A test for Heckscher-Ohlin using value-added exports

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Abstract

Empirical evidence for the Heckscher-Ohlin model has been inconclusive. We test whether the predictions of the Heckscher-Ohlin Theorem with respect to labor and capital find support in value-added trade. Defining labor-capital intensities and endowments as the ratio of hours worked to the nominal capital stock, we find evidence against Heckscher-Ohlin. However, taking the ratio of total factor compensations, and thus accounting for differences in technologies, we find strong support for it. That is, labor-abundant countries tend to export value-added in goods of labor-intensive industries. Moreover, differentiating between broad industries, we find support for nine out of twelve industries.

Keywords: Heckscher-Ohlin model, value-added trade

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1 Introduction

Empirical evidence for the predictions of the Heckscher-Ohlin model is mixed. While some studies support the reasoning that countries export relatively more of the goods

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which use their abundant production factor intensively (Romalis, 2004; Morrow, 2010),
others do not find results in favor of the Heckscher-Ohlin Theorem (Baldwin, 1971;
Trefler, 1995). One potential reason for this shortcoming is that data on gross trade is
used, while the predictions of trade models may be more accurate for trade in terms of
value-added, as Leamer (1980) already pointed out.

With the recent availability of data on trade in value-added, the aim of this paper is to
investigate whether the Heckscher-Ohlin Theorem accurately predicts value-added trade
flows. Methodologically, we employ a similar approach to Ito, Rotunno, and Vézina
(2017), who were among the first ones to empirically test the Heckscher-Ohlin frame-
work with value-added trade data. Specifically, they use the 2013 release of the World
Input-Output Database (Timmer, Dietzenbacher, Los, Stehrer, & de Vries, 2015) and
show that skill-abundant countries tend to export value-added in products of skill-
intensive industries. However, they do not find evidence that labor-(capital-)abundant
countries tend to export value-added in products of labor-(capital-)intensive industries.

Since more detailed data on capital and labor is available and the modelling of the
Socioeconomic Accounts has been improved with the 2016 release of the WIOD (see
Gouma, Chen, Woltjer, & Timmer, 2018), we aim to reinvestigate this issue, and test
whether the Heckscher-Ohlin Theorem with respect to labor and capital holds for trade
in value-added.

The paper is structured as follows: Section 2 provides a short description of the
Heckscher-Ohlin framework. Section 3 reviews the empirical evidence. Section 4 de-
scribes the applied data sources in this paper, and the calculation of value-added ex-
ports. Then, we describe the methodological approach, before we report our results and
conclude.

2 The Heckscher-Ohlin Model and its empirical evidence

Although foundations of the model were already laid out earlier in his dissertation, the
main theories of the Heckscher-Ohlin model were presented in a book published by the
Swedish economist Bertil Ohlin (1935). However, Eli Heckscher (1919) had studied the
topic as well and some of the elements in Ohlin’s work came from an article published
by Heckscher in 1919, which is why he was mentioned as a co-developer.

The Heckscher-Ohlin Theorem, one of the central theorems in the model, links relative
factor endowments to patterns of international trade. Assuming that both countries have
the same technology but differ in their initial factor endowments, the Theorem states
that countries export goods, which use their abundant factor more intensively. That is,
we should be able to observe that countries with an abundance in labor export goods using labor more intensively.

2.1 Empirical evidence

Empirical evidence on the predictions of the Heckscher-Ohlin Theorem is mixed. Most early empirical studies on the Heckscher-Ohlin Theorem were carried out on US data. Leontief (1953) used US trade data to test the model’s predictions. He found that, even though the US have an abundance of capital, they export relatively more labor-intensive goods, while also importing more goods that were relatively more capital-intensive. These results go strictly against the predictions of the Theorem and became known as the Leontief Paradox.

