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Effects of the European Monetary Union on High-Technology Exports

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Abstract
Our study estimates the effects of the European Monetary Union (EMU) on high-technology (HT) export and assesses the potential knowledge spillovers of such trade. Irrespective of the importance of the HT trade channel, none of the previous studies in the literature focus on the effects of a common currency on HT trade. Increasing trade in the HT sector may lead to more efficient use of resources and help countries to move towards a knowledge-based economy. Moreover, it may lead to higher overall growth. After considering multilateral resistances, pair fixed effects and bias correction in the preferred (three-way bias-corrected) model, EMU membership becomes negative and statistically non-significant for HT exports. Furthermore, our findings indicate that the effect of the EMU on HT exports is country-specific, which lends support to the notion of non-homogenous knowledge transfer and country-related knowledge-based economic development within the EMU.

Keywords Trade · Exports · European Monetary Union · High technology · Knowledge-based economy · Poisson Pseudo-maximum Likelihood

1 Introduction

The impact of the common currency on trade has generated an extensive amount of research since the seminal paper of Rose (2000). Irrespective of this interest, some important topics

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remain unanswered. The impact of the common currency on sectoral trade, especially on trade in the high-technology (HT) sector, is unknown despite the vital role of this sector in the economic performance of the EU. This study endeavours to fill this gap by estimating the impact of the Euro on HT trade between EU member countries.

HT trade is related to the policy goals of the EU. The development of a knowledge-based economy and new technologies has assumed the utmost importance, especially in Europe, as stated in the Lisbon Strategy (Audretsch et al. 2009). One goal of the Lisbon Agenda was to transform the EU into the world's most competitive and most dynamic knowledge-based economy by 2010. Moreover, Dohse and Soltwedel (2006) argue that by adopting the European policy strategy of producing a competitive knowledge economy, most European countries have focused on research and development (R&D). Thus, the evolution of the HT sector is of essence for the future of the EU and is a core part of the EU strategy. One of the major welfare implications behind the common currency, the Euro, was the boost in trade, which would result in output growth. Typically, previous studies estimated only the impacts of the EMU on total trade. However, since the HT sector plays a special role in boosting productivity and increasing welfare and lies the heart of the EU policy itself, it is important to examine how the common currency has affected HT trade specifically. We expect that this trade could play an important role in technology transfer between member nations and boost their outputs. Moreover, asymmetries in HT trade can provide information about the sectoral convergence/divergence among member countries, which is highly relevant for the success of the Euro, and by extension, the common monetary policy.

2 Motivation of the Study: Relation of HT Trade to the EMU

Godin (2004) state that the concept of "high tech" has become popular in member countries of the Organisation for Economic Co-operation and Development (OECD), as OECD itself actively promotes high technology as the new foundation of competitiveness and a symbol of an advanced knowledge-based economy. Moreover, the HT sector is closely related to the complexities of the economy and production (see Hausman et al. 2013). The economic complexity of a nation comprises many traditional determinants of economic growth, such as education and R&D. Grossman and Helpman (1991), Romer (1992), and Barro and Sala-i-Martin (1995) propose that countries that are more open to the rest of the world have a greater ability to absorb the technological advantages generated in leading nations. This suggests that the more open the economy of a nation, the higher its factor productivity. Trade in terms of HT goods may thus provide an extra boost for national welfare. In this study, we explicitly estimate the effects of the common currency, namely the EMU, on HT trade between the EU member countries.

The effects of the EMU on aggregate trade have been researched ever since the launch of the common currency (for a survey, see, e.g., Baldwin 2006). An increase in trade due to the adoption of a common currency further increases welfare (Frankel and Rose 2002). We contribute to this relatively large body of the literature by providing new insights. We use ex-post data and provide the very first estimates of the effects of the EMU on HT trade in particular. We also try to reveal the possible asymmetries in the reactions of the countries involved in HT trade in the EMU. In this study, we explicitly examine how the adoption of the common currency affected the exports of the HT sectors between EU member

countries.[1] In previous works, the HT sectors are aggregated with the entire trade volumes between countries; thus, HT trade has not been examined in previous studies that assessed the impacts of Preferential Trade Agreements (PTAs) or the common currency on trade. This is a serious shortcoming, since HT sectors play a potentially important role in the growth of nations, given that an overall increase in trade boosts growth.

Krugman (1979) points out how trade allows technology to become available to the less high tech countries as well, thus increasing global productivity. It is expected that the competitiveness of a given HT sector will become evident according to the amount of trade with it. Both innovations in a high-tech country and technology transfer via trade increase global output. Thus, technology and knowledge are acquired through more frequent trade, and an examination of the trade effects of the EMU on HT trade within the EU would provide valuable insights.

Moreover, valid empirical evidence shows that the technology gap between trading partners may not be too wide. Filippini and Molini (2003) provide evidence from Asia, showing that the HT gap may also decrease the amount of trade. If both trade partners have similar technological capabilities, a high volume of intra-industry trade is expected. This similarity hypothesis is consistent with predictions by both the neoclassical and new trade theories. In effect, they propose that technological level would impact the size of HT exports. If the trade partners shared a similar enough technological level, the extraction of trade barriers would enlarge the HT trade. On the other hand, if the technological levels of the trade partners are very dissimilar, it is likely that the increase in trade will occur for more traditional goods. The increases in productivity and output are smaller in the latter case. In this study, we also provide country-level estimates of the impacts of the EMU on HT trade.

A large number of studies have examined the impacts of PTAs on global trade (see, e.g., Frankel 1997). As per the overall inference concerning PTAs for Europe, the trade flows are mostly explained by the EU members' sizes, development levels, proximities as well as sharing a common language and borders. Frankel and Wei (1993) report that the stabilisation of bilateral exchange rates in the 1980s under the exchange rate mechanism of the European monetary system might be partly responsible for the increase in intra-European trade. The EC effect became statistically significant from 1985 onwards. Estimates suggest that intra EC trade exerts an effect of approximately 65%, with the memberships in 1973 and 1983 each boosting trade by half that amount (Frankel 1997).

Frankel (1997) also stresses the significance of disaggregated data. Trade in manufactured goods and agriculture was significantly boosted within the EU countries due to trade agreements. The Treaty on European Union, which was signed in Maastricht in 1992, led to the establishment of the EU. It initiated a common market for the whole EU area, wherein not only trade and services, but also labour and capital were free to move without barriers. All these agreements had significant impacts on trade and

[1] The control group consists of EU members. Its purpose is to control the effects of membership to the EMU (and ensure EU policy harmonisation in general (see, e.g., Baldwin 2006; Flam 2009). Thus, we do not examine trade creation or diversion with respect to countries outside the EU zone. This could be of importance, as Carrere (2006) found that most trade agreements resulted in an increase in intra-regional trade beyond the levels predicted in the gravity models which were often coupled with a reduction in import and export from the rest of the world, suggesting evidence of trade diversion. Trade diversion is highly likely; for example, in 2019, HT products represented 19% of the total extra EU imports and 18% of the total extra EU exports. China ranked first for HT imports to the EU, ahead of the US and the UK. The US ranked first in terms of EU exports of HT products, followed by China and the UK (Eurostat, April 2020).

welfare. Cecchini (1988) and Baldwin (1989) estimate that by the end of the century, the gross national product of the EU increased by 2.5–6.5% as the result of the creation of the single market in 1992. Notably, the establishment of the single market has helped increase market efficiency as well as capital and labour market flows. Increasing economic integration finally led to the establishment of an economic and monetary union. The third stage of the EMU was launched on 1 January 1999. Its creation was the final stage of the EU integration process. Berger and Nitsch (2008) propose that the EMU can be regarded as a continuum or culmination of the economic integration preceding the introduction of the Euro. The European Commission (1990) reports the potential benefits and costs of forming an economic and monetary union. Two of the major expected gains of the monetary union were the elimination of both transaction costs connected to exchange rates and the uncertainties caused by exchange rate fluctuations. Flam (2009) state that the elimination of currency transaction costs and the uncertainty connected to exchange rates produce an effect similar to that caused by a productivity increase in firms, thus stimulating trade (as a common currency affects the intensive as well as extensive margins of trade). These direct gains increase capital stock, which also leads to dynamic indirect gains. To summarize, the benefits are expected to outweigh the disadvantages. However, no attempts have been made to estimate the effects of the EMU on trade in HT sectors which, as per growth theories, could be of particular economic importance.

The European Free Trade Association (EFTA), creation of the EU and the PTAs that followed aimed to boost trade between member countries. Our study focuses only on the effects of this final step of the integration process, namely the EMU membership, on trade. There are several reasons for this choice. First, the benefits of EMU membership have been a topic of active research during the last two decades, but all the studies have ignored the potentially significant role of HT trade. That is, we lack information about the effects of the EMU on trade in the HT sector. It is also interesting to assess to what extent trade in the HT sector explains EMU membership. In effect, using dummies on the right-hand side of the gravity equations and assuming them as exogenous might be misleading and bias the results, since memberships are not random variables but are likely to reflect endogeneity in trade agreements for reasons not observable but correlated with the level of trade. This might bias the results. Magee (2003) points out that countries are likely to be preferential trade partners if they undertake significant bilateral trade, are similar in size and are both democracies. Baier and Begstrand (2004) lend support to this notion by providing empirical evidence that the variables of typical gravity equation explain the likelihood of having a free trade agreement (FTAs). Moreover, Egger et al. (2011) note that ignoring the problem of endogeneity leads to biased estimates of the impacts of PTAs on trade. Joining the EMU is a long process of convergence which lasts for several years (as defined in the Maastricht Treaty). Among others, pre-membership countries must adhere to specific currency-related mandates as per the European Exchange Rate Mechanism (ERM) target zone. In effect, joining the EMU could have already exerted some effects caused by the lower exchange rate volatility and expectations of the EMU membership.

To sum up, in this study, we answer two main research questions:

- What are the overall effects of the EMU on HT exports?
- Are the effects of the EMU on HT exports alike across different countries?

We approach these questions by applying the traditional gravity model. Gravity models have been widely used to infer the effects of custom unions, exchange rate mechanisms, ethnic ties, linguistic identities and international borders on trade flows (Anderson and van Wincoop 2003). Empirical evidence from the ex ante evaluation of the effects of the EMU lend support to the positive impact of the common currency on trade between countries sharing this currency[2]. However, the early empirical applications of the gravity equation have also encouraged criticism[3], typically regarding the estimation strategies and methods that produce excessive estimates of the degree to which trade might increase.

We contribute to the literature in multiple aspects. We focus on the impacts of the common currency on HT exports. Thus, this paper provides a new and topical viewpoint for the trade literature by examining the possible channel of the growth effects of trade, particularly HT trade. We also use novel bias correction on two- and three-way PPML estimations. Our study disentangles the heterogeneous effects of the Euro on HT trade between the Euro area member countries. Our results indicate that the impact of the EMU on HT exports is close to zero, which is in line with the novel trade studies (see, e.g., Santos Silva and Tenreyro 2010; Camarero et al. 2014; Berger and Nitsch 2008). Our study also reveals some new insights; the EMU increases exports in HT sectors, but not unanimously across all member economies, indicating that knowledge spillover and diffusion via trade might not be evenly dispersed among the member states.

Our findings lend support to the notion that EMU membership has significantly expanded HT exports between some member countries. We interpret this finding as the execution of the Lisbon Strategy creating a competitive and dynamic knowledge-based economy in the EU. However, the finding on HT trade was not unanimous for all EMU membership countries. The non-unanimous reaction across the member economies suggests that knowledge spillover and diffusion via trade might not be evenly dispersed between the member countries. Moreover, assuming the effects of HT trade on the growth and production structure of the member countries might lead to differences in the production structure and non-synchronous economic shocks, which might further challenge not only the homogeneity of the production structure between member countries, but also the success of the common monetary policy.

