \equiv \mathbf{V}^c - s^{cc^*} \mathbf{V}^{c^*}
\]

Equation (11) is an identity equation. Because equation (9) imposes a restriction \(E^{cc^*} = 0\), the difference between these two equations, \(-\mathbf{B}^c E^{cc^*}\), represents the deviations in the HOV model generated from identical and homothetic tastes.

**Empirical Strategy for Testing Technique and Taste**

To study the empirical failures of the HOV model caused by identical techniques, we first define the pair-wise HOV errors from equations (6) and (8). In the empirical exercises below, we concentrate on tradable sectors since the consumption vector in nontraded sectors are subject to government spending such as national defense and since the introduction of nontraded goods is an important independent element of Davis and Weinstein’s success. These HOV errors are then given by:

\[
E^{cc^*}_S = \mathbf{B}^c \mathbf{T}^c - s^{cc^*} \mathbf{B}^{c^*} \mathbf{T}^{c^*} - (\mathbf{V}^c - s^{cc^*} \mathbf{V}^{c^*})
\]

\[
E^{cc^*}_P = \mathbf{B}^c \mathbf{T}^c \mathbf{X}^c - \sum_{c' \neq c} \mathbf{B}^{c^*} \mathbf{M}^{c^*} - s^{cc^*} \mathbf{B}^{c^*} \mathbf{X}^{c^*} - \sum_{c' \neq c} \mathbf{B}^{c^*} \mathbf{M}^{c^*} - (\mathbf{V}^c - s^{cc^*} \mathbf{V}^{c^*})
\]

where the superscript \(T\) indicates tradable sector.

The improvement in the HOV equation from equation (6) to (8), or \(E^{cc^*}_P - E^{cc^*}_S\), is the amount of missing trade caused by identical techniques.

Second, to study the empirical failures of the HOV model caused by identical and homothetic tastes, we define the pair-wise HOV errors from equations (9) and (11).

\[
E^{cc^*}_M = \mathbf{B}^c \mathbf{T}^c - s^{cc^*} \mathbf{B}^{c^*} \mathbf{T}^{c^*} - (\mathbf{B}^{c^*} - \mathbf{B}^c) \mathbf{D}^c - \mathbf{V}^c - s^{cc^*} \mathbf{V}^{c^*}
\]

\[
E^{cc^*}_I = \mathbf{B}^c \mathbf{T}^c - s^{cc^*} \mathbf{B}^{c^*} \mathbf{T}^{c^*} - (\mathbf{B}^{c^*} - \mathbf{B}^c) \mathbf{D}^c - \mathbf{B}^c \mathbf{E}^{cc^*} - \mathbf{V}^c - s^{cc^*} \mathbf{V}^{c^*}
\]

Here, we compare the pair-wise HOV model that imposes the assumption of identical and homothetic preferences, equation (9), with equation (11) that drops this assumption. Again, the improvement, \(E^{cc^*}_I - E^{cc^*}_M\), is the amount of missing trade explained by nonhomothetic tastes and different per capita incomes. By comparing these deviations, \(E^{cc^*}_P - E^{cc^*}_S\) and \(E^{cc^*}_I - E^{cc^*}_M\), we discover the contributions of technique versus preference for the missing trade of the HOV.
model. We next divide the 406 country pairs into North-North pairs, North-South pairs, and South-South pairs and apply the four specifications of the pair-wise HOV models to each subset. This will allow us to isolate the contributions of technique differences and consumption differences.

In order to understand the direction of the preference-driven and technology-driven errors, consider the simple 2x2x2 case wherein a developed country $c$ and a developing country $c''$ both produce labor-intensive and capital-intensive goods. Since country $c$ is capital abundant and country $c''$ is labor abundant, country $c$ exports the capital-intensive good and imports the labor-intensive good. If both countries consume under identical and homothetic preferences, we can predict the volume of relative factor trade from relative factor abundance adjusted by $(B^{c''} - B^c)D^c$, equation (9). Now, consider the case of a violation of this assumption so that country $c$ consumes relatively more of the capital-intensive good and less of the labor-intensive good. Here, the volume of factor trade declines because countries consume their abundant factors more intensively. Moreover, if we impose identical and homothetic preferences and predict the consumption vector of country $c$ from that of country $c''$, there is a systematic error in demand: $E^{c''}$, which is positive (overestimation) for a labor-intensive good and negative (underestimation) for a capital-intensive good. Thus, the preference-driven error in factor trade, $E^{c''} - E^{c''}$, is also systematic: The element of the vector $E^{c''} - E^{c''}$ would be negative for labor and positive for capital.

Next, still in the context of the 2x2x2 model, consider the case of the technology-related HOV errors. The strict HOV model, or equation (6), does not generally hold and is associated with significant amounts of missing trade. Equation (8), which allows technique differences, can be used by separating the net export vectors ($T^c$ and $T^{c''}$) into export and import vectors ($X^c$, $X^{c''}$, $M^{c''}$, and $M^{c''}$). Then, substitute these vectors into equation (8) to measure factor content of trade using producer countries’ actual techniques. Typically, a capital (labor) abundant country employs more capital-intensive (labor-intensive) techniques for both sectors. Thus, factor content of trade measured with country $c$’s techniques ($B^cT^{c''}$) with equation (6) understates labor content of trade and overstates capital content of trade. The introduction of equation (8)

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13 A numeric example is in the Appendix I.
eliminates such systematic errors and reduces the amount of missing trade, and the element of
the improvement in missing trade $E_{rp}^{cc} - E_{s}^{cc}$ is negative for labor and positive for capital.

