CHARLES UNIVERSITY IN PRAGUE

FACULTY OF SOCIAL SCIENCES

Institute of International Studies

Master thesis

2022 **JIAYI ZENG**

CHARLES UNIVERSITY IN PRAGUE

FACULTY OF SOCIAL SCIENCES

Institute of International Studies

Jiayi Zeng

Intra-industry trade and human capital endowment: a case of EU-CEE trade

Master thesis

Prague 2022

Author: Jiayi Zeng

Supervisor: Ing. Vilém Semerák, M.A., Ph.D.

Academic Year: 2021/2022

Bibliographic note

ZENG, Jiayi. *Intra-industry trade and human capital endowment: a case of EU-CEE trade*. 56 p. Mater thesis. Charles University, Fakulty of Social Sciences, Institute of International Studies. Supervisot Ing. Vilém Semerák, M.A., Ph.D.

Abstract

To assess the effect of human capital endowment on intra-industry trade between CEE countries and the EU, this paper used trading data from 2000-2019 in the machinery sector between the Visegrad and Germany as the representative. Meanwhile, this paper used secondary and tertiary educational attainments separately as the proxy for human capital endowment and included other factors influencing intra-industry trade. Before the econometric regression, a descriptive statistical analysis was carried out, and we recognized that the intra-industry trade between the CEE countries and the EU is of vertical nature. According to regression results, we found that the domestic market size and the difference in economic mass had a positive relationship with the intra-industry trade of CEE countries. Similarly, the GDP per capita was positively correlated to intra-industry trade in this area. In addition, geographical distance and contiguity levied significant impacts on intra-industry trade of CEE countries. However, the effect of EU membership was nonsignificant in our sample. More importantly, secondary and tertiary educational attainments had opposite influences on intra-industry trade between CEE countries and the EU, which implies that although they have high educational attainments, the CEE countries occupied the lowest quality market segments in Europe.

Keywords

International trade; intra-industry trade; vertical intra-industry trade; CEE countries; human capital endowment; EU accession

Range of thesis: 56 pages

Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague … **2/8/2022** **Jiayi Zeng**

Acknowledgments

I would like to extend my deep gratitude to all those who have offered me a lot of help and support in the process of my thesis writing.

First and foremost, my sincere thanks go to Ing. Vilém Semerák, M.A., Ph.D., my supervisor, who has offered me numerous valuable comments and suggestions with incomparable patience. He is always willing to help me solve any academic or practical problems in my thesis responsively. And he encouraged me profoundly throughout my thesis writing.

Also, I owe sincere thanks to all my classmates since we study together and work together. We always offer advice and help each other to polish the thesis. We totally understand each other and support each other during the thesis writing.

Last but not least, I am deeply indebted to my family, who have unconditionally supported me and shared with me my worries, frustrations, and happiness during the thesis writing period and throughout all my academic years.

Institute of International Studies
Master thesis proposal

Main research question

1.What is the nature of CEE-EU trade?
2. What is the effect of human capital endowment on intra-industry trade between CEE countries and the EU during the post-accession period?

Research Motivation

According to Falvey (1981) and Falvey and Kierzkowski (1987), factor endowments are the determinants of vertical intra-industry. Human capital as an important component in factor proportion theory is supposed to be positively related to vertical intra-industry trade. In addition, governments always expect high levels of educational attainment to translate into high labor skill factors, in turn obtaining a comparative advantage. As a result, they can specialize in the production of high-quality varieties.

However, previous studies of the relationship between human capital endowment and intra-industry trade for the CEE case had inconsistent conclusions. Some papers concluded a negative role of human capital endowment on intra-industry trade, while other papers suggested that human capital endowment is insignificant. In addition, the data sample is out of date. Only a very small proportion of them used the post-accession data, and the data they used ended up being stuck in 2010, a decade ago.

Besides, Ferragina & Pastore (2005) expected that, in the long term, the comparative disadvantages of CEECs in the high-skill sectors should be evident as soon as their human capital adapts to the needs of the market economy.

Research methods and data

This research will use econometric regression to examine the effect of human capital endowment on intra-industry trade of CEE countries during 2000-2019. And this paper will use both secondary and tertiary educational attainments to proxy for the nation's human capital endowment. Data is available in Eurostat and World Bank databank. In terms of the control variable, this paper will add total GDP, geographical distance between capitals, GDP per capita, EU membership, and contiguity to the equation. Data is accessible in the World Bank databank and CEPII databases. This paper use trade in the machinery sector between the Visegrad member countries and Germany as representative of CEE-EU trade. The volume of intra-industry trade and its share will be calculated by the author based on the original trade flows which are available in CEPII databases. Besides the regression analysis with a fixed effect model, this paper will also use descriptive statistics to check variables, and clarify the nature of CEE-EU trade.

Contents

Introduction

Intra-industry trade exists when countries import and export products within one industry simultaneously. It can be divided into two subtypes: one is horizontal intra-industry trade which refers to trade in products of similar quality but differentiated, and the other is vertical intra-industry trade which denotes trade in differentiated products of different qualities. Since the 1960s, the proportion of intra-industry trade in international trade has expanded dramatically, and it now plays a more prominent role in the trade of manufactured goods among developed industrial nations, which accounts for the vast bulk of world trade (Krugman et al., 2012). Therefore, intra-industry trade has become a widespread topic with its growing role in international trade, and there are an increasing number of researchers discussing and providing a theoretical foundation for this topic (Brulhart, 2009). Krugman (1979) and Lancaster (1980) first built up a new trade model to explain intra-industry with three characteristics: increasing return to scale, monopolistic competition, and product differentiation. It departed from the classic trade model introduced by Heckscher and Ohlin, which explained trade as a consequence of the nation's differences in factor endowments. However, the so-called new trade model was criticized for its empirical validity (Hummels & Levinsohn, 1995; Torstensson, 1996; Greenaway, Hine, & Milner, 1994, 1995). They suggested that the new trade model can only partly explain the intra-industry trade since it ignored the quality differentiation. Therefore, the subsequent studies followed two streams to analyze the quality differentiation in the intra-industry trade. The first model, called the neo-Heckscher-Ohlin model, was carried out by Falvey (1981) and Falvey and Kierzkowski (1987). They followed the logic of the classic Heckscher-Ohlin model to explain intra-industry trade with factor endowments and input factor differences. Falvey and Kierzkowski (1987) suggested that capital-abundant countries have the production specialization in high-quality products and export them, while labor-abundant countries specialize in and export low-quality products. Because high-quality products need more unit factor inputs and are capital-intensive. Intra-industry trade then takes place between countries with different factor endowments. The second model is the economic geography model carried out by Helpman and Krugman (1985) and Greenaway and Torstensson (2000). They emphasized the importance of economic sizes and transaction costs that give rise to intra-industry trade. If the countries are more similar in size, the volume and the share of intra-industry trade are higher because they mutually have

higher demands for each other's varieties. Furthermore, larger countries are supposed to specialize in high-quality products. Therefore, vertical intra-industry trade, characterized by quality differentiation, can be determined by the differences in factor endowments across countries and economic sizes. The CEE countries generally have high educational attainments, which the government hopes could translate into productivity. As a result, intra-industry increases.

At the same time, the bilateral trade between CEE countries and EU-15 aroused many interests, especially since the 1990s. CEE countries and the EU had more and more business cooperation and signed trade agreements, which boosted the trade between them. The critical point of integration between Eastern and Western Europe was 2004, when eight CEE countries joined the EU. Mortensen and Richter (2000) expected that joining the EU could remove most trade barriers and reduce transaction costs. As the medium- and long-term effects of EU accession, intra-industry trade between CEE countries could increase. The construction of tighter economic linkages between European nations as a result of the founding and extension of the EU resulted in an increase in intra-industry trade among European nations. During the past two decades, Central and Eastern European nations have redirected their trade from former Soviet bloc members to the EU Member States, and the proportion of international commerce with the EU has increased (Jambor, 2014). However, the literature analyzing the relationship between human capital endowments and intra-industry trade of CEE countries is out of date. Some of them used trading data prior to the accession. While others using post-accession data ended up being stuck in 2010, which is already 10 years ago. What's more, the role of human capital endowment in intra-industry trade in CEE countries is unclear. Ferto (2005) and Jensen & Lüthje (2009) claimed a positive relationship between human capital endowment and intra-industry trade. However, Ferragina & Pastore (2005) suggested that the impact of the human capital endowment is nonsignificant on vertical intra-industry trade of CEE countries. Jambor (2014) and Fainštein and Netšunajev (2011) even found a negative correlation between human capital endowment and intra-industry trade in agriculture products. In order to fill these research gaps, this paper used the trading data from 2000 to 2019 to investigate the effect of human capital endowment on intra-industry trade between CEE countries and the EU.

As industrialized countries, a large part of the foreign trade of the CEE countries takes place in the machinery sector (Chapter 84-85). In 2019, the total trade volume of

CEE countries was 1785.3 billion US dollars, around 30% of which took place in the machinery sector with a trading volume of 521.77 billion US dollars. Therefore, this paper uses the trading data of the machinery sector. Within central and eastern Europe, the Visegrad group[2] (the Czech Republic, Slovakia, Hungary, and Poland) is significant economically, which contributed to 73.64% of total trade volume with a value of 1314.7 billion. US dollars. The Visegrad Group's share of trade in the products categorized in Chapters 84-85 is approximately 80% in all CEE countries. In other words, the Visegrad member countries could be representatives of the trade in the machinery sector of all CEE countries. And Germany is the major origin of imports and destination of exports of the products of the Visegrad group from the machinery sector. Therefore, we collected trading data in the machinery sector between the Visegrad member and Germany in order to demonstrate the EU-CEE trade.

The aim of the paper is to provide empirical evidence on the role of human capital endowment in intra-industry trade in CEE countries. The bilateral trade in the machinery sector between the Visegrad member countries and Germany is the representative of the EU-CEE trade in this paper. Therefore, the bilateral trading data in the machinery sector between the Visegrad member countries and Germany from 2000 to 2019 was collected. In addition, this paper also examines the relationships between intra-industry trade of CEE countries and other factors. Similar to Fainštein & Netšunajev (2011), we first test the economic size and the geographical distance, then we add the variables to capture the factor endowments, including the human capital endowment and capital endowment. Meanwhile, this paper takes a close look at descriptive statistics of variables at great length before the econometric regression analysis. The contributions of this paper are as follows. Firstly, this study demonstrates that the nature of the EU-CEE trade and its stylized characteristic. Secondly, this paper uses post-accession data to examine the relationship between human capital endowment and intra-industry trade in CEE countries. And secondary and tertiary educational attainments are used in this paper separately as the proxies for the nation’s human capital endowment. Thirdly, this paper also investigated other factors of intra-industry trade in the EU-CEE case, including the market sizes, GDP per capita geographical distance, common border, and EU membership.

The remaining part of this paper ia structured as follows. Section 1 is the literature review, including reviewing the theoretical framework of intra-industry trade, summarizing past empirical evidence about the relationship between human capital and

intra-industry trade, and also reviewing previous literature on the CEE intra-industry trade. Section 2, methodology, introduces the data and econometric specifications used to examine the relationship between human capital endowment and intra-industry trade in the CEE-EU trade. Descriptive statistical analysis of variables and the nature of CEE-EU trade are also included in Section 2. Then, Section 3 is the results of econometric estimates and discussions about key findings. Section 4 is the summary conclusions.

1. Literature Review

This section first reviews the previous studies on the basic theories of intra-industry trade, followed by the review of the past papers about the relationship between human capital and intra-industry trade as well as papers about EU-CEE trade. Then, the research gap and contribution of this paper is be carried out.

1.1 Theoretical framework

Intra-industry trade exists when countries import and export products within one industry simultaneously. Based on the quality of traded goods, intra-industry trade can continue to be divided into horizontal and vertical categories. Products that are horizontally differentiated are substitutes for each other, but vertically differentiated products cannot be substituted by the other. Therefore, horizontal intra-industry trade happens when countries export and import similar goods within the industry, while vertical intra-industry trade refers to trading in goods with different qualities (WTO, 2012). The literature on intra-industry trade emerged with Balassa (1966) and Grubel (1967). In these papers, trade liberalization, as a result of tariff reductions or the establishment of customs unions, would cause intra-industry specialization between countries with similar industrialization levels. Because countries preferred to shift their factors to new lines of products, but not entirely new industries, in reaction to foreign competition. The traditional model of intra-industry trade was carried out by Krugman (1979) and Lancaster (1980). The so-called new trade theory suggested that intra-industry trade is featured by increasing return to scale, monopolistic competition, and product differentiation instead of a consequence of comparative advantages. They concluded that intra-industry trade is a result of scale economy motives of industrialized countries and diversified preference toward the same product. Therefore, product differentiation is not necessarily caused by the international difference in technology and factor endowments.

What's more, Lancaster (1980) even found a negative relationship between comparative advantage and intra-industry trade. However, the empirical validity of these models has come under scrutiny in many subsequent studies (Hummels & Levinsohn, 1995; Torstensson, 1996; Greenaway, Hine, & Milner, 1994, 1995). These findings have acted as a considerable disruption to the past monopolistic competition

model of intra-industry trade, justifying a simplification of econometric testing in favor of models that are not reliant on the monopolistic competition. The criticism came from two aspects. Firstly, empirical studies by Hummels and Levinsohn (1995) and Torstensson (1996) argued that monopolistic competition models perform poorly because the industrial determinants of intra-industry trade have been proven to be sensitive to a variety of econometric issues. Hummels and Levinsohn (1995) found that the distance variable and tax policy toward multinational firms have empirically significant impacts on intra-industry trade but were missed by the previous model. When looking into Swedish data, Torstensson (1996) pointed out two questions: one was measurement errors, and the other was the problematic crude use of proxy variables for product differentiation. Secondly, more significant evidence was found by Greenaway, Hine, and Milner (1994, 1995) that vertical IIT, rather than horizontal IIT, accounts for the majority of total IIT, which led to the wrong specification in previous estimations.

Therefore, the model introduced by Krugman (1979) and Lancaster (1980) can explain horizontal intra-industry trade, but vertical intra-industry trade, characterized by quality differentiation, is primarily linked to the traditional trade theory of comparative advantage. The empirical studies followed two streams to analyze how the quality differentiation of the same product can generate international trade. The first model was introduced by Falvey (1981) and Falvey and Kierzkowski (1987), called the neo-H-O model. This model explained the vertical intra-industry trade as a natural outcome of differences in countries' factor endowments and differences in factor input requirements of different quality products. The second model is the economic geography model, carried out by Helpman and Krugman (1985) and Greenaway and Torstensson (2000). This model analyzed the determinant of intra-industry trade in the aspect of transaction costs and market size

1.1.1 Neo-Heckscher-Ohlin Models

These models in Falvey (1981) and Falvey and Kierzkowski (1987) discuss intra-industry trade under the context of perfect competition and comparative advantage. They assume two countries (home and foreign), two goods (a homogeneous product and a differentiated one), and two factors (labor and capital). They did not deny the existence of increasing return to scale and imperfect competition, but they did not

regard them as the prerequisites for intra-industry trade, especially for vertical intra-industry trade. However, the vertical intra-industry trade can be caused by differences in factor endowments of countries and differences in factor input requirements of different quality products. The neo-Heckscher-Ohlin Model suggested that, in a multi-product industry, capital-abundant countries have the production specialization in high-quality products and export them, while labor-abundant countries specialize in and export low-quality products. One of the underlying assumptions is intra-industry trade in a multi-product industry where the range of output is restricted to that obtained from a specific type of capital (Falvey, 1981). Second, the capital intensity of the product increases as its quality increases (Falvey, 1981). Therefore, the requirements of factors input to produce are differentiated for varieties of different quality. Higher quality means a more significant unit input in capital for a given input in labor. Besides, countries have their own comparative advantage due to differences in factor endowments. Under this structure, intra-industry trade takes place in multi-product industries between countries with their own comparative advantage. Vertical intra-industry trade is a product specialization within industries along the quality spectrum.

The advantage of the Neo-Heckscher-Ohlin Model is that it can not only explain the source of vertical intra-industry trade, but also clarify the trade pattern. The product specialization of vertical-differentiated products is driven by the factor input requirements of the product and factor endowments of the country. Countries tend to specialize in and export products whose production is intensive in factors with which the countries are abundantly endowed. However, in the monopolistic competition model, either the location of production is arbitrary and unimportant, or the relative costs determine it as in the traditional methods (Falvey & Kierzkowski, 1987). As for the trade volume, the Neo-Heckscher-Ohlin Model analysis the relation between trade volume and three parameters: factor endowments, technology, and income distributions, based on the impact effect as well as the secondary effect. The differences in factor endowments and technology reduce the volume of intra-industry trade (Falvey & Kierzkowski, 1987).

This model is supported by many studies when analyzing the intra-industry trade for different countries and country groups. Central and Eastern European countries are found with a comparative advantage in labor intensity in production, where a positive relationship between factor endowment and vertical intra-industry trade exists (Fertö 2005; Černoša 2009). In Cabral, Falvey, and Milner (2006), intra-industry trade

between the UK and other mid-income countries arises from inter-country differences in labor skill endowments and differences in skill factor intensities of varieties' production. Cabral, Falvey, and Milner (2009) complemented the research by studying the intra-industry trade between the EU members and other middle-income and developing countries, in which they divided labor skills into four levels. They found that the factor endowments are relatively accurate predictors of the factor input for production of vertical intra-industry trade. Conversely, Ferragina and Pastore (2005) pointed out the limitations of the Neo-Heckscher-Ohlin Model. They argued that this model neglected other important factors affecting quality differentiation, such as the market size and the degree of openness of the economy. In addition, they also doubted the identical input-output ratio for all countries for a given quality, because it was unreasonable to use only one available technology to produce at a given standard.

1.1.2 Economic geography model

Another significant development of the traditional view of intra-industry trade is the economic geography model, which adds the consideration of trade costs and market size. The basic model is carried out by Helpman and Krugman (1985). They amended the Heckscher-Ohlin Model by including static economies of scale in order to discuss the context of monopolistic competition and the resulting product differentiation. In Helpman and Krugman (1985), each differentiated product is produced by one company in one country due to the increasing return to scale and high trade costs. Then, countries tend to exchange varieties of differentiated products, and intra-industry trade takes place. If the countries are more similar in size, the volume and the share of intra-industry trade are higher because they mutually have higher demands for each other's varieties. They use multinational companies to explain product differentiation. MNCs with a vertical-integrated chain have comparative advantages in different countries because of the different factor intensities required by different stages of production. Therefore, the production locations disperse across countries. However, it is contradictory to the previous conclusion that similar countries have a larger volume of intra-industry trade, because similarity diminishes the comparative advantages (Cantwell, 1986).