We also analyzed the effects of the EMU on *total exports*. The results of this study lead us to argue that the overall EMU variable is positive and statistically significant, indicating that EMU membership increases *total exports*. Thus, EMU membership is an important determinant of *total exports*, which is in line with the results of previous meta-analyses (e.g., Head and Mayer 2014). As a consequence, countries sharing a common currency are likely to trade compared to those with different currencies.

The remainder of this paper is organized as follows. Section 3 discusses the connections between the gravity model and trade. Next, the model and variables are presented, followed by a description of the empirical results. The final section presents the conclusions along with a discussion of the potential implications and limitations of this study.

[2] See, for instance, Rose (2000), Rose and van Wincoop (2001), Glick and Rose (2002, 2016), Nitsch (2001), Flam and Nordström (2007) and De Nardis et al. (2008).

[3] For criticisms of the Euro's trade effects and reviews of the most significant empirical studies on the topic, see, for example, Baldwin (2006) and Baldwin and Taglioni (2007).

3 The Gravity Model and Trade

The gravity model of international trade is commonly employed for analysis of trade flows between countries[4]. The simplest model explains trade flow between two countries through their Gross Domestic Products (GDPs; size) and the distance between them. Gravity models typically utilize additional explanatory variables that are important from the perspective of the phenomenon in question. The impacts of PTA on trade flows are predominantly analyzed with this equation. However, studies about the effects of the EMU on HT trade and exports are lacking.

Kepaptsoglou et al. (2010) report the results of a meta-analysis of the empirical studies of trade flows and FTA effects during 1999–2009. Many works, such as Rose (2000), Glick and Rose (2002) and Egger (2004), have analyzed whether trade agreements, currency unions or common markets create or divert trade[5]. Gravity models have also been applied to research on trade policy implications and factors affecting trade flows, such as the monetary union (e.g., the EMU)[6], foreign direct investments[7], border effects[8], domino effects[9], and transportation costs[10]. The effects on trade of specific products have been studied by certain authors, such as Flam and Nordström (2003), Kangas and Niskanen (2003) and Sarker and Jayasinghe (2007)[11].

Earlier studies on the trade effects of the EMU note that its impact on trade between countries sharing a common currency is positive. Baldwin (2006) report these effects to range from 5–10%[12] in these studies. Furthermore, Disdier and Head (2008) analyze 1467 distance effects (103 articles) as part of their meta-analysis and report that the negative effect of distance remained high after the mid-20th century. Head and Mayer (2014) augment their dataset using up to 159 papers and over 2500 estimates before conducting a meta-analysis[13]. Their results reveal that GDP elasticities are close to unity, but the GDP elasticity of the destination country is slightly lower (0.84) than the GDP of the originating country. Additionally, the distance elasticity is close to –1 (–0.93). Membership in the EU is associated with a mean coefficient of approximately 0.14. The

[4] Head and Mayer (2014) suggested that this is due to three factors: 1) researchers realised that a large portion of trade data is missing and that gravity models could be used to estimate the missing values, 2) various studies established the relationship between fixed effects in gravity models and varied underlying theories and 3) a convergence gradually occurred, helping scholars connect the dots between the gravity model and the literature concerning heterogeneous firms.

[5] The main results of selected studies on currency union effects are summarised in Appendices 2–4.

[6] See, for instance, Bun and Klaassen (2007). However, Aristotelous (2008) argue that the earlier literature typically studies trade as a whole and pays less attention to individual country effects. Head and Ries (1997) examine the effects on Canadian industries of the Canada–US FTA following its introduction in 1988. Only a few papers, notably Micco et al. (2003) and Aristotelous (2006, 2008), concentrate on studying whether an EMU effect is evenly widespread among EMU members. Arghyroy (2000) analyse the trade effects of the accession of Greece to the EU.

[7] See, for example, De Sousa and Lochard (2011) and Coeurdacier et al. (2009).

[8] See, for instance, Nitsch (2000) and Head and Mayer (2002).

[9] See, e.g., Sapir (2001). The domino effect means that increased integration within FTA members negatively impacts non-members and speeds up their membership applications.

[10] See, for example, Egger (2008).

[11] Some works focus on the determinants of trade in the used manufacturing/machine sector. Examples include Bond (1983), Mainwaring (1986), Navretti et al. (2000) and Pelletiere and Reinert (2004).

[12] Frankel (2008) argue that the effects of the Euro on trade are typically estimated to be smaller than the trade effects of other currency unions. This is not due to country size, lags (the EMU is younger than other currency unions) or reverse causality. Instead, they attributed these differences to sample size. Thus, the Euro's trade effects expand with a larger numbers of countries and over longer periods.

[13] They extend the distance estimates sample and also analyze estimates other than distance. Their set of new papers augments Disdier and Head's (2008) sample by assessing all papers published in the top five journals, including the *Journal of International Economics* and the *Review of Economics*.

effects of a common currency on trade, estimated in terms of the mean over 104 estimates by Head and Mayer (2014), is found to be 0.79, which indicates a doubling of trade[14]. Glick and Rose (2016) corroborate these results by estimating that membership to the EMU boosts export by approximately 50%.

Also, in contrast with earlier studies as well as the reported trade effects of other currency unions, Santos Silva and Tenreyro (2010) determine that impact of the EMU on trade is close to zero. They explain these results by highlighting that Euro zone countries have historically traded more intensely than other country groups. Camarero, Gómes and Tamarit (2014) posit that the creation of the EMU is best interpreted as a progression of policy changes which decrease the explicit effects of the Euro on trade. Furthermore, Berger and Nitsch (2008) and Mika and Zymek (2018) report similar results, namely, no significant Euro trade effects.

4 Modelling and Variables

In this study, HT sectors are based on the classification used by the OECD STAN BTDIxE Bilateral Trade Database (see Appendix 1). The data comprise the BTDIxE with the exports and imports of goods broken down by industry (trade values are broken down using the 3rd revision of the International Standard Industrial Classification, ISIC Rev. 3) and end-use categories simultaneously (Zhu et al. 2011). The data in the fourth version are maintained and updated by the OECD and are estimates of imports and exports from OECD member as well as a large number of non-OECD countries. The data are expressed in US dollars[15] and cover the years from 1990 to 2019 for several countries.

Our data cover 27 EU member countries[16] and the period of 1995–2019 because of lack of data for all the EU countries examined before 1995. The review period also limits the analysis to the period prior to the impact of the Euro crisis. Moreover, limiting the data to after 1992 is logical, since the EU changed its method of collecting trade statistics in 1993 (Baldwin 2006). However, we believe that the available data are sufficient (time is needed for adjustment) to reveal the Euro's effects on trade.

4.1 Econometric Specifications and Variables

The gravity equation employed for the econometric analysis to estimate the effects of the EMU on overall bilateral (HT) trade (exports + imports) is as follows:

[14] Head and Mayer (2014) argue that this average is larger than the preferred novel estimates (see Baldwin 2006) even though it is lower than the effect reported by Rose (2000), which indicates a tripling of trade due to the common currency. The referenced common currency trade estimates apply to common currency agreements in general and are not specific to the EMU.

[15] Baldwin (2006) note that the common method uses real variables in order not to estimate the trend. However, Baldwin (2006) argue that using US dollars would be reasonable, and deflation of nominal trade and GDP values using the US price index is inappropriate. Furthermore, by including dummy time variables, the mistaken deflation process can be corrected, because all bilateral trade and GDP values are divided by the same price index value.

[16] The data of the following countries are used: Austria, Bulgaria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden, and the UK. Thus, our data consist of only EU member countries.

$$\ln(E_{ijt}) = \beta_0 + \beta_1 \ln(Y_{it}) + \beta_2 \ln(Y_{it}) + \beta_3 \ln(D_{ij}) + \beta_4 EU_{ijt} + \beta_5 EMU_{ijt} + \beta_6 \text{COMBORD}_{ij} + \beta_7 \text{COMLANG}_{ij} + \beta_8 \text{COLONY}_{ij} + \varepsilon_{ijt} \quad (1)$$

where ln denotes a natural logarithm, i and j refer to the two countries being analyzed, t refers to the specific year in the period from 1995 to 2019, and ε is the error term. E denotes the dependent variable (i.e., the US dollar value of HT trade between countries i and j in period t).

The sizes of the reporting and partner countries are typically measured using per capita income, income, population or population density. The first independent variables, Y_{it} and Y_{jt}, denote the GDPs[17] of countries i and j, and they are supposed to capture the effects of economic size on trade (and exports). Table 1 presents the independent variables. Bigger countries (in terms of population, GDP or GDP/capita) create the potential for higher demand for foreign products. Krugman (1980) argued that countries with bigger home markets also enjoy larger exports. Therefore, Y_{it} and Y_{jt} are expected to affect trade positively.

Transportation costs, such as tariffs and infrastructure performance, are found to affect trade flows. Reliable data concerning transport costs are usually unavailable, and these costs are thus approximated using the physical distances between trade partners. Let D_{ij} indicate the simple distance between the most important cities. Distances are calculated using the latitudes and longitudes of these cities[18]. A negative relationship between distance and trade flow is expected, the assumption being that bigger distances involve extra time and effort and entail higher costs (i.e., transport costs rise, making the trade of goods and services between countries more difficult).

Common explanatory variables in the gravity models include factors indicating barriers to trade (e.g., different language, borders and cultural heritage; lack of past colonial relationships and the same country serving as the reporting and partner country). A dummy variable of countries sharing a border (COMBORD_{ij}) is used. This variable takes the value one if the trading partners share a border and zero otherwise. Moreover, a dummy variable for countries sharing a common official language (COMLANG_{ij}) is often used, which takes the value one if trading partners share a common official language and zero otherwise. A dummy variable of countries with past colonial relations (COLONY_{ij}) is applied, and it takes the value one if the trading partners ever had colonial relations and zero otherwise.

Participation in custom unions or trade agreements is of great interest, since the seminal study by Rose (2000) reports that countries belonging to the same currency union traded three times more than countries not sharing the same currency. Augmenting gravity models with dummy variables, following the approach of Rose (2000), is now common practice to control the effects of factors such as EU membership. EU_{ijt} is a dummy variable describing membership to the EU. It takes the value one when both countries i and j are members of the EU and zero otherwise. In earlier studies, countries belonging to the same trade association reportedly trade more frequently. Thus, we suppose that a common EU membership has a positive effect on HT trade.

[17] Source: The World Bank's World Development Indicators. GDP values are converted to international dollars using purchasing power parity rates. Inclusion of exchange rate variables is quite rare in gravity models (see, e.g., Baldwin 2006). Furthermore, Baldwin (2006) argue that there is little difference in the results even if the exchange rate variables (sometimes used in the literature) turn out to be significant, because they arise from a correlation between themselves and the time residual for the relative prices term. We do not use exchange rate variables in our study.

[18] See Mayer and Zignago (2005).