Multiple studies have since been carried out with the goal of testing the Heckscher-Ohlin Theorem in different settings to find an explanation for the Leontief Paradox. Bowen, Leamer, and Sveikauskas (1987) employed an extensive cross-sectional data set including 27 countries and 12 factors. Carrying out sign tests, they were able to support the model’s prediction in only 61% of all cases. Other early empirical tests, such as the papers written by Baldwin (1971) and Leamer (1980) were also unable to confirm the Theorem.

One possible reason for this mixed evidence is that some of the strong assumptions that are necessary for the model may not hold in reality. In particular, it is doubtful that technologies are in fact equal across countries. One indication that this is indeed not the case was presented by Trefler (1995). He proposes that differences in a country’s factor abundances should allow conclusions about its trade volumes. However, when testing the hypothesis, he finds that trade volumes are substantially lower than what the model would predict. Trefler (1995) then shows that the predictions become significantly better once differences in technologies, and therefore in productivities, across countries are being accounted for. Following this approach, Davis and Weinstein (2001) test the Heckscher-Ohlin Theorem while relaxing the assumption of common technologies on a data set including 10 countries. They find that in this framework the predictive power of the model increases both when performing a sign test on the direction of trade as well as when looking at missing trade. However, differences in predictive power vary strongly and depend on the exact specifications of the model.

Romalis (2004) chooses a different approach and introduces a model with transport costs and monopolistic competition. When he tests the model’s predictions using bilateral trade data for the United States, he finds that countries trade those commodities more strongly that use their abundant factors more intensively. Extensions of the model
by Morrow (2010) and Regolo (2012) are also able to support the HO-Theorem in most specifications with their respective samples.

The papers mentioned so far show that verifying the predictions of the Heckscher-Ohlin Theorem is difficult and depends on both the framework used and the data available. One further explanation is that data on gross exports may not adequately capture what countries are in fact producing competitively.\(^1\) Specifically, gross exports do not only incorporate domestic value-added but also foreign value-added and double-counted exports (Koopman, Wang, & Wei, 2014).

The difference between gross and value-added trade data is becoming increasingly more relevant, as global value chains have been deepening over the last decades (Johnson & Noguera, 2017). It was already pointed out by Leamer (1980) that using value-added trade data may be necessary to provide evidence for Heckscher-Ohlin. However, there has been no data to adequately test whether trade in value-added follows the predictions more closely. The release of the World Input-Output Database (WIOD) in 2010 and other inter-country Input-Output Tables have enabled such testing and sparked an increase in publications working with the data set. One recent and relevant study by Ito et al. (2017) uses the WIOD in order to investigate whether the explanatory power of Heckscher-Ohlin differs depending on whether gross export or value-added data is employed.

The data used by Ito et al. (2017) spans from 1995 to 2009 and includes 40 countries with 34 sectors. They follow the approach by Chor (2010), thereby generalizing the approaches developed by Davis and Weinstein (2001) and Trefler and Zhu (2010). When looking at manufacturing, Ito et al. (2017) find that countries from their sample, which are relatively skill-abundant, export more skill-intensive value-added. This is true for different specifications and both for the cross-sectional data as well as the panel. However, using gross exports instead of value-added, the authors find no support for the prediction of the model with respect to manufacturing.

Both for services and total trade, value-added coefficients also lean more towards the predictions of the Heckscher-Ohlin Theorem. However, the difference to the gross trade coefficients is not significant. Applying robustness checks developed by Romalis (2004) and Trefler and Zhu (2010), they find further confirmation for their previously obtained results. The main contribution of Ito et al. (2017) is twofold: First, they demonstrate that using value-added and gross export data may not always lead to the same result. Second, and more importantly, they show that, in the context of skill-abundance, the Heckscher-Ohlin Theorem finds stronger support with value-added data, although only

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\(^1\) For example, Timmer, Miroudot, and de Vries (2019) show that export specializations differ depending on whether one investigates gross or value-added trade.
for manufacturing.