Greenaway and Torstensson (2000) reinterpreted Helpman and Krugman's work and levied more importance on quality differentiation and vertical intra-industry trade. With their assumption of two quality products within the industry, production in low-

quality varieties has constant returns to scale and in a perfect market, while production in high-quality varieties is under monopolistic competition with an increasing return to scale. They found robust evidence for the conclusion that the larger countries and the countries with relatively abundant human capital tend to specialize in high-quality products. It is contradictory to Falvey and Kierzkowski (1987), who found that the labor-abundant country has a comparative advantage in low-quality products. However, the same result can be drawn. Different countries produce the varieties of different qualities within the industry, and then the vertical intra-industry trade takes place between countries with quality differentiation. This model successfully separated the effect of factor endowment and market size on vertical intra-industry trade and found that the volume of intra-industry trade is proportional to both. Besides, Greenaway and Torstensson (2000) claimed that the reduction in trade costs increases the production concentration.

1.1.3 Geographical distance is also considered

In the gravity model, geographic distance also affects the transaction costs in the way that transaction costs will reduce between close countries geographically. More and more empirical evidence showed that the geographic distance between countries plays an important role in intra-industry trade (Balassa, 1986a, 1986b; Balassa & Bauwens, 1987; Hummels & Levinsohn, 1995; Stone & Lee, 1995; Blanes & Martin, 2000). Looking into the intra-industry trade of Mexico, Ekanayake (2001) found a negative relationship between intra-industry trade and geographic distance. This view is supported by Leitão (2011), who examined the US data on intra-industry trade. However, Hirschberg, Sheldon, and Dayton (1994) found that the negative effect is less pronounced at a certain distance when analyzing data from food processing industries. In terms of the vertical intra-industry trade, there are contradictory findings. Türkcan and Ates (2011) detected a negative correlation between geographical distance and vertical intra-industry trade with the data of the US auto-parts industry. Łapinska et al. (2019) found the same result when analyzing the intra-industry trade of Poland in the clothing and footwear sector. In contrast to their findings, Zhang, Witteloostuij, and Zhou (2005) recognized a strong positive relationship between geographical distance and vertical intra-industry trade with the panel data of China.

In conclusion, vertical intra-industry trade should be explained with the comparative advantage and increasing returns to scale. Both the factor endowments and economic geography theories can, respectively, and very importantly, explain part of the determinants of intra-industry trade. Vertical intra-industry trade is positively related to the size of the domestic market. And the capital-abundant country should specialize in the production of varieties of high quality.

1.2 Empirical evidence on human capital and vertical IIT

In this section, we reviews empirical evidence on three topics. The first topic is the measurement and decomposition of intra-industry trade. The classic measurement method was carried out by Grubel and Lloyd (1975). In order to address the drawbacks of the classic GL index, the unit value index (Abdel-Rahman, 1991; Greenaway et al., 1994 and 1995) and the FF index (Fontagné & Freundenberg, 1997) were introduced to define intra-industry trade and its vertical component. The second group of papers is about the relationship between human capital and vertical intra-industry trade since 2000. The third group of papers is related to the studies about intra-industry trade in the CEE countries.

1.2.1 Measurement of intra-industry trade

Besides the source and the nature of intra-industry trade reviewed above, the measurement of intra-industry trade was also discussed heatedly, and various methods were used. There are two methods widely used: the classic Gruel-Lloyd (GL) index (Gruel & Lloyd, 1975) and the unit value method, which was first used in Abd-el-Rahman (1991) and was developed by Greenaway et al. (1994 and 1995).

The first measurement of intra-industry trade is the GL index used in Gruel and Lloyd (1975). This classic index is calculated as follows:

$$GL_i = 1 - \frac{|X_i - M_i|}{(X_i + M_i)}$$

where X_i and M_i are the values of export and imports of the industry (product) i in a particular country.

By construction, the GL index varies between 0 and 1. If the value equals 0, the country only exports or imports the product i, indicating the absence of intra-industry

trade but inter-industry trade. Conversely, if the country both imports and exports within the industry, the GL index will be closer to 1 as the similarity in the value of imports and exports increases. The extreme case is a complete intra-industry trade with a GL index of 1. And the GL index also can be aggregated to the level of countries as follows:

$$GL = \sum_{i=1}^{n} GL_i w_i$$

where w_i is the share of industry i in total trade.

Although Greenaway et al. (1994) suggested that it could extend to 25%, many later studies argued that the results increasing from 15% to 25% did not fundamentally change the segmentation of trade into horizontally and vertically differentiated products (Blanes & Martin, 2000; Gullstrand, 2002; Crespo & Fontoura, 2004). Therefore, the criterion of 15% is used to separate the horizontal and vertical intra-industry trade. In Greenaway et al. (1995), the GHM method measuring the horizontal or the vertical IIT was structured as follows:

$$GHM_k^p = \frac{\sum_j \left[\left(X_{j,k}^p + M_{j,k}^p \right) - \left| X_{j,k}^p - M_{j,k}^p \right| \right]}{\sum_j \left(X_{j,k} + M_{j,k} \right)}$$

where X and M are exports and imports, respectively, while p distinguishes horizontal IIT or vertical IIT, j is the number of product groups and k is the number of trading partners.

Then Blanes and Martin (2000) added a criterium into the model to distinguish high and low vertical IIT. If the unit value of the product is lower than 0.85 (1-15%), it belongs to low vertical IIT, which means that the country specializes in low-quality products within the industry. Conversely, a unit value higher than 1.15 (1+15%) of a product illustrates a high vertical IIT. And therefore, the country has the production specialization of high-quality varieties in the industry.

However, the interpretation of the GL index may have some problems. The first problem is related to the level of aggregation, which may lead to the wrong conclusion. There are two biases: sectoral and geographical. To start with the sectoral bias, Ferragina & Pastore (2005) criticized the work of Smith and Dràbek (1995) for the reason that the three-digit level used in their paper could be too rough. Therefore, the conclusion of the growing intra-industry trade between EU and CEE countries was doubtful. Becchetta et al. (2012) also gave an example of the wrong conclusion of intra-industry trade due to the aggregation level. Bilateral trade happens between countries A

and B when A only exports car parts (powertrains, gearboxes, braking modules) to B, while B only exports assembled cars to A. If the trade data is collected and analyzed at the level of the automobile industry, a wrong conclusion about the existence of intra-industry trade comes out. In fact, it is a one-way trade of intermediate goods for final goods in the same industry. It is a consequence of splitting up the international production processes, which is also known as the global value chain. Therefore, the selection of the disaggregation level is significant for the trade analysis. As for the geographical bias, it happens when we do not separate the trading partners and calculate the bilateral trade data. Instead, we treat them as a whole, and there is just one trade partner. As a result, the erroneous conclusion that there is intra-industry trade can be drawn. Therefore, we need to strictly compute the trading data on a bilateral basis.

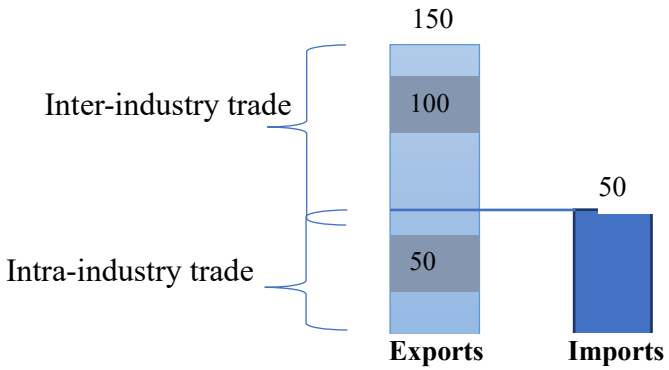
The second problem is that categories would be simultaneously described as intra-industry trade and inter-industry trade when using the GL index, and therefore, the share of intra-industry trade would be underestimated. For instance, the exports and imports of product *i* of country *j* are 150 and 50, respectively. Following Gruel-Lloyds (1975), the trade overlap of 100 (50+50) is recognized as intra-industry trade, and the remaining 100 (200-100) is recognized as inter-industry trade. As a consequence, the exports are divided into two parts and explained differently: 50 of them are explained by intra-industry trade, and 100 of them are explained by inter-industry trade. Figure 1 illustrates this problem. Then the GL index calculated is 0.5, which means that intra-industry trade accounts for 50% of total trade. However, 200 (150+50) are all intra-industry trade in nature. Therefore, the share of intra-industry trade is underestimated, and the interpretation of trade flows is problematic. To solve this problem, Fontagné and Freundenberg (1997) suggested an alternative (the FF index) to distinguish intra-industry trade. They classified the trade flows and calculated the share of each category in the total trade. In Fontagné and Freundenberg (1997), exports and imports are defined separately as majority flows and minority flows based on their values. Then, the paper proposed that two-way trade (intra-industry trade) only exists when the value of minority flows is more than 10% of the value of the majority flows. Formally:

$$\frac{Min(X_i, M_i)}{Max(X_i, M_i)} > 10\%$$

Conversely, if the minority flow is less than 10% of the majority flow, the trade is classified as inter-industry trade in nature, because the minority flow is too small to represent the structural feature of the trade (Fontagné & Freundenberg, 1997). The FF

index decomposes trade into one-way trade (inter-industry trade) and two-way trade (intra-industry trade). Meanwhile, using the FF index, we can avoid the problem that the same flow, named the majority flow, is divided into two parts with both an intra- and inter-industry trade in nature.

Figure 1-Two explanations of the same trade flow



The third problem of the classic GL index is the lack of distinction between horizontal IIT and vertical IIT. Focusing on the data of total intra-industry trade, the classic GL index fails to detect the nature and the quality of the traded products. Therefore, vertical IIT and quality differentiation are neglected. In order to deconstruct the different components of IIT, the unit value method is carried out. The underlying theory is that the price differences will review the different qualities of products, where horizontal IIT trades homogeneous products of the same quality and price, while vertical IIT trades products of different qualities and different corresponding prices. (Stiglitz, 1987; Falvey, 1981). This method introduces the notion of unit value which is calculated by dividing the total value of traded products by their quantity. According to Greenaway et al. (1995), if the ratio of the unit value of export to the unit value of import falls in the range of 15% at the five-digit SITC level, the traded product is horizontally differentiated. Otherwise, the product is vertical differentiated. Therefore, horizontal IIT takes place when

$$1-\alpha \leq \frac{UV_i^X}{UV_i^M} \leq 1+\alpha, \qquad \alpha = 15\%$$

And vertical IIT happens when

$$\frac{UV_i^X}{UV_i^M} < 1-\alpha \quad or \quad \frac{UV_i^X}{UV_i^M} > 1+\alpha$$

Where UV is the unit value, X and M are exports and imports for product i, respectively.

Combining the FF index and the unit value method, we can categorize trade into three types: two-way trade in similar products (horizontal IIT), two-way trade in different-quality products (vertical IIT), and one-way trade (inter-industry trade). Table 1 shows the classification in detail.

Table 1-Combination of FF index and unit value method to define IIT

		Minority flow/Majority flow		
		≥ 10%	< 10%	Total
Unit value difference	≤15%	Horizontal IIT	Inter-industry trade	Total horizontal trade
	> 15%	Vertical IIT	Inter-industry trade	Total vertical trade
	Total	Total IIT	Total inter-industry trade	Total trade

1.2.2 Previous studies on human capital and vertical IIT

There are many papers detecting the relationship between human capital and vertical intra-industry trade. However, the conclusions are distinctly different. On one hand, human capital is found to have a positive relationship with vertical IIT (Blanes & Martín, 2000; Martín-Montaner & Ríos, 2002; Ferto; 2005; Ferragina & Pastore, 2005; Fainštein & Netšunajev, 2011). When looking into the Spanish trading data, Blanes and Martín (2000) and Martín-Montaner and Ríos (2002) drew the same conclusion that human capital is positively related to vertical IIT. However, there are some differences between their studies. First, they use different proxies for the human capital endowment of Spain. Blanes and Martín (2000) used the years of schooling, while Martín-Montaner and Ríos (2002) used the fraction of the population who has started lower and upper schooling. Besides, Martín-Montaner and Ríos (2002) replaced the Grubel-Lloyd index with the ratio of low-quality vertical IIT to total vertical IIT. The higher this ratio is, the more specialized in low qualities the industry would be. The ratio highlighted the low specialization of production in Spain, and the authors got the solid result of a positive correlation between human capital and vertical IIT. In terms of the CEE countries, both Ferto (2005) and Fainštein & Netšunajev (2011) detected a positive correlation between human capital and vertical IIT. In Ferto (2005), trading data of agri-food products between Hungary and the EU in 1992-98 was used to investigate the relationship

between vertical IIT and human capital endowment measured by secondary educational attainment ratio. And the authors found that human capital is positively related to vertical IIT. However, departing from the usual strategy of empirical testing, Ferto (2005) took the export destination into consideration whether it is a high-income country or not. This alternative was used to capture the distinction between high- and low-quality exports. Similarly, Fainštein & Netšunajev (2011) found a positive correlation between human capital endowment and vertical IIT when examining the bilateral trade of Estonia, Latvia, and Lithuania from 1999-2007. However, one of the findings in Fainštein & Netšunajev (2011) cannot be neglected. Although human capital endowment measured by education expenditure per capita is positively related to vertical IIT, it is also positively related to horizontal IIT with a higher magnitude. In contrast to these two papers, Ferragina and Pastore (2005) commented that the human capital endowment is nonsignificant for vertical IIT of CEE countries. When testing the data of trade competitors in the EU market, a significant positive relationship between human capital endowment and vertical IIT was found if excluding the CEE countries' data. The nonsignificant effect of human capital on the vertical IIT of CEE countries needed interpretation. First, with a high level of educational attainment, CEE countries still serve the lowest quality industries in the EU market. What's worse, according to Falvey (1981) and Falvey and Kierzkowski (1987) that the factor endowments push the product specialization, the CEE countries were continuously pushed to specialize in low-quality products in the industry, while old EU members specialized in high-quality products (Ferragina & Pastore, 2005).

On the other hand, Jambor (2014) detected a negative correlation between human capital and vertical IIT. With the data on bilateral trade between the New Member States and other EU-27 countries of agricultural goods from 1999-2010, Jambor (2014) found that human capital is negatively related to vertical IIT. In this paper, the human capital endowment of new members is measured by agricultural labor per capita (annual working units/person), with which the author wanted to highlight the industry-specific characteristic. Therefore, Jambor suggested that trade in agri-food products of different qualities could happen in countries with similar factor endowments. It is contradictory to the theory of Falvey (1981) and Falvey and Kierzkowski (1987). However, the possible reason for this inconsistency may be the wrong use of the variable proxy for human capital endowment. Similarly, Jensen and Lüthje (2009) found that the differences in human capital endowments seem not to be important as a driving

force behind vertical IIT. They detected a positive but not significant correlation when using the trading data in 1996-2005 between the EU-15 and four CEE countries (Hungary, Slovakia, Poland, and the Czech Republic). Compared to factor endowments, domestic market size, geographical distance, average income per capita, and income distribution overlap play a more significant role in driving vertical IIT. Jensen and Lüthje (2009) used the fraction of the population who attained at least upper secondary education to measure the human capital of countries.

Table 2 summarizes the empirical studies mentioned above. Although the measurements of the human capital endowment are various and undefined, educational attainment is the most frequently used method.

Table 2- Summary of papers about human capital and vertical IIT since 2000

Author	Year	Country coverage	Period	Measurement	Opinion
Jambor	2014	New Member States and the EU-27	1999-2010	Agricultural labor per capita	Negative correlation
Fainštein & Netšunajev	2011	Estonia, Latvia, and Lithuania and World	1999-2007	Education expenditure per capita	Positive relationship
Jensen & Lüthje	2009	The Visegrad group and EU-15 countries	1996-2005	The fraction of the population attaining at least upper secondary education	Positive but insignificant correlation
Ferragina & Pastore	2005	EU-CEE trade as well as other competitors	1988-1994	The fraction of the population over 25 that has completed upper secondary education	Positive relationship, but nonsignificant for CEECs
Ferto	2005	Hungary and the EU	1992-1998	Secondary educational attainment	Positive relationship
Martín-Montaner & Ríos	2002	Spanish trade with OECD countries	1988-1992	The fraction of the population who has started lower and upper schooling	Positive relationship
Blanes &	2000	Spain with trading	1988-	Years of schooling	Positive relationship

Martín		partners	1995		

Economic integration was supposed to be a significant driver of intra-industry trade (Ferragina & Pastore, 2005). However, there are few papers studying the relationship between human capital and the vertical IIT using post-accession data. Instead, other trade indicators shown in Table 3 were used to investigate their relationship with human capital. Cieślik (2016) detected a negative relationship between the volume of CEE's exports and their literacy rate, a component of the human development index. Mulliqi et al. (2018) found the positive impact of both secondary and tertiary educational attainments on the market share of exports in CEE countries. They used the same proxy for human capital as Jensen & Lüthje (2009). Therefore, educational attainments are important proxies for human capital, and both secondary and tertiary levels should be tested in our research.

Table 3 - Human capital and other trade indicators

Author	**Year**	**Country coverage**	**Period**	**Argument**
Mulliqi, Adnett, Hisarciklilar, & Rizvanolli	2018	CEE countries	1995-2010	Secondary and tertiary educational attainments have a positive impact on export market share for CEE countries.
Cieślik, Michałek, & Mycielski	2016	CEE countries	1970-2009	A negative relationship between the literacy rate and the volume of exports of CEE countries.

1.2.3 Empirical studies of IIT in CEE countries

Recent studies on trade in CEE countries appeared mainly between 2005 and 2014, which discussed the IIT between CEE countries and EU-15 members and its determinants (Ferto, 2005; Ferragina & Pastore, 2005; Caetan & Galego, 2007; Gabrisch, 2009; Jensen & Lüthje, 2009; Fainštein & Netšunajev, 2011; Ambroziak, 2012; Jambor, 2014; Łapińska, 2016). Some of them investigated all CEE countries (Jambor, 2014; Gabrisch, 2009; Caeten & Galego, 2007; Ferragina & Pastore, 2005), while other papers just focused on parts of central and eastern Europe. Ambroziak (2012) and Jensen and Lüthje (2009) examined the intra-industry trade in the Visegrad group

countries, including the Czech Republic, Hungary, Poland, and Slovakia. Fainštein & Netšunajev (2011) investigated the intra-industry trade in the Baltic area, including Estonia, Latvia, and Lithuania. One limitation of these papers is related to the sample. In most of these papers, the research period of the trading data was before the accession to the EU of CEE countries in 2004.

