# Is the Human Capital Content of Trade Calculations Affected by Measurement Practices? Evidence from Swedish Data

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**Abstract**

*This study of the human capital content of trade builds on the previous research of the connection between production, trade and factor endowments, core elements of the Heckscher-Ohlin-Vanek (HOV) model. However, one aspect that can be improved is the question of how to empirically measure the different variables used in the HOV-model. Therefore, this study contributes to the literature by presenting a systematic investigation of the role of various technical definitions and measurement issues in the computation of the human capital content of trade in Sweden in 2006-2013. Our results show that the calculations are influenced by how the different variables involved are measured. They also show that the specialization pattern for Sweden has slightly moved away from industries intensively using high skilled labor over the measured period.*

**Keywords:** HOV-model, measurements, human capital
**JEL classification codes:** F11, J24

# 1. Introduction

The size of a country's factor content of trade has been a central issue in international economic research since the end of the 1960s. The concept of the factor content of trade originates from Vanek (1968), who recognized that trade could be thought of as the international exchange of the services of factors embodied in those products that traditional theory addresses.[1] Vanek's new formulation allowed an extension of the logic of the Heckscher-Ohlin theory to settings in which the pattern of trade may be indeterminate but in which the net factor content of trade may nonetheless be determinate.

The straightforward prediction of the links between production, trade and factor endowments in the Heckscher-Ohlin-Vanek (HOV)-model is, however, widely at odds by empirical evidence. An increasing number of empirical studies (e.g. Bowen *et al*., 1987; Davis and Weinstein, 2001b; Maskus, 1985; Trefler, 1993 and 1995) supports Trefler (1995, p. 1029)'s statement that the theoretical prediction have "… a success rate that is matched by a coin toss".

There is, however, one aspect of the problem regarding the poor fit of the empirical data, that has not been paid enough attention in the literature so far, and this is the problem of how to measure the different variables used in the factor content calculations. This paper contributes to the literature by presenting a systematic investigation of the role of various technical definitions and measurement issues in the computation of the human capital content of trade.

For this purpose, the human capital content of Swedish trade is estimated with various methods and data sources for the period 2006 – 2013. Focus here is on one particular factor, and that factor is human capital.[2] Countries' endowments of human capital will be increasingly important in the determination of comparative advantage, and hereby of industrial location, international specialization and trade. Since human capital (or skilled labor) is not a homogeneous factor of production[3], it can be measured in several ways. In the Leontief paradox/factor content of trade literature, there have

[1] The idea can also be traced back to Travis (1964) and Melvin (1968). It was, however, Leamer (1980) that introduced the Heckscher-Ohlin-Vanek theorem into the Leontief paradox literature.

[2] Labor, skilled or unskilled, has low mobility compared to commodities, many services and physical capital. According to IMF (2007) the global labor supply of skilled workers, measured as persons with university-level education, has increased by around 50 percent over the last 25 years, and trade has been the most important channel to access this increased pool of global labor.

[3] At least not in the short run.

been several different measures used to capture human capital. For example, Kenen (1965) uses earning differences, Lundberg and Wiker (1997) use educational attainment and Bowen *et al.* (1987), Webster (1993), Maskus *et al.* (1994) and Engelbrecht (1996) use occupational status. Due to available data, this study uses educational attainment to measure human capital. This way of measuring human capital has several characteristics; i) there is no clear cut correspondence between educational proficiency and vocational aptitude; ii) educational systems differ slightly between countries and; iii) the educational attainment level measure does only include formal education and not informal education and training.

In the process of measuring the human capital content of trade, it opens up a number of questions about how to measure the different concepts involved. Choices have to be made when the most preferred data is not available and/or when theory gives no guidance to what alternative data source or calculation method to choose. The importance of different solutions to such methodology choices is illustrated by how much they affect the human capital content of Swedish trade during the period 2006-2013.

The remainder of the paper is organized as follows. Section 2 presents a theoretical derivation of the Heckscher-Ohlin-Vanek theorem, and the specific equation used to address the various measurement issues in the empirical part, with a brief review of previous empirical studies. Section 3 introduces the dataset and describes variables used in the paper. Section 4 contains the empirical calculations addressing the various measurement issues. Section 5 presents calculations of the human capital content of trade in Sweden over the period 2006-2013, using the preferred measure from the empirical section. Conclusions and final remarks are provided in Section 6.

# 2. Theoretical background and previous empirical studies

## 2.1. Theory

The standard multifactor, multicommodity, and multicountry model for predicting trade in factor services is the HOV-model.[4] This model is a generalization of the two good, two factor and two country Heckscher-Ohlin trade model and it states that, if trade is balanced, countries will have an embodied net export (import) of factors in which they have an abundant (scarce) relative endowment, where abundance and scarcity are defined in terms of a factor-price-weighted average of all resources. The basic assumptions behind the model are identical technologies across countries; identical and homothetic preferences across countries; differing factor endowments; free trade in products and services; and no factor intensity reversals. If all countries have their endowments within their cone of diversification, factor prices will be equalized for all factors across countries.[5]

Let $c = 1, \ldots, C$ index countries; $i = 1, \ldots, I$ industries; and $f = 1, \ldots, F$ factors respectively. Let $\mathbf{A} = \left[a_{if}\right]'$ be the amount of production factors used to produce one unit of output in each industry, where the rows of the matrix measure the different factors and the columns measure the different industries. The $\mathbf{A}$ matrix should measure the total factor demand, i.e. direct plus indirect use of input factors, since the total factor intensities are relevant for the explanation of trade flows in the case with more traded products than factors (Hamilton and Svensson, 1983 and Deardorff, 1984). The total factor demand for country $c$, $\mathbf{A}^c_{total}$, is the product between the direct factor input requirements matrix for country $c$, $\mathbf{A}^c_{direct}$, and the Leontief-inverse,

$$\mathbf{A}^c_{total} = \mathbf{A}^c_{direct}(\mathbf{I} - \mathbf{B}^c)^{-1} \tag{1}$$

where $\mathbf{I}$ is the identity matrix and $\mathbf{B^c}$ the technical coefficients matrix computed from the domestic input-output table for country $c$.[6]

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[4] This section is based on Feenstra (2003).

[5] The presence of non-tradables can be ignored as long as there is factor price equalization (Davis and Weinstein, 2001c).

[6] The inclusion of sub-indices *direct* and *total* in equation (1) were only made to illustrate the difference between the two factor input requirements matrices in the equation, and they will be dropped hereafter. Furthermore, when using $\mathbf{A^c}$ or $\mathbf{A}$ for now on, it is the total factor demand that is referred to (if not otherwise stated).

Let $\mathbf{Y^c}$ be the $(I \times 1)$ vector of each industry's output; $\mathbf{D^c}$ the $(I \times 1)$ vector of demand for each good; then the net-export vector can be written $\mathbf{T^c}=\mathbf{Y^c} - \mathbf{D^c}$. The factor content of trade, i.e. the $(F \times 1)$ vector of net trade in factor services, can then be written as $\mathbf{F^c} \equiv \mathbf{A^c T^c}$. With identical technologies across countries and factor price equalization for all factors, all countries face the same total factor input requirements matrix, i.e. $\mathbf{A^c} = \mathbf{A}$. The interpretation of $\mathbf{F^c} \equiv \mathbf{AT^c}$ is straightforward: a positive value of an element in $\mathbf{F^c}$ indicates that the factor is exported and a negative value indicates that the factor is imported.

The goal of the HOV-model is to relate the factor content of trade to the underlying endowments of production factors in the country. By calculating $\mathbf{AY}^c$, the demand for factor *f* in country *c*, and using the assumption of full employment of all resources, the following can be written: $\mathbf{AY^c} = \mathbf{V^c}$, where $\mathbf{V^c}$ is the endowment of factor *f* in country *c*. With factor price equalization, free trade and that the consumers in all countries have identical and homothetic taste, a country's consumption vector must be proportional to world consumption, i.e. $\mathbf{D^c} = \mathbf{s^c D^w}$, where $\mathbf{s^c}$ is country *c*'s proportion of world consumption (adjusted for the trade balance) and $\mathbf{D^w}$ the world consumption. Since world production is equal to world consumption, due to the full employment assumption, the following can be written:

$$\mathbf{AD^c} = \mathbf{s^c AD^w} = \mathbf{s^c AY^w} = \mathbf{s^c V^w} \tag{2}$$

Using equation (2) together with the expressions for $\mathbf{AY^c}$ and $\mathbf{AD^c}$, the following equation emerges,

$$\mathbf{F^c} \equiv \mathbf{AT^c} = \mathbf{V^c} - \mathbf{s^c V^w} \tag{3}$$

which is the HOV-equation.[7] Equation (3) is a statement of the HOV-theorem and it states that the factor content of trade of country *c* (the left hand side of the equality sign) is equal to country *c*'s endowment of production factors relative to the world endowment of those factors (the right hand side). If country c's endowment of a production factor exceeds country c's share of the world endowment of that factor (measured by country c's share of world GDP), then country *c* is abundant in that factor, and if country c's endowment fall short, it is scarce.

[7] The left hand side of the equality sign is sometimes labeled the production side or the *measured* factor content of trade, and the right hand side is sometimes labeled the absorption/consumption side or the *predicted* factor content of trade.

Using the production side of equation (3), net trade in embodied services of production factors *f* for country *c*, i.e. an element in $\mathbf{AT^c}$, and summing it over industries *i*, the comparison of the factor content of trade can be written in difference form,

$$F_f^c = \sum_{i=1}^{I} X_i^c a_{if}^c - \sum_{i=1}^{I} M_i^c a_{if}^c = \sum_{i=1}^{I} X_i^c \sum_{i=1}^{I} x_i^c a_{if}^c - \sum_{i=1}^{I} M_i^c \sum_{i=1}^{I} m_i^c a_{if}^c, \qquad (4)$$

or as a ratio,

$$z_f^c = \frac{\sum_{i=1}^{I} x_i^c a_{if}^c}{\sum_{i=1}^{I} m_i^c a_{if}^c}, \qquad (5)$$

where $X_i^c$ and $M_i^c$ are exports (imports) from (to) industry *i* in country $c$, $x_i^c$ and $m_i^c$ the share of the *i*th industry in the total exports (imports) from (to) country $c$, and $a_{if}^c$ the total use of factor *f* per unit of production from the *i*th industry in country *c*.[8]

The interpretation of the *z*-measure in equation (5) is straightforward: the average requirements of a factor *f*, weighted by trade shares, per unit of exchange of exports, compared to the average requirements of the imports.[9] This measure will give information about the difference in export- and import structure with respect to a particular factor's intensity in products and services, regardless of the trade balance. Equation (5) will form the basis of the empirical analysis in Section 4.