Table 1 Definitions of variables

Variables	Definitions
E_{ijt}	Dependent variable, HT trade (thousands, US$) or HT exports (× 100 US$)
GDP reporting	GDP of reporting country
GDP partner	GDP of partner country
Distance	Distance between the respective pairs of countries
EU membership	Membership in the EU 1 = both countries i and j are members of the EU 0 = otherwise
EMU overall	Membership in the EMU[a] 1 = both countries i and j are members of the EMU 0 = otherwise
COMBORD	Common border 1 = countries share a common border 0 = otherwise
COMLANG	Share a common official language 1 = countries share a common official language 0 = otherwise
COLONY	Have ever had a colonial relations (linkages) 1 = countries have had colonial relations 0 = otherwise
EMU Austria	Membership in the EMU 1 = Austria and the other country, j, are members of the EMU 0 = otherwise

The Treaty on the European Union was signed in Maastricht in 1992, and it led to the establishment of the EU. One of the community's goals was the creation of a common market. Increasing economic integration finally led to the establishment of economic and monetary union. The third stage of the EMU was launched on 1 January 1999 in 11 EU countries: Austria, Belgium, Finland, France, Germany, Italy, Ireland, Luxembourg, the Netherlands, Portugal and Spain. Greece joined the EMU on 1 January 2001. Since the birth of the EMU-12 (the first 12 members), Slovenia (in 2007), Cyprus (in 2008), Malta (in 2008), Slovakia (in 2009), Estonia (in 2011) and Latvia (in 2014) have joined the group. However, several EU members have not adopted the Euro as their currency, namely the Czech Republic, Denmark, Hungary, Poland, Sweden and the UK (which have been EU members since 1 May 2004, 1973, 1 May 2004, 1 May 2004, 1995 and 1973, respectively). Thus, adequate data exist with regard to members and non-members in the third stage of the process, which harmonised the economic and monetary policies of the EU members by introducing a single currency (the Euro) and fixing exchange rates.

The dummy EMU variable is designed to capture pairs of countries which use the Euro as their currency. It takes the value zero whenever at least one of the countries is not a member of the EMU.

In most trade studies, the effect of the EMU is positive, meaning that countries sharing a common currency are more likely to trade compared to those with a different currency. Furthermore, Aristotelous (2008) argue that EMU effects on trade might be realized through the following three key elements: 1) lower transaction costs, 2) elimination of exchange rate volatility (uncertainty), and 3) enhanced competition. Our purpose is to estimate the impacts of these elements on HT trade. We use the ordinary least squares (OLS) estimation and the Poisson pseudo Maximum Likelihood (PPML) estimator in our analysis of HT exports.

Logarithmic transformations in OLS estimations suffer from one problem; the zero values of bilateral exports are excluded from the analysis. Santos Silva and Tenreyro (2006) argue that this issue could be addressed by a multiplicative form of the gravity equation, and they propose the so-called PPML technique. Furthermore, the traditional approach of taking logarithms to linearize the gravity equation alongside using the OLS estimation may lead to situations where the error term variance depends on regressors creating heteroscedasticity problems. This issue could also be addressed by the PPML technique (Santos Silva and Tenreyro 2006, 2010). Thus, the PPML

approach can take account of information in zero trade flows. It also considers heteroscedasticity (Santos Silva and Tenreyro 2006; Yotov et al. 2016).

Head and Mayer (2013) argue that heteroscedasticity is a minor concern in logarithmic standard old regressions. In their opinion, the main problem with linear logarithmic regressions is the possibility of inconsistent estimates. Head and Mayer (2013) propose that using the PPML approach instead leads to consistent estimates when the dependent variable takes zero values frequently (see also Santos Silva and Tenreyro 2006, 2010). Thus, "the PPML estimator can be used to estimate theory-consistent general equilibrium effects of trade policies" (Yotov et al. 2016). First, we estimate the EMU membership effects on HT exports.

5 EMU Effects on HT Exports

5.1 OLS Estimation Without Multilateral Resistance Terms

We analyze the effects of the EMU on bilateral HT exports. We start our analysis with the OLS estimation including standard gravity variables. The multilateral resistances are not taken into account in the standard OLS model. The following model is used.

$$\begin{aligned}\ln\left(E_{ijt}\right) = {} & \beta_0 + \beta_1 \ln(Y_{it}) + \beta_2 \ln(Y_{it}) + \beta_3 \ln\left(D_{ij}\right) + \beta_4\left(EMU_{ij}\right) + \beta_5\left(EU_{ij}\right) \\ & + \beta_6 \mathrm{COMBORD}_{ij} + \beta_7 \mathrm{COMLANG}_{ij} + \beta_8 \mathrm{COLONY}_{ij} + \varepsilon_{ijt}\end{aligned}$$

where $\ln(E_{ijt})$ denotes the logarithm of bilateral international exports from exporter i to importer j at time t. Table 1 shows the independent variables. The model errors for the trading partners may be correlated. However, the model errors for countries belonging to different trading country pairs are assumed to be uncorrelated. As a consequence, the standard errors are clustered by exporter-importer.

Table 2 (Model 1) explains approximately 73% of the variance in the dependent variable which can be considered as a strong fit. Overall, our model is in line with the findings of the earlier literature. However, the overall EMU variable is non-significant. The model does not consider multilateral resistances with a set of exporter-time and importer-time fixed effects.

5.2 Estimations with Multilateral Resistance Terms

Barriers to trade exist between pairs of countries (termed as bilateral trade resistance). Moreover, one should take note of the barriers to trade that every country faces with all its trading partners (namely multilateral trade resistance). We try to take account of the multilateral resistances in our analysis with a set of exporter-time and importer-time fixed effects. Yotov et al. (2016) argue that exporter-time as well as importer-time fixed effects consider the exporter's and importer's GDPs and other exporter- and importer-specific (observable and unobservable) characteristics influencing bilateral trade (see also Anderson and van Wincoop 2003). Our OLS model is as follows:

$$\begin{aligned}\ln\left(E_{ijt}\right) = {} & \beta_1 In\left(D_{ijt}\right) + \beta_2\left(EMU_{ijt}\right) + \beta_3\left(EU_{ijt}\right) + \beta_4 COMBORD_{ijt} + \beta_5 COMLANG_{ijt} \\ & + \beta_6 COLONY_{ijt} + \pi_{it} + x_{it} + \varepsilon_{ijt}\end{aligned}$$

Table 2 Estimates of the EMU's effects on HT exports[a], OLS estimations

	Pooled OLS (1)	Pooled OLS (2)	Pooled OLS (3)	Pooled OLS (4)	Pooled OLS (5)
Ln GDP (reporting)	1.140***	–	–	–	–
Ln GDP (Partner)	0.848***	–	–	–	–
Ln distance	–1.223***	–1.257***	–1,575***	–	–
EU membership	1.054***	0.696***	0,198	0.198	–
EMU overall	0.106	0.161	–0,140	-0.140	-0,129
Common border (share a border)	–0.089	–0.014	2,972***	–	v
Share a common language	0.394	-0.049	1,326***	–	–
Have ever had a colonial relations	0.854***	0,664**	3,544***	–	–
Asymmetric Country-pair id effects	no	no	yes	yes	yes
Exporter time fixed effects	no	yes	yes	yes	yes
Importer time fixed effects	no	yes	yes	yes	yes
Observations	17855	18287	18287	18287	18287
R^2	0.731	0.863	0,917	0,917	0,916
Constant	–33.554***	11.766***	17,589***	4,259***	4,499***

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

where $\ln(E_{ijt})$ denotes the logarithm of bilateral exports from exporter i to importer j at time t. π_{it} denotes a vector of exporter-time fixed effects, and χ_{jt} a set of importer-time fixed effects. π_{it} and χ_{jt} are intended to capture outward multilateral resistances and inward multilateral resistances, respectively. Both fixed effects will absorb the exporter value of output and importer expenditures as well as other observable and unobservable exporter and importer characteristics affecting bilateral trade (see Yotov et al. 2016). Standard errors are clustered by exporter-importer.

For the OLS estimations, we used exporter-time and importer-time fixed effects (Model 2 in Table 2) to control for the unobservable multilateral resistances and characteristics varying over time for the exporters and importers (Anderson and van Wincoop 2003; Yotov et al. 2016). The R^2 value is even higher (0.863) compared to that of the traditional OLS model (Model 1). The estimates of distance are higher compared to that of the traditional OLS model. The overall EMU effect is higher compared to that in Model 1, but the coefficient is non-significant. After including the pair fixed effects, the overall EMU variable becomes negative but remains statistically non-significant (Models 3–5 in Table 2).

We also use the PPML estimator in our analysis (Models 1–6 in Table 3). As stated previously, this estimator can account for the information in zero trade flows as well as heteroscedasticity (Santos Silva and Tenreyro 2006; Yotov et al. 2016). We include pair fixed effects with panel trade data in our gravity and PPML estimations. The pair fixed effects consider the observable and unobservable time-invariant trade costs of bilateral trade. Thus, unobservable trade policy connections with the gravity model error term (or unobservable cross-sectional trade costs) are controlled for with country pair fixed effects. Yotov et al. (2016) consider an example of reverse causality, where a country liberalizes its trade with another country which has been its meaningful trading partner. Thus, the pair fixed effects are supposed to account for the endogeneity of trade policy variables. They also consider the time-invariant bilateral trade costs (Baier and Bergstrand 2007; Yotov et al. 2016).

Table 3 Estimates of the EMU's effects on HT exports[a], PPML estimations

Dependent variable is HT exports	PPML (1)	PPML (2)	PPML (3)	PPML bias-corrected two-way (4)	PPML bias-corrected three-way (5)	PPML bias-corrected three-way (6)
Ln GDP (Reporting)						
Ln GDP (Partner)	–	–	–	–	–	–
Ln distance	-0.388***	–	–	-0.388***	–	–
EU membership	0.434*	–0.133	–	0.434*	–0.159	–
EMU overall	0.158	-0.042	-0,046	0.158	-0.050	–0,055
Common border (share a border)	0.242***	–	–	0.242**	–	–
Share a common language	-0.018	–	–	-0.018	–	–
Have ever had a colonial relations	0.337**	–	–	0.337*	–	–
Asymmetric Country-pair id effects	no	yes	yes	no	yes	yes
Exporter time fixed effects	yes	yes	yes	yes	yes	yes
Importer time fixed effects	yes	yes	yes	yes	yes	yes
Observations	18287	18287	18287			
R^2	0.941	0.985	0.985			
Constant	21.430***	19.767***	19.640***			

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

The model in multiplicative form is expressed as follows:

$$E_{ijt} = \exp\left(\beta_1 In(D_{ijt}) + \beta_2(EMU_{ijt}) + \beta_3(EU_{ijt}) + \beta_4 COMBORD_{ij} + \beta_5 COMLANG_{ij} + \beta_6 COLONY_{ij} + \pi_{it} + x_{it} + \varepsilon_{ijt}\right)$$

HT export is the dependent variable in the PPML estimations. Negative logarithmic values cannot be used in PPML estimations. The standard errors are clustered by exporter-importer.

After considering the exporter-time and importer-time fixed effects in the two-way gravity model, the overall EMU variable is positive and statistically non-significant (Model 1 in Table 3). Including pair fixed effects (Models 2 and 3) in our gravity estimations with panel trade data results in the sign of the beta coefficient of the overall EMU variable turning negative, and this value remains statistically non-significant.

It has been shown that PPML with two-way (exporter-time and importer-time) fixed effects and three-way (exporter-time, importer-time and country-pair) fixed effects has non-negligible biases (Weidner and Zylkin 2020). We also use bias correction in the PPML estimations (Models 4–6 in Table 3). The results show that the sign of the overall EMU variable in the two-way bias-corrected model (Model 4) is positive, and the value is statistically non-significant. The preferred specification (Table 3 in Model 6), namely the three-way bias-corrected model, shows that the sign of the overall EMU variable is negative, and its value remains statistically non-significant.

It is worth stressing that PPML estimations show negative and statistically non-significant overall EMU effects even after considering the bias correction (preferred model, namely Model 6 in Table 3).