As for the econometric results, they all found a significant negative relationship between geographical distance and intra-industry trade, no matter total intra-industry trade or vertical intra-industry trade. Similarly, they had consistent views on the role of the differences in GDP in proxy for the economic size, which is positively correlated to both total and vertical intra-industry trade, except for Łapińska (2016). However, they drew different conclusions on the relationship between intra-industry trade and the differences in GDP per capita. Fainštein & Netšunajev (2011) and Jensen & Lüthje (2009) suggested that the GDP per capita is negatively correlated to intra-industry trade, while other papers believed that the capital factor endowment proxied by GDP per capita encourages intra-industry trade (Ferto, 2005; Ferragina & Pastore, 2005; Caetan & Galego, 2007; Gabrisch, 2009; Ambroziak, 2012; Jambor, 2014; Łapińska, 2016). Meanwhile, Ambroziak (2012) used another proxy for the relative geographical position between the trading partners. That is the dummy variable indicating whether the two countries are contiguous. Ambroziak (2012) found that having a common border is positively related to the intra-industry trade volume.

After reviewing these papers, we found that fixed effect model and random effect model are the most often used methods to analyze panel data of IIT of CEE countries. The fixed effect model was used to capture the cross-country heterogeneity, and the random effect model was used to capture the time-invariant variables, such as distance. Therefore, we uses these two models to form the regression model to test the panel data in the methodology part and discuss the results of regression in the results and discussion part later. Table 4 summarizes the empirical studies mentioned above.

Table 4 – Summary of papers about IIT in CEE countries since 2005

Author	**Year**	**Country coverage**	**Period**	**Methodology**	**Signs on Total IIT**	**Signs on Vertical IIT**
Łapińska	2016	Poland and the	2002-2011		DGDPC: +	

		EU			Distance: - DGDP: -	
Jambor	2014	The new Member States and the EU-27	1999-2010	Static panel-corrected standard errors model and dynamic finite sample correction	DGDPC: + Distance: - DGDP: +	DGDPC: + Distance: - DGDP: -
Ambroziak	2012	The Visegrad group and world	1995–2008	Random effects	DGDPC: + Distance: - DGDP: + Common border: +	DGDPC: + Distance: - DGDP: + Common border: +
Fainštein & Netšunajev	2011	The Baltics and world	1999-2007	Fixed effects, random effects, dynamic panel data model	DGDPC: - Distance: - DGDP: +	DGDPC: - Distance: - DGDP: +
Jensen & Lüthje	2009	The Visegrad group and EU-15 countries	1996-2005	Fixed effects, random effects		DGDPC: - Distance: - DGDP: +
Gabrisch	2009	The new Member States and EU-15	1993-2004	Pooled regression, fixed effects, Random effects	DGDPC: - Distance: -	DGDPC: - Distance: - DGDP: +
Caetan & Galego	2007	The new Member States and EU-15	1993-2001	Random effects	DGDPC: + Distance: - DGDP: +	DGDPC: + Distance: - DGDP: +
Ferto	2005	Hungary and the EU	1992-1998	Random effects		DGDPC: + Distance: - DGDP: +
Ferragina & Pastore	2005	EU-CEE trade as well as other competitors	1988-1994	OLS pooled regressions and sectoral regressions		GDPC: + GDP: + EU: +

1.3 Research gap and the contribution of this paper

According to Falvey (1981) and Falvey and Kierzkowski (1987), factor endowments are the determinants of vertical intra-industry. Human capital as an important component in factor proportion theory is supposed to be positively related to vertical intra-industry trade. In addition, governments always expect high levels of educational attainment to translate into high labor skill factors, in turn obtaining a

comparative advantage. As a result, they can specialize in the production of high-quality varieties.

However, previous studies of the relationship between human capital endowment and intra-industry trade for the CEE case had inconsistent conclusions. Some papers concluded a negative role of human capital endowment on intra-industry trade, while other papers suggested that human capital endowment is insignificant. In addition, the data sample is out of date. Only a very small proportion of them used the post-accession data, and the data they used ended up being stuck in 2010, a decade ago. In order to fill in this gap, this paper first finds out the nature of the CEE-EU trade and its stylized characteristics. More importantly, using data from the period 2000-2019, this paper investigates the relationship between human capital and intra-industry of CEE countries in the post-accession period and gives some implications for the transformation of educational levels. In addition, this paper also examines the relationships between intra-industry trade of CEE countries and other factors, including the market sizes, geographical distance, common border, and EU membership.

2. Methodology

In this section, the quantitative method used in this paper is introduced. The first part includes the data sample, including the selection of countries, products, and time period of trading data. The second part is variables that are included in the econometric specification, followed by the descriptive statistic of variables and the nature of the Visegrad-Germany trade in the third part. The last part introduces the regression specification.

2.1 Sample and data

This study chooses four countries as research subjects which are the Czech Republic, Slovakia, Hungary, and Poland. They are also known as the Visegrad Group formed in 1991, and the Group together is the fourth biggest economy in the European countries. Meanwhile, we used data in the Harmonized System (HS) classification with a 6-digital code. This study focuses on Section 16 – Machinery sector, which is categorized in Chapters 84 and 85. And the Visegrad group is a representative group of the international trade of manufacturing goods of Central and Eastern European

countries. There are several considerations for the country selection. First, a large part of the CEE countries' foreign trade occurs in the machinery sector (Chapter 84-85), with a share of 30% in the year 2019[3]. And the Group mentioned above contributes the vast majority of the machinery trade of CEE countries, with a percentage of around 80% in the year 2019[4]. The second consideration is the availability of data for trade flows and explanatory variables. The panel data of the Visegrad members from 2000 to 2019 was collected. In terms of the selection of the trading partner, Germany has the overwhelming position vis-à-vis other countries because Germany is the biggest partner of CEE countries both in exports and imports as shown in Table 5. As the main destination of exports and origin of imports of CEE countries, Germany constitutes 20-30% of the international trade in the machinery sector (Chapter 84-85) of these countries. In addition, some competitors of the Visegrad members in the German market are selected. China and the U.S. are the biggest trading partners of Germany in Asia and North America, respectively. France, Netherlands, Austria, the UK, and Italy are EU-15 members which traded most goods in the machinery sector in the German market and competed with the Visegrad members as shown in Table 6. Therefore, the panel data used in this study is the bilateral trade of goods coded in HS Chapters 84 and 85 with 6-digit between the Visegrad members, their competitors and Germany. The country selected in the sample is shown in Table 7. In total, there are 220 annual observations from 11 countries over 20 years.

Table 5 – Germany's role in the exports and imports of the Visegrad Group

Year 2019	**Exports**			**Imports**		
	Total	Chapter 84	Chapter 85	Total	Chapter 84	Chapter 85
Czech Republic	31.1%	32.5%	35.3%	27.2%	30.9%	22.6%
Slovakia	21.6%	26.7%	22.4%	18%	19.2%	17.8%
Hungary	26.5%	31.7%	32%	25%	32.5%	26.2%
Poland	25.4%	32.4%	20.5%	26.6%	23.1%	25.9%

Notes: This table illustrates Germany's role in the exports and imports of the Visegrad member countries by showing the percentages of exports to Germany and imports from Germany in the Visegrad member countries. The total columns mean all trading products between Germany and one of the Visegrad member countries. And the Chapter 84 and Chapter 85 columns only include the trading products categorized in these two specific chapters between Germany and one of the

Visegrad member countries. The trade volume in dollar amount can be found in Appendix.

Source: https://oec.world/en/profile/country/

Table 6 – The main exporters and importers of German machinery sector in 2009

Chapter 84				**Chapter 85**			
Export		Import		Export		Import	
Country	Percentage	Country	Percentage	Country	Percentage	Country	Percentage
USA	11.1%	CHN	15.2%	CHN	9.93%	CHN	17.2%
CHN	8.64%	CZE	8.56%	USA	7.81%	CZE	8.84%
FRA	6.86%	ITA	6.8%	NLD	5.46%	NLD	6.76%
GBR	5.08%	FRA	6.61%	FRA	5.42%	HUN	6.16%
POL	4.63%	NLD	6.6%	CZE	5.1%	POL	4.85%
ITA	4.38%	USA	6.35%	ITA	4.77%	USA	4.6%
AUT	4.38%	AUT	5.98%	POL	4.62%	FRA	4.07%
NLD	4.37%	POL	5.56%	AUT	4.33%	ROU	3.41%
CZE	3.76%	HUN	4.23%	HUN	4.32%	AUT	3.08%
HUN	2.27%	GBR	4.01%	GBR	4.18%	ITA	2.93%

Notes: This table lists the top 10 importers and exporters of the machinery sector of Germany with their share in total trade in Chapters 84-85 in Germany in the year 2019. The detailed information about trade volume between Germany and these countries can be found in Appendix.

Source: https://oec.world/en/profile/country/

Table 7 – Country selection list

CEE countries	**Competitors**		**Trading partner**
The Czech Republic	China	Austria	Germany
Slovakia	The U.S.	Italy	
Hungary	France	The UK	
Poland	Netherlands		

2.2 Variables

The second part introduces the variables used in the regression model, including the intra-industry trade index as the dependent variable and educational attainments as the independent variable. Besides, some explanatory variables are added to analyze trade flows.

2.2.1 Dependent variable

In order to examine the impact of human capital endowment on intra-industry trade, the IIT index, the Gruel-Lloyd index, is employed as the dependent variable in the

econometric specification. As we discussed above, the classic GL index alone has some problems in interpretation, so it must be complemented with additional indicators. First, the same trade flow, usually the majority flow, was divided into two parts: both intra- and inter- industry in nature. Second, the classic GL index cannot distinguish horizontal and vertical IIT. In order to address these deficiencies, we amended the classic GL index and add two criteria to define and subtract intra-industry trade from total trade. What's more, vertical and horizontal IIT are categorized in this process. The detailed procedures for classifying IIT are as follows:

(1) For product k, confirm that there are bilateral trade flows between exporters and importers. If not, it belongs to one-way trade (inter-industry trade) and should be excluded from IIT calculation.

(2) Separate import and export trade flows into majority flow and minority flow based on their values and confirm that the ratio of the minority flow to the majority flow is larger than 10%. If not, it belongs to inter-industry trade and is excluded from the calculation of IIT.

(3) Compute the unit values of imports and exports by dividing the value by the quantity and then calculate the ratio of the unit value of export to that of import.

a). If the unit value ratio falls between 0.85 and 1.15, it is horizontal IIT;

b). If the unit value ratio is lower than 0.85 or higher than 1.15, it is vertical IIT.

Total intra-industry trade is the sum-up of values of products verified in step 2, and total vertical IIT is the sum-up of values of products satisfied the requirement in 3b. Then, the industry IIT ratio can be calculated with the adjusted value. The data of trade flows are available in the CEPII BACI database and some own calculations are needed.

2.2.2 Independent variable

The purpose of this paper is to examine the relationship between human capital endowment and intra-industry trade, and therefore human resource endowment is, unsurprisingly, the independent variable in this study. However, it is hard to construct a human capital variable due to the measurement difficulty. And previous empirical studies adopted various proxies for human capital endowment, including average years of schooling, the educational attainments for each level, the educational expenditure per capita, and others. As discussed above, there are two commonly used proxies with

statistical significance in the empirical studies: average years of schooling and educational attainment ratio.

Average years of schooling

UNESCO (2022) defines this indicator as "the average number of completed years of education of a country's population aged 25 years and older, excluding years spent repeating individual grades." In light of this, it is the sum of the enrollment ratios for primary, secondary, and tertiary education by age. This indicator is calculated as,

$$= \sum_i YR_i PER_i$$

where i is the education level, YRi is the number of years needed to complete the ith level of education, PERi is the fraction of the population for which the ith level is the highest level of education attained. A relatively higher value illustrates a large proportion of the adult population based on the highest level of education attained or completed, reflecting a good education system.

Educational attainments

The educational attainment of a specific level of education is the share of the population aged over 25 that attained or completed this specific level of education (World Bank, 2022). Compared to the previous one, this indicator focuses on a specific level of education and does not refer to the differences in the number of years of schooling at each level between countries. Theoretically, educational attainment is closely linked with the skills and competencies of a country's population, which could be used as a proxy for both the quantitative and qualitative aspects of the human capital endowment. Empirically, educational attainment ratios were always used in the previous papers, which found this indicator performed better with a higher statistical significance (Ferragina & Pastore, 2005; Ferto, 2005; Jensen & Lüthje, 2009). Ferto (2005) and Ferragina and Pastore (2005) focused on secondary educational attainment and only used this level indicator to examine the relationship between human capital and IIT. However, tertiary education attainment was found to be significant when analyzing the impact of human capital on trade, especially for CEE countries (Jensen & Lüthje, 2009; Mulliqi, Adnett, Hisarciklilar, & Rizvanolli, 2018). Therefore, in this paper, we use educational attainment indicators, and both secondary and tertiary educational

attainment are included and examined. Data for Visegrad countries are available in the Eurostat database and the USA data is accessible in the World Bank databank[1].

2.2.3 Explanatory variables

In addition to the independent and dependent variables, some explanatory variables are added to make the model more precise and economically significant. The explanatory variables are proxies for factor endowments, economic sizes, and geographical distance. Table 8 summarizes all variables with descriptions and data sources.

Factor endowment

According to Falvey (1981) and Falvey and Kierzkowski (1987), differences in factor endowments across countries and differences in factor input requirements of different quality products could give rise to vertical intra-industry trade. Therefore, factor endowments should be included as explanatory variables. Besides the human capital endowment discussed above, the capital endowment is also an important component of factor proportion theories. Empirical literature usually catches the capital endowment of a country by the GDP per capita of the country. A relatively high value indicates that the country has a relatively abundant capital factor for production, and therefore this country should produce and export capital-intensive products. Therefore, this paper uses GDP per capita as a proxy for the capital endowment of a country. Data on GDP per capita for individual countries are available in the World Bank databank, which is measured in US dollars.

Economic size

According to the economic geography model (Helpman & Krugman, 1985; Greenaway & Torstensson, 2000), larger countries tend to specialize in the production of high-quality goods. Due to the various tastes and demands of different-quality varieties, intra-industry trade happens between larger countries and other countries. Meanwhile, the gravity model of international trade, a classic model for trade analysis, also suggests that bilateral trade volume is positively related to the economic sizes of trade partners. A widely used proxy for economic size is the nation's total GDP. For

ease of comparison, the total GDP of each country in this study is measured in billion US dollars. Data for individual countries are available in the World Bank databank.

Geographical distance

In the gravity model of international trade, distances between trade partners weaken the bilateral trade flows. Because geographical proximity partly mirrors the similarity in culture and language, and thus in consumption patterns. In addition, geographical proximity reflects less information and transaction costs. Therefore, geographical distance should be considered in the model when analyzing trade flows. According to the previous literature, the distance between capitals of trading partners is commonly used in empirical studies (Fainštein & Netšunajev, 2011; Jensen & Lüthje, 2009; Caetano & Galego, 2007).

Common border

However, the geographical distance alone caused bias in the gravity model, and a dummy variable illustrating if trading partners are contiguous is added (Baldwin & Taglioni, 2006). It is especially for the European country, the countries are close to each other, but not every pair of countries borders each other. What's more, Borchert and Yotov (2017) claimed that the effect of contiguity on trade is increasing, while geographical distance had less impact on trade. Therefore, we also added a dummy variable indicating whether the two countries are contiguous in the regression equation. Having a common border is suggested to increase intra-industry trade (Ambroziak, 2012).

EU membership

Accession to the EU is found to be positively correlated to intra-industry trade volume (Ferragina & Pastore, 2005). EU membership improves the intra-industry trade in the sense that it reduces transaction costs and information costs. Meanwhile, Mortensen and Richter (2000) suggested that accession to the EU not only reduces transaction costs but also removes non-tariff barriers, which significantly encourages bilateral trade between the EU members. Therefore, the dummy variable indicating whether the country is an EU member is added to the regression model.

Table 8 - Variable definition and data sources

Variable	Variable name	Definition	Source
Dependent variable			
IIT	Intra-industry trade index	The volume of the total intra-industry trade and of the total vertical intra-industry trade, measured in million US dollars.	CEPII BACI database and own calculation
Variables of interest			
SEC	Secondary educational attainment	The share of the population aged 25 that attained or completed at least upper secondary education.	World Bank databank, Eurostat database, Chinese government reports.
TER	Tertiary educational attainment	The share of the population aged 25 that attained or completed at least short-cycle tertiary education.	World Bank databank, Eurostat database, Chinese government reports.
Control variables			
GDPC	GDP per capita	The nation's total GDP divided by the population, measured in US dollars	World Bank data
GDP	Total GDP	The nation's total GDP, measured in million US dollars.	World bank data
DIS	Distance	The distance between the capitals of the bilateral trading partners.	CEPII Gravity database
Border	Common border	The dummy variable equals 1 if the country shares a common border with Germany	
EU	EU membership	The dummy variable equals 1 if the country is an EU member.	

2.3 Descriptive statistics of variables

In this section, before the regression analysis, we first analyze the country-specific characteristic, including the educational attainments, total GDP, and GDP per capita in the first part. And in the second part, we explain the nature of Visegrad-Germany trade using the bilateral trading data of the machinery sector in HS Chapters 84-85.

2.3.1 Variables of interests and control variables

This part uses descriptive statistics to analyze the variables of interest and control variables.

To start with, we focus on educational attainments which are shown in Table 9. In terms of secondary level, the overall average for all selected countries was 0.74, which was similar to the mean value of old EU members, while the Visegrad group had the higher secondary educational attainments mean with a ratio of 0.87. The USA has a similar mean value to the Visegrad group. However, China had the lowest secondary educational attainment among all countries. Although in 2019, China's education level is still only 0.292, which is steadily increasing but still much smaller than other countries. One reason is that China is a developing country. Meanwhile, China has a large population base, most of which is in underdeveloped areas. The Czech Republic had the highest average ratio of secondary attainment of 0.91 among all countries, and other group members also had mean values over 0.85 except Hungary. OECD (2014) also highlighted the upper secondary attainment of the Czech Republic and attached the importance to the vocational programmes included in this level. Vocational education plays a vital position in the education system of the Czech Republic. Well over 50% of young people aged 15-19 are enrolled in pre-vocational or vocational courses at the upper secondary level. Another outstanding characteristic is that about 22% of upper secondary school students in the Czech Republic are enrolled in joint vocational courses combining school and work, while vocational courses in other countries were just school-based. This design of the Czech education system is more practical and equips students with experience, skills, and competencies to integrate more quickly into their work and perform better in the workplace, which in turn will increase their output (National Institute for Education, 2011). It is a channel to transform education into the nation’s output. As for the old EU members, Italy had the lowest secondary attainment average among them, with a value of 0.54, which was considerably below the overall

mean and the Group mean. One possible reason is that Italy expensed less on educational institutes. Italy is one of the ten countries with the lowest expenditure on secondary and higher education institutions as a percentage of GDP in OECD countries (OECD, 2021). Therefore, the expenditure per student was lower than the average level.