## 2.2 Empirical studies

The seminal empirical critique of the Heckscher-Ohlin trade model is the Leontief study from 1953, where he found, contrary to the expectations of that time, that the capital-labor ratio embodied in imports exceeded the ratio embodied in exports by approximately 30 percent. This was, however, not a formal test of the Heckscher-Ohlin model, but it clearly indicated that there was a discrepancy between theory and empirics. The Leontief paradox has generated a vast literature over the years (see the surveys by Leamer, 1984; Leamer and Levinsohn, 1995; Feenstra, 2004; and parts of Zeddies, 2013 and Bernhofen, 2010). Leamer (1980) showed that Leontief had applied the wrong test of the Heckscher-Ohlin model. He showed that a comparison of capital-output ratios in exports and imports were theoretically inappropriate. Leamer used the HOV-model instead, together with Leontief data for the

[8] Equation (4) can also be written as: $F_f^c = \sum_{i=1}^{I} X_i^c a_{if}^c - \sum_{i=1}^{I} M_i^c a_{if}^c = \sum_{i=1}^{I} T_i^c a_{if}^c$, where $T_i^c$ is net-exports of industry *i* in country *c*.

[9] This measure was introduced by Lundberg and Wiker (1997).

United States in 1947 and he showed that the U.S. actually was revealed by trade to be capital abundant.

Leamer and Bowen (1981) emphasized the importance of using separate measures of all three concepts of the HOV-model, i.e. trade, factor input requirements, and factor endowments, when testing the HOV-model appropriately. One of the first studies following this recommendation was performed by Bowen *et al.* (1987), who used the U.S. 1967 input-output table together with trade in 1967 and the 1966 supply of twelve resources (factors) for 27 countries to compute the factor content of net exports. The factors embodied in trade were then compared with actual endowments to determine the extent to which data conform to the HOV-calculations. They used both rank- and sign tests[10] and the results showed that the HOV-calculations did no better than a coin-flip. They found support for a model in favor of Hicks neutral technological differences and non-proportional consumption. Other studies have continued finding discrepancies between theory and the empirical data (e.g. Trefler, 1993 and 1995).

Subsequent work in the field of testing the HOV-model have taken at least two directions; either have they focused on relaxing the underlying theoretical assumptions (e.g. Bowen *et al.*, 1987, model *inter alia* technological differences between countries; Trefler, 1993, model the productivity of factors in different countries; Trefler, 1995, model differences in the factor input requirements matrix; Reimer and Hertel, 2010, model non-homothetic preferences; and Trefler and Zhu (2010), using individual countries‘ technology matrices instead of a single matrix adjusted for production technology differentials); or have they tested the HOV-model in a setting that corresponds closer to those underlying assumptions (e.g. Davis *et al.*, 1997 on Japanese regions; Norberg, 2000 on Swedish regions; and Requena-Silvente *et al.*, 2008 and Artal-Tur *et al.*, 2011 on Spanish regions).

Lundberg and Wiker (1997) calculated the factor content of services of skilled labor (classified by level of educational attainment) embodied in trade in manufactures, for a sample of OECD countries over the period 1970-1985, using several measures of the factor content of trade, including the *z*-measure

[10] The rank test makes a comparison of all factors for each country in the study in pairs and ranks them, i.e. if country A is found to be relatively more abundant in factor *f* than factor *k* relative to country B, then net exports by country A relative to country B of factor *f* will be greater than net exports by country A relative to country B in factor *k*. The sign test compares the sign of the actual relative factor contents of trade between two countries with the sign of the predicted relative factor contents of trade.

described in equation (5).[11] The Swedish 1985 input-output table was used for all countries and all years. Moreover, they used Swedish data from 1990 on employment by education and by four-digit SNI69 industry code,[12] which was also used to represent all countries and all years. This means that the production technology is held constant both over time and across countries. The study investigated what role skill intensive production had on the trade pattern of the OECD countries and they found, *inter alia*, that Sweden were revealed by trade to be abundant in skilled labor. Other studies that, among other findings, also come to this conclusion are Bowen *et al.* (1987) and Torstensson (1992 and 1995).

Norberg (2000) analyzes the factor content of Swedish regions' net trade in 1995, and compares this to the predictions of the HOV-model. She is using data on regions instead of countries, together with regional input-output tables and data on two labor categories, viz. labor with secondary education and labor with higher than secondary education, and she finds that the HOV-model is a poor predictor of Swedish region's trade.[13]

# 3 Data, variables definition and measurement issues

Our final data is extracted from Swedish firm-level data. This data cover all Swedish firms and consists of several linked register-based data sets from Statistics Sweden, i.e. Labor Force Statistics (RAMS), Business Statistics (FEK) and the Foreign Trade Statistics. The data is collected for the period 2006-2013. Several exclusions were made: all private firms with less than 10 employee; all firms that belong to the public sector and the financial sector.

## *3.1 Variables definition*

*A. Direct factor input requirements*:

The $a_{if}^{c}$ variable in equation (5) is either the elements of the direct factor input requirements matrix or the elements of the total factor input requirements matrix.[14] Both matrices are used to represent the factor input requirements,

[11] This measure is also used in Lundberg (1999).

[12] This is the Swedish ISIC rev.2 analogue.

[13] This is in concordance with Requena-Silvente *et al.* (2008) on Spanish regions, using data from 1995, but contrary to Davis *et al.* (1997) who found that the HOV-model performed well in the case of Japanese regions, using data from 1985.

[14] The connection between direct and total factor input requirements is shown in equation (1). Total factor input requirements are discussed further below.

depending on which topic is investigated in section 4. An individual entry in the direct (and indirectly in the total) factor input requirements matrix is computed by the following,

$$a_{ift}^{c} = \frac{w_{ift}^{c}}{q_{it}^{c}} \tag{6}$$

Since $w_{ift}^{c}$, the sum of factor $f$'s wages in industry $i$ in country $c$ at time $t$, and $q_{it}^{c}$, the gross production in industry $i$ in country $c$ at time $t$, are only available from two different data sets, equation (6) is actually measured as,

$$a_{ift}^{c} = \frac{w_{ift}^{c}}{\sum_{f=1}^{F} w_{ift}^{c}} \frac{\sum_{f=1}^{F} w_{ift}^{c}}{q_{it}^{c}}, \quad \forall t \tag{7}$$

The first right hand side term in equation (7) is taken from the database RAMS, and the second term is taken from the database FEK.[15]

*B. Total factor input requirements*:
In subsection 4.3, annual symmetrical input-output tables (SIOTs) for Sweden retrieved from the World Input-Output Database (WIOD) is used.[16] Those tables divides the Swedish economy into 35 industries. In subsection 4.4 the official Swedish 2010 input-output table from Statistics Sweden's national accounts are used in the calculations. This input-output table divides the Swedish economy into 65 industries. In the comparison of U.S. and Swedish technology in the same subsection, the U.S. and the Swedish 2010 input-output tables from WIOD are used.[17]

*C. Educational level*:
In the database RAMS, all workers can be grouped according to their highest completed educational level, ranging from those with no secondary education to those with longer (≥ 3 years) post-secondary education. Both employment and wage data are collected for the labor force with at least a completed post-secondary education. Those workers are divided into four

[15] Wage taken from RAMS is annual earnings and wage taken from FEK is labor costs inclusive of social security costs. Index $t$ is introduced in the equations to reflect the fact that most calculations in the empirical part are performed over time. In the empirical part, however, super-index $c$ and/or sub-index $t$ might be dropped in the presentation, depending on which measurement problem that is addressed.
[16] The WIOD contain SIOT:s covering 27 EU countries and 13 other major countries in the world for the period from 1995 to 2011. See Dietzenbacher *et al.* (2013), Timmer *et al.* (2015) and www.wiod.org for further information about WIOD.
[17] There are several ways to construct SIOTs and the so called industry technology assumption (ITA) is the method used to create both the Input-Output tables in the WIOD and the official Swedish Input-Output table for 2010 compiled by Statistics Sweden. See also Bohlin and Widell (2006) for further information on constructing ITA Input-Output tables.

non-exclusive educational groups; i) those with less than 3 years of post-secondary education ii) those with 3 years or more of post-secondary education; iii) those with less than 3 years post-secondary education with scientific or technical alignment and iv) those with 3 years or more of post-secondary education with scientific or technical alignment.

*D. Exports and imports*:
Data on Swedish exports and imports of products are collected from the foreign trade statistics database.[18] The statistics on the foreign trade consists of two statistical systems, Extrastat and Intrastat. Extrastat is register-based statistics received from the Swedish Customs, originating from the import and export declarations for the importer of the products from, or exporter of the products to non-EU countries (third countries). Intrastat is a comprehensive survey with a cutoff designed by the EU's statistics agency Eurostat.[19]

*E. Statistical classification*
Each firm in the databases RAMS and FEK are classified according to the Swedish Standard Industrial Classification (SNI), which is based on EU:s recommended standard NACE. Due to a change in SNI-classification in the relevant period (2006-2013), the data is collected at the five-digit level of the SNI 2002 classification for the period 2006-2009 and according to the SNI 2007 classification for the period 2010-2013 (the NACE Rev. 1.1 and Rev. 2 Swedish analogues).[20] Data on exports and imports in the database Foreign Trade Statistics are classified according to Swedish Standard Classification of Products by Activity (SPIN), which is based on the EU Classification of Products by Activity (CPA). Similar to the firm data, the SPIN classification has also changed over the relevant period and SPIN 2002 is used for the period 2006-2009 and SPIN 2007 for the period 2010-2013.