3. Empirical Results and North-South Biases in Preferences

Evaluating the four HOV equations (6), (8), (9), and (11) requires data on actual
techniques, Input-Output tables, and bilateral imports for multiple countries. Thus, we employ a
data set for a group of 29 countries in the year 2000. There are two factors, aggregate labor
and physical capital, and 30 industrial sectors. The data set is similar to that in Davis and
Weinstein (2001) who developed a 35-sector data set of 10 advanced members of the OECD and
a rest of the world aggregate. In contrast to theirs, this data set disaggregates the rest of the
world aggregate into 19 countries, which enables testing the HOV models bilaterally and sorting
the country pairs according to the differences between any two countries’ development levels.

Deviations from Identical and Homothetic Preferences

Final demand ($D^c$) in this paper is the sum of final consumption of households, final
consumption and investment of government, gross fixed capital formation, and changes in
inventories. According to Markusen’s model, the income elasticity of a labor-intensive good is
less than unity and that of a capital-intensive good is more than one. This condition is crucial to
defend the later discussion on the systematic missing trade arising from nonhomothetic
preferences in conjunction with per capita income differences. In order to tie our explanation of
“missing trade” a bit more to Linder and Markusen, we used our data to estimate income
elasticities. Note that these estimates serve to corroborate somewhat the Markusen story, but are
never explicitly used in our calculations. To estimate the income elasticity, we regress per capita
final demand on a constant and per capita GDP across countries for each of the industries. Table
1 provides the coefficients on per capita GDP from the cross-industry seemingly unrelated
regressions (SUR) model. Products such as agriculture goods and food products are examples of
the income inelastic goods; and motor vehicles and office machinery are examples of the income
elastic goods. Further, Figures 1-1 and 1-2 provide the scatter plots between income elasticities
and capital intensities across industries for China and the United States. In China, while the

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14 The detailed methodology to develop the data is in Appendix II. To estimate the pair-wise models, we use 29
countries. Chinese techniques are employed to account for factor content of bilateral imports from the rest of the
world as well as from China.
income elastic goods are produced with capital-intensive techniques, the income inelastic goods are produced with labor-intensive techniques. Although this tendency does not hold well for some developed countries (see Figure 1-2, the example of the United States), most countries, 65.5 percent, exhibit positive correlations.\textsuperscript{15}

Now, we turn to the issue of deviations from identical and homothetic tastes. Figure 2-1 provides a casual picture of the North-South differences in consumption bundles. Developing countries tend to consume more of agriculture products, food, and transportation services and less of motor vehicles, financial services, and business services (including real estate). The portion of income allocated for other sectors seems similar regardless of development levels.

To examine the significance of nonhomotheticity in preferences, we take empirical steps similar to Hunter (1991). We first develop a world consumption vector by aggregating all countries’ consumption vectors and allocate it to each country by its consumption share ($\hat{c}$). This procedure enables us to obtain the counterfactual consumption vector for country $c$ under the assumption of identical and homothetic preferences, $\hat{c}^T$. We next develop the difference between the counterfactual consumption ($\hat{D}^T$) and actual consumption ($D^T$), and make a ratio of them $\varepsilon_c = (D^T - \hat{D}^T) / D^T$. If $\varepsilon_c$ is negative (positive), a country consumes this good less (more) than the global average. Figure 2-2 provides the tendency of $\varepsilon_c$ across sectors for the subsets of developed and developing countries. The sectors are ordered by the differences of $\varepsilon_c$ between the North and the South. The deviations from counterfactuals are not negligible for most sectors. For example, developing countries spend 40.4 percent more and developed countries consume 36.2 percent less on food products. The deviations are relatively smaller for the North since most countries in the data set are rich countries and the consumption share of the North relative to the world aggregate is quite large (70.9 percent). In addition, $\varepsilon_c$ for the South correlates positively, 0.249, with average labor techniques ($B_{itL}$) and that for the North correlates negatively, -0.532. Even though these correlations strongly reflect the values of the agricultural sector, these relationships are consistent with Markusen’s (1986) assumption: Developing countries consume relatively more of labor-intensive goods.

\textit{Performance of the Pair-Wise HOV Models}

\textsuperscript{15} Turkey provides the strongest positive correlation, 0.517, and New Zealand provides the strongest negative correlation, -0.316. The median correlation across 29 countries is 0.084.
To study the performance of the HOV model, standard testing procedures are developed (e.g., Bowen, Leamer, and Sveikauskas, 1987; Trefler, 1995; Davis and Weinstein, 2001). First, a sign test is used to elicit the probability of sign coincidences between measured and predicted relative factor content of trade. If the specification holds perfectly, the sign would fit with 100 percent probability. A slope test involves regressing measured relative factor content of trade on predicted one without an intercept. If the pair-wise HOV specification holds, the regression coefficient would be unity. Finally, variance ratios are developed for each factor, computing the variance of measured relative factor content of trade over the variance of the predicted one. The ratio should be unity but previous literature has shown that this number tends to be close to zero. Here, we sort the countries from the richest, the United States, to the poorest, Indonesia, by real GDP per capita so that country $c$ is always richer than country $c''$.