As for the tertiary educational attainments, the overall mean for all the countries was 0.23. Compared to the secondary level, the overall mean sharply decreased by around 50%, from 0.74 to 0.23. Such a downward change was even more pronounced in the Visegrad case since the Group mean declined sharply by almost 70%, from 0.87 to 0.19. Compared to the Visegrad members, the old EU members had higher tertiary educational attainment with a ratio of 0.27. The USA and the UK had the highest attainments of tertiary-level education among all selected countries, with ratios of 0.40 and 0.35, respectively. It can be explained by the high-quality tertiary education in these two countries which own many well-known universities and colleges. Nine of the top ten universities in the QS World University Rankings 2019 were from the US and UK, five from the USA, and four from the UK. Conversely, the tertiary educational attainments of the Visegrad members were just around 20%. The Czech Republic had the highest educational attainment at the secondary level, while it also had the lowest educational attainment at the tertiary level. One possible reason is that the Czech Republic has a well-established vocational education system at the upper secondary level, which allows students to occupy a job after graduation successfully. Therefore, fewer students choose further study at the tertiary level. Another problem raised the low tertiary educational attainment is that the opportunity to access higher levels of education is not the same for all people, which is affected by the educational levels of their parents. According to OECD (2014), the Czech Republic suffered lower educational mobility since around 66% of Czechs reached the same level of education as their parents, and only 21% outperformed their parents. Among the old members of the EU, Italy performed poorly in tertiary educational attainment. One reason is that Italy had a lower expenditure per student in tertiary education with an amount of 12,305 US dollars, which is 28% lower than other OECD countries (OECD, 2021).

Then we look into the educational attainments at the secondary and tertiary levels of the Visegrad members from 2000 to 2019 shown in Figure 2. The first finding is that secondary educational attainments in the Visegrad members mainly fell in the range of 80% to 90%, except in Hungary. The Czech Republic was the first member state to reach 90% upper secondary educational attainment in 2006. It was followed by

Slovakia and Poland, which also reached 90% educational attainments at this level. In contrast, the level of upper secondary education in Hungary is consistently lower than in the other three countries, by roughly 7% in 2019. Such a gap took Poland 13 years to catch up from 2006 to 2019. In terms of the tertiary educational attainments, they were much lower than that at the secondary level. However, they experienced rapid growth of more than 15%, except in Hungary. The largest growth took place in Poland, which increased from 11% in 2000 to 32% in 2019 by around 20%. The reason is that three-quarters of students attended public institutions and were funded by the public sector (OECD, 2019). Conversely, Hungary had the highest tertiary educational attainments of 14% at the beginning, but it was caught up by Poland, the Czech Republic, and Slovakia. Meanwhile, Germany had higher tertiary educational attainment than the Visegrad members, which is not evident at the secondary level.

Then we investigate the descriptive characteristics of other explanatory variables, total GDP and GDP per capita, which is shown in Table 10. As the top 2 biggest economies around the world, the USA and China have the largest mean values. However, the range of China is much larger than that of the USA, which mirrors the rapid growth in China economically. The evidence of the rapid growth also can be found in the GDP growth rate in Figure 3. China joined the World Trade Organization in 2001, and since then, China's international trade volume has soared. Part of the high GDP growth is also due to this. However, the GDP per capita in China is much below the average amount. As for the Visegrad members, they have smaller economic sizes and GDP per capita compared to the old EU members. Germany's GDP per capita is two or three times as much as theirs. The Linder hypothesis used the GDP per capita to measure the development level of the country. According to the GDP per capita shown in Figure 4, China and Slovakia, as developing countries, have the lowest level of GDP per capita. The GDP per capita of Visegrad member countries is much lower than that of old EU members and the USA, which illustrates a different development level. Therefore, Germans are more likely to have similar demand preferences to the residents of old EU members and the USA.

Table 9 – Descriptive statistic of educational attainments of individual country

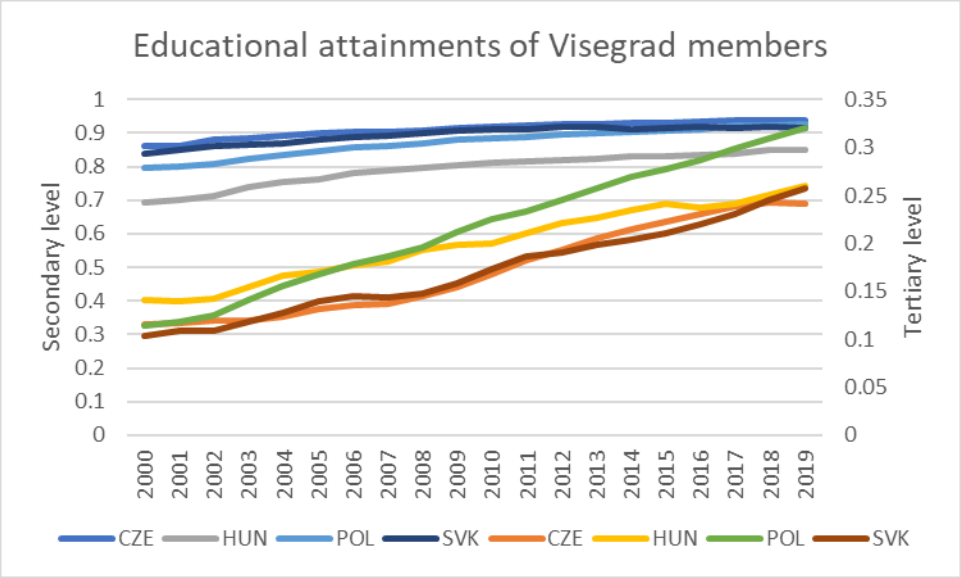
	Secondary level			**Tertiary l**		
Country	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**

AUT	0.83	0.856	0.798	0.24	0.338	0.173
CHN	0.21	0.292	0.111	0.09	0.145	0.036
CZE	0.91	0.939	0.861	0.17	0.243	0.115
FRA	0.71	0.805	0.622	0.29	0.380	0.216
DEU	0.85	0.869	0.813	0.26	0.299	0.223
HUN	0.79	0.850	0.694	0.20	0.260	0.140
ITA	0.54	0.622	0.430	0.15	0.196	0.097
NLD	0.73	0.796	0.661	0.31	0.404	0.240
POL	0.87	0.926	0.798	0.22	0.320	0.114
SVK	0.89	0.919	0.838	0.17	0.258	0.103
GBR	0.75	0.811	0.644	0.35	0.447	0.283
USA	0.87	0.898	0.852	0.40	0.452	0.361
Visegrad	0.87	0.939	0.694	0.19	0.32	0.103
Old EU members	0.74	0.869	0.430	0.27	0.447	0.097
Total	0.74	0.939	0.111	0.23	0.452	0.036

Notes: This table demonstrates the descriptive statistic of educational attainments. For each individual country and country groups, the mean, maximum, and minimum values of educational attainments of different levels are shown, including secondary and tertiary levels.

Source: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=edat_lfse_03&lang=en; https://data.worldbank.org/indicator/SE.SEC.CUAT.UP.ZS; https://data.worldbank.org/indicator/SE.TER.CUAT.ST.ZS; Chinese government public reports.

Figure 2 – Secondary and tertiary educational attainments of Visegrad members



Source: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=edat_lfse_03&lang=en

Table 10 – Descriptive statistic of explanatory variables

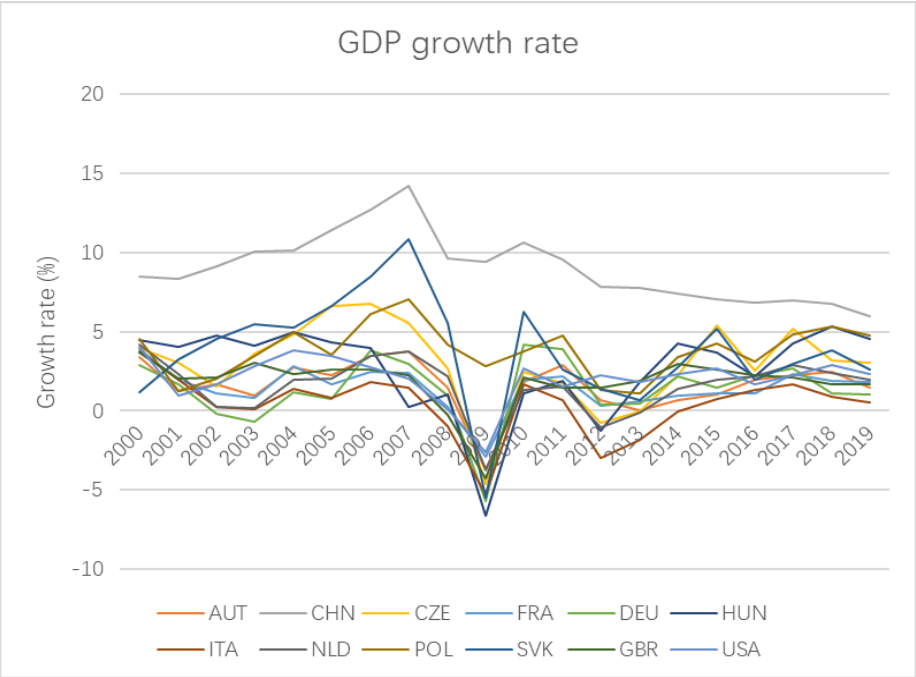
	Total GDP in million USD		GDP per capita in USD	
Country	**Mean**	**Range**	**Mean**	**Range**
AUT	362,484	257,879	42,946.6	27,361.22
CHN	6,545,918	13,068,591	4,795.2	9,184.47
CZE	176,625	190,670	16,898.4	17,631.11
FRA	2,395,357	15,64,664	36,920.5	23,099.61
DEU	3,219,743	2,031,499	39,291.6	24,395.54
HUN	120,886	116,308	12,144.5	12,111.38
ITA	1,910,290	1,261,978	32,312.7	20,807.32
NLD	761,064	534,391	45,688.4	31,665.44
POL	416,004	425,061	10,928.3	11,230.75
SVK	78,945	76,370	14,605.3	13,963.36
GBR	2,561,765	1,462,274	40,776.0	22,846.81
USA	15,279,479	11,121,624	49,413.9	28,764.84
Visegrad	198,115	\	13,644.1	\
Old EU members	11,210,701	\	39,656.0	\
Total	2,308,220	\	28,893.45	\

Notes: This table demonstrates the descriptive characteristics of the nation's total GDP and GDP per capita. For each individual country, the mean value and the range of these two explanatory variables are shown. The range is calculated from the maximum value minus the minimum value. In addition, the mean values of specific country groups and the whole group are shown.

Source: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD;

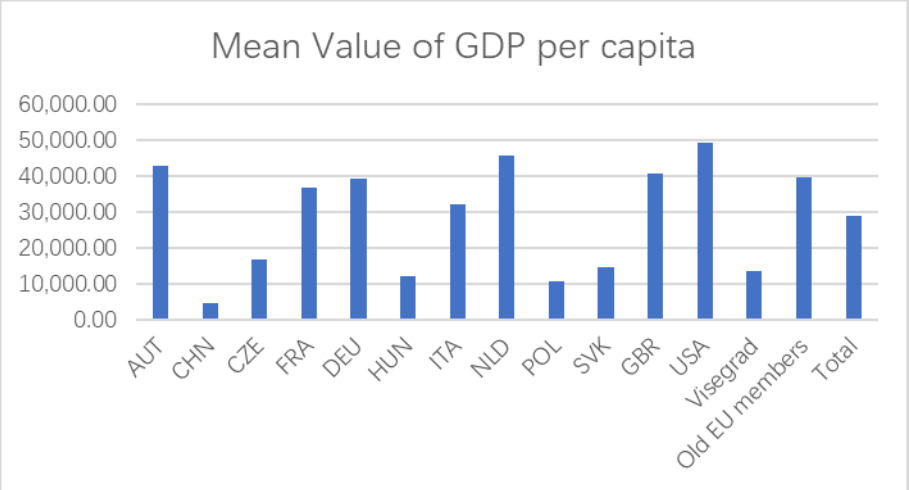
https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

Figure 3 – The GDP growth rates of selected countries



Source: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG

Figure 4 – the mean value of GDP per capita of selected countries



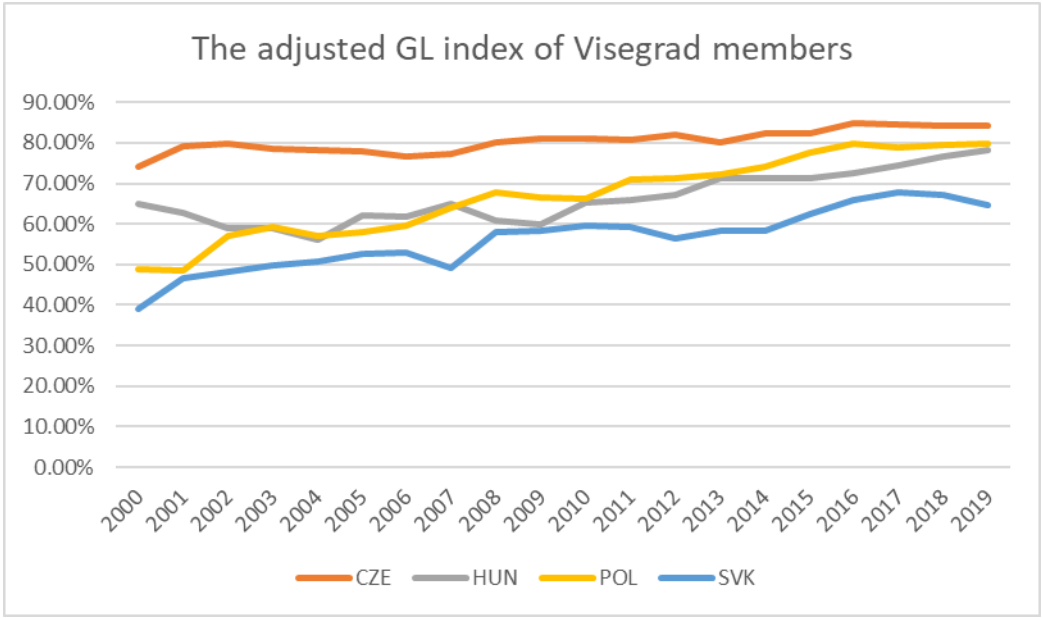
Source: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

2.3.2 The nature of Visegrad-Germany trade

Intra-industry trade between the Visegrad Group and Germany, the largest economy in the EU and the Group's most important trading partner, has also been growing year by year in general. We followed the analysis and calculation procedures mentioned in section 2.1 to compute the adjusted GL index and analyze the IIT between them. According to the pooled data of all bilateral trade between Visegrad members and Germany, the adjusted GL index shown in Figure 5 illustrates that the proportion of

intra-industry trade with Germany increased since 2000 in every country's case. Among them, the Czech Republic consistently has the largest adjusted GL index, with values in excess of 70% all the time. In the case of Poland, the GL index was initially around 50%, ranking third in the Group. However, it grew the fastest, reaching 80% in 2019. The change mirrors the rapid growth of intra-industry trade in Poland. One possible reason for this is that the Czech Republic and Poland share a border with Germany. According to the gravity model of international trade, geographical proximity reveals fewer transaction costs and more trade volume as a result. More importantly, compared to Germany, Poland is relatively abundant in labor, while Germany is relatively abundant in the capital. Therefore, the product specification in products with different qualities took place. Besides, the Czech Republic and Poland also are the main recipients of substantial FDI from Germany. In terms of Hungary, the overall situation was one of growth. However, from 2000 to 2004, the index declined. After becoming a member of the EU in 2014, the share of intra-industry trade started to grow again. Slovakia also had a share of intra-industry trade over 60%.