Some compilations have been done to merge the different data sets, mainly due to the changes in industry- and product classifications that have been done. In some cases, conversions between different classifications have been performed, e.g. from SNI 2002 to SNI 2007 in 2010 (the RAMS-data) and SPIN 2007 to SPIN 2002 for exports in the period 2006-2009. Values on the different variables used to calculate the $z$-value in equation (5) are left in

[18] Trade in services are excluded in this study due to low representability of the data.
[19] The Intrastat survey refers to Swedish firms that have an annual export of products to the EU of at least 4,5 MSEK (2006-2013), or importation of products from other EU countries for at least 2.2 MSEK (the period 2006-2008) and 4,5 MSEK (2009-2013).
[20] The merging of RAMS and FEK (on firm-level) gives on average around 220 000 matches per year over the relevant period.

nominal form, since the calculations eliminate the need to convert them into real values. Finally, the Manufacturing sector refer to categories 15-37 in SNI 2002 and 10-33 in SNI 2007 and the goods sector to categories 01-37 in SNI 2002 and 01-33 in SNI 2007.[21]

## *3.2 Measurement issues*

The first measurement issue (subsection 4.1) examines whether the input-output matrices used are good averages of each industries factor input requirements. Next issue (subsection 4.2), the use of fixed or variable factor input requirements are compared and evaluated. In subsection 4.3 the choice of what educational measure to use to represent skilled labor is elaborated. Several different educational levels and alignments are used and compared. In subsection 4.4 the issue of using direct or total factor input requirements in the calculations is examined. This matter is dealt with in two ways, first a comparison between calculations using direct factor input requirements with those using total factor input requirements are done (by means of the Swedish 2010 input-output table) for the period 2006-2013. Secondly, a comparison between the calculations using the 2010 input-output table with calculations using annual input-output tables are done for the period 2006-2011.[22] The fifth measurement issue (subsection 4.5) concerns the assumption of a common technology matrix among different countries. Here both the Swedish 2010 and the U.S. 2010 input-output tables from the WIOD are used together with direct factor input requirements from Sweden. The next issue (subsection 4.6) concerns the level of aggregation of the industries. Here calculations using direct factor input requirements (aggregated into 5, 4, 3 and 2-digit level respectively) are used and examined. The last issue (subsection 4.7) concerns the size of the trade vector. This is dealt with in two ways, first calculations using the manufacturing sector only, manufacturing and goods sectors and finally all sectors (inclusive of the service sector) are compared. Second, firm level data on 5-digit level are used to calculate the factor input requirements for each individual firm. Those numbers are then used to compare manufacturing sector firms with service sector firms with respect to their variation.

In evaluating the various measurement issues discussed and listed above, both the level of $z$ and the relative variation of $z$ over time will be considered.

[21] In this text, there is a distinction between sector, industry and firm. A sector, e.g. the manufacturing sector, contains of a number of industries (who are based on the SNI classification). Each industry contains of a number of firms producing the same or similar product.
[22] The annual tables are taken from WIOD and covers the period 2006-2011.

# 4 Effects of alternative solutions to measurement problems

In this section, the different measurement problems stated in section 3.2 will be addressed more thoroughly. In addition, alternative solutions will be investigated, by comparison of various calculations with a base case human capital content of trade trajectory (a baseline). This baseline is computed using direct factor input requirements, which vary annually, on five digit level, using the manufacturing sector only and labor with at least 3 years of post-secondary educational level attained as the only factor of production. Small adjustments will be done to the baseline calculations in some of the applications, making it possible to compare the baseline with the specific case. Otherwise stated the calculation of the baseline is done according to the description above. All figures and tables are based on author's own calculations.

## *4.1 Measurement errors in the factor input requirements matrix*

A first measurement issue concerns the factor input requirements matrix **A**. The elements in available input-output matrices consist of average values and not the theoretically preferred marginal values. If industry *i* is heterogeneous, it could be the case that the $a_{if}^{c}$, an element in the factor input requirements matrix, in export intensive firms is greater than the industry average, i.e. $\frown{a}_{if}^{c} > \bar{a}_{if}^{c}$. Although not all firms in an industry are exporters, all contribute to the wage shares for that industry. Bernard and Jensen (1997), for example, find that exporting plants are quite different when it comes to factor requirements compared to plants within the same industry that do not export. This could bias the calculations of *z* in equation (5) either way.[23]

In Table 4.1 descriptive statistics of the skill intensity, for exporting- and non-exporting firms, for each year of the period 2006-2013 is presented.

[23] When discussing measurement problems, errors in data collection, computational mistakes etc. are not included.

***Table 4.1: Descriptive statistics of skill intensity: exporting versus non-exporting firms in the manufacturing sector***

| | Exporting firms | | | | Non-exporting firms | | | |
|---|---|---|---|---|---|---|---|---|
| | | Standard Deviation | | | | Standard Deviation | | |
| Year | Mean | Between | Within | Total | Mean | Between | Within | Total |
| 2006* | 0.0372 | 0.0270 | 0.0504 | 0.0571 | 0.0495 | 0.0523 | 0.0511 | 0.0652 |
| 2007* | 0.0367 | 0.0279 | 0.0431 | 0.0509 | 0.0502 | 0.0495 | 0.0602 | 0.0752 |
| 2008* | 0.0384 | 0.0280 | 0.0484 | 0.0560 | 0.0547 | 0.0548 | 0.0654 | 0.0809 |
| 2009* | 0.0422 | 0.0327 | 0.0470 | 0.0559 | 0.0615 | 0.0797 | 0.0666 | 0.0888 |
| 2010* | 0.0437 | 0.0351 | 0.0600 | 0.0678 | 0.0578 | 0.1458 | 0.0767 | 0.1053 |
| 2011 | 0.0410 | 0.0389 | 0.0548 | 0.0636 | 0.0437 | 0.0695 | 0.0533 | 0.0689 |
| 2012 | 0.0429 | 0.0372 | 0.0569 | 0.0656 | 0.0428 | 0.0666 | 0.0435 | 0.0594 |
| 2013 | 0.0446 | 0.0387 | 0.0545 | 0.0643 | 0.0439 | 0.1014 | 0.0428 | 0.0683 |

*Notes*: The decomposition is modeled using firm level data for all firms with at least 10 employees in the manufacturing sector in Sweden. The number of observations varies across the years. 3 205 – 3 641 for exporting firms and 894 – 1 073 for non-exporting firms. "Within standard deviation" represents changes within industries, and "between standard deviation" represents shifts across industries. A firm is defined to be an exporter if the export share in total sales is greater than 0. The null-hypothesis is that the average skill intensity in non-exporting firms is equal to that in exporting firms. * F-test of the hypothesis that the difference between the average skill intensity of exporting firms are equal to non-exporting firms is rejected at 1% level. Bartlett's test for equal variance shows that we can reject the assumption that the variances of the two groups are homogenous (at 1% level for all years except for 2013, which is rejected at 5% level).

The results in Table 4.1 show that there seems to be a small but, for several years, significant difference in skill intensity between exporting and non-exporting firms. The average skill intensity is increasing up to 2010 for exporting firms and 2009 for non-exporting firms, showing that the downturn of the Swedish economy in 2008/2009 did not only affect low-skilled labor but also high-skilled labor. However, the average skill intensity is higher for non-exporting firms for most of the years, indicating that the factor input requirements used in this study might be biased upwards. Another interesting result is that the within industry deviation is higher than the between industry deviation for exporting firms, and the other way around for most years for non-exporting firms. This implies that exporting firms are more heterogeneous than non-exporting firms, but it does not help in assessing the direction of a possible bias of the factor input requirements.

Another issue, which cannot be investigated with the data used for Table 4.1, is whether import coefficients are equal to export coefficients. If factor price equalization does not prevail, the factor input requirements, $a_{if}^{c}$, can and, most likely, will be different between exports and imports. Davis and Weinstein (2001a) pay attention to this problem and use a model, developed by Deardorff (1982) and Helpman (1984), which measures the factor content of trade with no factor price equalization. The core result of their study is that the factor content of trade should be measured using the producers' technology, i.e.

$$F_f^c = A_f^c X^c - \sum_{c^*} A_f^{c^*} M^{cc^*} \tag{8}$$

where $c$ denotes country $c$, $c^*$ all other countries, $A_f^c$ row $f$ in the total factor input requirements matrix, $X^c$ exports from country $c$ and $M^{cc^*}$ imports from $c^*$ to $c$.[24] However, to follow this procedure, one needs to collect bilateral trade data for country $c$ together with each country's factor input requirements matrix. It is possible to get hold on bilateral trade data for Sweden and its trading partners, but data on each of Sweden's trading partners' factor input requirements are practically impossible to get, especially if total factor input requirements are used in the calculations. It is a shortcoming this exercise cannot be performed here, but the data requirements cannot be fulfilled.

Trefler (1993) deals with this problem in a completely different way, by allowing all factors in every country to differ in their productivities. The U.S. is used as a benchmark country with factor productivities normalized to unity. One result from this exercise is that the HOV-equation no longer becomes testable, since it holds as an identity by the choice of productivity parameters.[25]

Although there seem to be a difference in skill intensity between exporting firms and non-exporting firms, and since the calculation of equation (8) cannot be done because of data shortage, the input coefficients in the data will be assumed that they are equal between the two categories among each industry. The import coefficients will also be assumed that they are equal to the export coefficients.

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[24] See also Trefler & Zhu (2011), Stone *et al*. (2011) and Morrow and Trefler (2015) for a similar approach. Artal-Tur *et al.* (2011) relaxes *inter* alia the assumption of factor price equalization and they found no or small improvement in the performance of the HOV-model in a regional setting (Spanish regions).

[25] Trefler recommends two methods to validate these results; the first is to check whether the productivity parameters are positive or not and; the second is to compare these parameters with other economic data to evaluate how *reasonable* those parameters are. This study, and Trefler (1995), has been criticized by Gabaix (1997), who shows that Trefler's calculation of cross-country differences in productivity of inputs is insensitive to the factor content of net exports. Gabaix show this by comparing Trefler's calculations with a calculation where the factor content of trade is forced to be equal to zero. In both cases, virtually identical numbers are obtained.

## 4.2 Fixed or variable factor input requirements

One measurement issue, which is specific to the question concerning the relative variation of the human capital content of trade over time, is whether to use current values of factor input requirements or, as is most often done, fixed coefficients, for a predetermined year, so all variables except trade is due to *t*. Lundberg and Wiker (1997) use fixed total factor input requirements, calculated using the Swedish input-output table from 1985, and direct factor input requirements for 1990, to cover the period 1970-1985. This is the same as assuming that the factor input requirements are constant over time.

In Figure 4.1 the outcome of the *z*-calculations using fixed- and variable factor input requirements are illustrated, respectively. The *fixed* curve is calculated using direct factor input requirements for 2009 only and annual trade data for the period 2006-2013, and the *variable*-curve is calculated using variable direct factor input requirements and annual trade data.[26]

[26] The choice of reference year (2009) in the calculation of fixed factor input requirements is not predetermined due to theory. The choice of a different reference year will only affect the level of the fixed curve (a vertical shift up or down) in figure 4.1.