Table 2 provides the results for the HOV tests. The standard HOV model, equation (6), with efficiency adjustment performs poorly as previously shown. For the combinations of all countries, the sign fits are 53.7 percent for labor and 70.2 percent for capital, the slope coefficients are 0.020 for labor and 0.221 for capital, and the variance ratios are 0.002 for labor and 0.198 for capital. The results are slightly better than in the previous literature, reflecting the importance of discarding nontraded sectors. The slope and the variance ratio tests indicate Trefler’s (1995) missing trade, particularly for labor. Specifically, the poor performance of labor services stems from the country pairs of developed and developing countries; the sign fit is only 39.9 percent and the variance ratio is 0.001.

One of the most important contributions of Trefler and Zhu (2010) is the introduction of global transactions of intermediate inputs. As shown by them, equation (8) improves the sign fits tremendously. In other words, the HOV model predicts precisely the direction of measured factor trade. The same thing happens here. While the proportions of correct signs significantly improve to 81.0 percent for labor and 83.7 for capital, the variance ratios are 0.030 for labor and 0.190 for capital. Of note, the great improvement in the direction of factor trade comes mainly from the success of the North-South country pairs; the sign fits improve to 89.9 percent for labor and 88.9 percent for capital. These results indicate not only the importance of allowing technical differences but also that technical gaps are significant between developed and developing countries. And, one might suspect that taste patterns are consistently different as well. We now turn to this issue.
Since equation (11) is the identity equation, all the HOV testing statistics fit almost perfectly. The deviations from the strict equality come from the truncation of nontradable sectors from the whole economy. We impose the assumption of identical and homothetic preferences on equation (11) to derive equation (9). That is, we mandate \( E^{cc^*} = 0 \). Therefore, the deterioration in testing statistics from equation (11) to (9) reported in Table 2 casts suspicion on the validity of identical and homothetic tastes. As it happens, the significant change is concentrated in labor services of country pairs involving developed and developing countries; while the proportion of correct signs does not change so much, the variance ratio is reduced from 0.806 to 0.314. Therefore, the difference in preferences does not change the direction of factor trade but matters for the amount of factor trade between developed and developing countries.

Table 3 provides the statistics for the direction and volume of missing trade explained respectively by technique or taste. For the relaxation in identical techniques, the volume of missing trade is reduced for labor and capital since \( (E^{cc^*}_P - E^{cc^*}_S) \) and \( E^{cc^*}_S \) correlate negatively: -0.892 for labor and -0.767 for capital. But there is also a strong negative correlation between \( E^{cc^*}_I - E^{cc^*}_M \) and \( E^{cc^*}_S \) for labor (-0.943), which indicates the relaxation in identical and homothetic tastes is critical in accounting for the volume of missing trade. Furthermore, this tendency is stronger for the country pairs with larger per capita income differences. This seems to give more weight to our demand side explanation of missing trade over some alternative like home biases (Trefler, 1995) and trade frictions – e.g. transport costs – (Davis and Weinstein, 2001; Waugh, 2010) unless those biases and frictions are systematically linked to per capita income differences between nations. Moreover, the volume of missing trade explained by preferences is much greater than that explained by techniques for labor services; while the ratio of the variance of \( E^{cc^*}_P - E^{cc^*}_S \) relative to \( E^{cc^*}_S \) is 0.027, the ratio of the variance of \( E^{cc^*}_I - E^{cc^*}_M \) relative to \( E^{cc^*}_S \) is 0.141. That is, the development-related biases in consumption present here are significant as previous literature showed (e.g., Markusen and Hunter 1988; Hunter 1991) but are concentrated in labor services between countries with significant per capita income differences.

Figures 3-1 and 3-2 provide a picture of the HOV errors generated from our four equations by plotting equations (6’), (8’), (9’) and (11’) on the vertical axis and the predicted relative factor content of trade \( (V^c - s^c V^c) \) on the horizontal axis. In these figures, the 45-degree line is the case of zero factor trade -- error equals prediction -- and the horizontal line is the case of a perfect fit -- no error -- for the HOV models. Previous literature showed that these
errors with the standard HOV model tend to be on the 45-degree zero-trade line, which is confirmed by our data. The improvements in the predictive power of the HOV model are clearly illustrated by the clock-wise rotations in trend-lines of each equation.\(^\text{16}\) As in Trefler (1995) and Davis and Weinstein (2001), the relaxation from the strict HOV assumptions gradually mitigates the errors in the HOV prediction. In particular, Figure 3-1 confirms that the improvement from preferences is as significant -- actually more so -- as that from techniques for labor.

*The Direction of HOV Errors Due to Preferences and Techniques*

As is well known and recounted above, the strict HOV model results in prediction errors. Table 4 provides the signs of HOV errors generated from the assumptions of identical techniques \((E_p^{c''} - E_s^{c''})\) and identical tastes \((E_I^{c''} - E_M^{c''})\). As discussed before, the directions of these errors are expected to be systematic in the North-South context: negative errors for labor services and positive errors for capital.\(^\text{17}\) Concerning the technology-driven HOV errors, 98.5 percent are negative signs for labor and 72.2 percent are positive signs for capital. These results support the idea that developed countries employ less labor and more capital than developing countries do.