Figure 5 – Adjusted GL index of Visegrad members' trade with Germany



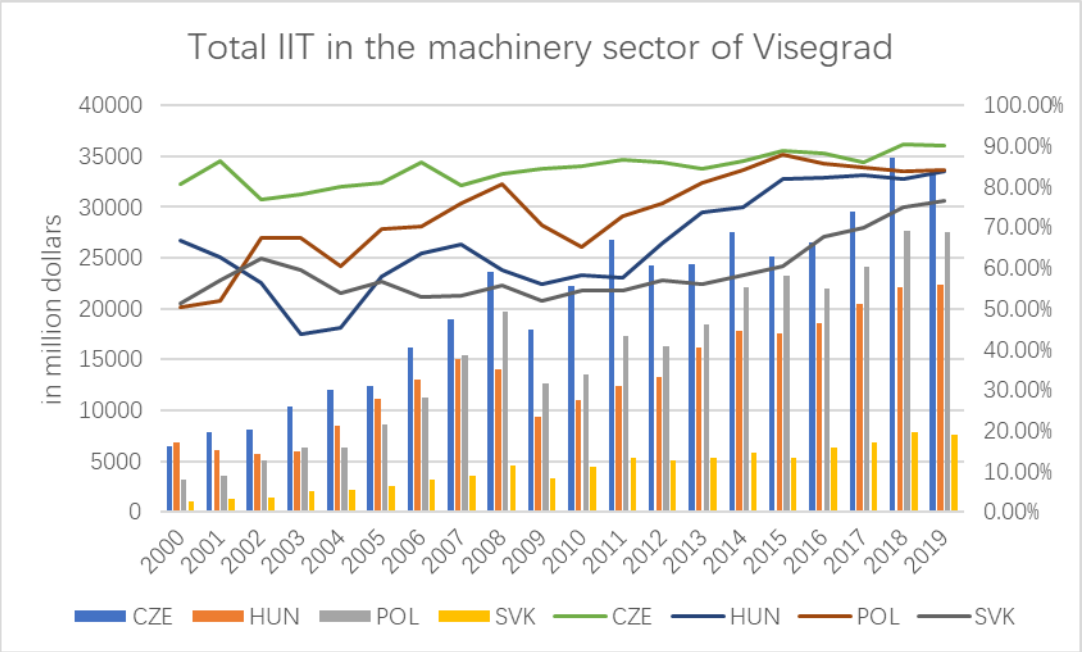
Source: http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37

Looking at data at a disaggregate level, the machinery sector (Chapters 84 and 85) accounts for the largest share of the Visegrad members' exports and imports. The trade volume and share of intra-industry trade over total trade are shown in Figure 6. Comparing the IIT index for all products and for the products in Chapters 84-85, we can

find that the IIT index for the machinery sector is almost 10 percent higher than that for the aggregate trade. Therefore, IIT between the Visegrad members and Germany concentrated on the machinery sector. Hungary had the most fluctuating index changes in the machinery sector that were similar to those in the aggregate data in the sense that the IIT index decreased from 2000 to 2003 and increased since its accession to the EU in 2004. Another distinctive feature was that Poland and Slovakia had the same ratio in 2000, but then the gap grew wider. As for the dollar amount, the volume of intra-industry trade in this sector has increased since 2000 for every country. Among the members, the growth was most pronounced in the Czech Republic and Poland. Hungary originally ranked second in the Group but was later overtaken by Poland. In addition, Hungary's IIT volume growth has gradually decelerated. Slovakia is the country with the smallest IIT volume with Germany as well as the least growth in trade volume. In terms of vertical intra-industry trade shown in Figure 7, the ratios of vertical type over the total IIT for all countries were around 80 %, which revealed that intra-industry trade between the Visegrad members and Germany in the machinery sector was of vertical nature. It is consistent with Greenaway, Hine, and Milner (1994, 1995), who found that vertical IIT, rather than horizontal IIT, accounts for the majority of total IIT. With regard to the numerical terms, vertical IIT was trending upwards across countries, but the vertical IIT ratio as a percentage of total intra-industry trade decreased for most of the countries. It was growing in absolute but decreasing in relative terms. In the Czech Republic and Hungary, the share of vertical IIT in the machinery sector fell by around 10 percent. Only Slovakia had maintained relatively stable ratios. According to the data from the Czech Republic and Poland, the volume of vertical IIT increased at a fast pace in these two countries. Conversely, the vertical IIT volume of Hungary decreased at the beginning of the period. Although it grew since 2003, it was quickly outpaced by Poland in 2007.

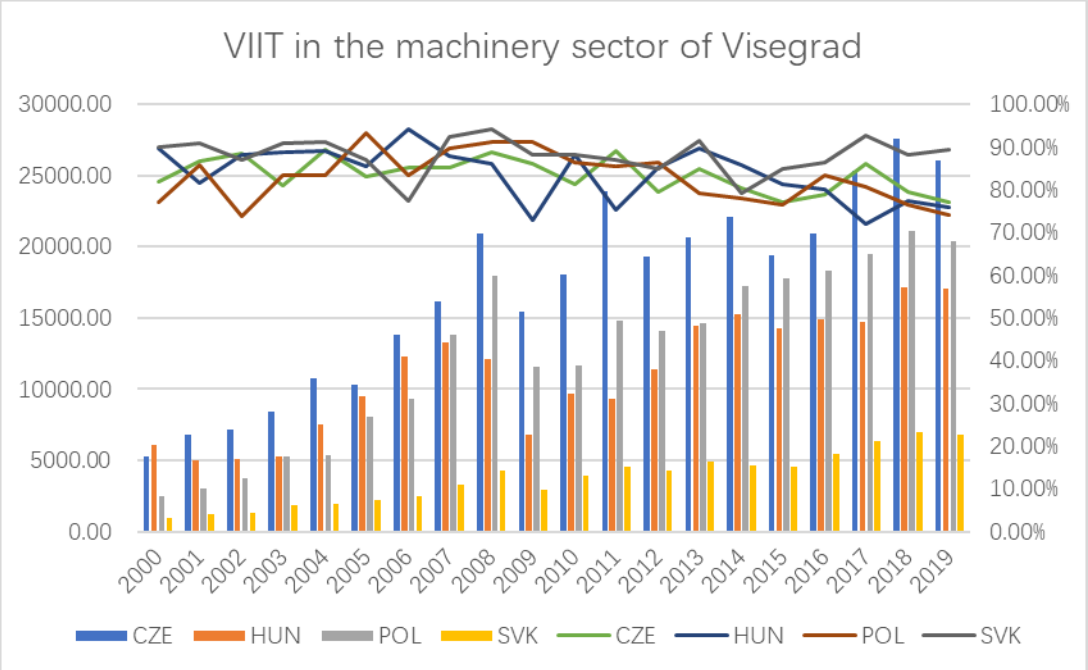
In conclusion, the trade between Visegrad members and Germany was intra-industry trade because the adjusted GL indices were over 50% for these four countries. What's more, the ratios of intra-industry trade over total trade increased in all members. Poland experienced growth of around 30 %, while Hungary and Slovakia increased by almost 20%. And the Czech Republic remained at a high level. Then we analyzed the vertical intra-industry trade using the disaggregated data from the machinery sector, and we found that although the vertical intra-industry increased in absolute terms, it did not increase in relative terms.

Figure 6 – Visegrad member's intra-industry trade in the machinery sector with Germany



Source: http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37

Figure 7 – Vertical IIT of Visegrad members in million dollars and percentage



Source: http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37

2.4 Econometric specification

Many previous empirical papers used the gravity model to analyze intra-industry trade (Fainštein & Netšunajev, 2011; Jambor, 2014). The basic model followed by Flam and Helpman (1987) is related to the market sizes and geographical distance. Therefore, we start with the gravity model to regress the volume of intra-industry trade against the GDP of both countries, distance, and EU membership of domestic countries. The specification is formed as follows:

$$lnIIT_{i,DE,t} = \alpha_1 lnGDP_{i,t} + \alpha_2 lnGDP_{DE,t} + \alpha_3 lnDIS_{i,DE} + \alpha_4 EU + \alpha_5 Border + \alpha_i + \gamma_t + e$$

Where *IIT* takes the value of total intra-industry trade and vertical intra-industry trade in year *t* between country *i* and Germany, respectively. $GDP_{i,t}$ is the total GDP of country *i* in year *t* and $GDP_{DE,t}$ is the total GDP of Germany in year t. *EU* as a dummy variable equals 1 if the country *i* joined in the EU. α_i is the country dummy variable and γ_t is the time dummy variable. *Border* is a dummy variable indicating if the country *i* share a common border with Germany.

We used this model to test the economic geography theory which attempted to explain the intra-industry trade with the economic sizes and transaction costs.

In the second model, we further included variables to capture the factor endowments according to the H-O model. Two production factors are chosen: capital endowment and human capital endowment. According to Mulliqi, Adnett, Hisarciklilar, & Rizvanolli (2018), both the educational attainments at the secondary and tertiary levels have impacts on the competitiveness of CEE countries' exports. Therefore, educational attainments at secondary and tertiary levels are used as the proxy for human capital endowments separately. And the specifications are as follows:

$$lnIIT_{i,DE,t} = \alpha_1 lnDGDP_{i,DE} + \alpha_2 InDIS_{i,DE} + \alpha_3 EU + \alpha_4 Border + \alpha_5 lnGDPC_{i,DE} + \alpha_6 DSEC_{i,DE} + \alpha_i + \gamma_t + e$$

$$lnIIT_{i,DE,t} = \alpha_1 lnDGDP_{i,DE} + \alpha_3 EU + \alpha_4 Border + \alpha_5 lnGDPC_{i,DE} + \alpha_6 DTER_{i,DE} + \alpha_i + \gamma_t + e$$

Where $DGDPC_{i,DE}$ is the difference in GDP per capita between country *i* and Germany in year *t*. $DSEC_{i,DE}$ is the difference in cumulative educational attainment in upper secondary level between country *i* and Germany and $DTER_{i,DE}$ is the difference in cumulative educational attainment of tertiary level between country *i* and Germany.

According to the review on previous studies about intra-industry trade, the fixed effect model is one of the models commonly used in the analysis. Therefore, this paper follows this model and discuss the results based on it. Meanwhile, we use the pooled model and the random effect model to robust the choice of the fixed effect model.

3. Results and discussion

This section introduces and summarizes the regression results of the economic specifications mentioned above. The first part is the empirical results of the economic geography model. And the second part is the results adding factor endowments variables. The last part is a conclusion about the key findings.

3.1 The gravity model

For the regression equation (1), we separately tested the total intra-industry trade and vertical intra-industry trade of competing countries in the German market by putting the natural logarithm transformation of total intra-industry trade volume and vertical intra-industry trade volume as dependent variables in the regression model respectively. We used pooled model, fixed effect model, and random effect model separately in this regression. And the regression results are shown in Table 11.

We first tested the total intra-industry trade in the pooled model. Ignoring the cross-country heterogeneity, the GDP of the domestic country and Germany's GDP are positively correlated to total intra-industry trade with a 1% significance level. This is consistent with the economic geography theory and with the results of previous studies (Fainštein & Netšunajev, 2011; Ferragina & Pastore, 2005). The volume of total intra-industry trade has a positive relationship with the economic sizes of trading partners. However, it is evident that the pooled model had biased results without taking cross-country heterogeneity into consideration, with an adjusted R of 0.78. This can be addressed by applying a fixed effect model. According to the F-test for the joint insignificance of country dummies, we can reject the null of no country effects at the 1% significance level. Similarly, the time effects are detected by the F-test for the joint insignificance of year dummies at the 1% significant level. Therefore, the fixed effect model with country and time effects combined is more appropriate.

According to the regression results of the two-way fixed effects model, the GDP of the domestic country and the EU membership are statistically positively correlated to the total intra-industry trade volume. The coefficient of the nation's GDP was 0.9788 with a t-statistic of 19.01, which indicates that a larger economic size encourages intra-industry trade. It can be explained by the gravity model in the sense that larger countries produce and consume more products, which boosts intra-industry trade. In addition, the coefficient of the dummy variable indicating EU membership was 0.2765, and the corresponding t-statistic was 5.06. Therefore, accession to the EU increases total intra-industry trade. It can be explained by the reason that accession to the EU might remove some trade barriers and decrease transaction costs, which was in line with the expectations of Mortensen and Richter (2000). They suggested that the decline of transaction costs is the medium- and long-term effect of accession. Another important variable in the gravity model, the geographical distance, is found to be statistically negatively correlated to total intra-industry trade volume. The coefficient of the distance between capital cities was -1.1589 with a t-statistic of -13.67, which illustrates that a country trade less within an industry with another country far from it. The negative effect of geographical distance on intra-industry trade can be explained by transaction costs. If two country is near to each other, the transportation costs of trade will reduce. Meanwhile, the geographical proximity partly reflects the similar country, language, and consumption patterns. Therefore, the information costs of trade decrease if trading partners are near to each other. The coefficient of the contiguity dummy was 0.1816 with a t-statistic of 1.93, which indicates that contiguity is positively correlated to total intra-industry trade at a 10% significance level. However, the GDP of Germany is insignificant in the fixed effect model. The possible reason is that the GDP of Germany across the period 2000-2019 is the same for all its trading partners. Therefore, the year dummies already captured the changes in the economic size of Germany. The existence of time effects was also detected by the Hausman test when comparing the fixed effect model and the random effect model. The null of random effects was rejected at the 1% significant level. Therefore, the variation across entities was not random and correlated to other independent variables in the model. What's more, the two-way fixed effect model is more appropriate with an adjusted R of 0.96, which means that the total intra-industry trade can be 96% explained by three selected variables, the domestic GDP, geographical distance, contiguity as well as the EU membership.

Then we used similar steps to analyze the vertical intra-industry trade of competing countries in the German market. According to the results shown in the Pooled for the vertical IIT column, the vertical intra-industry trade is positively related to the GDP of the domestic country as well as the GDP of Germany, ignoring cross-country heterogeneity. It is consistent with the result of previous studies that vertical intra-industry trade is proportional to the economic mass of domestic and foreign countries (Ferragina & Pastore, 2005; Jensen & Luthje, 2009). And the distance between the two countries is significantly negatively correlated to vertical intra-industry trade, which can be explained by the gravity model. However, the coefficient of the EU membership dummy is negative and insignificant, which means EU accession discourages vertical intra-industry trade. It does not make sense because accession to the EU removes some trade barriers and decreases trade costs. Meanwhile, the adjusted R of the pooled model was only 0.75.

Therefore, the pooled model is inappropriate, and the fixed effect model with country effects and time effects combined was applied to address the weakness of the pooled model. Both country effects and time effects can be supported by the separate Chow F-test for joint significance of country effects and time effects, and we can reject both the nulls of no country effects and time effects at a 1% significance level. And the GDP of Germany should be omitted because it is absorbed in time effects. The results of the two-way fixed effect model are shown in Table 11 Column 6. Based on the results, we can find vertical intra-industry trade is statistically positively correlated to the GDP of the domestic country and EU accession, while it is statistically negatively correlated to geographical distance. The coefficient of GDP in the domestic country was 0.9729 with a t-statistic of 19.02, which illustrates that a larger domestic market encourages vertical intra-industry trade. The reason is larger markets have greater demand, and they are more possible to have different tastes and requirements for goods of different qualities. And vertical intra-industry trade takes place. Compared to the result of the two-way fixed effect model for total intra-industry trade, the effects of domestic market size on total and vertical intra-industry trade are similar in magnitude and statistical significance. The coefficient of EU membership was 0.2545 with a t-statistic of 4.69, which indicates that accession to the EU will encourage vertical intra-industry trade with Germany. As for the geographical distance, its coefficient was -1.1485 with a t-statistic of -13.64. Similar to the result of total intra-industry trade, geographical distance has a negative relationship with vertical intra-industry trade with statistical

significance. And the effects of the geographical distance on total and vertical intra-industry trade are similar in magnitude, with coefficients of -1.1589 and -1.1485, respectively. The coefficient of the contiguity dummy was 0.1046 with a t-statistic of 1.09. It was significant for total intra-industry trade but not for vertical intra-industry trade. Because having a common border could reduce transportation costs, and horizontal intra-industry trade is more sensitive to transportation costs than vertical intra-industry trade. The random effect model is rejected by the Hausman test, and the variation across countries is proved to be a time-variant. Meanwhile, the adjusted R of the random effect model is smaller than that of the fixed effect model, with values of 0.96 and 0.87, respectively. Using the gravity model in this paper, we found the adjusted R^2 was always higher than 85%, which was consistent with the previous empirical evidence. And it indicated that the models used in this paper had really high explanatory power.

Table 11 – Summary of regression results of the first econometric specification

Regression	**(1) Pooled**	**(1) Two-way FE**	**(1) RE**	**(1) Pooled**	**(1) Two-way FE**	**(1) RE**
Dependent variable	**Total IIT**	**Total IIT**	**Total IIT**	**Vertical IIT**	**Vertical IIT**	**Vertical IIT**
Country group	All	All	All	All	All	All
lngdp	0.4337*** (13.79)	0.9788*** (19.01)	0.9311*** (18.17)	0.4872*** (177.45)	0.9729*** (19.02)	0.9150*** (17.68)
lngdpde	0.8674*** (7.24)	\	0.0994 (1.08)	.8918*** (7.12)	\	0.1265 (1.36)
EU	0.1704* (1.72)	0.2765*** (5.06)	0.2293*** (4.06)	-0.0182 (-0.19)	0.2545*** (4.69)	0.2188*** (3.82)
lndis	-0.1958** (-2.52)	-1.1589*** (-13.67)	-0.9296*** (-6.43)	-0.4154*** (-6.85)	-1.1485*** (-13.64)	-0.9020*** (-6.33)
Border	0.3480*** (5.07)	0.1862* (1.93)	-0.1754 (-0.55)		0.1046 (1.09)	
Constant	-1.1053 (-0.64)	9.2790*** (45.40)	8.7821*** (6.02)	-0.5771 (-0.32)	9.1662*** (45.155)	8.2223*** (5.64)

Country effects	No	Yes	Yes	No	Yes	Yes
Time effects	No	Yes	\	No	Yes	No
$\mathbf{R_{adj}^2}$	0.7841	0.9600	0.8807	0.7507	0.9584	0.8775

Notes: This table concludes the regression results of the first economic specification, which is designed to test the economic geography model. ***/**/* stands for the significant level of 1%/5%/10%, respectively. In the (1) Two-way FE for the Total IIT column, the country effects and time effects are proved by the F-tests of joint insignificance. The p-values of the F-test are 0.000 and 0.002, respectively. Therefore, we can reject the nulls at the 1% significance level. The Hausman test in the (1) RE for the Total IIT column with a probability of 0 to draw a wrong conclusion enabled us to reject the random effect model at the 1% significance level. In the (1) Two-way FE for the Vertical IIT column, the F-test for joint insignificance of country effects and time effects can reject the null at 1 significance level since the p-values are 0.0000 and 0.0002, respectively. The Hausman test used in the (1) RE for the vertical IIT column can reject the null of random effects at the 1% significant level.

3.2 Factor endowments

In the regression equation (2), we have additional variables to capture the factor endowments differences between different countries. We treat secondary educational attainments and tertiary educational attainments separately as the proxy for human capital endowment in the regression equations (2) and (3) in order to divide their effects. In addition, in the analysis of factor endowments, we dropped the USA from the sample. Otherwise, the role of geographical distance was wrongly concluded.