## 3 Data & Methodology

**Data.** The empirical analysis is based on the two latest releases, i.e. 2013 and 2016, of the World Input-Output Database as well as the respective Socioeconomic Accounts (Timmer et al., 2015). The 2016 release is applied for calculating value-added exports. It covers 56 industries in 43 different countries plus the rest of the world, annually between 2000 and 2014. A comprehensive list of countries is provided in the Appendix. The industries are classified according to the International Standard Industrial Classification (ISIC) Rev. 4.

Value-added exports can be retrieved from inter-country Input-Output Tables following Johnson and Noguera (2012) and Koopman et al. (2014). Also, Aslam, Novta, and Rodrigues-Bastos (2017) provide an accessible summary of the method. Consider the basic structure of a general Input-Output-Table with \( S \) industries and \( C \) countries and thus a total number of \( N = S \times C \) observed industries, where the gross output vector \( \mathbf{X} \in \mathbb{R}^N \) is given by

\[
\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{Y} \tag{1}
\]

The vector of final demand is denoted as \( \mathbf{Y} \in \mathbb{R}^{N \times C} \), while \( \mathbf{A} \in \mathbb{R}^{N \times N} \) is the matrix of input-output-coefficients, where \( [\mathbf{A}]_{ij} \) indicates how many units of \( x_i \) are required to produce one unit of \( x_j \). The matrix \( (\mathbf{I} - \mathbf{A})^{-1} \) is the well-known Leontief inverse with \( [(\mathbf{I} - \mathbf{A})^{-1}]_{ij} \) reflecting how many units of \( x_i \) are required to produce one unit of the final good \( y_j \).

Then, we define the diagonal matrix \( \mathbf{V} \in \mathbb{R}^{N \times N} \), which captures the domestic value-added shares, such that

\[
[V]_{ii} = [I]_{ii} - \sum_{n=1}^{N} [A]_{ni} \tag{2}
\]

Value-added exports of industry \( i \) in country \( c \) to country \( d \neq c \) are now given as an element of the matrix \( \mathbf{VX} \in \mathbb{R}^{N \times C} \), which is defined as

\[
\mathbf{VX} = \mathbf{V} \times (\mathbf{I} - \mathbf{A})^{-1} \times \mathbf{Y} \tag{3}
\]

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2 The WIOD is one of three major databases for inter-country Input-Output Tables. The remaining two databases are OECD TiVA and EORA. We decided to use the WIOD for two reasons: (1) Data quality: The EORA would be the most attractive in terms of coverage, but there has been severe critique with respect to data quality (Kowalski, Gonzalez, Ragoussis, & Ugarte, 2015, p. 155). (2) Industry Classification: In comparison to the OECD TiVA, the WIOD uses a more detailed industry classification scheme.
Eventually, value-added exports for 2,290 industries (of 2,264 available in total) to 42 countries each are observed. This is, because rows and columns containing only zeros need to be excluded, since singularity issues in obtaining the Leontief inverse otherwise occur.

Then, we reshape the matrix $\mathbf{VX}$ for each year and create one balanced panel dataset including 1,476,420 observations, where the value-added exports of each industry in all covered countries to each other country in the dataset are recorded.

Moreover, the Socioeconomic Accounts, which are provided in the WIOD, are included in our analysis. Specifically, this includes industry-level data on the capital stock, the number of employees, and capital and labor compensation. This can be utilized to define a labor-capital ratio at industry-level. These data are matched to the value-added export data.

Additionally, we include data of the Socioeconomic Accounts of the 2013 WIOD-release, since these include data on educational attainment, i.e. the hours worked by low-, medium-, and high-skilled employees on industry level. This is the data used by Ito et al. (2017). However, we face two problems in using this data. First, the older release covers fewer countries, and different years (1995 to 2009). Second, it is based on a different industry classification system, i.e. ISIC Rev. 3. Nonetheless, we impute the data on skill-levels for the countries and years we have by matching the previous industry classification to the new one. All in all, the number of observations with respect to educational attainment is significantly smaller than for capital and labor. We will, thus, include regression models containing skill-levels include rather as a robustness check and replication exercise with respect to Ito et al. (2017).