The relaxation in preferences generates 84.8 percent negative errors in \(E_I^{c''} - E_M^{c''}\) for labor, suggesting preferences are indeed nonhomothetic as Markusen (1986) assumed. In the case of capital, however, the probability is closer to a coin-flip (59.1 percent). As in Nishioka (2010), this is because the variations in techniques, or capital-intensity, stem mainly from labor requirements; there are no significant differences in capital usages across tradable sectors within a country. Therefore, regardless of the systematic differences in consumption bundles, the term \(-B^c_{K_I}E^{c''}\) tends to be random for capital since the capital technique of industry \(i\) for country \(c''\), \(B^c_{K_i}\), cannot clearly distinguish, for example, a “capital-intensive” chemical sector from a “labor-intensive” apparel sector particularly, for developed countries.

5. Conclusion

\(^\text{16}\) Equation (6) is the strict HOV. From equation (6), identical techniques are modified to obtain equation (8). Equation (9) imposes identical and homothetic preferences. In other words, all assumptions except preferences are relaxed. Finally, no assumption is imposed for equation (11).

\(^\text{17}\) Since we sort the countries from the richest to the poorest by per capita GDP, country \(c\) is always richer than country \(c''\), which is consistent with the discussion in the previous section.
The development stage of a country affects not only its production specialization but also its consumption bundle. This paper concentrates on the demand side of the HOV model by developing an empirical method to measure the volume and direction of missing trade caused by the assumption of identical and homothetic preferences.

Countries seem to “specialize” in consuming relatively more capital-intensive (and income elastic) goods (e.g., automobiles and real estate) as they develop. This development-related pattern of consumption creates missing trade in the HOV prediction: The more any two countries’ income gap increases, the more the HOV model over-predicts the volume of factor trade. We also compare the volume of the preference-related missing trade with that of the technique-driven missing trade. Surprisingly, the imposition of identical and homothetic preferences causes more missing trade than does that of identical techniques. As in Davis and Weinstein (2001), the modification in identical techniques is crucial to obtain the right direction of factor trade relative to the HOV prediction. This paper confirms the importance of allowing technical differences and factor price differentials in the HOV model (e.g., Davis and Weinstein, 2001; Hakura, 2001; Schott, 2003; Choi and Krishna, 2004; Lai and Zhu, 2007). However, we further provide another important bias in the HOV prediction related to the development levels of countries.
References


Appendix I

Appendix 1: Identity Equation in Hakura’s (2001) Modified Model

Assume there are two countries: a developed country $c$ and a developing country $c''$, two goods: agriculture sector $A$ and manufacturing sector $M$, and two factor inputs: labor $L$ and capital $K$.

For simplicity, price of these two goods are unity. To produce each goods, two countries employ different techniques:

$$\begin{bmatrix}
L_A & L_M \\
K_A & K_M
\end{bmatrix}$$

and

$$\begin{bmatrix}
L_{A} & L_{M} \\
K_{A} & K_{M}
\end{bmatrix}$$

The production vectors of both countries are $Y^c = \begin{bmatrix} 2 \\ 6 \end{bmatrix}$ and $Y^{c''} = \begin{bmatrix} 6 \\ 2 \end{bmatrix}$ and factor endowment vectors are $V^c = \begin{bmatrix} 10 \\ 22 \end{bmatrix}$ and $V^{c''} = \begin{bmatrix} 28 \\ 10 \end{bmatrix}$.

(1) Identical and Homothetic Preferences

Both countries consume 4 units of both goods under the assumption of identical and homothetic preferences: $D^c = D^{c''} = \begin{bmatrix} 4 \\ 4 \end{bmatrix}$. Therefore, net-trade vectors are $T^c = \begin{bmatrix} -2 \\ 2 \end{bmatrix}$ and $T^{c''} = \begin{bmatrix} 2 \\ -2 \end{bmatrix}$.

By data construction, equation (2) is identity equation. To show that equation (9) must hold with identical and homothetic preferences, insert corresponding vectors in equation (9) with $s^{c''} = 1$.

$$B^c T^c - s^{c''} B^{c''} T^{c''} - (B^{c''} - B^c) D^c = V^c - s^{c''} V^{c''}$$

$$\begin{bmatrix}
2 & 1 \\
2 & 3
\end{bmatrix} \begin{bmatrix}
-2 \\
2
\end{bmatrix} - \begin{bmatrix}
4 & 2 \\
1 & 2
\end{bmatrix} \begin{bmatrix}
2 \\
-2
\end{bmatrix} - \begin{bmatrix}
\begin{bmatrix}
4 & 2 \\
1 & 2
\end{bmatrix} - \begin{bmatrix}
2 & 1 \\
2 & 3
\end{bmatrix}
\end{bmatrix} \begin{bmatrix}
4 \\
4
\end{bmatrix} = \begin{bmatrix}
10 \\
22
\end{bmatrix} - \begin{bmatrix}
28 \\
10
\end{bmatrix}$$

(2) Violation in identical and homothetic Preferences

The developed country consumes 3 units of agriculture goods and 5 units of manufacturing goods; the developing country consumes 5 units of agriculture goods and 3 units of
manufacturing goods. Therefore, $D^c = \begin{bmatrix} 3 \\ 5 \end{bmatrix}$, $D^e = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$ and $T^c = \begin{bmatrix} -1 \\ 1 \end{bmatrix}$ and $T^e = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$. As in Markusen (1986), North-South trade is reduced because of the nonhomothetic preferences.