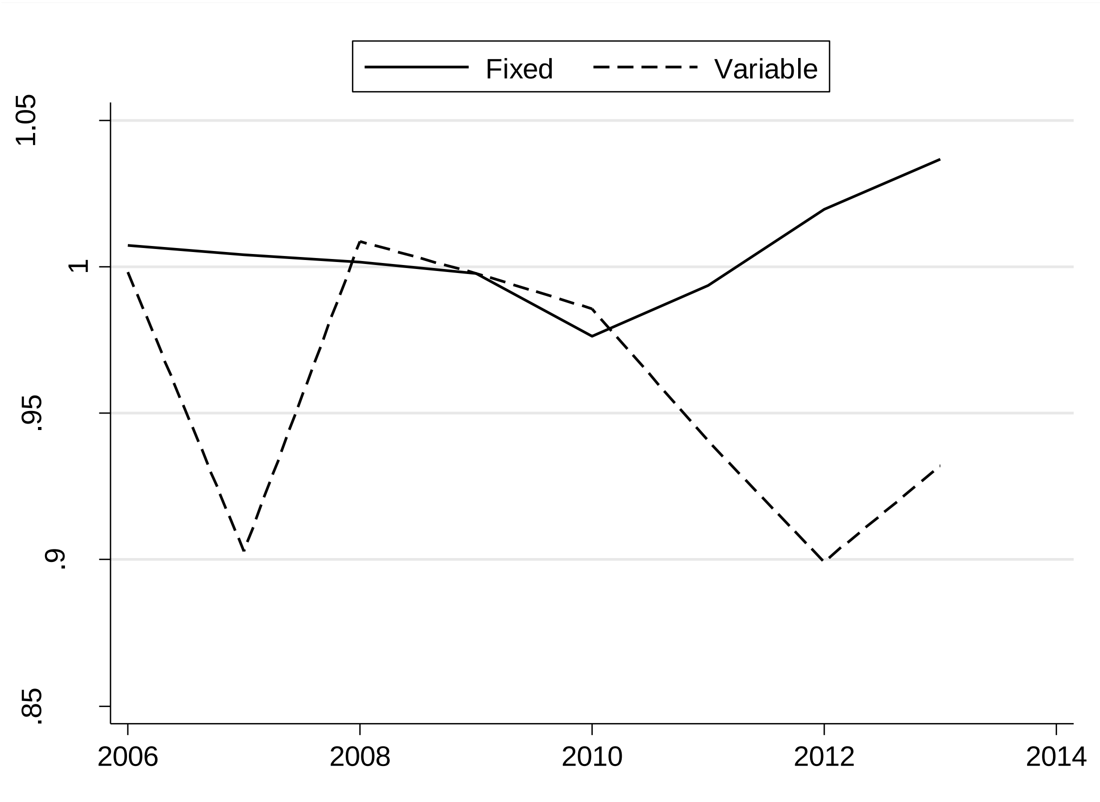


***Figure 4.1: Comparison between fixed and variable factor input requirements in the manufacturing sector***

*Note*: The variable curve is calculated according to the base case model. The fixed curve is also calculated in accordance with the base case model, but using fixed direct factor input requirements for 2009 instead.

There is a big gap, approximately 10 percentage points, between the two curves during some of the years, and the correlation between them over the period is -0.52, which is moderate.

The comparison between using fixed input requirements and using annual values in the calculations of the *z*-value, gives us a somewhat interesting picture. Why is there a different development between the variable and fixed estimates, where the fixed curve evolves more damped over the period? When using fixed factor input requirements the calculations only captures the changing trade pattern of the factor services over time, but in the variable case, it captures both the changing trade pattern and the change in factor input requirements over time. The difference between the two curves is affected, according to the differentiation of equation (5) in Appendix A, by the correlation between net exports and the change in factor input requirements in the different industries. There seem to be some kind of business cycle effect affecting the curves, and the level of *z* affects the difference between the two curves as well. The choice between calculating *z* with fixed- or variable factor input requirements seems to matter when evaluating the relative variation of *z* over time, since there is a different trend between the two curves.

### *4.3 The choice of educational level and alignment*

Another measurement issue concerns what educational level and/or educational alignment to choose as a proxy for skilled labor. Since educational level have been chosen as the measure of human capital (see Section 1 above), different educational levels- and alignments can be chosen. The calculations of *z* using four different educational measures (se Section 3.1) containing post-secondary education are illustrated in Figure 4.2.

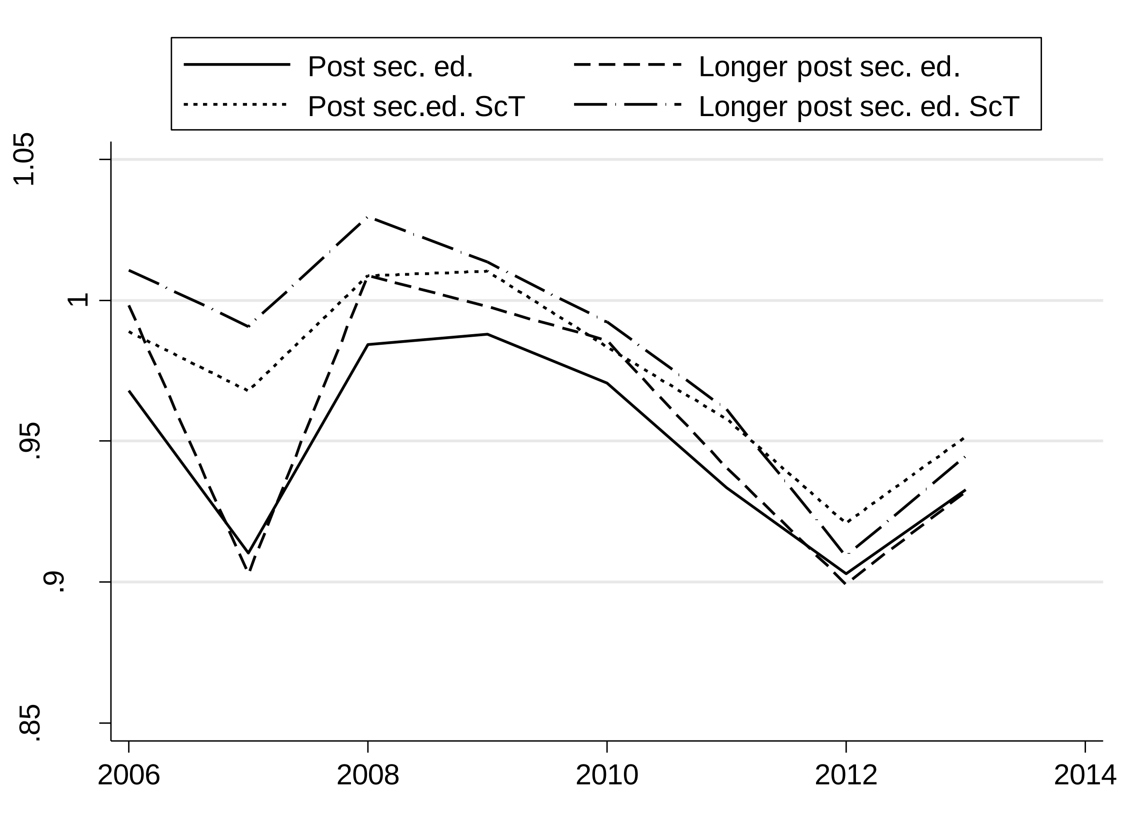


***Figure 4.2: A comparison between z-curves computed using different educational measures of skilled labor in the manufacturing sector***

Note: All curves are calculated in accordance with the baseline. "*Post sec. ed*." is z calculated using a post-secondary education of less than 3 years completed; "*Post sec. ed. ScT*" using a post-secondary education with scientific or technical alignment of less than 3 years completed; "*Longer post sec. ed*." those with a post-secondary education of at least 3 years completed; and "*Longer post sec. ed. ScT*" those with a post-secondary education with scientific or technical alignment of at least 3 years completed respectively.

The four curves in Figure 4.2 are strongly positively correlated, 0.81-0.98, with each other (see Table B.1 in Appendix B). The difference in the levels of the four curves, on a year-to-year basis, is decreasing over the time-period.

Due to the strong positive correlation and the level differences between the curves in Figure 4.2, the conclusion gives that the choice of educational level does not matter much when evaluating the relative variation of *z* over time. It only takes on importance in evaluating the level of *z*.

## 4.4 Direct or total input coefficients

The question whether to use direct or total factor input requirements is considered next. In theory, total factor input requirements should be used in the calculations[27], but in practice, not all studies do so. One reason being that there are few input-output tables available, another that those available are too highly aggregated.[28] This is especially true when studying several countries and using country-specific input-output tables.

In this subsection, the official Swedish 2010 input-output table calculated by Statistics Sweden is used together with annual direct factor input requirements to compute total factor input requirements for each year over the period 2006-2013. The calculated total factor input requirements are then used together with annual trade data to compute *z*. All data used are in concordance with the input-output industries, making it possible to perform the required vector multiplications acquired to calculate the *z* measure for the manufacturing sector only.[29] The results of the calculations is illustrated in Figure 4.3.

[27] See Hamilton and Svensson (1983) or Deardorff (1984).
[28] See subsection 4.5 concerning problems of aggregation.
[29] One result of these calculations were that all data for the period 2006-2009 had to be converted from SNI 2002 to SNI 2007 classification. This were done because the Swedish SIOT from 2010 are based on SNI 2007 classification.