**Methodology.** Methodologically, we closely follow Ito et al. (2017). Given the available data, we employ two different definitions of labor-capital intensity and endowments. That is, (i) as the ratio between total labor compensation and capital compensation in the respective industry, and (ii) as the ratio between total hours worked and the nominal capital stock.

To test for the Heckscher-Ohlin Theorem, we estimate the following model

$$
\log(VX)_{odit} = \alpha_{dit} + \sigma_{ot} + \beta_1 \log\left(\frac{1}{k}\right)_{oit} + \beta_2 \left[\log\left(\frac{1}{k}\right)_{oit} \times \log\left(\frac{L}{K}\right)_{ot}\right] + \varepsilon_{odit} \tag{4}
$$

The subscripts $o$, $d$, $i$, and $t$ denote the exporting country, the destination country, the exporting industry, and time, respectively. That is, $\alpha_{dit}$ and $\sigma_{ot}$ are importer-industry-year- and exporter-year-dummies. Lower-case letters denote industry-level variables,
while upper-case letters denote country-level ones. The coefficient of interest is $\beta_2$. For a given exporting country and a given market, which is captured in $\alpha_{dit}$, a labor-abundant country should engage in value-added exports of labor-intensive goods. Hence, a significantly positive $\beta_2$ can be seen as supporting the Heckscher-Ohlin model.

In robustness checks, we include data on skill intensity and endowments. Analogously to Ito et al. (2017), we combine medium- and low-skilled employees to a group of unskilled labor force. Hence, skill intensity is measured as the ratio between the hours worked by high-skilled and unskilled employees. The extended regression model, then, is

$$
\log(VX)_{odit} = \alpha_{dit} + \sigma_{ot} + \beta_1 \log \left( \frac{L}{K} \right)_{oit} + \beta_2 \left[ \log \left( \frac{L}{K} \right)_{oit} \times \log \left( \frac{L}{K} \right)_{oot} \right] \\
+ \gamma_1 \log \left( \frac{l_{hs}}{l_{us}} \right)_{oit} + \gamma_2 \left[ \log \left( \frac{l_{hs}}{l_{us}} \right)_{oit} \times \log \left( \frac{L_{hs}}{L_{us}} \right)_{oot} \right] + \varepsilon_{odit} \quad (5)
$$

4 Results

The regression results are displayed in Table 1. Columns 1 and 2 show the estimation results for labor-capital intensity and endowments defined as the ratio of factor compensations, while columns 3 and 4 refer to the definition of the ratio of hours and the nominal capital stock. For all regressions we use robust standard errors accounting for heteroskedasticity (White, 1980).

Defining labor-capital intensity and endowments as the ratio of factor compensations, we find a significantly positive coefficient for $\beta_2$ (column 1). This suggests that countries with an abundance in labor export relatively more goods, which use labor more intensively. This is in line with the prediction of the Heckscher-Ohlin Theorem.

However, when we define the labor-capital intensities and endowments as the ratio of hours worked to total capital stock, our results change (column 3). Coefficients for this specification can be seen in column 3, where $\beta_2$ is significantly negative. This would suggest that labor-abundant countries export relatively fewer goods which use labor intensively in their production.

As a robustness check, we perform the same regression as Ito et al. (2017) and include terms that capture the relative skill abundances and intensities. The results are shown in columns 2 and 4 of Table 1. Our sample becomes significantly smaller due to the restricted data availability, as outlined in Chapter 4, but the coefficients $\beta_1$ and $\beta_2$ are similar to the first model. Results with respect to skill-abundance and intensity are in line with what Ito et al. (2017) report. There, the authors also find positive and significant
coefficients for skill intensities and endowments. However, in their case, coefficients capturing relative labor endowments and intensities are insignificant, contrary to what we find.