First, we investigated the role of secondary educational attainment in total and vertical intra-industry trade volume using the regression equation (2). Total intra-industry trade and vertical intra-industry trade were used as the dependent variable, respectively, and the regression results were shown in Table 12 Columns 2-8. The regression shown in the second column used all countries, while in the third column, regression was operated by excluding the USA. According to the results shown in the first column of Table 12, the differences in human capital endowments and in economic sizes, and EU membership were significantly positively related to total intra-industry trade. However, the regression results for the difference in GDP per capita, geographical distance, and common border are questionable. The coefficient of the difference in GDP per capita was 0.0409 with a t-statistic of 1.56, which illustrates a nonsignificant relationship between GDP per capita and total intra-industry trade. It is inconsistent with several theories. According to factor endowment theory, GDP per capita as a proxy for the capital endowment of the nation is positively related to intra-industry trade volume because capital-abundant countries have a comparative advantage in high-quality products and would produce them. According to the Linder hypothesis, GDP per capita

as a proxy for the nation's development is positively related to intra-industry trade volume in the sense that countries with similar development levels trade more with each other because they would consume and produce similar quality goods in similar industries. Therefore, the result of the difference in GDP per capita is doubtful. Similarly, the coefficient of the geographical distance between capitals was -0.0507 with a t-statistic of -0.59, showing a nonsignificant negative relationship between geographical distance and total intra-industry trade. However, the gravity model proved that geographical distance plays a significant role in the bilateral trade volume of trading partners because of the reduction of transportation costs and information costs. With this logic, the common border should be positively correlated with the intra-industry trade volume because countries having a common border are supposed to have partly similar cultures and languages which could reduce information costs. However, the coefficient of the dummy variable indicating a common border was -0.2763 with the corresponding t-statistic of -2.02, which shows a significant negative relationship between the common border and total intra-industry trade. These regression results are unexpected and are contradictory to the theories. Therefore, we adjusted the dataset and dropped the trading data of the USA. The results of regression without the USA data are shown in Table 12 Columns 3-6.

According to the results shown in the third column of Table 12, factor endowments are positively correlated to total intra-industry trade volume. The difference in human capital endowment, proxied by secondary educational attainment, was statistical significance and economic magnitude. The coefficient of human capital difference was 5.8608 with a t-statistic of 6.66. It suggested that the difference in human capital endowment across countries is statistically positively related to the total intra-industry trade between them. It is consistent with the neo-Heckscher-Ohlin model, which explains the intra-industry trade as the result of the country's difference in factor endowments. If countries have more skilled labor, they have comparative advantages in high-quality products. Similarly, the difference in GDP per capita has a positive relationship with the total intra-industry trade at the 10% significant level. Its coefficient was 0.0525, and the corresponding t-statistic is 1.89. The capital-abundant countries have comparative advantages in high-quality products, which are capital-intensive. Comparing these two proxies for factor endowments, we found that human capital endowment is more important than capital endowment in explaining total intra-industry trade in economic magnitude and statistical significance. The effect of GDP per capita

has another explanation. According to the Linder Hypothesis, which explains intra-industry trade from the demand side, countries with similar income levels are supposed to consume and produce similar products, usually high-quality products. Therefore, they will trade with each other in similar industries. In addition, the coefficient of GDP difference was 0.3416 with a t-statistic of 7.54, which illustrates that the difference in economic size is statistically positively correlated to the total intra-industry trade. However, the effect of the difference in economic mass is less than the effect of the difference in human capital endowment in magnitude, with coefficients of 5.86 and 0.342, respectively. As for the geographical distance with a coefficient of -0.5833 and a t-statistic of –2.66, it is found to be negatively correlated to the total intra-industry trade at the 1% significance level. The gravity model provides an explanation for the negative relationship between geographical distance and total intra-industry trade. Another proxy for the geographical position of countries, the common border dummy, is proved to be a determinant of total intra-industry trade with statistical significance at the 1% level. Its coefficient was 1.8772 and the corresponding t-statistic is 20.61, which illustrates that a common border significantly increases total intra-industry trade between countries sharing it. Both the dummy variable indicating a common border and geographical distance are statistically significantly associated with total intra-industry trade. Therefore, the relative geographical position of trading partners plays a significant role in total intra-industry trade. However, the coefficient of the EU membership dummy was 0.1575 with a t-statistic of 1.63. Therefore, although EU membership is positively correlated to the total intra-industry trade but without statistical significance at the 10% level. Overall, the model is statistically significant because the adjusted R square of the model was 0.9151, and F-statistic was 66.03. In order to robust the fixed effect model, the Hausman test was operated with the null of random effects existing. The χ^2-value of the test was 104.55with a p-value of 0, which demonstrated that we could reject the null hypothesis that the random effect model fits better at the 5% significance level.

Then, we decomposed the total volume of intra-industry trade and focused on the vertical intra-industry trade only. According to the results shown in Table 12 Column 4, we found that all explanatory variables are statistically significant. When taking vertical intra-industry trade as the dependent variable in the regression equation, we also detected a positive relationship between the difference in secondary educational attainment and vertical intra-industry trade with statistical significance at the 1% level. The coefficient of the difference in secondary educational attainment was 5.5243 with

the corresponding t-statistic of 8.48, which illustrates that the difference in human capital endowment boosts the vertical intra-industry trade. What's more, the effect of educational attainment on vertical intra-industry trade is similar to that on total intra-industry trade in magnitude since the coefficients were 5.86 and 5.52, respectively. The reason is that the difference in human capital endowment generates comparative advantages for countries. The country with more skilled labor has the comparative advantage in high-quality products, while the country with less skilled labor has the comparative advantage in producing products of low quality. Then, vertical intra-industry trade takes place between these two countries because residents have different tastes and demands for goods of different qualities. And vertical intra-industry trade contributes to the majority part of total intra-industry trade in the machinery sector in Germany. In terms of the difference in GDP per capita, its coefficient was 0.0454, and the corresponding t-statistic is 1.68, which suggests that the difference in GDP per capita is positively correlated to the vertical intra-industry trade with the 5% significance level. It can be explained by the neo-Heckscher-Ohlin model. Higher quality requires a more significant unit input in capital for a given input in labor (Falvey, 1981). Therefore, the capital intensity of products increases as their quality increases. Countries that are relatively abundant in the capital factor have a comparative advantage in producing high-quality products, while other countries are supposed to produce low-quality products due to the opportunity cost and comparative advantage. Then, vertical intra-industry trade takes place when countries trade with one another for varieties of different quality. As for the market size, the coefficient of the difference in the nation's GDP was 0.3727 with a t-statistic of 8.48, which illustrates that the difference in domestic market size is positively correlated to vertical intra-industry trade. It is consistent with the previous studies (Jambor, 2014; Ambroziak, 2012; Jensen & Lüthje,2009). In terms of the geographical position, the signs are all expected. The coefficient of the distance between trading partners was -0.4958 with a t-statistic of -2.33. Therefore, the geographical distance is negatively correlated to vertical intra-industry volume with a 5% significance level. Besides, there is a statistically significant positive relationship between the common border and the vertical intra-industry trade. Because the coefficient of the dummy variable of contiguity was 1.7769 with a corresponding t-statistic of 20.12. Therefore, having a common border can significantly increase vertical intra-industry trade. Last, EU membership is positively correlated to vertical intra-industry trade volume at a 10% significance level since its coefficient was

0.1582 with a t-statistic of 1.68. Accession to the EU is not as significant as other explanatory variables in boosting vertical intra-industry trade in the machinery sector in Germany. The overall significance of the model is high, with an adjusted R^2 of 0.9153 and an F-statistic of 66.19.

Then we used regression equation (3) to examine the impact of human capital endowment on intra-industry trade by replacing secondary educational attainment with tertiary educational attainment. We still treated total and vertical intra-industry trade separately as dependent variables to test the role of the human capital endowment. The significant relationships between human capital endowment and total as well as vertical intra-industry trade are detected. Column 5 summarizes results when using total intra-industry trade. The difference in tertiary educational attainment is significantly negatively correlated to total intra-industry trade with a coefficient of -6.4959 and a corresponding t-statistic of -10.74. It is similar to the result of Jambor (2014). In addition, the coefficient of the GDP per capita difference was 0.0148 with a t-statistic of 0.64. Therefore, the difference in GDP per capita is nonsignificant in this regression, and its effect on intra-industry trade is insignificant. Similarly, EU accession with a coefficient of 0.0821 and a t-statistic of 1.01 was found to be insignificant in determining the total intra-industry trade of CEE countries. It was consistent with the result when using secondary educational attainment proxy for human capital endowment. As for the difference in economic sizes, its coefficient was 0.2488, and the corresponding t-statistic is 6.71, which illustrates that the difference in market size is significantly positively correlated to the total intra-industry trade. Besides, the coefficient of the dummy variable indicating if trading partners share a common border was 0.8915 with a t-statistic of 8.04. Therefore, having a common border significantly increased the total intra-industry trade of CEE countries.

In addition, we also examined the effect of tertiary educational attainment on vertical intra-industry trade in CEE countries, and the results are shown in Column 6. The coefficient of the difference in tertiary educational attainment was -6.0103 with the corresponding t-statistic of -10.03, illustrating that the difference in tertiary educational attainment was negatively related to vertical intra-industry trade. And GDP per capita as a proxy for the nation's capital endowment is nonsignificant in determining vertical intra-industry trade of CEE countries because its coefficient was 0.0097 and the corresponding t-statistic is 0.43. Similarly, we found accession to the EU did not significantly increase vertical intra-industry trade of CEE countries. However, the

difference in the economic sizes was significantly positively correlated to the vertical intra-industry trade of CEE countries since the coefficient of the difference in economic mass is 0.2852 with a t-statistic of 7.76. According to the results shown in Column 6, another significant determinant of vertical intra-industry trade is whether trading partners share a common border, the coefficient of which was 0.8915 with a t-statistic of 8.04. Therefore, having a common border boosted vertical intra-industry trade of CEE countries. In general, the adjusted R^2 values and F-statistics of the model including factor endowments were high, which indicated that the models are reliable with significant explanatory power.

We did two more regressions focusing on the Visegrad member countries to test the effect of tertiary educational attainments. Columns 7-8 show the regression results on total intra-industry trade and vertical intra-industry trade separately. Tertiary educational attainments were negatively correlated to total and vertical intra-industry trade of the Visegrad member countries. The coefficients and corresponding t-statistic were -4.9251 (-2.53) and -6.8764 (-2.98), respectively. However, all other explanatory variables were nonsignificant.

Table 12 – Summary of regression results of equations (2) and (3)

Regression	**(2)**	**(2)**	**(2)**	**(3)**	**(3)**	**(3)**	**(3)**
Dependent variable	Total IIT	Total IIT	Vertical IIT	Total IIT	Vertical IIT	Total IIT	Vertical IIT
Country Group	All	Exclude the USA	Exclude the USA	Exclude the USA	Exclude the USA	Visegrad Group	Visegrad Group
dsec	5.2778*** (6.42)	5.8608*** (6.66)	5.5243*** (8.48)				
dter				-6.4959*** (-10.74)	-6.0103*** (-10.03)	-4.9251** (-2.53)	-6.8764*** (-2.98)
lndgdpc	0.0409 (1.56)	0.0525* (1.89)	0.0454* (1.68)	0.0148 (0.64)	0.0097 (0.43)	-0.6216 (-1.40)	-0.7066 (-1.35)
lndgdp	0.3310*** (7.56)	0.3416*** (7.54)	0.3727*** (8.48)	0.2488*** (6.71)	0.2852*** (7.76)	-3.4150 (-1.63)	-2.7607 (-1.11)
lndis	-0.0507 (-0.59)	-0.5833*** (-2.66)	-0.4958** (-2.33)				

eu	0.1877** (2.00)	0.1575 (1.63)	0.1582* (1.68)	0.0821 (1.01)	0.0938 (1.16)	0.0291 (0.19)	0.0573 (0.32)
border	-0.2763** (-2.02)	1.8772*** (20.61)	1.7769*** (20.12)	0.8087*** (-7.22)	0.8915*** (8.04)		
Constant	11.1473*** (20.14)	12.0619*** (9.18)	11.0115*** (8.64)	13.65*** (23.04)	12.9824*** (22.10)	71.0719** (2.45)	62.5256* (1.82)
$\mathbf{R_{adj}^2}$	0.9184	0.9151	0.9153	0.9369	0.9343	0.9658	0.9501
F-stat	71.93	66.03	66.19	90.61	86.79	65.05	43.91
Hausman test		104.55(0.000)	105.08(0.000)				

Notes: For the econometric specifications (2) and (3), only the fixed effect model is used to obtain the regression results. Because the result from part one illustrates that the fixed effect model is the most appropriate model to analyze the trading data with the gravity model. However, we still use the Hausman test in this step to robust the choice of the fixed effect model. The χ^2-value of the Hausman test is listed in the table together with the corresponding p-value in parentheses. This table summarizes the regression results of equations (2) and (3), columns 2-4 for equation (2), and columns 5-8 for equation (3). Only the regression shown in the second column used all countries, while the regressions in columns 3-6 excluding the U.S.A. The last two columns only focus on the Visegrad group. And the t-statistic of coefficients is in parentheses. ***/**/* stands for the significant level of 1%/5%/10%, respectively.

3.3 Key findings

Because the nature of intra-industry trade in the machinery sector of Germany is vertically differentiated in nature, the significant determinants for total and vertical intra-industry trade are similar.

In conclusion, there are five key findings according to the empirical results of regression equations. (2) The domestic market size and the difference between economic mass are significant driving forces to intra-industry trade between the Visegrad Group and Germany. (3) The geographical proximity matters too. Two variables were used to proxy for the relative geographical position between trading partners: the geographical distance between capitals and a dummy variable indicating whether trading partners share a common border. The geographical distance is suggested to be statistically negatively correlated to intra-industry trade. And having a common border boosts the intra-industry trade between trading partners with statistical significance. (4) EU membership has a positive relationship with intra-industry trade, but it is not always significant. (1) Human capital endowment is significantly correlated to intra-industry trade in the Visegrad. The difference in secondary educational

attainment has a positive relationship with intra-industry trade, while tertiary educational attainment has an opposite sign, which is negatively correlated to intra-industry trade. (5) The difference in GDP per capita has a positive correlation with intra-industry trade, but it is not as significant as the human capital endowment.

3.4 Discussions about key findings

This part compares the key findings mentioned above with the previous literature and discusses them.

The first finding is related to the human capital endowment. This paper used two proxies for the nation's human capital endowment to separate the labor with different skill levels. One is secondary educational attainment; the other is tertiary educational attainment. However, the regression results were different since the signs were opposite. The difference in secondary educational attainment was found to be significantly positively correlated to the intra-industry trade in CEE countries, which is consistent with the results from Fainštein and Netšunajev (2011), Jensen and Lüthje (2009), and Ferto (2005). They all suggested a significant positive role of human capital endowment in intra-industry trade in CEE countries. The factor proportion theory can explain the positive relationship. However, this paper detected a significant negative relationship between tertiary educational attainments and intra-industry trade in CEE countries. Although Mulliqi, Adnett, Hisarciklilar, & Rizvanolli (2018) found that tertiary educational attainment was positively correlated to the CEE countries' export market share, it did not boost intra-industry trade in CEE countries with statistical significance.
The first possible reason is that tertiary educational attainment more reflects the nation's development level because richer countries typically have higher tertiary educational attainments. It is also supported by the regression results. When using tertiary educational attainments, the coefficient of GDP per capita became nonsignificant. If so, the Linder effect explains the negative relationship between the difference in tertiary educational attainment and intra-industry trade of CEE countries. The larger difference in development levels between the two countries, the less possible they trade within the industry with each other. Because they have different demands and develop different industries. Second, the Chinese trade with European countries matters. Second, it could be caused by labor attained tertiary level o education moved from CEE countries to Western Europe countries, such as Germany, for better work opportunities and higher

wages after new member states acceded to the EU (Baas, Brücker, & Hauptmann, 2009). Therefore, CEE countries lose high-skilled labor and still specialize in low-quality products (Ferragina & Pastore, 2005). It also raises another problem, whether CEE countries overstate the level of education they provide (Ferragina & Pastore, 2005). The last possible reason is that tertiary educational attainment is not a good proxy for human capital endowment when studying intra-industry trade. According to the result shown in Table 12 Column7-8, other explanatory variables were nonsignificant in the model when focusing on the Visegrad member countries.

The second finding is related to the economic size. This paper found that domestic economic size has a positive correlation with the intra-industry trade. It is consistent with the gravity model of international trade, which claims that trade between two countries is proportional to their economic mass. The reason is that larger economies have more demand for differentiated goods and, at the same time, they produce more goods. Therefore, they trade with other countries with differentiated goods. The positive relationship between market size and intra-industry trade is also supported by previous studies (Fainštein & Netšunajev, 2011; Ferragina & Pastore, 2005). They claimed that larger countries with more capital enable them to specialize in high-quality products. This paper also found a statistically significant positive relationship between the difference in economic sizes of trading partners and intra-industry trade between them. It is consistent with the result of the majority of past papers testing the IIT in CEE countries (Jambor,2014; Ambroziak,2012; Fainštein & Netšunajev, 2011; Jensen & Lüthje, 2009). The greater the difference in economic sizes, the larger the intra-industry trade volume. Because the larger countries have product specialization due to increasing returns to scale.

The third finding is related to geographical proximity, proxied by the distance between capitals and a dummy variable indicating if trading partners have a common border. Geographical distance is found to have a significant negative relationship with intra-industry trade volume. It can be explained by the gravity model of international trade, which claims the distance between trading partners discourages their intra-industry trade. Because distant location partly reflects the differences in culture and consumption patterns of the two countries. Besides, the far distance between the two countries also increases transportation costs of trade. This negative relationship between distance and intra-industry trade is also detected by previous studies (Łapińska,2016; Jambor, 2014; Ambroziak, 2012; Fainštein & Netšunajev, 2011; Gabrisch, 2009; Caetan

& Galego, 2007). Another proxy for geographical proximity is the dummy variable showing if the trading partners share a common border, which is also a commonly used proxy in the gravity model (Baldwin & Taglioni, 2006). This paper found that having a common border significantly increases intra-industry trade of the Visegrad member countries, which is consistent with the result of Ambroziak (2012). What's more, the regression results shown in Table 12 were in line with Borchert and Yotov (2017), who suggested that the impact of contiguity is increasing while the effect of geographical distance decreases. Because the coefficient of contiguity dummy is significantly larger than that of geographical distance in magnitude.

The fourth finding is related to EU membership. This paper detected a positive but nonsignificant correlation between EU membership and intra-industry trade. It is contradictory to Łapińska (2016) and Ferragina and Pastore (2005). They suggested that accession to the EU was a significant driving force in the intra-industry trade of CEE countries. There are several possible reasons to explain the inconsistency. First, there might be overlaps between the EU membership dummy and border dummy. Second, joining the EU prompted the labor mobility between CEE countries and EU-15 members. Skilled labor moves and aggregates in industrialized regions, such as Germany, which harms the export of CEE countries, especially exports of high-quality products (Kahanec, 2013). Third, German trade with the US and China also affects the significance of EU membership. The US has established a trade tradition with Germany since the 1940s, and China is becoming the biggest trading partner in recent years. Fourth, after CEE countries joined the EU in 2004, several crises took place in Europe and worldwide, during which new member states suffered a severe decline in exports. Shelburne (2010) claimed that the global financial crisis had a greater impact on the trade of European emerging economies than on the trade of other parts of the world and attributed this to the high dependence on external capital of these countries. Broll (2014) identified the reason for the severe decline in exports as the financial crisis increased the trade financing costs, especially for emerging markets with increased risk perception. Although the Czech Republic, Hungary, and Poland did not join Eurozone, the Euro sovereign debt crisis still negatively impacted their international trade, especially in the machinery sector (Li, Shi, & Huang, 2013). Last but not least, the result of this paper may be biased due to the limited sample selection.