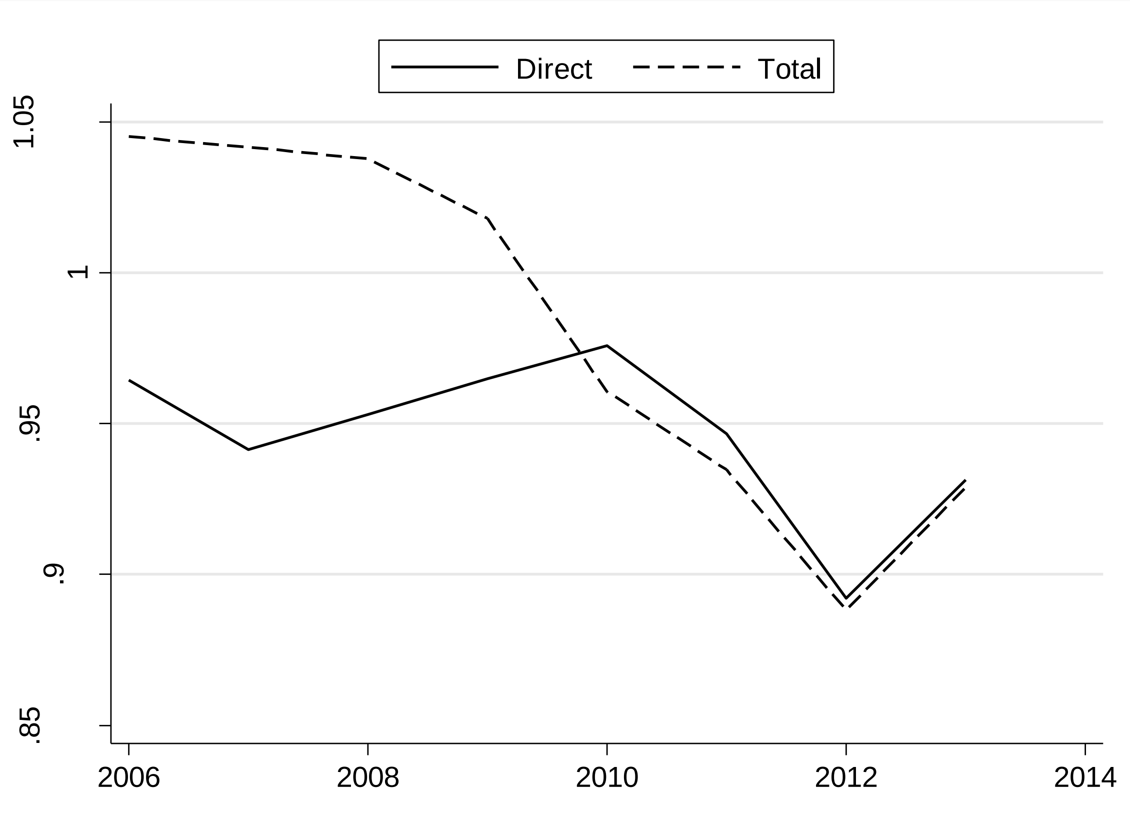


***Figure 4.3: Direct versus total factor input requirements of skilled labor in the manufacturing sector***

*Note*: The total curve is calculated using the Swedish 2010 input-output table, and the variable curve is calculated in accordance with the baseline on a 2-digit level.

The two curves representing *z*, computed by total (dashed curve) and direct factor input requirements (filled curve) respectively, have a diverged trajectory in the first part of the measured period (2006-2009), but they follow each other quite close in the later part of the period (2010-2013). This different behavior of the curves between the two periods is probably due to the change in industrial classification from SNI 2002 to SNI 2007, which affects direct input requirements and trade shares in the calculations.

The use of a single SIOT in the calculations of the total factor input requirements for the entire period could constitute a problem in interpreting both the level of the *z*-value for a single year and for the development of *z* over time. Therefore, the conclusion here will be that total factor input requirements are theoretically correct and should be used in those cases where point estimates matter.

A better comparison between total and direct factor input requirements would, though, be to use annual input-output tables for the whole period, but unfortunately, Statistics Sweden have only compiled two input-output tables during the relevant period for Sweden, viz. 2008 and 2010. However, by using the WIOD tables, this exercise can be performed for the period 2006-2011. Those calculations are presented in Figure 4.4 below.

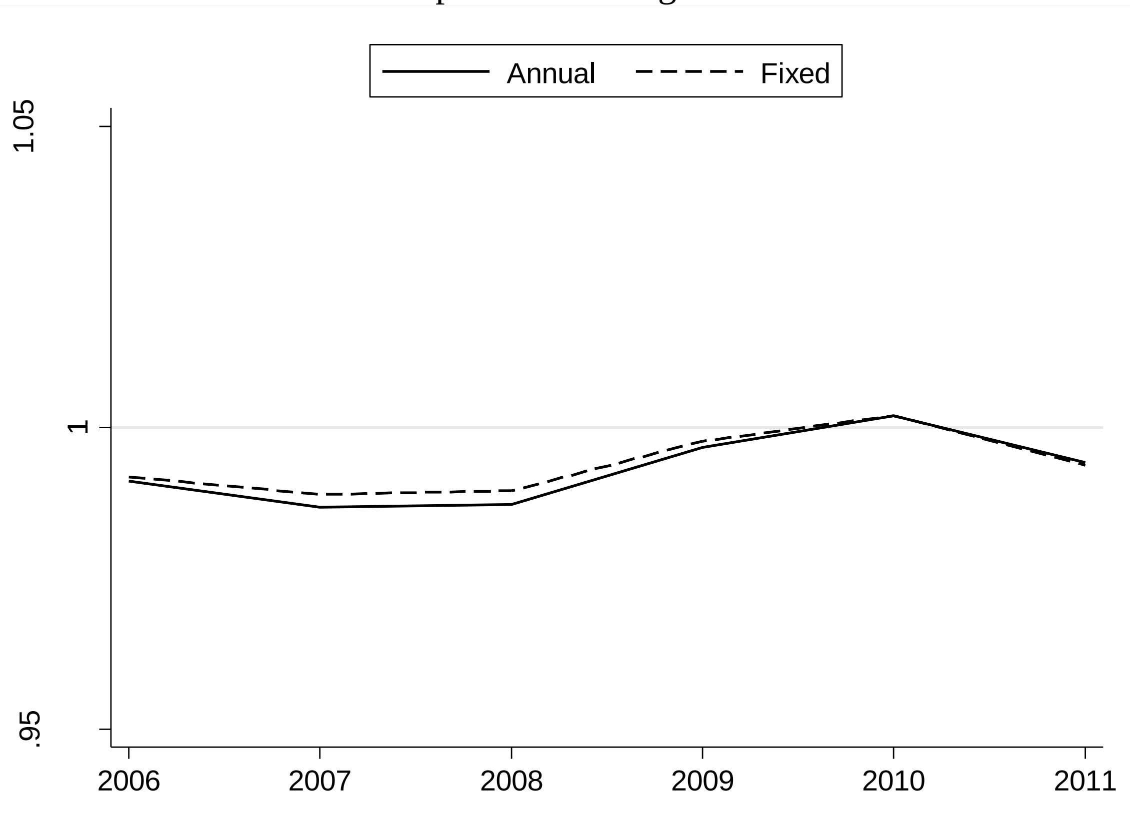


***Figure 4.4: Comparison of the z-calculations using annual or fixed SIOTs for the manufacturing sector***

*Note*: The annual curve (filled line) is computed using the annual Swedish SIOTs from WIOD; and the fixed curve (dashed line) is computed using the 2010 Swedish SIOT from WIOD. Both curves are computed in accordance to the baseline.

The annual and the fixed curves in Figure 4.4 are almost collinear over the period and the level of *z* are almost identical for each year. The reason for this result may be the high aggregation of the SIOTs used in the calculations (2-digit level), since the only difference between the two curves in the construction are the SIOTS.

Those results indicate that the choice between using one SIOT representing the chosen period and using annual SIOTs for that period is unimportant. This is in sharp contrast to Bohlin and Widell (2006), who shows that annual SIOTs are preferred to a single one since the technical coefficients in the SIOTS (see $\mathbf{B^C}$ in equation 1) change rather large over time.

The conclusion here will be that when evaluating the relative variation of *z* over time, it does not seem important to use SIOTs in the calculations (at least not after the change in industry classification to SNI 2007 in 2010). It only takes on importance in evaluating the level of *z*.

## 4.5 International comparison using national factor input requirements

In several studies of the factor content of trade, one country's factor input requirements matrix, direct or indirect, is often used to represent all countries in the study. The use of such a common matrix for all countries is theoretically correct due to the underlying assumptions of the HOV-model, specifically assumptions like identical technology across countries and factor price equalization, but empirically it has been rejected by several studies (e.g. Davis and Weinstein, 2001b; and Trefler, 1993).

In this subsection, the *z* calculations are performed utilizing both Swedish and U.S. SIOTs from WIOD.[30] The results of these calculations are illustrated in Figure 4.5.

[30] For further description of the data used, see Section 3.

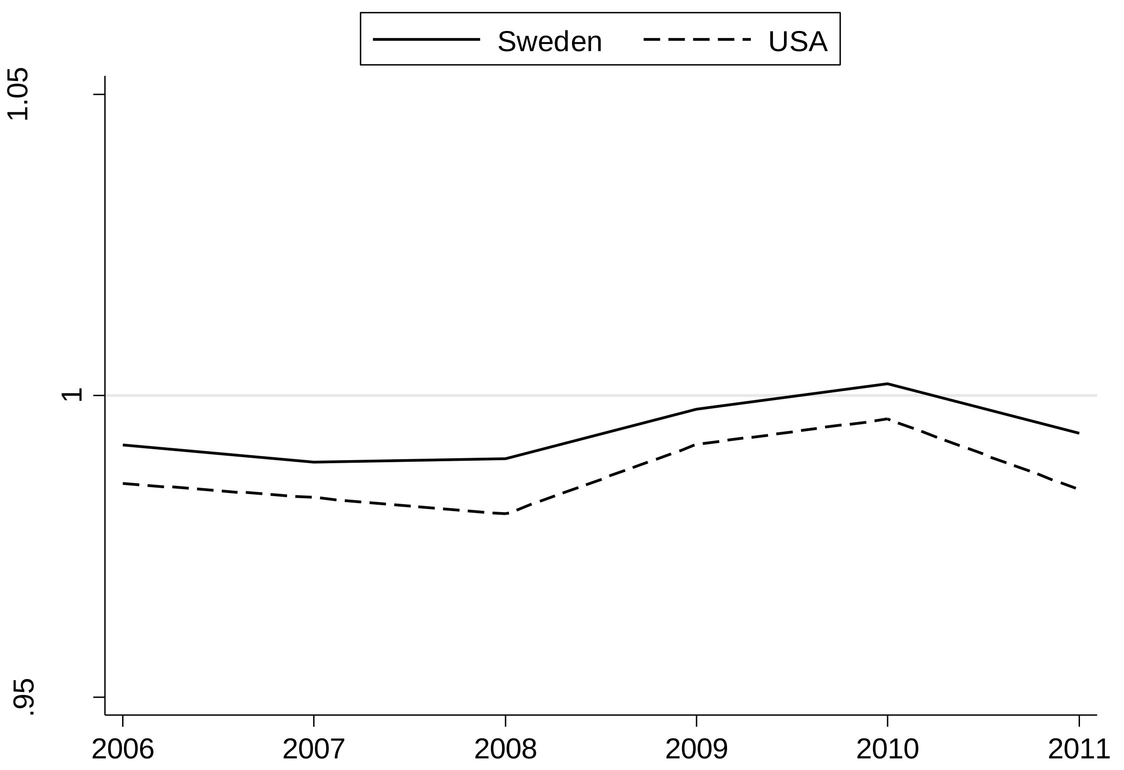


***Figure 4.5: Comparison of the z-calculations using different technology matrices for the manufacturing sector***

*Note*: The filled curve is calculated using the Swedish 2010 SIOT from WIOD, Swedish direct factor input requirements and annual trade; and the dashed curve is calculated using the U.S. 2010 SIOT from WIOD, Swedish direct factor input requirements and annual trade.