Our preferred HT exports results are in line with those of Santos Silva and Tenreyro (2010), who determine that the impact of the EMU on trade is close to zero. They explain the results by highlighting that the Euro zone countries have historically traded more intensely than other country groups. Camarero, Gómes and Tamarit (2014) posit that the creation of the EMU is best interpreted as a progression of policy changes which decrease the explicit effects of the Euro on trade. Furthermore, Berger and Nitsch (2008) report similar results, namely no significant Euro trade effects.

Márquez-Ramos and Martínez-Zarzoso (2011) note that trade policy barriers are only one element of overall trade costs. They compare the reduction in trade barriers with improving trade facilitation as promoting trade. Moreover, their sectoral data analysis shows that the number of days and number of documents needed for trade as well as information technology achievements serve as factors promoting HT exports among developed countries. However, our data include the old lower-middle income Eastern Bloc countries (Gross National Income (GNI) between US$1,036 and US$4,045 as of 1 July 2020) and their upper-middle income counterparts (GNI between US$4,046 and US$12,535 as of 1 July 2020; see, e.g., World Bank 2020). As a consequence, our dataset consists of high-income countries as well as those for which factors other than trade facilitation might affect exports to a greater degree.

5.3 EMU Effects on HT Exports in EMU Member Countries: Two-Way Gravity Model Estimations

Next, we take a closer look at the effects of the EMU on HT exports in the EMU member countries. Tables 4 and 5 reveal how HT exports among the countries belonging to the EMU have changed since joining the monetary union. To sum up, these HT exports changed unevenly between 1999 and 2019, revealing how countries have gained from EMU membership.

EMU dummy variables are used. They take the value one whenever the reporting country shares EMU membership with the partner country. HT exports are the dependent variable for the PPML models. Each country is estimated separately. The original standard errors and bias-corrected standard errors of two-way gravity models are shown in Tables 6, 7, and 8. The beta coefficients differ across models, but the bias correction changes the standard errors of the coefficients. The standard errors are clustered by exporter-importer.

The results of the PPML models (Tables 6, 7, 8) show that after considering exporter-time and importer-time fixed effects, the effect of EMU membership on HT exports becomes negative and statistically significant after bias correction on standard errors for Slovenia and Slovakia. By contrast, HT exports increase for Ireland and Italy. However, the two-way models do not consider the potential endogeneity of the EMUs.

5.4 EMU Effects on HT Exports in EMU Member Countries: Three-Way Gravity Model Estimations

As stated previously, the two-way gravity models do not take account of potential endogeneity. Including the pair fixed effects into the models accounts for the endogeneity of the trade policy variables. Consequently, the variables of the standard gravity model that do not vary over time, such as distance, are excluded from the models. Again, each country is estimated separately, and the standard errors are clustered by exporter-importer pairs.

Table 4 HT exports change with non-EMU countries in 1995-1999 and with non-EMU and EMU countries between year of EMU membership (typically 1.1.1999) and 2019, %

Reporting country	Trade with countries by EMU membership	HT exports change before EMU membership %	HT exports change during the EMU membership %
Austria	non-EMU SUM	-54.9	117.4
Austria	non-EMU Mean	-28.4	310.6
Austria	EMUSum		206.8
Austria	EMUMean		70.5
Belgium	non-EMU SUM	-64.9	167.8
Belgium	non-EMU Mean	-44.2	405.8
Belgium	EMUSum		186.8
Belgium	EMUMean		59.4
Cyprus	non-EMU SUM	96.4	25.4
Cyprus	non-EMU Mean	307.9	81.2
Cyprus	EMUSum		1.6
Cyprus	EMUMean		-26.6
Estonia	non-EMU SUM	1445.5	-76.9
Estonia	non-EMU Mean	3412.6	-71.7
Estonia	EMUSum		44.6
Estonia	EMUMean		28.5
Finland	non-EMU SUM	-49.6	-72.7
Finland	non-EMU Mean	-20.0	-48.4
Finland	EMUSum		-60.0
Finland	EMUMean		-77.8
France	non-EMU SUM	-72.8	20.4
France	non-EMU Mean	-56.8	127.5
France	EMUSum		86.2
France	EMUMean		3.5
Germany	non-EMU SUM	-65.2	215.8
Germany	non-EMU Mean	-44.7	496.5
Germany	EMUSum		171.6
Germany	EMUMean		50.9
Greece	non-EMU SUM	-62.9	58.4
Greece	non-EMU Mean	-37.5	181.6
Greece	EMU SUM		1427.1
Greece	EMU Mean		833.2
Ireland	non-EMU SUM	-43.1	-7.8
Ireland	non-EMU Mean	-9.7	74.1
Ireland	EMUSUM		139.7
Ireland	EMUMean		33.2

The results of the PPML models (Table 9) considering exporter-time, importer-time and pair fixed effects show that none of the countries benefit from the monetary union (see also Tables 4 and 5; Appendix Fig 1). Table 9 reveals that for Latvia and the Netherlands our bias corrected estimates are negative and statistically significant. Latvia joined the EMU in 2014, and the Netherlands, in 1999. HT exports from Latvia to other countries grew rapidly from 1995 to 2014. However, after joining the EMU, the growth of HT exports to the EMU countries has been much slower. In particular, the data relating to the Netherland's EMU membership are quite long to reveal the effects of the third stage of the EMU process. For the Netherlands after EMU membership (both countries belong to the EMU), the growth of HT exports to EMU countries has been much lower compared to that to non-EMU countries (Table 5 and Appendix Fig 1).

Table 5 HT exports change with non-EMU countries, Luxembourg was removed, because there are no observations before Luxembourg's EMU membership in 1995-1999 and with non-EMU and EMU countries between year of EMU membership (typically 1.1.1999) and 2019, %

Reporting country	Trade with countries by EMU membership	HT exports change before EMU membership %	HT exports change during the EMU membership %
Italy	non-EMU SUM	-71.7	102.6
Italy	non-EMU Mean	-55.1	282.7
Italy	EMUSum		156.9
Italy	EMUMean		42.7
Portugal	non-EMU SUM	-78.3	229.5
Portugal	non-EMU Mean	-65.6	522.4
Portugal	EMUSum		123.8
Portugal	EMUMean		24.4
Slovenia	non-EMU SUM	1.7	43.9
Slovenia	non-EMU Mean	83.0	139.8
Slovenia	EMUSum		177.4
Slovenia	EMUMean		84.9
Spain	non-EMU SUM	-77.7	108.9
Spain	non-EMU Mean	-64.6	294.6
Spain	EMUSum		138.6
Spain	EMUMean		32.6
the Netherlands	non-EMU SUM	-77.5	205.4
the Netherlands	non-EMU Mean	-64.3	477.0
the Netherlands	EMUSum		147.7
the Netherlands	EMUMean		37.6
Latvia	non-EMU SUM	673.3	-70.8
Latvia	non-EMU Mean	1987.9	-67.6
Latvia	EMUSum		99.6
Latvia	EMUMean		88.6
Lithuania	non-EMU SUM	323.7	-0.8
Lithuania	non-EMU Mean	1171.0	-0.8
Lithuania	EMUSum		24.9
Lithuania	EMU Mean		24.9
Malta	non-EMU SUM	-77.4	24.3
Malta	non-EMU Mean	-56.5	65.7
Malta	EMUSum		14.0
Malta	EMUSum Mean		-17.7
Slovak republic	non-EMU SUM	193.6	27.3
Slovak republic	non-EMU Mean	560.6	69.7
Slovak republic	EMUSum		17.6
Slovak republic	EMUSum Mean		-2.0

Glick and Rose (2016) use a large sample of countries and a panel model with country-pair fixed effects to show that the effects of the EMU compared to those of other currency unions differ and that the EMU has boosted bilateral exports by approximately 50%. In contrast to this and other studies that show positive effects of the EMU on trade, we propose that it is difficult to identify a single, overall EMU effect on HT exports between countries. Our findings may be attributable to issues such as trade openness, the different levels of economic development of the studied countries or possibly larger effects of the EMU on other industries. Unfortunately, our data cannot provide a firm-level explanation. However, this study does offer novel evidence on the impacts of the EMU on the HT exports of the members of the monetary union.

Table 6 Estimates of the EMU's effects, Luxembourg was removed, because there are no observations before Luxembourg's EMU membership on HT exports[a], PPML two-way gravity models (exporter-time FE, importer-time FE)

Dependent variable is HT exports	beta	Original SE	Bias-corrected SE	Dependent variable is HT exports	beta	Original SE	Bias-corrected SE
Ln distance	-0.387	0.072***	0.088***	Ln distance	-0.386	0.072***	0.087***
Common border (share a border)	0.258	0.076***	0.097***	Common border (share a border)	0.259	0.077***	0.097***
Share a common language	-0.009	0.250	0.289	Share a common language	-0.020	0.285	0.328
Have ever had a colonial relations	0.294	0.145**	0.182	Have ever had a colonial relations	0.296	0.148**	0.185
EU membership	0.496	0.239**	0.256*	EU membership	0.496	0.239**	0.256*
EMU Austria	0.046	0.285	0.340	EMU Belgium	0.071	0.239	0.274
constant	21,436***			constant	21,425***		
R^2	0,941			R^2	0.941		
Ln distance	-0.386	0.072***	0.087***	Ln distance	-0.384	0.071***	0.087***
Common border (share a border)	0.258	0.076***	0.096***	Common border (share a border)	0.259	0.076***	0.097***
Share a common language	-0.008	0.249	0.287	Share a common language	-0.007	0.249	0.287
Have ever had a colonial relations	0.293	0.144**	0.181	Have ever had a colonial relations	0.290	0.144**	0.181
EU membership	0.497	0.239**	0.256*	EU membership	0.499	0.239**	0.256*
EMU Cyprus	0.277	0.530	0.561	EMU Estonia	-1.547	1.582**	1.815
constant	21,428***			constant	21,415***		
R^2	0,941			R^2	0.941		
Ln distance	-0.386	0.072***	0.087***	Ln distance	-0.386	0.072***	0.087***
Common border (share a border)	0.258	0.076***	0.096***	Common border (share a border)	0.258	0.076***	0.096***
Share a common language	-0.008	0.249	0.287	Share a common language	-0.008	0.249	0.287
Have ever had a colonial relations	0.292	0.144**	0.181	Have ever had a colonial relations	0.292	0.144**	0.181
EU membership	0.497	0.239**	0.256*	EU membership	0.497	0.239**	0.256*
EMU Latvia	0.114	0.478	0.520	EMU Lithuania	0.500	0.585	0.605
constant	21,429***			constant	21,430***		
R^2	0.941			R^2	0.941		

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.Each country is estimated separately. Standard errors are clustered by exporter-importer

5.5 Using EMU Partnerships as the Leading Indicator

We also move the EMU values (EMU series) one and two observations backwards (leading indicator). Table 10 (Models 5 and 6) show that the EMU did not affect HT exports one year before the real EMU partnership came into being. We also analyze if the EMU affected HT exports 2 years before the real EMU partnership (Table 11). Our bias-corrected three-way gravity modelling results show that the EMU partnership dummy variable is negative and statistically significant, indicating that EMU would have affected HT exports negatively two years before the EMU partnership was realized. Notably, the qualification for full EMU membership required fixing the country's exchange rate as per the ERM type target zone

Table 7 Estimates of the EMU's effects on HT **exports**[a] , PPML two-way gravity models (exporter-time FE, importer-time FE)