A possible explanation for the contradictory results between the two applied definitions of labor-capital intensity and endowments lies in the Leontief paradox (Leontief, 1953). One crucial assumption of the Heckscher-Ohlin model is that countries have identical production technologies. Leontief (1953) did not account for such differences in technologies when he tested the Theorem and, as a result, found evidence against it. Only later, when this assumption was relaxed and differences in technologies were accounted for, empirical support for the Theorem emerged. This is reflected in our results as well. When we use the ratio of hours worked to the capital stock, our results contradict the Theorem. This is due to the fact that this specification does not account for differences in technologies between countries. However, when we define the labor-capital intensities and endowments as the ratio of compensations, we implicitly control for differences in technologies. As a result, we find support for the Heckscher-Ohlin Theorem.

| Dependent variable: | log(VX) |
|---------------------|---------|
| Compensations       | log(\(l_k\)) -0.324*** (0.002) |
|                     | log(\(l_k\)) × log(\(L_{K}\)) 0.245*** (0.004) |
| Hours/capital stock | log(\(l_{hs}\)/\(l_{us}\)) 0.201*** (0.008) |
|                     | log(\(l_{hs}\)/\(l_{us}\)) × log(\(L_{hs}\)/\(L_{us}\)) 0.156*** (0.004) |

Observations | 1,353,446 | 734,464 | 1,409,088 | 763,016 |
R²           | 0.161 | 0.158 | 0.132 | 0.122 |
Adjusted R²  | 0.161 | 0.158 | 0.132 | 0.122 |

Note: Standard errors accounting for heteroskedasticity (White, 1980) are applied. *p<0.1, **p<0.05, ***p<0.01

In Table 2 we report results for each broad industries according to the International
Table 2: Regression results per broad industry category according to ISIC Rev. 4

Dependent variable: \( \log(VX) \)

|       | A       | B       | C       | D,E     | F       | G       |
|-------|---------|---------|---------|---------|---------|---------|
| \( \log(\frac{L}{K}) \) | \(-0.046^{***}\) | \(-1.018^{***}\) | \(-0.437^{***}\) | \(-0.122^{***}\) | \(-0.404^{***}\) | \(-0.207^{***}\) |
|       | (0.005) | (0.014) | (0.004) | (0.010) | (0.012) | (0.009) |
| \( \log(\frac{L}{K}) \times \log(\frac{L}{K}) \) | \(-0.319^{***}\) | 1.055^{***} | 0.109^{***} | 0.337^{***} | 0.583^{***} | \(-0.414^{***}\) |
|       | (0.013) | (0.021) | (0.008) | (0.018) | (0.027) | (0.022) |

| Observations | 68,026 | 26,574 | 491,791 | 76,003 | 25,972 | 78,776 |
| R\(^2\)     | 0.091  | 0.294  | 0.165   | 0.166  | 0.211  | 0.232  |
| Adjusted R\(^2\) | 0.091  | 0.294  | 0.165   | 0.165  | 0.211  | 0.232  |

|       | H       | I       | J       | K       | L       | M       |
|-------|---------|---------|---------|---------|---------|---------|
| \( \log(\frac{L}{K}) \) | \(-0.538^{***}\) | \(-0.146^{***}\) | \(-0.149^{***}\) | \(-0.213^{***}\) | \(-0.419^{***}\) | \(-0.072^{***}\) |
|       | (0.006) | (0.018) | (0.007) | (0.008) | (0.006) | (0.007) |
| \( \log(\frac{L}{K}) \times \log(\frac{L}{K}) \) | 0.647^{****} | 0.249^{***} | \(-0.056^{***}\) | 0.158^{***} | 0.030^{***} | 0.060^{***} |
|       | (0.011) | (0.047) | (0.014) | (0.016) | (0.006) | (0.016) |

| Observations | 123,840 | 26,402 | 100,018 | 70,004 | 26,445 | 108,016 |
| R\(^2\)     | 0.234  | 0.179  | 0.175   | 0.145  | 0.335  | 0.138  |
| Adjusted R\(^2\) | 0.234  | 0.178  | 0.175   | 0.145  | 0.334  | 0.138  |