To show that equation (9) does not hold without identical and homothetic preferences, insert corresponding vectors in equation (9) with $s^{cc} = 1$.

$$B^c T^e - s^{cc} B^e T^c - (B^e - B^c) D^c - B^c E^{cc} = V^c - s^{cc} V^c$$

$$\Leftrightarrow \begin{bmatrix} 2 & 1 & -1 \\ 2 & 3 & 1 \end{bmatrix} - \begin{bmatrix} 4 & 2 & 1 \\ 1 & 2 & -1 \end{bmatrix} - \begin{bmatrix} 4 & 2 \\ 1 & 2 \\ 2 & 3 \end{bmatrix} \begin{bmatrix} 3 \\ 5 \end{bmatrix} \neq -18$$

$$\Leftrightarrow \begin{bmatrix} -14 \\ 10 \end{bmatrix} \neq \begin{bmatrix} -18 \\ 12 \end{bmatrix}$$

The missing trade is generated by the violation of identical and homothetic preferences.

With the information above, the errors in consumption vector will be $E^{cc} = \begin{bmatrix} 2 \\ -2 \end{bmatrix}$. Therefore, the adjustment term of preference errors should be $B^c E^{cc} = \begin{bmatrix} 4 & 2 \\ 1 & -2 \end{bmatrix} = \begin{bmatrix} 4 \\ -2 \end{bmatrix}$.

Thus, $B^c T^c - s^{cc} B^e T^c - (B^e - B^c) D^c - B^c E^{cc} \equiv V^c - s^{cc} V^c$ holds since

$$B^c T^c - s^{cc} B^e T^c - (B^e - B^c) D^c - B^c E^{cc} \equiv V^c - s^{cc} V^c$$

$$\Leftrightarrow \begin{bmatrix} -14 \\ 10 \end{bmatrix} - \begin{bmatrix} 4 \\ -2 \end{bmatrix} \equiv \begin{bmatrix} -18 \\ 12 \end{bmatrix}$$

Here, $E^{cc}_t - E^{cc}_M = -B^c E^{cc} = \begin{bmatrix} -4 \\ 2 \end{bmatrix}$ is the amount of missing trade explained by identical tastes.
Appendix 2: Technical Difference and Factor Content of Trade

(1) The Standard HOV Model

Consider the case of identical and homothetic preferences: \( D^c = D^{c*} = \begin{bmatrix} 4 \\ 4 \end{bmatrix} \).

\[
B^c T^c - s^{c*} B^c T^{c*} \neq V^c - s^{c*} V^{c*}
\]

\[
\begin{bmatrix}
2 & 1 \\
2 & 3
\end{bmatrix}
-\begin{bmatrix}
2 & 1 \\
2 & 3
\end{bmatrix}
\neq
\begin{bmatrix}
-18 \\
12
\end{bmatrix}
\]

\[
\begin{bmatrix}
-4 \\
4
\end{bmatrix}
\neq
\begin{bmatrix}
-18 \\
12
\end{bmatrix}
\]

(2) Adjustment in Techniques

Now, we need to divide \( T^c = \begin{bmatrix} -2 \\ 2 \end{bmatrix} \) and \( T^{c*} = \begin{bmatrix} 2 \\ -2 \end{bmatrix} \) into export and import vectors: \( X^c = \begin{bmatrix} 0 \\ 2 \end{bmatrix} \).

\[
X^{c*} = \begin{bmatrix} 2 \\ 0 \end{bmatrix},
M^{c*} = \begin{bmatrix} 2 \\ 0 \end{bmatrix},
\text{and } M^{c*} = \begin{bmatrix} 0 \\ 2 \end{bmatrix}.
\]

\[
B^c X^c - \left[ \sum_{c \neq c} B^c M^{c*} \right] - s^{c*} B^c V^{c*} = B^c X^c - \left[ \sum_{c \neq c} B^c M^{c*} \right] \neq V^c - s^{c*} V^{c*}
\]

\[
\begin{bmatrix}
2 & 1 \\
2 & 3
\end{bmatrix}
-\begin{bmatrix}
4 & 2 \\
1 & 2
\end{bmatrix}
-\begin{bmatrix}
4 & 2 \\
1 & 2
\end{bmatrix}
+\begin{bmatrix}
2 & 1 \\
2 & 3
\end{bmatrix}
\neq
\begin{bmatrix}
-18 \\
12
\end{bmatrix}
\]

\[
\begin{bmatrix}
-12 \\
8
\end{bmatrix}
\neq
\begin{bmatrix}
-18 \\
12
\end{bmatrix}
\]

Even though the amounts of missing trade decrease, the identity does not hold by data construction (Trefler and Zhu, 2005). Here, \( E^{c*}_p - E^{c*}_s = \begin{bmatrix} 6 \\ -4 \end{bmatrix} - \begin{bmatrix} 14 \\ -8 \end{bmatrix} = \begin{bmatrix} -8 \\ 4 \end{bmatrix} \) is the amount of missing trade explained by identical technique.
Appendix II

The data set in this paper is similar to that of Maskus and Nishioka (2009). Since the measurement of bilateral factor content of imports is an important element of Trefler and Zhu (2010), we add the bilateral trade data obtained from the OECD STAN bilateral trade database (2006). Because of the availability of the data on bilateral trade, we are forced to drop Israel. Since China’s share in world trade is significant in the year 2000 and the industry-level employment data is available from ILO LABORSTA Internet, we add China in the data set. In this paper, countries with an average wage (real GDP per capita) less than $19,500 U.S. dollars (2000, PPP) are deemed to be developing countries.