Dependent variable is HT exports	beta	Original SE	Bias-corrected SE	Dependent variable is VAR00072 HT exports	beta	original SE	Bias-corrected SE
Ln distance	-0.383	0.072***	0.087***	Ln distance	-0.403	0.072***	0.087***
Common border (share a border)	0.258	0.076***	0.097***	Common border (share a border)	0.225	0.082***	0.104**
Share a common language	-0.010	0.249	0.287	Share a common language	0.005	0.251	0.289
Have ever had a colonial relations	0.291	0.144**	0.181	Have ever had a colonial relations	0.297	0.144**	0.181
EU membership	0.506	0.240**	0.257**	EU membership	0.474	0.240**	0.257*
EMU Finland	-0.317	0.236	0.275	EMU France	0.290	0.159**	0.218
constant	21,403***			constant	21,549***		
R^2	0,941			R^2	0,941		
Ln distance	-0.385	0.072***	0.087***	Ln distance	-0.386	0.072***	0.087***
Common border (share a border)	0.257	0.076***	0.098***	Common border (share a border)	0.258	0.076***	0.096***
Share a common language	-0.011	0.246	0.285	Share a common language	-0.008	0.249	0.287
Have ever had a colonial relations	0.299	0.143**	0.180*	Have ever had a colonial relations	0.293	0.144**	0.181
EU membership	0.494	0.239**	0.256*	EU membership	0.498	0.239**	0.256*
EMU Germany	0.042	0.104**	0.138	EMU Greece	-0.064	0.231**	0.258
constant	21,417***			constant	21,428***		
R^2	0,941			R^2	0,941		
Ln distance	-0.372	0.072***	0.088***	Ln distance	-0.391	0.072***	0.087***
Common border (share a border)	0.287	0.080***	0.099***	Common border (share a border)	0.254	0.077***	0.097***
Share a common language	0.063	0.231	0.272	Share a common language	-0.001	0.249	0.287
Have ever had a colonial relations	0.386	0.153***	0.194**	Have ever had a colonial relations	0.281	0.144**	0.181
EU membership	0.472	0.238**	0.255*	EU membership	0.477	0.239**	0.256*
EMU Ireland	0.788	0.382***	0.476*	EMU Italy	0.409	0.184**	0.202**
constant	21,306***			constant	21,471***		
R^2	0.942			R^2	0.941		

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Each country is estimated separately. Standard errors are clustered by exporter-importer

regime at least two years before the adoption of the Euro. Thus, the country pre-commits to applying for the full membership within a 2-year period. We interpret this result as a verification of our previous findings about the effects of the EMU membership on HT trade.

5.6 HT Exports Explaining EMU Partnerships (Lagged HT Exports)

As the final step, we estimate a probit model for the EMU membership. We explain the EMU membership by adding the HT exports and the usual explanatory variables in the gravity

Table 8 Estimates of the EMU's effects on HT exports[a], PPML two-way gravity models (exporter-time FE, importer-time FE)

Dependent variable is HT exports	beta	Original SE	Bias-corrected SE	Dependent variable is HT exports	beta	original SE	Bias-corrected SE
Ln distance	-0.406	0.071***	0,086***	Ln distance	-0.385	0.072***	0.087***
Common border (share a border)	0.262	0.076***	0,098***	Common border (share a border)	0.259	0.076***	0.096***
Share a common language	-0.028	0.250	0,288	Share a common language	-0.007	0.249	0.287
Have ever had a colonial relations	0.314	0.145**	0,183*	Have ever had a colonial relations	0.291	0.144**	0.181
EU membership	0.510	0.240**	0,258**	EU membership	0.497	0.239**	0.256*
EMU Netherlands	-0.496	0.222***	0,306	EMU Portugal	0.351	0.330	0.376
constant	21,585***			constant	21,422***		
R^2	0,942			R^2	0,941		
Ln distance	-0.386	0.072***	0,087***	Ln distance	-0.386	0.072***	0.087***
Common border (share a border)	0.256	0.076***	0,096***	Common border (share a border)	0.258	0.076***	0.096***
Share a common language	-0.009	0.249	0,287	Share a common language	-0.006	0.249	0.287
Have ever had a colonial relations	0.298	0.144**	0,181	Have ever had a colonial relations	0.290	0.145**	0.181
EU membership	0.499	0.239***	0,256*	EU membership	0.495	0.239**	0.256*
EMU Slovenia	-1.164	0.593***	0,633*	EMU Spain	0.121	0.208	0.256
constant	21,428***			constant	21,426***		
R^2	0,941			R^2	0,941		
Ln distance	-0.384	0.072***	0,087***	Ln distance	-0.386	0.072***	0.087***
Common border (share a border)	0.249	0.076***	0,096***	Common border (share a border)	0.258	0.076***	0.096***
Share a common language	-0.004	0.249	0,287	Share a common language	-0.007	0.249	0.287
Have ever had a colonial relations	0.292	0.144**	0,181	Have ever had a colonial relations	0.293	0.144**	0.181
EU membership	0.502	0.239**	0,257*	EU membership	0.498	0.239**	0.256*
EMU Slovakia	-0.638	0.320***	0,355*	EMU Malta	0.480	0.430	0.492
constant	21,421***			constant	21,427***		
R^2	0.941			R^2	0.941		

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

Each country is estimated separately. Standard errors are clustered by exporter-importer, observations 18287

model equation. The results in Table 12 lend support to the notion that HT exports explain the EMU membership. In effect, these results propose that endogeneity is a potential problem in the EMU estimations as well, as already pointed out by a number of other studies on the effects of PTA on trade (e.g., Baier and Begstrand (2004), Magee (2003), Egger et al. (2011)). Our result thus verifies that we should use estimation methods that take into account the possible endogeneity of the PTA programs and exchange rate arrangements. The findings support our thinking that the inferences should be based on the effects of the EMU on HT trade via the three-way gravity estimation and PPML models, which consider the potential endogeneity problem.

Table 9 Estimates of the EMU's effects, Luxembourg was removed, because there are no observations before Luxembourg's EMU membership on HT exports[a], PPML three-way gravity models, (exporter-time FE, importer-time FE, country-pair FE)

Dependent variable is HT-exports	Original estimates		Bias-corrected estimates	
	beta	SE	beta	SE
EMU Austria	0.066	0.145	0.056	0.162
EMU Belgium	-0.115	0.209	-0.140	0.298
EMU Cyprus	-0.020	0.483	0.033	0.552
EMU Estonia	-0.892*	0.745	-1.280	1.256
EMU Latvia	-0.594***	0.308	-0.720*	0.380
EMU Lithuania	-0.090	0.154	-0.087	0.176
EMU Finland	0.136	0.132	0.165	0.147
EMU France	-0.028	0.107	-0.018	0.141
EMU Germany	0.045	0.072	0.068	0.089
EMU Greece	0.551***	0.310	0.677	0.438
EMU Ireland	0.369*	0.275	0.485	0.457
EMU Italy	0.077	0.082	0.087	0.107
EMU Netherlands	-0.231**	0.126	-0.307*	0.164
EMU Portugal	-0.251	0.277	-0.315	0.407
EMU Slovenia	0.200	0.237	0.218	0.266
EMU Spain	-0.182	0.199	-0.231	0.309
EMU Slovakia	-0.071	0.265	-0.076	0.299
EMU Malta	-0.460	0.382	-0.547	0.477
Asymmetric Country-pair id effects	x	x	x	x
Exporter time fixed effects	x	x	x	x
Importer time fixed effects	x	x	x	x

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.

Each country is estimated separately. Standard errors are clustered by exporter-importer

5.7 EMU Effects on Total Exports

We also estimate EMU membership effects on *total exports* (Tables 13, 14, 15) to allow comparability to other studies. In sum, the OLS estimates in Table 13 show that a currency union membership is more likely when countries speak the same language, are geographically close (positive common border coefficient and negative distance coefficient) and share former colonial relations. However, the overall EMU variable is statistically non-significant. Our two-way gravity models (Table 14) that take account of multilateral resistances show that the overall EMU variable is positive but statistically non-significant.

However, after adding country-pair fixed effects to the gravity model, the sign of the overall EMU variable remains positive, and its value is statistically non-significant (Models 1 and 2 in Table 15). It has been shown that the PPML approach with two-way and three-way fixed effects has non-negligible biases (Weidner & Zylkin 2020). As a consequence, we use the bias-corrected PPML (Zylkin 2020) in Models 4–6 (Table 14) and Models 3 and 4 (Table 15). The results show that the sign of the overall EMU variable in the two-way bias-corrected model (Model 5) is positive, and the value is statistically non-significant.

Our three-way estimates (Models 1 and 2 in Table 15) show that the impact of the EMU on total exports is close to zero (see, e.g., Santos Silva and Tenreyro 2010; Camarero et al. 2014; Berger and Nitsch 2008). However, after bias correction, the preferred specification (Model 4 in Table 15) of the three-way bias-corrected model shows that the sign of the overall EMU variable turns positive, and its value becomes statistically significant. As a consequence, our

Table 10 Estimates of the EMU's effects on HT exports[a], 1 year leading EMU partnership indicator, PPML estimation

Dependent variable is HT exports	PPML1 year lag two-way(1)	PPML1 year lag three-way(2)	PPML1 year lag three-way(3)	PPML bias- corrected1 year lag two-way (4)	PPML bias-corrected1 year lag three-way (5)	PPML bias-corrected1 year lag three-way (6)
Ln GDP (reporting)	–	–	–	–	–	–
Ln GDP (Partner)	–	–	–	–	–	–
Ln distance	-0.388***	–	–	–0.388***	–	–
EU membership	0.434*	-0.115	–	0.434*	-0.137	–
EMU overall (1 year lead)	0.142	-0.109	-0,117	0.143	-0.135	-0,144
Common border (share a border)	0.242***	–	–	0.243**	–	–
Share a common language	–0.017	–	–	–0.017	–	–
Have ever had a colonial relations	0.333**	–	–	0.333*	–	–
Asymmetric Country-pair id effects	no	yes	yes	no	yes	yes
Exporter time fixed effects	yes	yes	yes	yes	yes	yes
Importer time fixed effects	yes	yes	yes	yes	yes	yes
Observations	18287	18287	18287			
R^2	0.908	0.985	0.985			
Constant	21.437***	19,784***	19,676***			

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

Table 11 Estimates of the EMU's effects on HT **exports**[a], two years leading EMU partnership indicator, PPML estimation

Dependent variable is HT exports	PPML2 year lag two-way (1)	PPML2 year lag three-way (2)	PPML2 year lag three-way (3)	PPML bias-corrected2 year lag two-way (4)	PPML bias-corrected2 year lag three-way (5)	PPML bias-corrected2 year lag three-way (6)
Ln GDP (reporting)	–	–	–	–	–	–
Ln GDP (Partner)	–	–	–	–	–	–
Ln distance	–0.388***	–	–	-0.388***	–	–
EU membership	0.432*	-0.096	–	0.432	–0.111	–
EMU overall (2 year lead)	0.136	-0.154	-0.164	0.136	-0.198*	-0,210*
Common border (share a border)	0.244***	–	–	0.244**	–	–
Share a common language	–0.017	–	–	–0.017	–	–
Have ever had a colonial relations	0.331**	–	–	0.331*	–	–
Asymmetric Country-pair id effects	no	yes	yes	no	yes	yes
Exporter time fixed effects	yes	yes	yes	yes	yes	yes
Importer time fixed effects	yes	yes	yes	yes	yes	yes
Observations	18287	18287	18287			
R^2	0.941	0.985	0.985			
Constant	*21.442***	*19,790***	19,702***			

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

Table 12 Estimates of the HT exports effects on EMU-membership[a], probit regression analysis

Dependent variable is EMU partnership	(1)	(2)	(3)	(4)	(5)
Ln GDP (reporting)	0.004	-0.015	-0.038	-0.056	-0.075*
Ln GDP (Partner)	0.015	-0.003	-0.023	-0.040	-0.058
Ln distance	0.341***	0.371***	0.402***	0.428***	0.456***
EU membership	2.680***	2.655***	2.624***	2.592***	2.555***
ln HT exports	0.035				
Ln HT exports 1 year before EMU partnership		0.054**			
Ln HT exports 2 years before EMU partnership			0.075***		
Ln HT exports 3 years before EMU partnership				0.091***	
Ln HT exports 4 years before EMU partnership					0.109***
Common border (share a border)	0.464*	0.489*	0.516*	0.543*	0.575*
Share a common language	1.087***	1.126***	1.172***	1.230***	1.302***
Have ever had a colonial relations	-0.790	-0.840	-0.897	-0.959	–1.032
Observations	17855	17855	17855	17855	17855
R^2	0.221	0.216	0.211	0.205	0,200
Correctly classified (%)	77,43	76.40	75.49	74.68	73.89
Constant	-6.469***	–5.841***	–5.129***	–4.537**	-3.890**

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

preferred three-way bias-corrected model for total exports suggests that EMU membership is an important determinant of total exports, which is in line with the meta-analysis results of Head and Mayer (2014).