*Note:* Standard errors account for heteroskedasticity (White, 1980). *p<0.1, **p<0.05, ***p<0.01
For a list of industry codes see page 43 of the ISIC documentation.
Standard Industrial Classification (ISIC). Endowments and intensities are defined as the ratio of factor compensations. While all coefficients are significant, we do not find universal support for Heckscher-Ohlin. That is, for nine out of twelve industries, we are able to report a positive coefficient $\beta_2$. Among those are e.g. construction, manufacturing and energy supplies. For wholesale and resale trade, agriculture and information and communication we find evidence against the Theorem.

Lastly, we report results for selected years, i.e. 2000, 2007, and 2014, in Table 3, defining intensities and endowments as the ratio of factor compensations. It is apparent that the explanatory power of the Heckscher-Ohlin model slightly decreases over time, especially between 2000 and 2007. The adjusted $R^2$ decreases from 0.377 in 2000 to 0.298 in 2007. One potential explanation for this observation is that trade explained by Krugman’s trade model (see Krugman, 1991) became more relevant.

Table 3: Results for selected years

| Dependent variable: | log(VX) | | |
|--------------------|--------|--------|--------|
|                    | 2000   | 2007   | 2014   |
| $\log(\frac{L}{K})$ | -0.293*** | -0.291*** | -0.349*** |
|                     | (0.015) | (0.015) | (0.015) |
| $\log(\frac{L}{K}) \times \log(\frac{L}{K})$ | 0.235*** | 0.214*** | 0.267*** |
|                     | (0.029) | (0.031) | (0.032) |
| Observations        | 91,256 | 93,148 | 92,312 |
| $R^2$               | 0.393  | 0.317  | 0.315  |
| Adjusted $R^2$      | 0.377  | 0.298  | 0.296  |

Note: *p<0.1; **p<0.05; ***p<0.01

5 Conclusion

Ever since its publication, economists have tried to find empirical validation for the Heckscher-Ohlin Theorem. The majority of the earlier attempts, among them the famous Leontief Paradox (Leontief, 1953), were unable to find support for it. After Trefler (1995) proposed that the assumption of identical technologies might not hold, economists

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3For a list of industry codes see page 43 of the ISIC documentation.
started taking this into account. However, the evidence was still far from conclusive. One possible reason for this is the gross trade data that was applied. It was first pointed out by Leamer (1980) that for providing evidence in favor of Heckscher-Ohlin value-added trade data may be necessary. The only recent emergence of such data has enabled the testing for the Theorem with value-added trade data. One recent paper by Ito et al. (2017) test for the Heckscher-Ohlin Theorem with value-added and gross trade data with respect to skill-abundance and skill-intensity, finding that value-added trade data more strongly support the predictions for manufacturing.

In our paper we follow the approach of Ito et al. (2017). However, we use a more recent release of the World Input-Output Database that includes more countries and a more detailed industry classification. We define two different measurements of labor-capital intensities and endowments. Defining it as the ratio between hours worked and the capital stock, we do not find support for the Heckscher-Ohlin Theorem. However, defining intensities and endowments as the ratio of factor compensations, results strongly support it. A likely explanation for this is that the latter definition takes differences in technologies into account and leads to support for the Theorem. We also compare different industries and find that in nine out of twelve cases, the Heckscher-Ohlin model can explain trade flows.

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**Appendix**

**List of countries (ISO 3166-1).** AUS, AUT, BEL, BGR, BRA, CAN, CHE, CHN, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IDN, IND, IRL, ITA, JPN, KOR, LTU, LUX, LVA, MEX, MLT, NLD, NOR, POL, PRT, ROU, RUS, SVK, SVN, SWE, TUR, TWN, USA.