(1) Input-Output Data

Input-output (I-O) tables (domestic and foreign tables) for Australia, Austria, Belgium, Brazil (*), Canada, China (*), the Czech Republic (*), Denmark, Finland, France, Germany, Greece (*), Hungary (*), Indonesia (*), Ireland, Italy, Japan, Korea (*), the Netherlands, New Zealand, Norway, Poland (*), Portugal (*), the Slovak Republic (*), Spain, Sweden, Turkey (*), the United Kingdom, and the United States for the year 2000 are taken from the OECD Input-Output database (2006). These I-O tables employ the ISIC Rev.3 with 48 industrial groups. To keep the consistency of sectors across 29 countries for several data sets, we aggregate the data into 30 industries.

Input-output matrices, final consumptions, gross outputs, exports, and imports are drawn from the I-O tables. Final consumption is the sum of final consumption of households, final consumption and investment of government, gross fixed capital formation, and changes in inventory. Therefore, the total use table of country \( c \) satisfies the equation \( T^c = (I - A^c)Q^c - D^c \) where \( A^c \) is a 30×30 indirect techniques for the unit intermediate requirements and \( (I - A^c)Q^c \) vector equals net output \( (Y^c) \) by construction. In addition, \( A^c \) is divided into domestic \( (A^{cc}) \) and foreign \( (A^{cc^*}) \) tables according to Trefler and Zhu (2010).

To convert the data into year 2000 international dollars, we use the country-level PPP rates from the Penn World Table 6.2 (Heston, Summers, and Aten, 2006). Unfortunately, we do not have the industry-level PPP rates. To adjust the data from previous years to the year 2000

18 (*) indicates developing countries, ranked by real GDP per capita, in the data set.
for Greece, Ireland, New Zealand, Norway, and Portugal, industrial gross outputs in the I-O tables are multiplied by the nominal growth rates obtained from the OECD STAN database (2005). For Australia, we use the growth rate of country-level nominal GDP to adjust the data from fiscal year 1998-1999 (average of these two years) to year 2000.

(2) Industry-Level Data for Factor Inputs

Physical Capital

Capital stock is developed from the discounted sum of real investment (gross fixed capital formation) from 1980 to 2000:

\[
K_i^t = \sum_{t=1980}^{2000} (1 - 0.1333)^{2000-t} I_n^t.
\]

For OECD countries, values for gross fixed capital formation (GFCF) are derived from the OECD STAN database (2005) and unreported data are estimated from the ISIC Rev.2 version of the OECD STAN database (1998). Refer to Maskus and Nishioka (2009) for a detailed strategy to interpolate the missing observations. For non-OECD countries (Brazil, Indonesia, and China), Greece, and Turkey, industry-level GFCF data is unavailable. Thus, we first develop country-level capital stocks and allocate them to 30 industries according to capital compensation data from the I-O tables. Finally, unreported years of the Czech Republic (1980-1994), Hungary (1980-1990), Poland (1980-1991), Portugal (1980-1994), and the Slovak Republic (1980-1992) are interpolated with industry-level growth rates for available years.

To convert GFCF figures into a real series, we use the prices of investment from the Penn World Table 6.2, and the U.S. industry-level prices for GFCF from the OECD STAN database (2005). After this conversion into year 2000 international dollars, we compute real capital stock data, using a depreciation rate of 0.1333. For Japan, industrial GFCF data are unavailable from the STAN database. Therefore, we take the total GFCF series from the World Development Indicators (World Bank, 2005) and Japan’s sectoral shares are obtained from the nominal investment matrix tables of the ESRI-Histat database (ISIC Rev.3). The OECD Economic Outlook (2008) provides the country-level stocks of physical capital in local nominal values for most OECD countries (i.e., Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Spain, Sweden, the United Kingdom, and the United States). We convert these countries’ total capital stocks to year
2000 international dollars and allocate them to 30 industries according to the sectoral values obtained from equation (A-1).

Working-Hour Adjusted Labor

Industrial labor inputs (total employments) for the year 2000 are derived from the OECD STAN databases (1998 and 2005), the ILO LABORSTA Internet (http://laborsta.ilo.org/), and the World Development Indicators (World Bank, 2005). Most data are available from these sources. If a country reports only aggregated industry sub-totals such as manufacturing and services, we allocate these to each industry according to the compensation of employees obtained from the I-O tables. For most OECD countries, country-level annual-working hours are available from the OECD Employment and Labor Market Statistics (2006). The data on weekly working hours are available from ILO LABORSTA Internet. We use the following equation, \( AH^c = AH^{US} \times WH^c / WH^{US} \) where \( AH^c \) is annual working hours and \( WH^c \) is weekly working hours for country \( c \), to estimate the annual working hours for Brazil, China, Indonesia, and Turkey. Weekly working hours are based on manufacturing from year 2000 for Indonesia and Turkey, year 2002 for Brazil and year 2003 for China. Finally, labor inputs are calculated from sectoral employments multiplied by countries’ annual working hours relative to the United States.