6 Conclusions

Our study contributes fresh insights to the literature on the effects of the PTA and common currency on trade. In particular, we augment the knowledge in the field by examining the

Table 13 Estimates of the EMU's effects on total exports[a]

Dependent variable is Ln (exports) for models 1-4	Pooled OLS (1)	Pooled OLS (2)	Pooled OLS (3)	Pooled OLS (4)
Ln GDP (reporting)	1.075***	–	–	–
Ln GDP (Partner)	0.851***	–	–	–
Ln distance	v1.175***	-1.305***	-1.579***	
EU membership	0.420***	0.320**	0.147*	0.147*
EMU overall	–0.010	0.079	0.003	0.003
Common border (share a border)	0.371**	0.291	1.093***	–
Share a common language	0.247	0.041	3.546***	–
Have ever had a colonial relations	0.581***	0.624***	-0.681***	–
Asymmetric Country-pair id effects	no	no	yes	yes
Exporter time fixed effects	no	yes	yes	yes
Importer time fixed effects	no	yes	yes	yes
Observations	17996	18428	18428	18428
R^2	0.859	0.925	0.966	0.966
Constant	–29.493***	16.565***	19.043***	8.610***

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

Table 14 Estimates of the EMU's effects on total exports[a], two-way gravity models

Dependent variable is total exports for models 1–6	PPML (1)	PPML (2)	PPML (3)	PPML (4) bias-corrected	PPML (5) bias-corrected	PPML (6) bias-corrected
Ln GDP (reporting)	–	–	–	–	–	–
Ln GDP (Partner)	–	–	–	–	–	–
Ln distance	–0.493***	–	–	-0.493*	–	–
EU membership	0.579***	0.109	–	0.579	0.109	
EMU overall	0.045	0.030	0.033	0.046	0.030	0.033
Common border (share a border)	0.435***	–	–	0.435	–	–
Share a common language	0.350**	–	–	0.350	–	–
Have ever had a colonial relations	0.395***	–	–	0.395	–	–
Asymmetric Country-pair id effects	no	no	no	no	no	no
Exporter time fixed effects	yes	yes	yes	yes	yes	yes
Importer time fixed effects	yes	yes	yes	yes	yes	yes
Observations	18428	18428	18428			
R^2	0.955	0.988	0.988			
Constant	18.999***	16.623***	16.726***			

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

impacts of a common currency (the Euro) on HT trade. The HT sector has been of special interest for the EU, as stated in the Lisbon Agenda, but none of the previous studies focus on the effects of the common currency on the growth of HT trade within the EU. This topic is important, as HT exports are posited to be a significant driver of knowledge spillovers and economic development in addition to impacting overall trade and growth positively.

Our results of the gravity model estimations for trade propose that economic size, EU membership, distance, common borders, colonial relations and EMU membership are the most important determinants of total export volumes. To estimate the impact of the EMU on export, we extend the analysis using a multilateral resistance term and a three-way gravity (PPML) estimation, and assess

Table 15 Estimates of the EMU's effects on total exports[a], three-way gravity models

Dependent variable is total exports for models 1–4	PPML (1)	PPML (2)	PPML (3) bias-corrected	PPML (4) bias-corrected
Ln GDP (reporting)	–	–	–	–
Ln GDP (Partner)	–	–	–	–
Ln distance	–	–	–	–
EU membership	0.109	-	0.102	
EMU overall	0.030	0.033	0.071*	0.075**
Common border (share a border)	–	–	–	–
Share a common language	–	–	–	–
Have ever had a colonial relations	–	–	–	–
Asymmetric Country-pair id effects	yes	yes	yes	yes
Exporter time fixed effects	yes	yes	yes	yes
Importer time fixed effects	yes	yes	yes	yes
Observations	18428	18428		
R^2	0.997	0.997		
Constant	16.623***	16.726***		

[a] Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors are clustered by exporter-importer

the possible endogeneity of EMU membership. Overall, the effect of the EMU as per the OLS estimation is negative and statistically non-significant. The PPML (preferred) model can consider information on zero trade flows as well as heteroscedasticity. Our three-way bias-corrected estimates show that the sign of the overall EMU variable turns negative while its value remains statistically non-significant. Thus, these results indicate that the impact of the EMU on HT exports is close to zero, which lends support to novel trade studies (see, e.g., Santos Silva and Tenreyro 2010; Camarero et al. 2014; Berger and Nitsch 2008). We also propose that the EMU does not affect all member countries' HT trade unanimously. Moreover, we provide evidence of the significance of the endogeneity of the EMU membership with respect to trade flows. HT trade seems to predict the EMU membership. Our estimates on the non-significant impacts of the EMU on HT trade corroborate our evidence concerning the impacts of the EMU on total exports.

Our study also suffers from some limitations. We examine only the reaction of the aggregated HT exports on the EMU membership. In the future, we plan to examine the impact of the EMU using more disaggregated sectoral- and firm-level trade data.

Appendix 1. Definition of HT sectors.

The definition of HT sectors is based on the additional aggregates in the OECD BTDIxE industry list (i.e., high R&D intensity activities). Further information about the OECD and R&D intensity taxonomy can be found at https://doi.org/10.1787/5jlv73sqqp8r-en

HT sector:

- Pharmaceuticals (21)
- Computer, electronics and optical products (26)
- Scientific R&D (72)
- Air, spacecraft and related machinery (3031)
- Software publishing (5821)

Table 16 High R&D intensity activities

High R&D intensity industries	R&D as a percent of GVA* manufacturing	High R&D intensity industries	R&D as a percent of GVA* non-manufacturing
3031: Air, spacecraft and related machinery	31.69	72: Scientific R&D	30.39
21: Pharmaceuticals	27.98	5821: Software publishing	28.94
26: Computer, electronics and optical products	24.05		

*GVA = Gross value added

Appendix 2

Table 17 Studies of currency union effects on trade and their results

Author(s)	Data	Country	Results
Rose (2000): One money, one market: Estimating the effect of common currencies on trade	Years 1970, 1975, 1980, 1985 and 1990 pooled	186 countries	Countries with a common currency trade 3.35 times more with each other compared to countries with different currencies
Rose and van Wincoop (2001): National money as a barrier to international trade: The real case for a currency union	Years 1970, 1975, 1980, 1985 and 1990 pooled	Nearly 200 countries	A rise in trade among members of the currency union implies a corresponding drop in trade with other countries and with member countries, i.e., the model implies both trade diversion and trade creation. 58% Euro effect
Glick and Rose (2002): Does a currency union affect trade? The time-series evidence	1948 – 1997, panel data	217 countries	Basic gravity model gives the Rose effect as 3.66 times more trade among currency union pairs; the fixed effect estimate is 1.9%.
Micco et al. (2003): The Currency Union Effect on Trade: Early Evidence from EMU	1992 – 2002	22 developed countries, 11 are Euro countries	Several sets of estimates, 5 – 20% Euro effects on trade between Euro countries.
Flam and Nordström (2003): Trade volume effects of the euro: Aggregate and sector estimates	1989 – 1997 vs. 1998 – 2002	20 industrialized countries of which 10 are Euro countries and 10 non-Euro countries	The Euro has increased the trade by 15% between Euro countries in 1998 – 2002 compared to 1989 – 1997, and the level of trade with outside countries increased by 8%.
Egger (2004): Estimating regional trading bloc effects with panel data	1986 – 1997, panel data	47 countries	Joining a trading bloc does not affect the short-term trade volume. Removal of EEA [EEA = European Economic Area, which consisted of member states of the European Union (EU) and European Free Trade Association (EFTA)] explains a reduction of intra-EEA trade volume by 4%.

Appendix 3

Table 18 Studies of currency union effects on trade and their results

Author(s)	Data	Country	Results
Baldwin and Taglioni (2007): Trade effects of the euro: a comparison of estimators	1994 –2003, panel data	Six-digit level bilateral product exports from a single country to aggregate nineteen destination countries	3 – 4% Euro effects on trade between Euro countries and 3 – 4% effect between Euro and non-Euro area.
Flam and Nordström (2007): Explaining large Euro effects on trade: The extensive margin and vertical specialization	1995 –2005, panel data	10 Euro and 10 non-Euro countries	26% Euro effects on trade between Euro countries and 12 – 14% effect between Euro and non-Euro area for the years 2002 – 2005 on average compared to 1995 – 1998.
De Nardis et al. (2008): The Euro's effects on trade in a dynamic setting	1988 –2004, panel data	23 countries, 13 EU members and 10 OECD countries	17% Euro effect in the long-term; in the short–term, the Euro effect is 4%.
Frankel (2008): The estimated effects of the Euro on trade: Why are they below historical evidence on the effects of monetary unions among smaller countries?	1948 – 2006, panel data		10 – 25% (small sample) and 300% (large sample) Euro effects on trade between Euro countries.
Santos Silva and Tenreyro (2010): Currency unions in prospect and retrospect	1993-2007, panel data	Comparing trade flows among Euro-12 with 1) those countries that were part of the EU in 1999 but not adopted the euro, 2) EEA countries and 3) added five additional OECD countries (Austria, Canada, Japan, New Zealand and the USA)	Euro's impact on trade has been close to zero

Appendix 4

Table 19 Studies of currency union effects on trade and their results

Author(s)	Data	Country	Results
Berger and Nitsch (2008): Zooming out: The trade effect of the euro in historical perspective	1948-2003, panel data	22 industrial countries	Euro's impact on trade disappears after controlling trend
Glick and Rose (2016): Currency unions and trade: A post-EMU reassessment	1948-2013, panel data	More than 200 countries	EMU has boosted exports by around 50%
Mika and Zymek (2018): Friends without benefits? New EMU members and the "Euro Effect" on trade	1992-2013 panel data	EU members + 8 developed economies (Australia, Canada, Iceland, Japan, New Zealand and Norway), baseline regressions are estimated on a sample of 153 countries	No robust evidence of a euro effect on trade