Figure 4.5 shows a close correspondence between the *z*-curve calculated using U.S. technology and the one calculated using Swedish technology. The correlation between the two curves is close to unity, so in this particular case, the conclusion is that it does not matter much if Swedish or U.S. total factor input requirements are used when evaluating the relative variation of *z* over time. It only takes on importance when evaluating the level of *z*. An interesting result though, is the upward shift of the *z*-curve when changing from U.S. technology to Swedish technology.

Another interesting result is that the curve using U.S. technology stays below one for the whole period, but the curve using Swedish technology rises above one around 2010 and drops below one after that. This indicates that Sweden changed from being a net importer of services of skilled labor, to become a net exporter of those services for a short period. This highlights somewhat the importance of correctly measuring the different variables used in the *z*-calculations, since the policy implication would be different whether the value of *z* is greater or less than one.

## *4.6 The level of aggregation of industries*

When reviewing the relevant literature up to 2010, one often runs into the problem with the level of aggregation of industries of the measured data. In many studies, the level of aggregation is quite high (*inter alia* Hakura, 2001, uses 23 industries for the years 1970 and 1980 for Belgium, France, Germany and Netherlands; Davis and Weinstein, 2002, uses 30 industries for 61 countries). This problem increases when the calculations are based on total factor input requirements instead due to highly aggregated input-output tables. A high level of aggregation could cause an aggregation bias in the calculations.

Feenstra and Hanson (2000) show, both theoretically and empirically, that aggregation bias can be substantial when aggregating different industries together. They also show that this is due to the domestic full employment condition.[31] In order to preserve this condition when aggregating factor input requirements, one needs to use domestic outputs as weights. However, they argue that this particular weighting scheme does not preserve the value of the factor content of trade. They also show that the aggregation bias will be zero in two cases only; first, if the disaggregated industries within each aggregated group have identical input requirements for each factor, or, secondly, if the input requirements vary but are completely uncorrelated with the ratio between net exports and output within each group.[32] In the empirical part of their study, they use the U.S. input-output table for 1982, which is divided into 371 industries in the manufacturing sector, for several years in the late 1980's and early 1990's. The authors show that using 4-digit SIC level compared to 2-digit SIC level results in an increase in both the production- and non-production labor embodied in net exports in 1982. The same direction of the aggregation bias is shown for all years of the study.

In what follows the *z*-equation is calculated using different levels of aggregation of the SNI 2002 and 2007 classifications. The result is illustrated in Figure 4.6.

[31] See Section 2.

[32] The case that there should be no correlation at all between input requirements and the net export to output ratio is not true for at least two reasons. The first reason is due to the abundant evidence from different studies, for example Davis and Weinstein (2001a) and Bernard and Jensen (1997), and the second is due to the spirit of the Heckscher-Ohlin theorem.

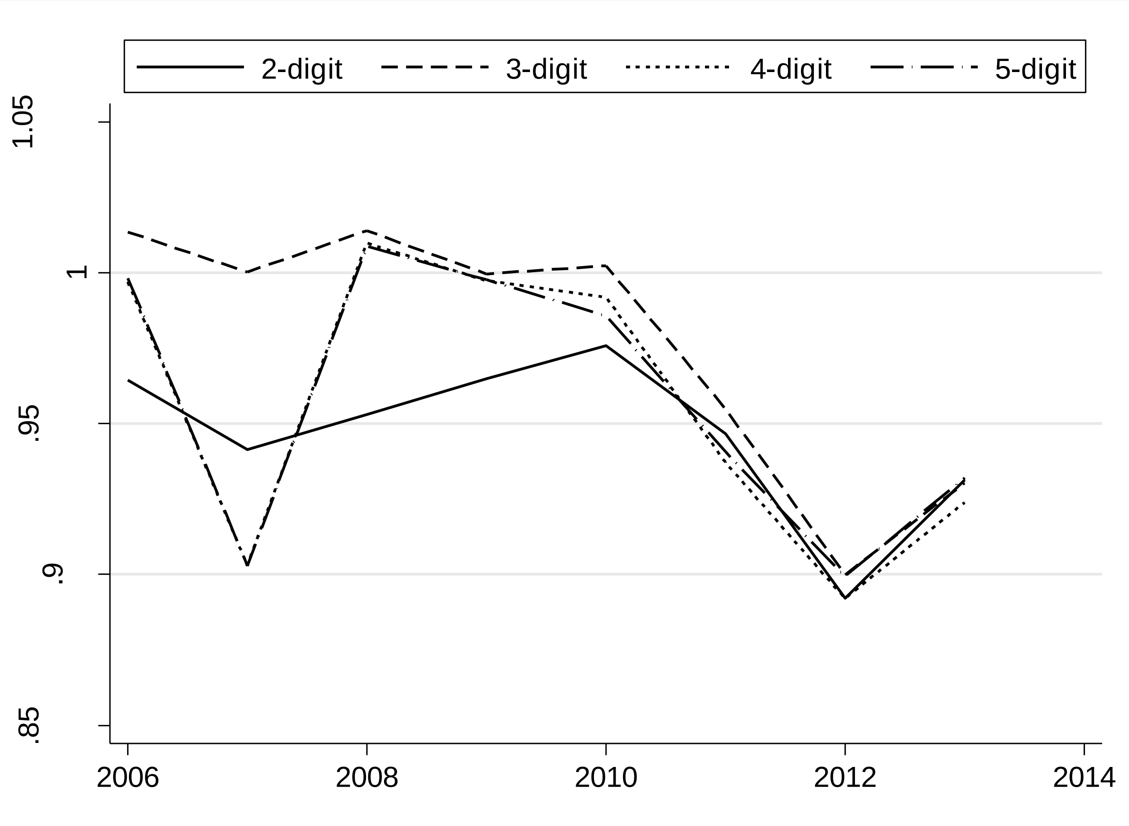


***Figure 4.6: Comparison between different aggregation levels for the manufacturing sector***

*Note*: All curves are calculated according to the base case model, with the exemption of the level of aggregation. The number in the name of the curves indicates the level of aggregation.

The different curves in Figure 4.6 show that the *z*-measure, calculated on 5-digit, 4-digit, 3-digit and 2-digit level respectively, are strongly positively correlated, 0.82-0.99 (see Table B.2 in Appendix B). The changing pattern due to the aggregation are to some extent caused by the industry classification in two ways. The first is that when aggregating industries together, more heterogeneity will be enforced into the measure, and this seems to lower the variation in the *z*-value over the measured period. The second is the change in classification from SNI 2002 to SNI 2007. This change seems also to lower the variation in the z-value between the different aggregations.

A conclusion that can be drawn from this subsection is that the level of aggregation does not matter much if the relative variation of *z* over time are of interest (at least not in the SNI 2007 period), but it takes on importance in the evaluation of the levels.

## *4.7 The trade vector*

In papers where calculations of the factor content of trade are carried out, trade are often limited to a trade-vector containing only trade in goods, or even manufactures. However, since the HOV-model is derived for all trade, it does not necessarily hold for a subset of trade (e.g. Lundberg and Wiker, 1997, uses industries in the manufacturing sector; and Davis and Weinstein, 2002, uses industries in the manufacturing sector together with the primary sector, i.e. agriculture and mining industries). An interesting exercise would be to compare the human capital content of trade in the services of skilled labor using the manufacturing sector only with that of using the goods sector.[33] The next step would then be to expand the trade-vector further to include the service sector as well. The results from this exercise is shown in Figure 4.7 below.

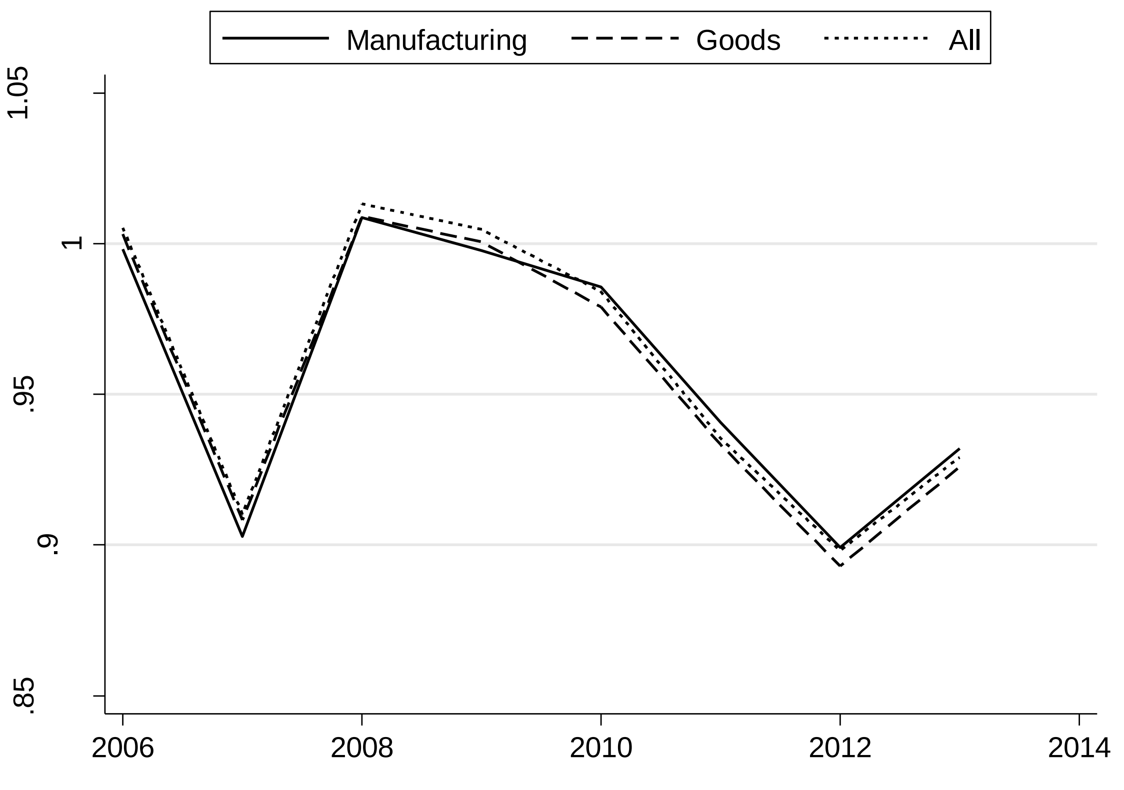


***Figure 4.7: Comparison between using different sector groupings***

*Note*: All three curves are calculated in accordance with the baseline, at the 5-digit level, using different sector groupings: manufacturing sector; goods sector; and all sectors.