(3) Industry-Level Bilateral Imports Trade

Bilateral imports for agriculture, mining, and manufacturing sectors of 26 countries (all countries in the data set except Brazil, China, and Indonesia) from each of all 29 countries are available from the OECD STAN Bilateral Trade database (2006). Bilateral imports for three countries (Brazil, Indonesia, and China) are obtained from the World Bank Trade, Production, and Protection (1976-2004) and UN comtrade. We scale these bilateral trade flows so that bilateral industry import totals match with the I-O tables. Because there are no bilateral trade data available for service industries, we allocate each service sector’s imports from the I-O tables into each of 29 trade partners according to the share of total manufacturing imports.
### Table 1: Income Elasticity of Demand

<table>
<thead>
<tr>
<th>Industries</th>
<th>Elasticity</th>
<th>$t$-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>-0.371</td>
<td>-3.847 **</td>
</tr>
<tr>
<td>Rubber and Plastics</td>
<td>0.254</td>
<td>1.179</td>
</tr>
<tr>
<td>Electrical machinery</td>
<td>0.339</td>
<td>1.893 *</td>
</tr>
<tr>
<td>Basic metals</td>
<td>0.346</td>
<td>1.998 **</td>
</tr>
<tr>
<td>Food products</td>
<td>0.421</td>
<td>5.192 **</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.527</td>
<td>4.369 **</td>
</tr>
<tr>
<td>Non-metallic products</td>
<td>0.579</td>
<td>2.663 **</td>
</tr>
<tr>
<td>Mining</td>
<td>0.600</td>
<td>1.907 **</td>
</tr>
<tr>
<td>Textiles</td>
<td>0.651</td>
<td>6.508 **</td>
</tr>
<tr>
<td>Wood</td>
<td>0.706</td>
<td>3.853 **</td>
</tr>
<tr>
<td>Communication equipment</td>
<td>0.719</td>
<td>4.833 **</td>
</tr>
<tr>
<td>Machinery and equipment</td>
<td>0.724</td>
<td>4.505 **</td>
</tr>
<tr>
<td>Other transport</td>
<td>0.745</td>
<td>3.195 **</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>0.911</td>
<td>7.989 **</td>
</tr>
<tr>
<td>Transport</td>
<td>0.931</td>
<td>4.900 **</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>1.094</td>
<td>8.919 **</td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>1.106</td>
<td>6.764 **</td>
</tr>
<tr>
<td>Motor vehicles</td>
<td>1.127</td>
<td>7.861 **</td>
</tr>
<tr>
<td>Paper</td>
<td>1.137</td>
<td>9.639 **</td>
</tr>
<tr>
<td>Finance</td>
<td>1.137</td>
<td>6.977 **</td>
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<tr>
<td>Fabricated metal products</td>
<td>1.233</td>
<td>5.047 **</td>
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<tr>
<td>Wholesale</td>
<td>1.241</td>
<td>10.121 **</td>
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<tr>
<td>Optical instruments</td>
<td>1.336</td>
<td>8.408 **</td>
</tr>
<tr>
<td>Business services</td>
<td>1.552</td>
<td>8.641 **</td>
</tr>
<tr>
<td>Office machinery</td>
<td>1.635</td>
<td>5.115 **</td>
</tr>
</tbody>
</table>

*Note*: ** (*) indicates the significance at 5% (10%) with robust errors.
Figure 1-1. Capital Intensity and Income Elasticity (China)

\[ y = 0.2959x - 0.6329 \]

\[ R^2 = 0.2117 \]

Figure 1-2. Capital Intensity and Income Elasticity (the United States)

\[ y = -0.0611x + 1.2384 \]

\[ R^2 = 0.0043 \]
Figure 2-1: Consumption Shares across Industries for North and South ( Tradable Sectors)