Appendix 5

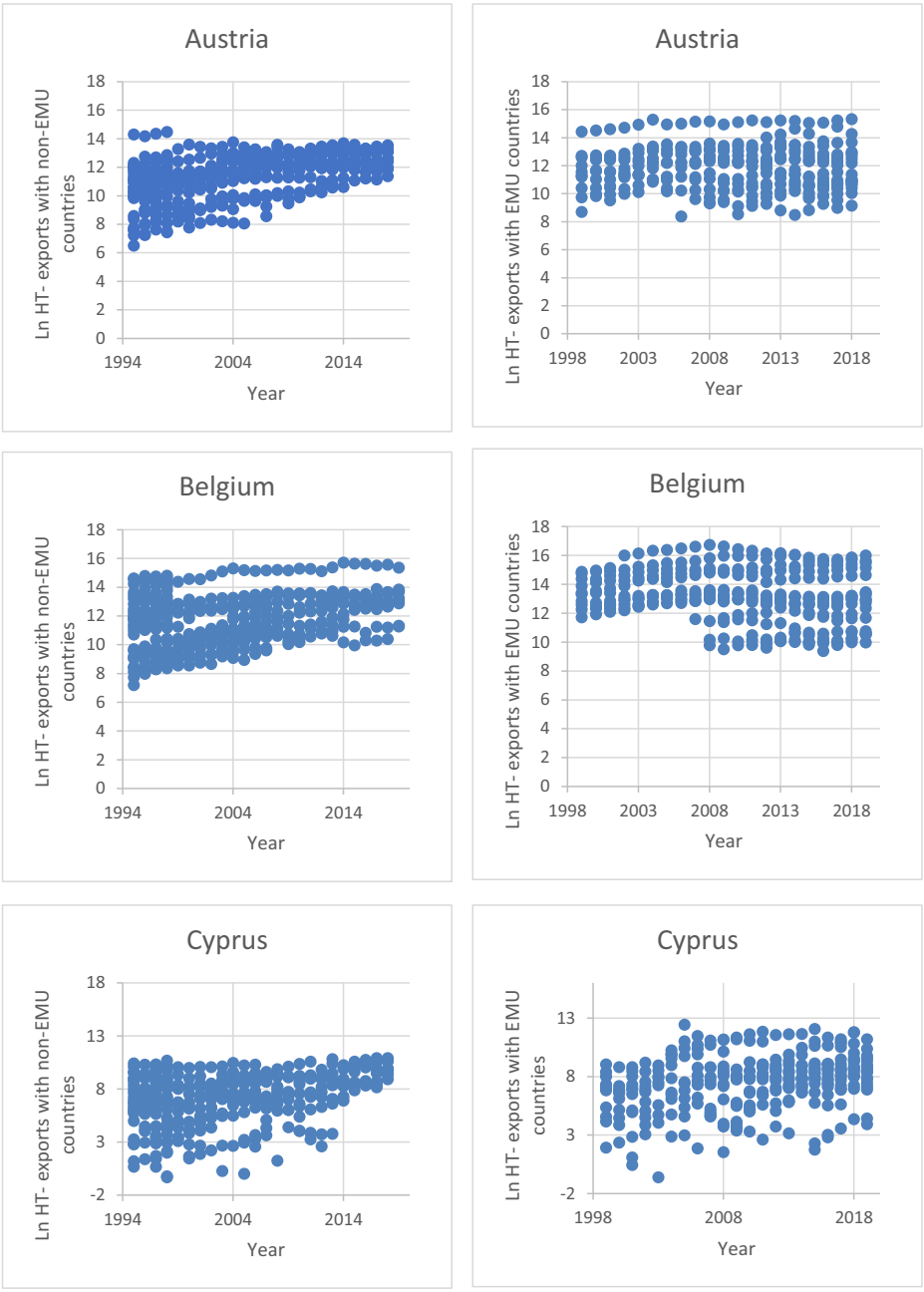
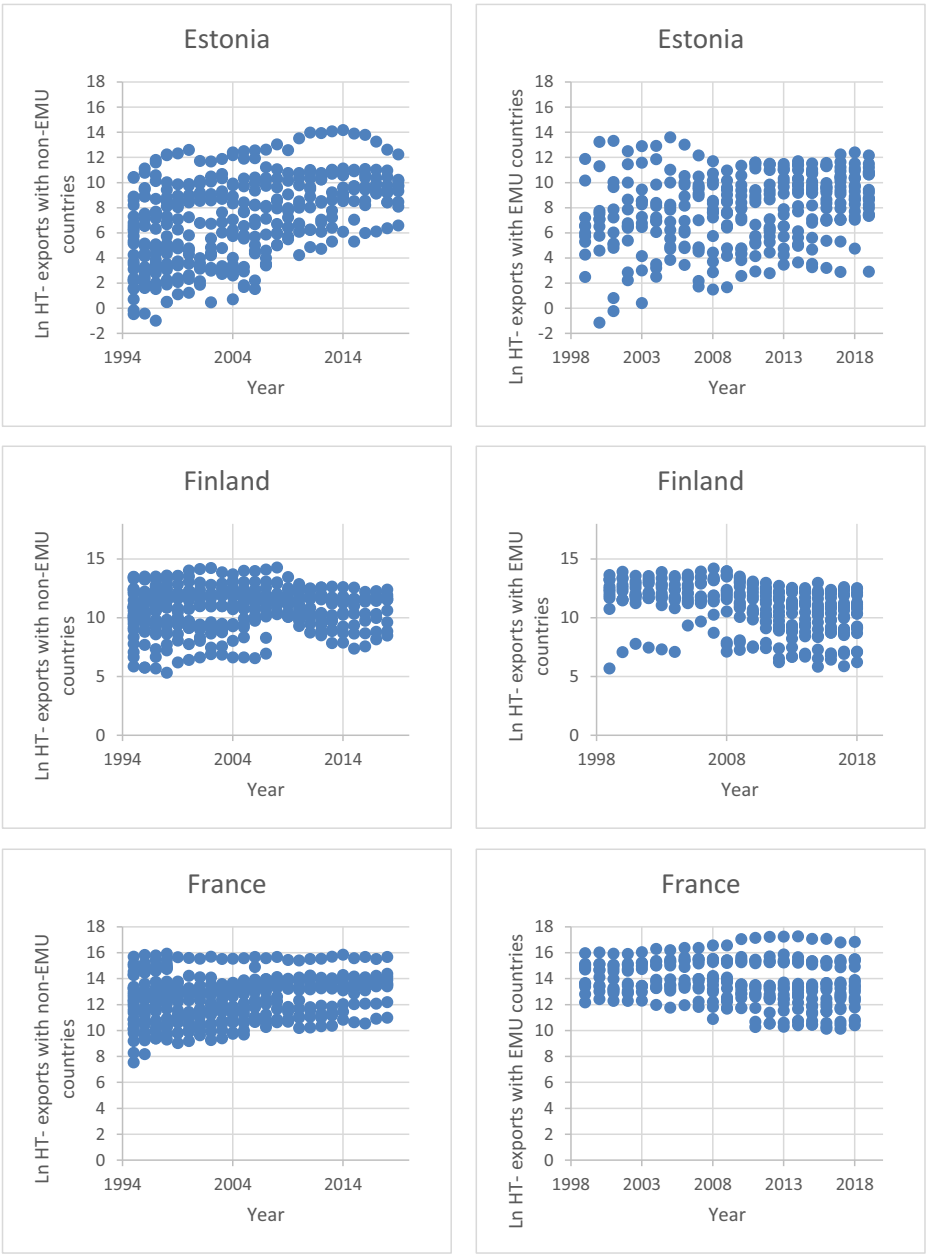


Figure 1. Ln HT-exports (€) with EU countries. Luxembourg was removed, because there are no observations before Luxembourg's EMU membership



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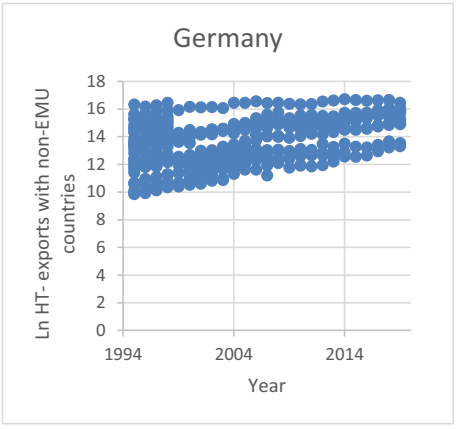

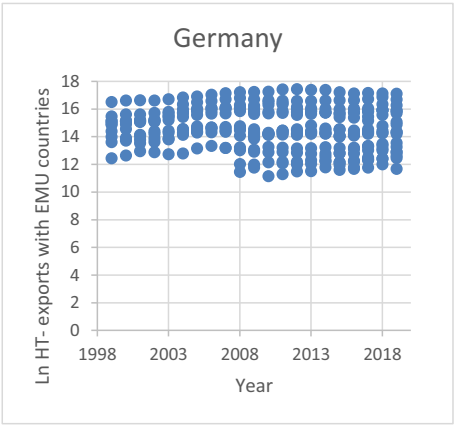

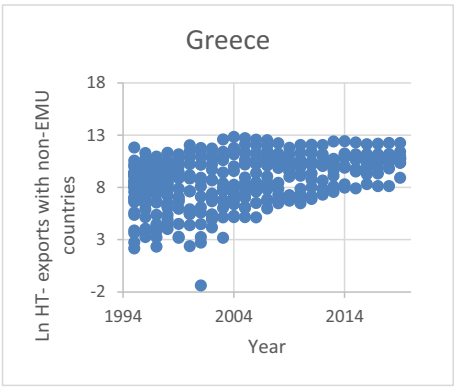

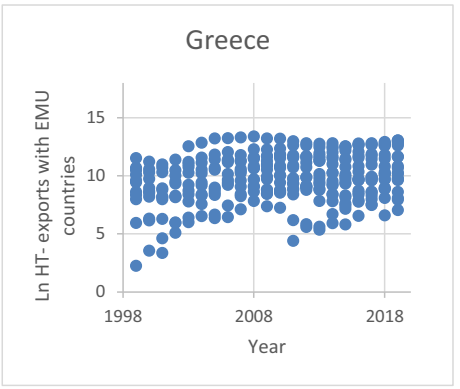

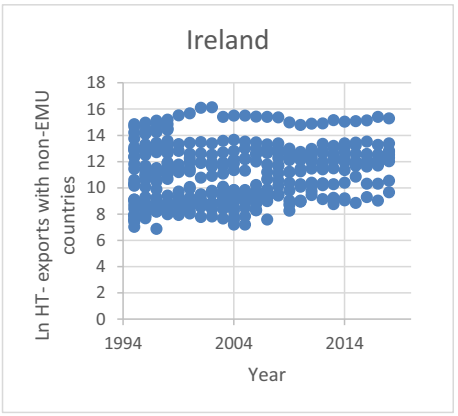

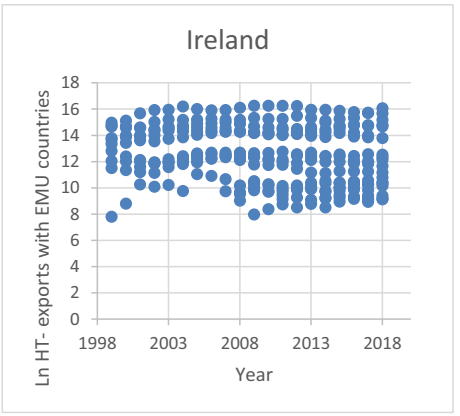

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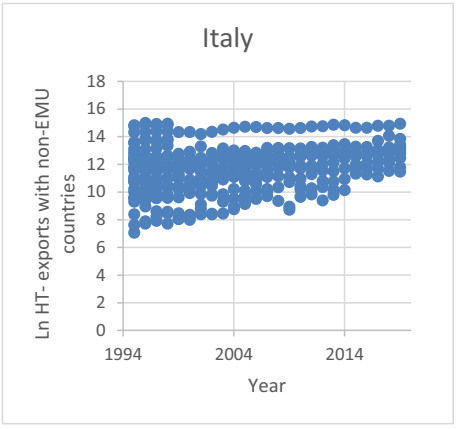