The different *z*-curves in Figure 4.7 are subject to small level shifts, and they follow each other closely over time. The three curves are strongly positively correlated, 0.99 (see Table B.3 in Appendix B). The negative trend of the

[33] The goods sector refer here to industries involving in agriculture, forestry, fishing, extraction industries and the manufacturing sector.

curves between 2008-2012 is to some extent caused by the global financial crisis of 2008-2009. One interesting result shown in Figure 4.7 is that the manufacturing sector seem to recover faster compared to the other sectors.[34]

A conclusion here is that it is not important to expand the trade vector beyond the baseline case, especially when studying the relative variation of $z$ over time.

In order to investigate if there still are differences between calculated direct factor input requirements of skilled labor for firms in the manufacturing sector and firms in the service sector, a comparison of the coefficient of variation (together with other measures) is carried out for the two groups respectively and they are shown in Tables 4.2 and 4.3.

***Table 4.2: Factor input requirements in the manufacturing sector on 5-digit level***

| Year | Obs. | Mean | Sd | Iqr | CV |
|---|---|---|---|---|---|
| 2006 | 4554 | 0.0401 | 0.0593 | 0.0333 | 1.4804 |
| 2007 | 4700 | 0.0397 | 0.0576 | 0.0325 | 1.4502 |
| 2008 | 4702 | 0.0421 | 0.0629 | 0.0331 | 1.4957 |
| 2009 | 4413 | 0.0465 | 0.0651 | 0.0384 | 1.4009 |
| 2010 | 4297 | 0.0467 | 0.0774 | 0.0347 | 1.6571 |
| 2011 | 4219 | 0.0416 | 0.0648 | 0.0320 | 1.5594 |
| 2012 | 4141 | 0.0429 | 0.0643 | 0.0325 | 1.4989 |
| 2013 | 4100 | 0.0444 | 0.0652 | 0.0348 | 1.4678 |

*Note:* iqr = inner quartile range; CV = coefficient of variation.

***Table 4.3: Factor input requirements in the service sector on 5-digit level***

| Year | Obs. | Mean | Sd | Iqr | CV |
|---|---|---|---|---|---|
| 2006 | 16858 | 0.1112 | 0.1512 | 0.1340 | 1.3596 |
| 2007 | 18045 | 0.1127 | 0.1522 | 0.1366 | 1.3500 |
| 2008 | 18675 | 0.1174 | 0.1558 | 0.1457 | 1.3273 |
| 2009 | 18701 | 0.1208 | 0.1573 | 0.1519 | 1.3027 |
| 2010 | 19954 | 0.1203 | 0.1562 | 0.1483 | 1.2978 |
| 2011 | 20681 | 0.1219 | 0.1558 | 0.1538 | 1.2786 |
| 2012 | 21346 | 0.1258 | 0.1599 | 0.1597 | 1.2707 |
| 2013 | 21925 | 0.1271 | 0.1610 | 0.1600 | 1.2666 |

*Note:* iqr = inner quartile range; CV = coefficient of variation.

When comparing Tables 4.2 and 4.3, it is found that the coefficient of variation for the firms in the manufacturing sector are higher than for firms

[34] Note that both the “other” curves includes the manufacturing sector.

in the service sector. This result indicates that an exclusion of firms in the service sector in the calculations could bias the results in an undesirable way. However, the results from Figure 4.7 shows small or no differences between incorporating the firms in the service sector or not in the *z* calculations. Anyway, the conclusion here is that it seems to be important to include the service sector in the calculation of the level of the *z*-value based on Tables 4.2 and 4.3. In cases where the variation over time of *z* is important, it does not seem important to expand the trade vector.

## 4.8 Summary of the various measurement issues

In conclusion, different measurement issues are found to be important depending on whether the purpose is to measure the level of *z* for a single year or whether to study the relative variation of *z* over time. The measurement issues considered in this study are sorted into these two categories in Table 4.4.

***Table 4.4 Summary Table for the measurement issues***

| Measurement issue: | Single year evaluation | Development over time |
|---|---|---|
| Measurement errors | - | - |
| Fixed or variable fact. inp. req. | ✓ | ✓ |
| Measure of human capital | ✓ | - |
| Direct or total requirements | ✓ | - |
| Common fact. inp. req. matrix | ✓ | - |
| Level of aggregation | ✓ | - |
| The size of the trade vector | ✓ | - |

Note: The symbol ”✓” denotes if the particular measurement issue takes on importance and ”-” denotes if the particular measurement issue is not important in the specific case.

The ideal case, according to our review in Section 4, for evaluating the level of the human capital content of trade in exports relative to imports (the *z*-measure), seem to be using total factor input requirements[35], together with the whole trade vector (i.e. including both goods and services), as disaggregated as possible, using the producers technology and bilateral trade data. In the case of the relative variation over time of z, variable factor input requirements are important to include in the calculations.

[35] Calculated with an input-output table from the specific year of the study.

# 5. The human capital content of Swedish trade: 2006-2013

When measuring the relative variation of the human capital content of Swedish trade over time, it is shown in section 4 that variable factor input requirements are important to include in the calculations. Furthermore, annually constructed input-output tables are to be preferred in calculating the total human capital content.[36] However, due to the short time period when annual input-out tables are available, two specifications of the model are used to examine the human capital content of Swedish trade over the period 2006-2013. The first is the base case model (the baseline), which comprises direct factor input requirements, which varies annually, on five digit level, using the manufacturing sector only and labor with at least 3 years post-secondary educational level attained as the only production factor. The second model is the variable total factor input requirements model (see subsection 4.4) which comprises total factor input requirements, which varies annually, on 2-digit level, using the manufacturing sector only and labor with at least 3 years post-secondary educational level attained as the only production factor.

Figure 5.1 shows that the specialization pattern for Sweden has moved away from industries intensively using high skilled labor in exports compared to imports, i.e. a weak negative long-term trend in *z* over the measured period (see the “direct”-curve). The level of *z* also shows that Sweden were a net importer of services of skilled labor for all years in the measured period except 2008.

[36] Based on Bohlin and Widell (2006).

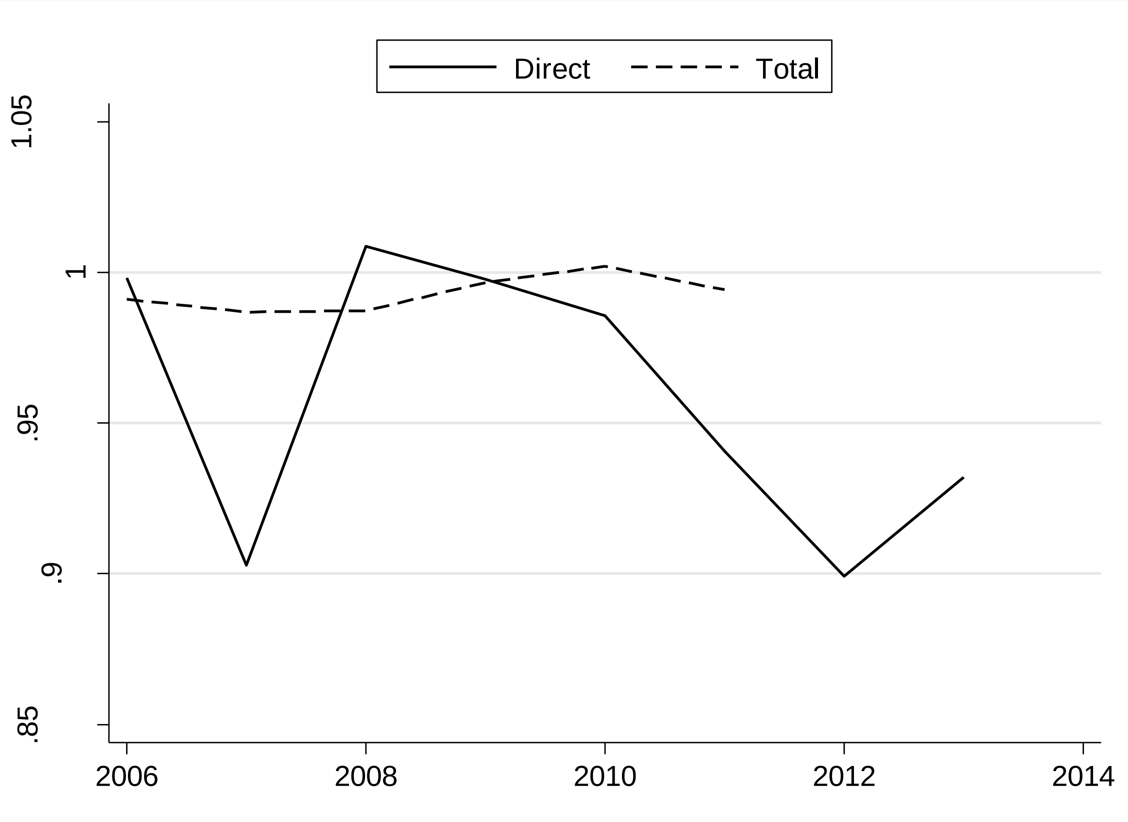


***Figure 5.1: Human capital content of Swedish trade 2006-2013***

*Note*: The filled curve is calculated in accordance with the baseline. The dashed curve is calculated in accordance with the baseline on a 2-digit level using annual SIOTs from WIOD.

When looking at the dashed curve in Figure 5.1, where annual SIOTs are used, the interpretation are slightly different: the variation of the human capital content of trade in exports relative to imports, are rather constant. In addition, the level of the *z*-value indicates that Sweden, for the measured period, both have been a net importer and a net exporter of services of skilled workers.