The fifth finding is related to the difference in GDP per capita, which was found to be positively correlated to intra-industry trade in this paper, but it is not as significant as

the human capital endowment. Many previous studies also detected this positive correlation (Ferto, 2005; Ferragina & Pastore, 2005; Caetan & Galego, 2007; Gabrisch, 2009; Ambroziak, 2012; Jambor, 2014; Łapińska, 2016). Factor endowment theory offers an explanation for this positive relationship. GDP per capita is a proxy for the capital endowment of the country, with a higher value of which the country is relatively capital-abundant. Therefore, countries with higher GDP per capita have a comparative advantage and specialize in high-quality products (Falvey, 1981; Falvey & Kierzkowski, 1987). Trade in products with quality differentiation takes place. However, factor endowment cannot explain the nonsignificant role of GDP per capita. The Linder theory offers a complementary, which explains GDP per capita as the proxy for the country's development level. Linder (1961) claimed that countries with similar development levels tend to trade more because they have similar preferences. They consume products with similar quality and would develop similar industries to produce similar quality products. Then trade between them takes place in similar-quality but differentiated products within the industry, which belongs to horizontal intra-industry trade. However, the trade between the Visegrad and Germany is vertical intra-industry trade in nature. Therefore, the effect of GDP per capita is not evident.

Conclusion

Intra-industry trade currently accounts for a greater proportion of the trade of manufactured goods among established industrial nations, which accounts for the vast majority of international trade (Krugman et al., 2012). However, the empirical studies examining the effect of the human capital endowment on intra-industry trade of CEE countries were outdated with data until 2010. What's more, they drew different conclusions on the effect of the human capital endowment. Therefore, this paper investigated the role of human capital endowment on intra-industry trade between CEE countries and the EU using the post-accession data from 2000-2019. Meanwhile, this paper clarified the nature of CEE-EU trade and found some stylized characteristics.

To examine the effect of human capital endowment on intra-industry trade between CEE countries and the EU, this paper used trading data from 2000-2019 in the machinery sector between the Visegrad and Germany as the sample. Based on these data on trade flows, this paper also calculated the adjusted GL index of the Visegrad member countries as well as the intra-industry trade volumes and shares of the machinery sector. In the econometric regression, secondary and tertiary educational attainments were used separately as the proxies for the nation's human capital endowment. This paper employed the fixed effect model to investigate the correlation between human capital proxy and the intra-industry trade between the Visegrad member countries and Germany. Both total and vertical IIT were tested. This paper also included other factors in the regression model, including the market sizes, GDP per capita, geographical distance, common border, and EU membership. Moreover, this paper took a close look at descriptive statistics of variables at great length before the econometric regression analysis, drew some stylized characteristics of countries, and recognized the nature of CEE-EU trade.

There are some important findings from this research. Firstly, the intra-industry trade between CEE and the EU dominated by manufactured goods was of vertical nature. However, vertical intra-industry trade increased in absolute terms, not in relative terms. Second, the human capital endowment was significantly correlated to intra-industry trade of CEE countries to the EU. However, intra-industry trade in CEE countries was positively correlated to the difference in secondary educational attainment but negatively correlated to tertiary educational attainment. Third, both geographic distance and common border had significant correlations with intra-industry trade of

CEE countries. Moreover, the effect of having a common border on intra-industry trade was larger than that of geographical distance statistical significance. Fourth, the EU accession was found to be nonsignificant in intra-industry trade of CEE countries to the EU.

The contribution of this paper is to recognize the important role of human capital endowment in determining intra-industry trade of CEE countries to the EU during the post-accession period. Besides, we used second and tertiary educational attainments separately to analyze labor with different levels of skills. The implication from the results is that the role of factor endowment in determining the product specialization process will continue to drive CEECs toward low-quality production parts and EU members toward high-quality production parts in each industry. Meanwhile, the negative relationship between tertiary educational attainment and intra-industry trade implies that although they have high educational attainments, the CEE countries occupy the lowest quality market segments in Europe. It is mainly related to the high-skilled labor mobility to the old EU member countries, which need more concern from CEE countries. And also, it raises doubt about the human capital statistics, which may exaggerate the levels of education CEE countries provide.

However, this research has some limitations. First, we use the representative group for the EU-CEE trade, which could raise biased results. Second, the measurement of human capital endowment did not consider the quality of education, which may be an important factor in affecting product quality and vertical intra-industry trade. Therefore, another avenue for future research relates to incorporating the quality of education as a factor affecting intra-industry trade of CEE countries in the post-accession period.

Notes:

1. The Chinese data is collected from the public reports of the population census in 2000, 2010, and 2020, respectively. The data for the remaining years are estimated by these three years ratios. We interpolate the Chinese data by calculating the observations between the official data and assuming stable gradual development during the years between the censuses. Because the overall attainment is likely to change only gradually. Source of data: file:///C:/Users/Tracy%20Zeng/Zotero/storage/YQ5WP4CG/content_60740.html; file:///C:/Users/Tracy%20Zeng/Zotero/storage/XTAEGFHV/t20210511_1817201.html;

2. Country groups used in the paper:
   (1) Visegrad group includes the Czech Republic, Hungary, Poland, and Slovakia.
   (2) Old EU members in this paper refer to Austria, France, Italy, the Netherlands, and the United Kingdom. Germany was included in the descriptive statistic, but not in the econometric regression analysis. The coverage of the United Kingdom is because this research used data from 2000-2019, which was before Brexit in 2020.
   (3) The Baltic countries refer to Estonia, Latvia, and Lithuania.
3. In 2019, the total international trade volume of CEE countries is 1785.3 billion US dollars, among which trade of 521.77 billion dollars took place in the machinery sector. Therefore, the share of trade in the machinery sector over total international trade in CEE countries is 29.22%.
4. The trade volumes in the machinery sector in the Czech Republic, Hungary, Poland, and Slovakia are 140.7, 90.2, 133.6, and 51.3 billion US dollars, respectively. Compared to the trade volume in the machinery sector in all CEE countries of 521.77 billion US dollars, the share of the Visegrad member countries is 79.69%.

Bibliography

Aahana, S. (2018) 'Linder's Theory of Demand and Trade Pattern | Economics', *Economics Discussion*, 15 March. Available at: https://www.economicsdiscussion.net/linders-theory-of-demand/linders-theory-of-demand-and-trade-pattern-economics/30832 (Accessed: 1 August 2022).

Abd-el-Rahman, K. (1991) 'Firms' competitive and national comparative advantages as joint determinants of trade composition', *Review of World Economics*, 127(1), pp. 83–97. Available at: https://doi.org/10.1007/BF02707312 (Accessed: 1 August 2022).

Ambroziak, Ł. (2012) 'FDI and Intra-Industry Trade: Theory and Empirical Evidence from the Visegrad Countries', *International Journal of Economics and Business Research*, 4. Available at: https://doi.org/10.1504/IJEBR.2012.044252 (Accessed: 1 August 2022).

Baas, T., Brücker, H. and Hauptmann, A. (2010) 'Labor Mobility in the Enlarged EU: Who Wins, Who Loses?', in M. Kahanec and K.F. Zimmermann (eds) *EU Labor Markets After Post-Enlargement Migration*. Berlin, Heidelberg: Springer, pp. 47–70. Available at: https://doi.org/10.1007/978-3-642-02242-5_2 (Accessed: 1 August 2022).

Bacchetta, M., Beverelli, C., Cadot, O., Fugazza, M., Grether, J.M., Helble, M., Nicita, A. and Piermartini, R. (2012) A practical guide to trade policy analysis. Geneva, CH: World Trade Organization.

Balassa, B. (1966) Tariff reductions and trade in manufacturers among the industrial countries. *The American Economic Review*, 56(3), pp.466-473.

Balassa, B. (1986) 'Intra-Industry specialization: A cross-country analysis', *European Economic Review*, 30(1), pp. 27–42. Available at: https://doi.org/10.1016/0014-2921(86)90030-9 (Accessed: 1 August 2022).

Balassa, B. and Bauwens, L. (1987) 'Intra-Industry Specialisation in a Multi-Country and Multi-Industry Framework', *The Economic Journal*, 97(388), pp. 923–939. Available at: https://doi.org/10.2307/2233080 (Accessed: 1 August 2022).

Baldwin, R. and Taglioni, D. (2006) *Gravity for Dummies and Dummies for Gravity Equations*. Working Paper 12516. National Bureau of Economic Research. Available at: https://doi.org/10.3386/w12516 (Accessed: 1 August 2022).

Bela, B. (no date) *Intra-industry trade among exporters of manufactured goods*, *World Bank*. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/969551467986351336/Intra-industry-trade-among-exporters-of-manufactured-goods (Accessed: 1 August 2022).

Blanes, J.V. and Martín, C. (2000) 'The nature and causes of intra-industry trade: Back to the comparative advantage explanation? The case of Spain', *Weltwirtschaftliches Archiv*, 136(3), pp. 423–441. Available at: https://doi.org/10.1007/BF02707288 (Accessed: 1 August 2022).

Borchert, I. and Yotov, Y.V. (2017) 'Distance, globalization, and international trade', *Economics Letters*, 153, pp. 32–38. Available at: https://doi.org/10.1016/j.econlet.2017.01.023 (Accessed: 1 August 2022).

Broll, U. and Jauer, J. (2014) How international trade is affected by the financial crisis: the gravity trade equation (No. 03/14). Dresden Discussion Paper Series in Economics.

Cabral, M., Falvey, R. and Milner, C. (2009) 'Does Skill Content Explain Total Trade and Intra-Industry Trade?*', *Oxford Bulletin of Economics and Statistics*, 71(5), pp. 601–619. Available at: https://doi.org/10.1111/j.1468-0084.2009.00555.x (Accessed: 1 August 2022).

Cabral, M., Falvey, R.E. and Milner, C.R. (2006) 'The Skill Content of Inter- and Intra-Industry Trade: Evidence for the United Kingdom', *Review of World Economics*, 142(3), pp. 546–566. Available at: https://doi.org/10.1007/s10290-006-0080-x (Accessed: 1 August 2022).

Caetano, J.M.M. and Galego, A. (2006) In Search for Determinants of intra-industry trade within an Enlarged Europe.

Černoša, S. (2009) 'Intra-Industry Trade and Industry-Specific Determinants in Slovenia', *Eastern European Economics*, 47(3), pp. 84–99. Available at: https://doi.org/10.2753/EEE0012-8775470304 (Accessed: 1 August 2022).

Cieślik, A., Michałek, J. and Mycielski, J. (2016) Globalization, international trade, and human development: a case of Central and Eastern Europe. *Czech J Soc Sci Bus Econ*, 5(2), pp.6-15.

Crespo, N. and Fontoura, M.P. (2004) Intra-industry trade by types: What can we learn from Portuguese data?. *Review of World Economics*, 140(1), pp.52-79.

Drábek, Z. and Smith, A. (1995) *Trade Performance and Trade Policy in Central and Eastern Europe*, *CEPR Discussion Papers*. 1182. C.E.P.R. Discussion Papers. Available at: https://ideas.repec.org/p/cpr/ceprdp/1182.html (Accessed: 1 August 2022).

Ekanayake, E.M. (2001) 'DETERMINANTS OF TRADE: THE CASE OF MEXICO', *The International Trade Journal*, 15(1), pp. 89–112. Available at: https://doi.org/10.1080/088539001300005468 (Accessed: 1 August 2022).

Fainštein, G. and Netšunajev, A. (2011) 'Intra-Industry Trade Development in the Baltic States', *Emerging Markets Finance and Trade*, 47(sup3), pp. 95–110. Available at: https://doi.org/10.2753/REE1540-496X4704S306 (Accessed: 1 August 2022).

Falvey, R.E. (1981) 'Commercial policy and intra-industry trade', *Journal of International Economics*, 11(4), pp. 495–511. Available at: https://doi.org/10.1016/0022-1996(81)90031-3 (Accessed: 1 August 2022).

Falvey, R.E. and Kierzkowski, H. (1987) Product quality, intra-industry trade and (im) perfect competition (No. ARTICLE).

FERRAGINA, A.M. and PASTORE, F. (2005) 'Factor Endowment and Market Size in EU-CEE Trade : Would Human Capital Change Actual Quality Trade Patterns?', *Eastern European Economics*, 43(1), pp. 5–33. Available at: https://doi.org/10.1080/00128775.2005.11041094 (Accessed: 1 August 2022).

Fertö, I. (2005) 'Vertically Differentiated Trade and Differences in Factor Endowment: The Case of Agri-Food Products between Hungary and the EU', *Journal of Agricultural Economics*, 56(1), pp. 117–134. Available at: https://doi.org/10.1111/j.1477-9552.2005.tb00125.x (Accessed: 1 August 2022).

Fontagné, L. and Freudenberg, M. (1997) Intra-industry trade: methodological issues reconsidered (Vol. 97, No. 1). Paris: Cepii.

Gabrisch, H. (2009) 'Vertical intra-industry trade, technology and income distribution: A panel data analysis of EU trade with Central-East European Countries', *Acta Oeconomica - ACTA OECON*, 59, pp. 1–22. Available at: https://doi.org/10.1556/AOecon.59.2009.1.1 (Accessed: 1 August 2022).

Greenaway, D., Hine, R. and Milner, C. (1994) 'Country-specific factors and the pattern of horizontal and vertical intra-industry trade in the UK', *Weltwirtschaftliches Archiv*, 130(1), pp. 77–100. Available at: https://doi.org/10.1007/BF02706010 (Accessed: 1 August 2022).

Greenaway, D., Hine, R. and Milner, C. (1995) 'Vertical and Horizontal Intra-Industry Trade: A Cross Industry Analysis for the United Kingdom', *The Economic Journal*, 105(433), pp. 1505–1518. Available at: https://doi.org/10.2307/2235113 (Accessed: 1 August 2022).

Greenaway, D. and Torstensson, J. (2000) Economic geography, comparative advantage and trade within industries: evidence from the OECD. Journal of Economic Integration, pp.260-280.

Grubel, H.G. (1967) 'Intra-Industry Specialization and the Pattern of Trade', *The Canadian Journal of Economics and Political Science / Revue canadienne d'Economique et de Science politique*, 33(3), pp. 374–388. Available at: https://doi.org/10.2307/139914 (Accessed: 1 August 2022).

Gullstrand, J. (2002) Does the measurement of intra-industry trade matter?. Weltwirtschaftliches Archiv, 138(2), pp.317-339.

Hamilton, C.B. and Winters, L.A. (1992) Opening up international trade with Eastern Europe. Economic Policy, 7(14), pp.77-116.

Helpman, E. and Krugman, P.R. (1985) *Market structure and foreign trade: Increasing returns, imperfect competition, and the international economy*. MIT press.

Hummels, D. and Levinsohn, J. (1995) 'Monopolistic Competition and International Trade: Reconsidering the Evidence*', *The Quarterly Journal of Economics*, 110(3), pp. 799–836. Available at: https://doi.org/10.2307/2946700 (Accessed: 1 August 2022).

Jambor, A. (2014) 'Country-Specific Determinants of Horizontal and Vertical Intra-industry Agri-food Trade: The Case of the EU New Member States', *Journal of Agricultural Economics*, 65(3), pp. 663–682. Available at: https://doi.org/10.1111/1477-9552.12059 (Accessed: 1 August 2022).

Jensen, L. and Lüthje, T. (2009) 'Driving forces of vertical intra-industry trade in Europe 1996–2005', *Review of World Economics*, 145(3), p. 469. Available at: https://doi.org/10.1007/s10290-009-0022-5 (Accessed: 1 August 2022).

Kahanec, M. (2013) Labor mobility in an enlarged European Union. In International handbook on the economics of migration (pp. 137-152). Edward Elgar Publishing.

Krugman, P. and Venables, A.J. (1995) 'Globalization and the Inequality of Nations', *The quarterly journal of economics*, 110(4), pp. 857–880.

Krugman, P.R., Obstfeld, M. and Melitz, M.J. (2012) 'International economics: Theory & policy'. Pearson Addison-Wesley.

Lancaster, K. (1980) 'Intra-industry trade under perfect monopolistic competition', *Journal of International Economics*, 10(2), pp. 151–175. Available at: https://doi.org/10.1016/0022-1996(80)90052-5 (Accessed: 1 August 2022).

Łapińska, J. (2016) 'Determinant factors of intra-industry trade: the case of Poland and its European Union trading partners', *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(2), pp. 251–264. Available at: https://doi.org/10.12775/EQUIL.2016.011 (Accessed: 1 August 2022).

Łapińska, J., Kądzielawski, G. and Dziuba, R. (2019) 'Country-Specific Determinants of Intra-Industry Trade in Clothing and Footwear between Poland and European Union Countries', *Fibres and Textiles in Eastern Europe*, 27, pp. 23–29. Available at: https://doi.org/10.5604/01.3001.0013.1816 (Accessed: 1 August 2022).

Leitão, N.C. (2011) 'United States' Intra-Industry Trade', *Economic Research-Ekonomska Istraživanja*, 24(2), pp. 68–76. Available at: https://doi.org/10.1080/1331677X.2011.11517456 (Accessed: 1 August 2022).

Li, N., Shi, M. and Huang, W. (2013) 'Impacts of the Euro sovereign debt crisis on global trade and economic growth: A General Equilibrium Analysis based on GTAP model'.

Linder, S.B. (1961) *An essay on trade and transformation*. Almqvist & Wiksell Stockholm.

Martín-Montaner, J.A. and Ríos, V.O. (2002) 'Vertical specialization and intra-industry trade: The role of factor endowments', *Weltwirtschaftliches Archiv*, 138(2), pp. 340–365. Available at: https://doi.org/10.1007/BF02707748 (Accessed: 1 August 2022).

UNESCO (2020). *Mean years of schooling*. Available at: http://uis.unesco.org/en/glossary-term/mean-years-schooling (Accessed: 1 August 2022).

Mortensen, J. and Richter, S. (2000) *Measurement of Costs and Benefits of Accession to the European Union for Selected Countries in Central and Eastern Europe (publication)*. Available at: https://wiiw.ac.at/p-187.html (Accessed: 1 August 2022).