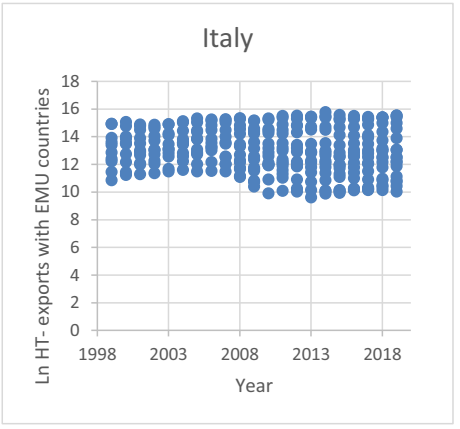

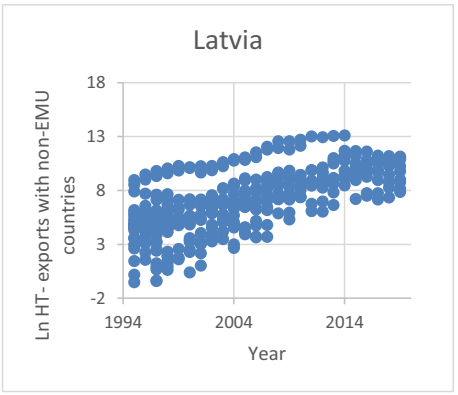

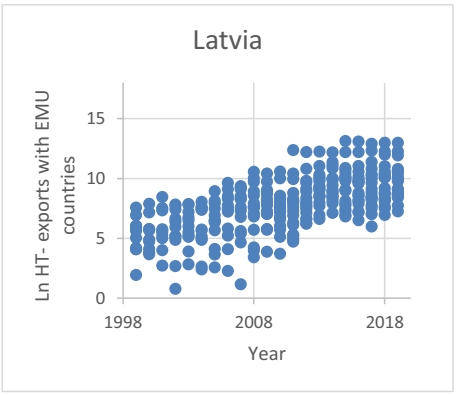

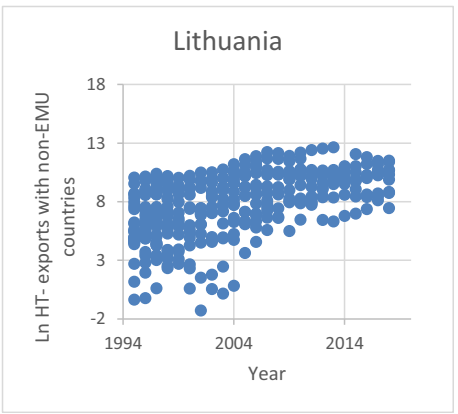

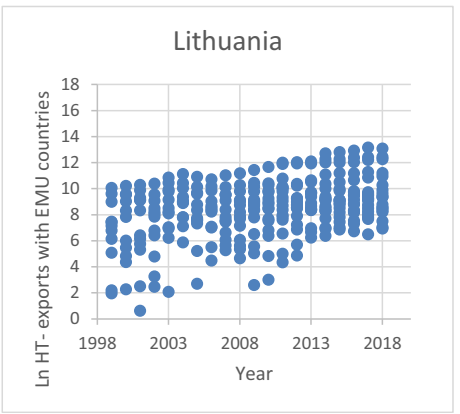

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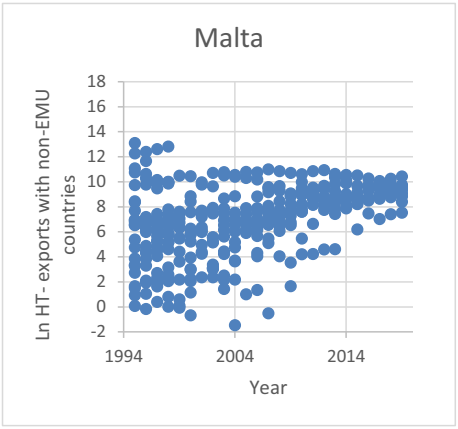

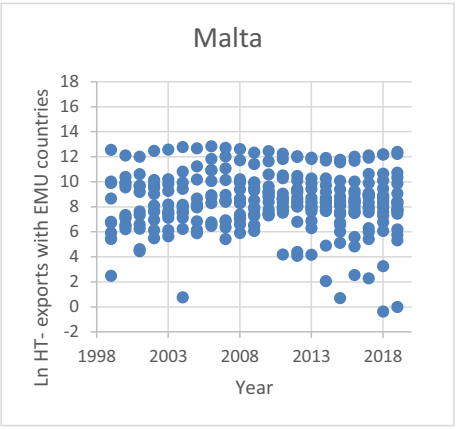

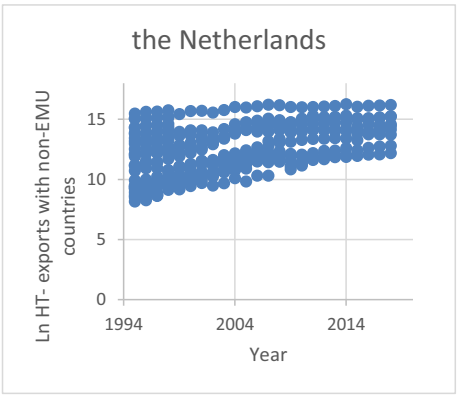

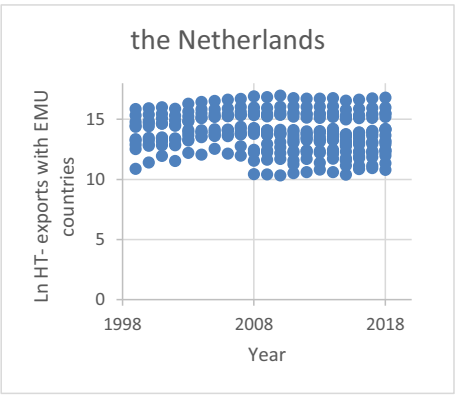

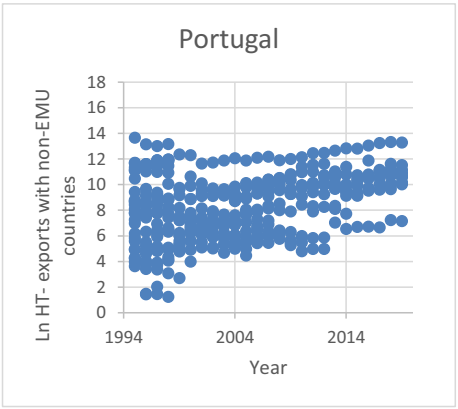

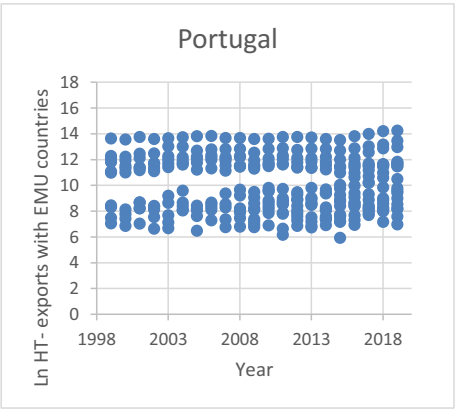

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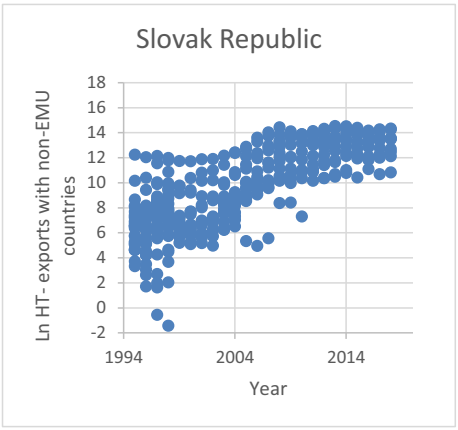

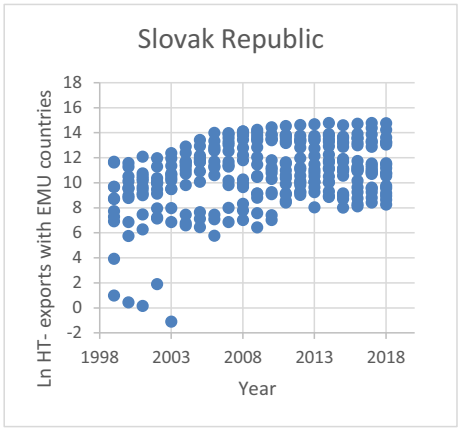

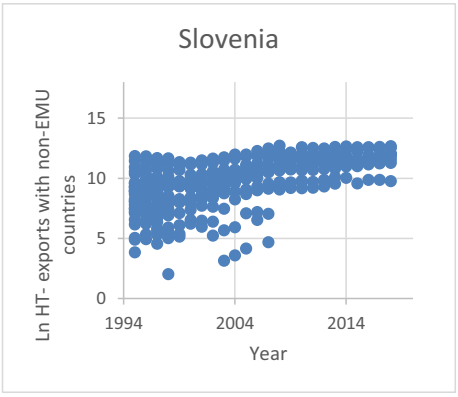

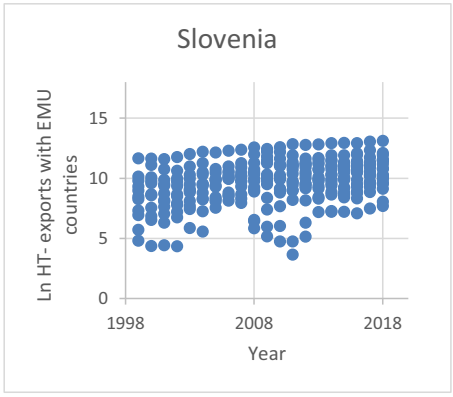

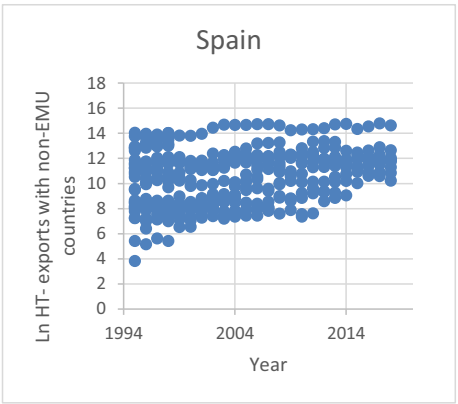

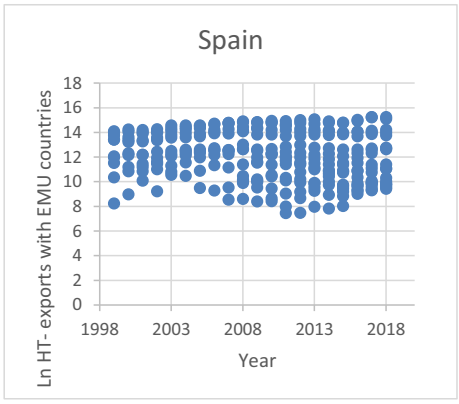

Figure 1. continue

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Declarations

Ethics approval and consent to participate The authors declare that the study did not involve Human Participants and/or Animals. The authors declare that the study did not require informed consents because our study does not meet the human subjects research criteria.

Conflict of interest The authors declare that they have no conflict of interest.

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