Figure 2-2: Deviations from the Neutralized Consumption Vectors ( Tradable Sectors)
<table>
<thead>
<tr>
<th></th>
<th>All (29 countries)</th>
<th>North Pairs</th>
<th>South Pairs</th>
<th>North-South Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observations</td>
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<td></td>
<td>Labor</td>
<td>Capital</td>
<td>Labor</td>
<td>Capital</td>
</tr>
<tr>
<td>1. Modification in Technique</td>
<td>406</td>
<td>406</td>
<td>153</td>
<td>153</td>
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<tr>
<td>Standard HOV Model</td>
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<td></td>
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</tr>
<tr>
<td>Equation (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Hakura 2001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sign Test</strong></td>
<td>0.537</td>
<td>0.702</td>
<td>0.601</td>
<td>0.686</td>
</tr>
<tr>
<td><strong>Slope Test</strong></td>
<td>0.020</td>
<td>0.221</td>
<td>0.279</td>
<td>0.252</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.149</td>
<td>0.245</td>
<td>0.524</td>
<td>0.350</td>
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<tr>
<td><strong>Variance Test</strong></td>
<td>0.002</td>
<td>0.198</td>
<td>0.139</td>
<td>0.183</td>
</tr>
<tr>
<td>Technology Modification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equation (8)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(Trefler and Zhu 2010)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Sign Test</strong></td>
<td>0.810</td>
<td>0.837</td>
<td>0.680</td>
<td>0.843</td>
</tr>
<tr>
<td><strong>Slope Test</strong></td>
<td>0.162</td>
<td>0.384</td>
<td>0.086</td>
<td>0.415</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.859</td>
<td>0.775</td>
<td>0.028</td>
<td>0.835</td>
</tr>
<tr>
<td><strong>Variance Test</strong></td>
<td>0.030</td>
<td>0.190</td>
<td>0.289</td>
<td>0.209</td>
</tr>
<tr>
<td>2. Modification in Tastes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified HOV Model</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Equation (9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Hakura 2001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Sign Test</strong></td>
<td>0.946</td>
<td>0.936</td>
<td>0.882</td>
<td>0.922</td>
</tr>
<tr>
<td><strong>Slope Test</strong></td>
<td>0.555</td>
<td>0.894</td>
<td>0.919</td>
<td>0.932</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.006</td>
<td>0.008</td>
<td>0.012</td>
<td>0.010</td>
</tr>
<tr>
<td><strong>Variance Test</strong></td>
<td>0.314</td>
<td>0.824</td>
<td>0.862</td>
<td>0.877</td>
</tr>
<tr>
<td>Identity Equation</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>without IHP and IT</td>
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<tr>
<td>Equation (11)</td>
<td></td>
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</tr>
<tr>
<td><strong>Sign Test</strong></td>
<td>0.970</td>
<td>0.938</td>
<td>0.928</td>
<td>0.954</td>
</tr>
<tr>
<td><strong>Slope Test</strong></td>
<td>0.898</td>
<td>0.920</td>
<td>0.986</td>
<td>0.966</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.001</td>
<td>0.007</td>
<td>0.011</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>Variance Test</strong></td>
<td>0.999</td>
<td>0.976</td>
<td>0.980</td>
<td>0.991</td>
</tr>
<tr>
<td></td>
<td>0.806</td>
<td>0.866</td>
<td>0.983</td>
<td>0.936</td>
</tr>
</tbody>
</table>
Table 3: Directions and Amounts of Improvements in HOV Errors

1. Modification in Identical Techniques

<table>
<thead>
<tr>
<th></th>
<th>All Pairs</th>
<th>North Pairs</th>
<th>South Pairs</th>
<th>North-South Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sign Mismatch</strong></td>
<td>Labor Services</td>
<td>0.857</td>
<td>0.719</td>
<td>0.782</td>
</tr>
<tr>
<td></td>
<td>Capital Services</td>
<td>0.865</td>
<td>0.863</td>
<td>0.855</td>
</tr>
<tr>
<td><strong>Variance Ratio</strong></td>
<td>Labor Services</td>
<td>0.027</td>
<td>0.668</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Capital Services</td>
<td>0.148</td>
<td>0.151</td>
<td>0.095</td>
</tr>
<tr>
<td><strong>Correlation</strong></td>
<td>Labor Services</td>
<td>-0.892</td>
<td>0.094</td>
<td>-0.829</td>
</tr>
<tr>
<td></td>
<td>Capital Services</td>
<td>-0.767</td>
<td>-0.772</td>
<td>-0.839</td>
</tr>
</tbody>
</table>

2. Modification in Identical Tastes

<table>
<thead>
<tr>
<th></th>
<th>All Pairs</th>
<th>North Pairs</th>
<th>South Pairs</th>
<th>North-South Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sign Mismatch</strong></td>
<td>Labor Services</td>
<td>0.734</td>
<td>0.621</td>
<td>0.636</td>
</tr>
<tr>
<td></td>
<td>Capital Services</td>
<td>0.483</td>
<td>0.510</td>
<td>0.364</td>
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<tr>
<td><strong>Variance Ratio</strong></td>
<td>Labor Services</td>
<td>0.141</td>
<td>0.040</td>
<td>0.056</td>
</tr>
<tr>
<td></td>
<td>Capital Services</td>
<td>0.015</td>
<td>0.011</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Correlation</strong></td>
<td>Labor Services</td>
<td>-0.943</td>
<td>-0.516</td>
<td>-0.334</td>
</tr>
<tr>
<td></td>
<td>Capital Services</td>
<td>-0.077</td>
<td>-0.249</td>
<td>0.113</td>
</tr>
</tbody>
</table>

Table 4: Sign of Improvements in HOV Errors

<table>
<thead>
<tr>
<th>Errors in Technique</th>
<th>Labor Services (negatives)</th>
<th>All Pairs</th>
<th>North Pairs</th>
<th>South Pairs</th>
<th>North-South Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8')-(6')</td>
<td></td>
<td>0.749</td>
<td>0.458</td>
<td>0.709</td>
<td>0.985</td>
</tr>
<tr>
<td>(11')-(9')</td>
<td>Capital Services (positives)</td>
<td>0.586</td>
<td>0.399</td>
<td>0.618</td>
<td>0.722</td>
</tr>
</tbody>
</table>

| Errors in Tastes    | Labor Services (negatives) | 0.719     | 0.556       | 0.709       | 0.848             |
|                     | Capital Services (positives) | 0.539     | 0.516       | 0.418       | 0.591             |
Figure 3-1: Errors in Labor Services for Four Specifications relative to Predicted Relative Labor Contents of Trade

Figure 3-2: Errors in Capital Services for Four Specifications relative to Predicted Relative Capital Contents of Trade