Mulliqi, A. *et al.* (2018) 'Human Capital and International Competitiveness in Europe, with Special Reference to Transition Economies', *Eastern European Economics*, 56(6), pp. 541–563. Available at: https://doi.org/10.1080/00128775.2018.1502612 (Accessed: 1 August 2022).

OECD (2019) *Education at a Glance 2019: OECD Indicators*. OECD (Education at a Glance). Available at: https://doi.org/10.1787/f8d7880d-en (Accessed: 1 August 2022).

OECD (2021) *Education at a Glance 2021: OECD Indicators*. Paris: Organisation for Economic Co-operation and Development. Available at: https://www.oecd-ilibrary.org/education/education-at-a-glance-2021_b35a14e5-en (Accessed: 1 August 2022).

Sapir, A., Begg, D., Smith, A., Wyplosz, C., Hamilton, C., Winters, L.A., Giavazzi, F., Norman, V., Danthine, J.P. and Neven, D., 1990. Monitoring European integration: the impact of Eastern Europe: a CEPR annual report.

National Institute for Education. *Secondary vocational education, National Institute for Education*. Available at: http://archiv-nuv.npi.cz/our-work/vet-1.html?lang=2 (Accessed: 1 August 2022).

Shelburne, R.C., 2010. The global financial crisis and its impact on trade: the world and the european emerging economies. *United Nations Economic Commission for Europe-Discussion Papers Series*, *2*.

Stone, J.A. and Lee, H.-H. (1995) 'Determinants of intra-industry trade: A longitudinal, cross-country analysis', *Weltwirtschaftliches Archiv*, 131(1), pp. 67–85. Available at: https://doi.org/10.1007/BF02709072 (Accessed: 1 August 2022).

Torstensson, J. (1996a) 'Can factor proportions explain vertical intra-industry trade?', *Applied Economics Letters*, 3(5), pp. 307–309. Available at: https://doi.org/10.1080/135048596356410 (Accessed: 1 August 2022).

Torstensson, J. (1996b) 'Determinants of Intra-Industry Trade: A Sensitivity Analysis*', *Oxford Bulletin of Economics and Statistics*, 58(3), pp. 507–524. Available at: https://doi.org/10.1111/j.1468-0084.1996.mp58003005.x (Accessed: 1 August 2022).

Türkcan, K. and Ates, A. (2011) 'Vertical Intra-industry Trade and Fragmentation: An Empirical Examination of the US Auto-parts Industry', *The World Economy*, 34(1), pp. 154–172. Available at: https://doi.org/10.1111/j.1467-9701.2010.01316.x (Accessed: 1 August 2022).

Winters, L. A. and Wang, Z. K. (1994) *Eastern Europe's international trade*. Manchester University Press. (Accessed: 1 August 2022).

World Development Indicators | DataBank (no date). Available at: https://databank.worldbank.org/reports.aspx?source=2&type=metadata&series=SE.SEC.CUAT.UP.ZS (Accessed: 1 August 2022).

Zhang, J., van Witteloostuijn, A. and Zhou, C. (2005) 'Chinese Bilateral Intra-Industry Trade: A Panel Data Study for 50 Countries in the 1992–2001 Period', *Review of World Economics*, 141(3), pp. 510–540. Available at: https://doi.org/10.1007/s10290-005-0041-9 (Accessed: 1 August 2022).

List of appendices

Appendices

Appendix 1: Country iso code (table)

Country name	ISO_number code	ISO_Alpha-3 code
Austria	40	AUT
China	156	CHN
The Czech Republic	203	CZE
France	251	FRA
Germany	276	DEU
Hungary	348	HUN
Italy	381	ITA
Netherlands	528	NLD
Poland	616	POL
Slovakia	703	SVK
The United Kingdom	826	GBR
The United States of America	842	USA

Appendix 2: Germany's role in the exports and imports of the Visegrad member countries (table)

Year 2019	**Exports**			**Imports**		
	Total	Chapter 84	Chapter 85	Total	Chapter 84	Chapter 85
Czech Republic	61.6	13.1	12.4	47.1	9.62	7.72
Slovakia	19.7	3.04	3.44	15	2.18	2.34
Hungary	31.9	6.47	8.63	28.6	5.79	6.54
Poland	69.8	11.8	7	68.6	8.5	6.79
Notes: This table illustrates the trade volume in billion US dollars between Germany and the Visegrad member countries. Columns 1-3 conclude the exports to Germany, and columns 4-6 conclude the imports from Germany. The total columns mean all trading products between Germany and one of the Visegrad member countries. And the Chapter 84 and Chapter 85 columns only include the trading products categorized in these two specific chapters between Germany and one of the Visegrad member countries. Except in Slovakia, the machinery sector in other member countries contributes to the largest part of the imports and exports.						

Source: https://oec.world/en/profile/country/

Appendix 3: The international trade volumes of CEE countries in the year 2019 (table)

Country	Total export	Total import	Machinery export	Machinery import	Total trade	Trade in the machinery sector

Czech Republic	198	174	75.4	65.3	372	140.7
Hungary	121	115	47.4	42.8	236	90.2
Poland	257	275	62.9	70.7	532	133.6
Slovakia	91.2	83.5	26.8	24.5	174.7	51.3
Estonia	17.2	20.5	4.28	4.41	37.7	8.69
Latvia	15.3	21.8	2.55	3.74	37.1	6.29
Lithuania	33.2	32.7	4.91	6.04	65.9	10.95
Slovenia	38.6	43.4	8.2	8.45	82	16.65
Romania	80.1	94.9	23.31	25.6	175	48.91
Bulgaria	34.9	38	6.81	7.67	72.9	14.48
Total	886.5	898.8	262.56	259.21	1785.3	521.77
Notes: This table illustrates the total international trade flows (exports and imports) and trade in the machinery sector (exports and imports) of CEE countries in the year 2019. The trade volumes are measured in billion US dollars.						

Source: https://oec.world/en/profile/country/

Appendix 4: The main importers and exporters of products in Chapters 84-85 of Germany in 2019

Chapter 84				**Chapter 85**			
Export		Import		Export		Import	
Country	Volume	Country	Volume	Country	Volume	Country	Volume
USA	28.5	CHN	23.2	CHN	15	CHN	24
CHN	22.1	CZE	13.1	USA	11.8	CZE	12.4
FRA	17.5	ITA	10.4	NLD	8.27	NLD	9.46
GBR	13	FRA	10.1	FRA	8.2	HUN	8.63
POL	11.8	NLD	10	CZE	7.72	POL	6.79
ITA	11.2	USA	9.71	ITA	7.22	USA	6.44
AUT	11.2	AUT	9.14	POL	7	FRA	5.69
NLD	11.1	POL	8.5	AUT	6.55	ROU	4.77
CZE	9.62	HUN	6.47	HUN	6.54	AUT	4.31
HUN	5.79	GBR	6.13	GBR	6.33	ITA	4.11
Notes: This table lists the top 10 importers and exporters of the machinery sector of Germany with their trade volume measured in billion US dollars.							

Source: https://oec.world/en/profile/country/

Appendix 5:Education level classification by International Standard Classification of Education

Less than basic	ISCED 0	Early childhood education (‘less than primary’ for educational attainment)
Basic	ISCED 1	Primary education
	ISCED 2	Lower secondary education
Intermediate	ISCED 3	Upper secondary education
	ISCED 4	Post-secondary non-tertiary education
Advanced	ISCED 5	First stage of tertiary education (not leading directly to an advanced research qualification)

	ISCED 6	Second stage of tertiary education (leading to an advanced research qualification)

Appendix 6: The adjusted GL index and share of vertical intra-industry trade for individual country

Country	Year	Adjusted index	VIIT share	Country	Year	Adjusted index	VIIT share
AUT	2000	89.61%	76.33%	NLD	2000	88.07%	88.40%
AUT	2001	87.64%	84.78%	NLD	2001	91.80%	87.71%
AUT	2002	87.60%	81.62%	NLD	2002	92.19%	84.26%
AUT	2003	91.72%	75.67%	NLD	2003	92.83%	65.21%
AUT	2004	91.12%	77.50%	NLD	2004	92.22%	67.89%
AUT	2005	91.01%	84.28%	NLD	2005	92.44%	88.68%
AUT	2006	88.70%	82.47%	NLD	2006	93.09%	88.09%
AUT	2007	86.72%	83.52%	NLD	2007	86.99%	82.98%
AUT	2008	89.09%	77.34%	NLD	2008	91.65%	83.86%
AUT	2009	87.36%	79.41%	NLD	2009	91.21%	83.42%
AUT	2010	84.54%	77.73%	NLD	2010	90.72%	83.29%
AUT	2011	84.24%	74.64%	NLD	2011	90.49%	68.86%
AUT	2012	86.31%	74.85%	NLD	2012	95.79%	92.38%
AUT	2013	89.35%	77.35%	NLD	2013	95.73%	90.79%
AUT	2014	88.55%	79.47%	NLD	2014	94.11%	85.91%
AUT	2015	89.54%	80.53%	NLD	2015	94.21%	92.97%
AUT	2016	89.11%	83.65%	NLD	2016	94.63%	90.41%
AUT	2017	87.41%	83.94%	NLD	2017	95.64%	85.80%
AUT	2018	89.30%	84.67%	NLD	2018	93.93%	81.77%
AUT	2019	88.64%	83.02%	NLD	2019	94.21%	85.04%
CHN	2000	47.89%	87.70%	POL	2000	50.47%	77.09%
CHN	2001	39.67%	85.11%	POL	2001	51.94%	85.89%
CHN	2002	33.82%	93.58%	POL	2002	67.46%	73.75%
CHN	2003	29.09%	95.37%	POL	2003	67.51%	83.50%
CHN	2004	26.89%	87.86%	POL	2004	60.34%	83.51%
CHN	2005	30.48%	90.52%	POL	2005	69.47%	93.16%
CHN	2006	30.40%	89.36%	POL	2006	70.32%	83.36%
CHN	2007	37.26%	80.64%	POL	2007	75.84%	89.67%
CHN	2008	37.78%	87.08%	POL	2008	80.78%	91.24%
CHN	2009	36.76%	76.42%	POL	2009	70.61%	91.07%
CHN	2010	36.58%	86.64%	POL	2010	65.29%	86.52%
CHN	2011	37.90%	88.74%	POL	2011	72.77%	85.44%
CHN	2012	40.05%	97.54%	POL	2012	76.05%	86.38%
CHN	2013	48.00%	94.37%	POL	2013	80.86%	79.23%
CHN	2014	51.38%	88.91%	POL	2014	84.00%	78.09%
CHN	2015	49.99%	82.94%	POL	2015	87.89%	76.51%
CHN	2016	50.27%	92.38%	POL	2016	85.65%	83.35%
CHN	2017	51.27%	88.67%	POL	2017	84.69%	80.66%

CHN	2018	52.88%	89.12%	POL	2018	83.77%	76.52%
CHN	2019	57.21%	96.02%	POL	2019	84.11%	74.16%
CZE	2000	80.78%	82.01%	SVK	2000	51.30%	89.96%
CZE	2001	86.26%	86.74%	SVK	2001	56.86%	90.96%
CZE	2002	76.99%	88.44%	SVK	2002	62.26%	87.10%
CZE	2003	78.28%	80.97%	SVK	2003	59.53%	91.05%
CZE	2004	80.09%	89.43%	SVK	2004	53.89%	91.14%
CZE	2005	80.83%	83.16%	SVK	2005	56.77%	86.88%
CZE	2006	86.08%	85.22%	SVK	2006	52.93%	77.46%
CZE	2007	80.25%	85.28%	SVK	2007	53.07%	92.36%
CZE	2008	83.24%	88.74%	SVK	2008	55.64%	94.29%
CZE	2009	84.29%	86.23%	SVK	2009	52.12%	88.30%
CZE	2010	85.20%	81.32%	SVK	2010	54.40%	88.35%
CZE	2011	86.62%	89.17%	SVK	2011	54.43%	86.89%
CZE	2012	86.13%	79.55%	SVK	2012	56.93%	85.01%
CZE	2013	84.44%	84.97%	SVK	2013	56.11%	91.45%
CZE	2014	86.45%	80.39%	SVK	2014	58.39%	79.07%
CZE	2015	88.86%	77.11%	SVK	2015	60.61%	84.88%
CZE	2016	88.08%	78.81%	SVK	2016	67.59%	86.40%
CZE	2017	86.17%	85.99%	SVK	2017	69.83%	92.60%
CZE	2018	90.48%	79.37%	SVK	2018	75.07%	88.22%
CZE	2019	90.16%	77.18%	SVK	2019	76.65%	89.37%
FRA	2000	91.34%	76.89%	GBR	2000	85.84%	63.70%
FRA	2001			GBR	2001	83.61%	79.14%
FRA	2002	88.66%	79.57%	GBR	2002	85.68%	68.87%
FRA	2003	87.26%	73.90%	GBR	2003	82.05%	74.12%
FRA	2004	85.94%	80.59%	GBR	2004	80.35%	75.00%
FRA	2005	86.87%	80.96%	GBR	2005	86.62%	79.72%
FRA	2006	89.28%	82.65%	GBR	2006	86.67%	86.04%
FRA	2007	89.02%	76.53%	GBR	2007	76.63%	84.03%
FRA	2008	91.14%	68.30%	GBR	2008	80.03%	89.48%
FRA	2009	89.61%	71.69%	GBR	2009	77.12%	83.25%
FRA	2010	90.62%	66.65%	GBR	2010	82.72%	84.03%
FRA	2011	87.56%	77.75%	GBR	2011	84.50%	89.08%
FRA	2012	88.61%	72.94%	GBR	2012	85.54%	83.16%
FRA	2013	90.96%	69.71%	GBR	2013	81.97%	80.37%
FRA	2014	87.16%	68.48%	GBR	2014	79.24%	79.47%
FRA	2015	89.54%	83.36%	GBR	2015	78.28%	80.89%
FRA	2016	87.96%	75.44%	GBR	2016	75.97%	72.33%
FRA	2017	88.34%	79.53%	GBR	2017	79.51%	85.47%
FRA	2018	89.83%	72.59%	GBR	2018	80.67%	82.77%
FRA	2019	89.67%	80.64%	GBR	2019	83.22%	84.85%
HUN	2000	66.90%	89.85%	USA	2000	85.90%	78.15%
HUN	2001	62.80%	81.71%	USA	2001	85.73%	83.20%
HUN	2002	56.29%	88.27%	USA	2002	82.64%	84.74%
HUN	2003	43.85%	88.76%	USA	2003	78.69%	77.27%
HUN	2004	45.24%	89.19%	USA	2004	75.90%	88.19%
HUN	2005	57.96%	85.62%	USA	2005	78.68%	83.43%

HUN	2006	63.65%	94.23%	USA	2006	69.52%	81.63%
HUN	2007	65.97%	87.98%	USA	2007	77.55%	80.09%
HUN	2008	59.58%	85.97%	USA	2008	80.52%	81.98%
HUN	2009	56.14%	72.83%	USA	2009	78.58%	80.13%
HUN	2010	58.29%	88.28%	USA	2010	82.32%	82.70%
HUN	2011	57.67%	75.27%	USA	2011	83.08%	80.64%
HUN	2012	66.02%	85.32%	USA	2012	81.80%	82.65%
HUN	2013	73.80%	89.81%	USA	2013	82.84%	84.13%
HUN	2014	74.95%	85.94%	USA	2014	80.92%	80.22%
HUN	2015	81.93%	81.31%	USA	2015	81.29%	74.75%
HUN	2016	82.20%	80.20%	USA	2016	80.71%	82.83%
HUN	2017	82.84%	72.09%	USA	2017	82.35%	83.82%
HUN	2018	81.93%	77.28%	USA	2018	79.10%	88.79%
HUN	2019	83.95%	76.04%	USA	2019	84.48%	86.71%
ITA	2000	81.48%	83.94%				
ITA	2001						
ITA	2002	81.38%	89.04%				
ITA	2003	84.98%	88.77%				
ITA	2004	86.22%	80.44%				
ITA	2005	87.51%	85.07%				
ITA	2006	88.04%	83.65%				
ITA	2007	79.72%	86.11%				
ITA	2008	84.33%	85.99%				
ITA	2009	87.26%	75.36%				
ITA	2010	77.91%	81.51%				
ITA	2011	79.33%	76.88%				
ITA	2012	87.12%	75.92%				
ITA	2013	84.59%	81.96%				
ITA	2014	89.01%	81.90%				
ITA	2015	90.81%	82.63%				
ITA	2016	90.81%	79.95%				
ITA	2017	88.62%	80.45%				
ITA	2018	90.39%	84.51%				
ITA	2019	90.54%	82.94%				

DISSERTATION PROJECT
Name: **Jiayi Zeng**
Programme: **IMESS**
E-mail: tjmsjze@ucl.ac.uk
Academic year: **2021/2011**
Dissertation title: Intra-industry trade and human capital endowment a case of EU-CEE trade
Expected date of submitting: **2/8/2022**
Head of the Seminar: **doc. PhDr. Jiří Vykoukal, CSc.**
Supervisor: **Ing. Vilém Semerák, M.A., Ph.D.**
Title:
Short description of the topic: **To assess the effect of human capital endowment on intra-industry trade between CEE countries and the EU, this paper used trading data from 2000-2019 in the machinery sector between the Visegrad and Germany as the representative. Meanwhile, this paper used secondary and tertiary educational attainments separately as the proxy for human capital endowment and included other factors influencing intra-industry trade. Before the econometric regression, a descriptive statistical analysis was carried out, and we recognized that the intra-industry trade between the CEE countries and the EU is of vertical nature. According to regression results, we found that the domestic market size and the difference in economic mass had a positive relationship with the intra-industry trade of CEE countries. Similarly, the GDP per capita was positively correlated to intra-industry trade in this area. In addition, geographical distance and contiguity levied significant impacts on intra-industry trade of CEE countries. However, the effect of EU membership was nonsignificant in our sample. More importantly, secondary and tertiary educational attainments had opposite influences on intra-industry trade between CEE countries and the EU, which implies that although they have high educational attainments, the CEE countries occupied the lowest quality market segments in Europe**
Proposed structure: **Abstract** **Table of Contents** **Introduction** **Literature review** **Methodology** **Results & Discussion** **Conclusion** **Bibliography** **Appendix**
Sources (basic selection):

World Bank databank, CEPII databases, Eurostat