However, it is probably the endowment of high skilled labor that is determining relative human capital intensity in the Swedish manufacturing sector in the long run. The endowment of high skilled labor in Sweden, measured as the proportion of the total population in the age group 25-64 with at least a post-secondary education, has increased slowly but steadily throughout the 2006-2013. This is also true for those individuals with at least 3 years of post-secondary education, as is shown in Figure 5.2.

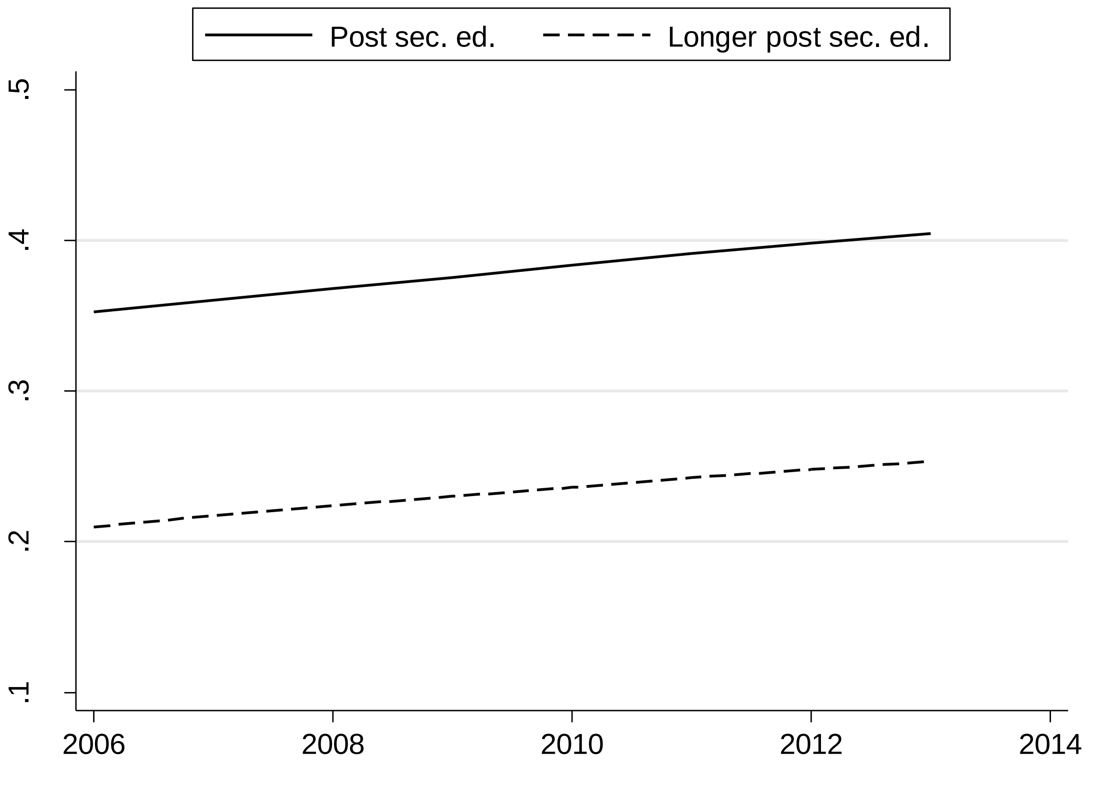


***Figure 5.2: Endowments of skilled people as percentage of total population in the age group 25-64 years.***
*Source*: Statistics Sweden.

An increase in the endowment of skilled labor is not evidence in itself of increased skill intensity in the Swedish manufacturing industries compared to the rest of the world. First, the endowment of skilled labor in Figure 5.2 is calculated as the proportion of the total population in age group 25-64 with a post-secondary education of less than 3 years completed (filled line) or a post-secondary education of at least 3 years or more completed (dashed line). When comparing those values with the *z*-values, which are calculated using firms in the manufacturing sector only (see Figure 5.1), problems may occur since, one, requirements of university graduates in other sectors than manufacturing are very high. Second, the size of the public sector also plays an important role, since the proportion of university-trained employees is much higher than in the private sector in general, and in the manufacturing sector in particular. Third, the annual increase in the endowment of skilled labor in Sweden could be higher, equal to or lower compared to the rest of the world, or, more specifically, compared to its biggest trading partners.

# 6. Conclusions and final remarks

This paper has presented several measurement issues related to the calculation of the human capital content of trade in exports relative to imports in Sweden. The analysis in Section 4 reveals to some extent the importance of including annual factor input requirements and annual input-output tables in the calculations, since the choice of measuring the relative variation of the human capital content of trade over time, seems only to be affected by those measurement issues. When calculating the level of the human capital content of trade in exports relative to imports, the calculations seem very dependent on how the different concepts involved in the calculations are measured.[37]

In Section 5, it is shown that the specialization pattern for Sweden has slightly moved away from industries intensively using high skilled labor. The *z*-value has been gradually declining during the measured period, indicating that the average requirements of high skilled labor in exports have been falling relative to average requirements in imports. When using total factor input requirements (the dashed line in Figure 5.1) the in the *z*-value calculations the above effects seem much more muted.

A general conclusion that can be deduced from the analysis is that the calculations of the level of the human capital content of trade is dependent on how the different concepts involved in the calculations are measured. If the structural measure used in the study is reliable, one conclusion is that the skill intensity in Swedish net trade of manufacturing products has been decreasing during the measured period. This result is important for future educational policy, since current endowment of skilled labor is influenced by past educational policy.

In order to extend this study, the same investigation as in Section 4 can be performed on data from other countries. This will give an opportunity to generalize, or not, the results from this study, in order to find out whether the results here are country specific or not. One other extension could be to use the information from bilateral trade to measure the human capital content of trade in exports relative to imports using the producers' technology (see subsection 4.1).

[37] See Table 4.4 for a summary of the different concepts.

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# Appendix

## A. Fixed or variable factor input requirements (differentiation)

In this note, a decomposition of the $z$-equation, equation (5), is performed in order to understand the forces behind the puzzling result whether to use fixed or variable factor input requirements when calculating the factor content of trade. Using equation (5), i.e.

$$z = \sum x_i a_i / \sum m_i a_i,$$

where $x_i = X_i / \sum_i X_i$, , $m_i = M_i / \sum_i M_i$, and $a_i = \frac{wL_i}{P_i Q_i}$, where $L_i$ is the number of skilled workers, $w$ wage for skilled workers, $p_i$ output price, $Q_i$ output volume in industry $i$ respectively, a total differentiation of equation (5) with respect to $x_i$, $m_i$ and $a_i$ gives,

$$dz = \sum_i \frac{a_i \sum_k a_k m_k}{(\sum_k a_k m_k)^2} dx_i - \sum_i \frac{a_i \sum_k a_k x_k}{(\sum_k a_k m_k)^2} dm_i + \sum_i \frac{x_i \sum_k a_k m_k - m_i \sum_k a_k x_k}{(\sum_k a_k m_k)^2} da_i \qquad \text{(A1)}$$

where $i = k$ . Rearranging and simplifying equation (A1) gives,

$$dz = \frac{1}{\sum_k a_k m_k}\left(\sum_i a_i dx_i + \sum_i x_i da_i\right) - \frac{\sum_k a_k x_k}{(\sum_k a_k m_k)^2}\left(\sum_i a_i dm_i + \sum_i m_i da_i\right).$$

Since $z = \sum x_i a_i / \sum m_i a_i$, and $i = k$ the equation can be simplified even further,

$$dz = \frac{1}{\sum_k a_k m_k}\left[\left(\sum_i a_i dx_i + \sum_i x_i da_i\right) - z\left(\sum_i a_i dm_i + \sum_i m_i da_i\right)\right].$$

Let the $z$-equation for fixed input requirements be denoted as $z^F = \sum x_i a_0^F / \sum m_i a_0^F$, and the equation for variable input requirements be denoted as $z^V = \sum x_i a_i^V / \sum m_i a_i^V$,. The difference $\Delta z = z^V - z^F$ will then depend on,

$$\Delta z = \frac{1}{\sum_k a_k m_k}\left(\sum_i x_i da_i - z \sum_i m_i da_i\right),$$

which is also equal to,

$$\Delta z = \frac{1}{\sum_k a_k m_k}\left(\sum_i (x_i - z m_i)\, da_i\right),$$

since $a_i$ is treated as a constant in the fixed case. The difference between fixed and variable factor input requirements do depend on a scale parameter, $1/\sum_k a_k m_k$, , and $\sum_i (x_i - z m_i)\, da_i$. In the case where $z = 1$ the difference is simply the sum of each sectors net trade times its change in skill intensity.[38] Then, a value of $\Delta z > 0$ will mean that there has been a positive (negative) general increase (decrease) in skill intensity in net exporting (importing)

[38] This result shall also be multiplied by the scale parameter.

industries.[39] In those cases where the level of $z$ is not equal to one, the interpretation will become more difficult, since the level of $z$ also affects the outcome. It seems, though, that if $z > 1$, it places a higher weight on the skill intensity in imports which increases the negative effect on $\Delta z$ downwards and the other way around if $z < 1$, if there is a positive increase in the factor input requirements.

[39] There is a special case, though, since when there is an equal change in all sectors skill intensity, positive or negative, the effect on $\Delta z$ will be zero.

# B. Tables

***Table B.1*** *Correlations: educational level*

| | Post sec. ed. | Longer post sec. ed. | Post sec. ed. ScT | Longer post sec. ed. ScT |
|---|---|---|---|---|
| Post sec. ed. | 1.00 | | | |
| Longer post sec. ed. | 0.98 | 1.00 | | |
| Post sec. ed. ScT | 0.91 | 0.88 | 1.00 | |
| Longer post sec. ed. ScT | 0.81 | 0.81 | 0.97 | 1.00 |

***Table B.2*** *Correlations: aggregation of SNI*

| | 2-digit | 3-digit | 4-digit | 5-digit |
|---|---|---|---|---|
| 2-digit | 1.00 | | | |
| 3-digit | 0.90 | 1.00 | | |
| 4-digit | 0.86 | 0.82 | 1.00 | |
| 5-digit | 0.84 | 0.79 | 0.99 | 1.00 |

***Table B.3*** *Correlations: Trade vector*

| | Manufacturing | Goods | All trade |
|---|---|---|---|
| Manufacturing | 1.00 | | |
| Goods | 0.99 | 1.00 | |
| All trade | 0.99 | 0.99 | 1.00 |