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Trade implications of the Euro in EMU countries: a panel gravity analysis

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Abstract In this paper, we study the intra-EMU and intra-Eurozone trade effects of the euro adoption on 29 European Economic and Monetary Union countries (including 17 Eurozone economies and Iceland) from the period 1994 through 2011. We employ a generalized gravity model that controls for an extended set of trade theory and policy variables. The gravity model is estimated using the robust panel data techniques that includes times effects, besides country-specific effects. The various econometric specifications of the gravity equation, on the whole dataset of 29 economies, yield positive and significant impact (to be around 14 %) of the euro currency adoption on bilateral trade flows. Next, euro effect on bilateral trade and exports on a smaller dataset is estimated. The estimated results suggest that bilateral trade and exports increase by 20.81 and 18.57 %, respectively, when both the countries belong to the Eurozone. This effect is larger than the one obtained when only one of the two trading partners uses the euro as its currency. In addition, the validity of the assumptions of Heckscher–Ohlin (H–O) theory are checked for the countries under study. The estimated results reject the H–O theory in favor of Modern Trade theories. However, the low value of the coefficient on respective variable suggests that, over the period, the type of trade among these countries has transited from inter-industry trade to horizontal intra-industry trade. This suggests that these developed European economies are on the path of economic convergence via intra-industry trade.

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1 Introduction

The theory of optimum currency areas has always been at the core of the discussion on western European integration. The formulation of the euro currency union in 1999 renewed interest into this theory. The literature suggests that there exist two extreme views that discuss the scope and importance of academic research into this area. At one extreme, Krugman (1993) has stated "…it is arguable that the optimum currency area issue ought to be the centerpiece of international monetary economics." At the other extreme, Buiter (2000) has argued, "the theory of Optimal Currency Area… is, unfortunately, one of the low points of post-World War II monetary economics." These two views again confronted each other with the recent euro-zone crisis (2009–2011) which raised a big question on the sustainability of currency unions. However, the debate is not a new one. Post World War II, one of the most hotly argued and debated issues that international monetary economics has faced is the effect of the adoption of a single currency on international trade flows. While the adoption of a single currency results in many advantages such as reduction in transaction costs and elimination of exchange rate volatility, etc., it also leads to certain costs (for instance, missing opportunity of using exchange rates as economic policy instruments and absence of an independent monetary policy). The first time that someone used the term optimum currency area (OCA hereafter) was Mundell (1961) when he published his seminal research paper entitled "A Theory of Optimum Currency Areas" in which he stressed 'factor mobility', especially the 'labour mobility' as an important criterion in forming an OCA. Following Mundell (1961), important contributions to the theory of OCA were made by the works of McKinnon (1963), Kenen (1969), Grubel (1970), Cordon (1972), Mundell (1973), Ishiyama (1975), Tower and Willett (1976), Kydland and Prescott (1977), Barro and Gordon (1983), Melitz (1991), Gandolfo (1992), Tavlas (1993), Krugman (1993, 2001), Buiter (1995), Obstfeld and Rogoff (1996), Frankel and Rose (1997), Edwards (1996) and Collins (1996), Blanchard and Wolfers (2000), Buti and Suardy (2000), Issing (2001), Alesina and Barro (2002), Calvo and Reinhart (2002), De Grauwe and Mongelli (2005), Dellas and Tavlas (2009), De Grauwe (2014).[1] Keeping in view the criteria that a geographic region should satisfy in order to form a currency union, the present study attempts to examine the feasibility and sustainability of the euro currency area via the trade implications of using the euro as a common currency.

Knowing the fact that the European Economic and Monetary Union (EMU) economies have gone a long process of integration (Berger and Nitsch 2008) even

[1] For an extensive summary of the various OCA criteria, see Broz (2005).

before the adoption of the euro,[2] the costs of adopting a single currency by these economies are very low. On the other hand, the benefit of lower export costs and reduction in exchange rate risk encourages these economies to expand the range of products they export and open up their economies (Baldwin et al. 2008). In addition, the high trade integration among these economies help benefits out-weigh costs of using the euro as a common currency. Several studies have tried to find out whether a common currency helps the member countries increase their trade with one another. With the pioneering work of Rose et al. (2000) and their finding that currency unions enhance trade by more than 296 %, a completely new stream of literature emerged and thrived (Engel and Rose 2000; Glick and Rose 2002; Nitsch 2002; Fidrmuc and Fidrmuc 2003; De Grauwe 1996, 2006; Baldwin and Taglioni 2006). The only question was, how large is the magic? (Baldwin and Taglioni 2006). For instance, Micco et al. (2003) find that for a pair of two countries that have adopted the euro, trade has enhanced by about 4–16 %. Other papers, including Barr et al. (2003), Baldwin et al. (2005), Bun and Klaassen (2002), De Nardis and Vicarelli (2003), Faruqee (2004), and Flam and Nordström (2003) report broadly similar, and often even larger, estimates. Among the recent works are: Baier and Bergstrand (2007), Barro and Tenreyro (2007), De Nardis et al. (2008), Fidrmuc (2004, 2009), Cafiso (2008), Rault et al. (2009), Siliverstovs and Schumacher (2009), Havránek (2010), Roy (2014), Westerlund and Wilhelmsson (2011), De Sousa (2012), Bergin and Lin (2012), Geldi (2012), Cieslik et al. (2012), and Camarero et al. (2014). These studies raised several questions ranging from the exact impact of common currency adoption on trade flows to the proper specification of a gravity model.

Inspired initially by Newton's law of gravitation (physics), the gravity model has become an important tool in the assessment of international trade flows. The first applications of gravity equation were merely intuitive without solid theoretical backings. These applications became easy targets by critics because of the lack of robust theoretical foundations. The use of the gravity model as one of the analytical means of international trade theory dates back to the studies by Tinbergen (1962) and Pöyhönen (1963). The model has been developed further by the studies of Linnemann (1966), Aitken (1973), Anderson (1979, 2010), Bergstrand (1985), Deardorff (1998), Anderson and Wincoop (2003), and Helpman et al. (2008), and Anderson et al. (2013). Previous studies used simple econometric techniques of Ordinary Least Squares (OLS) which were heavily criticized by later studies (for instance, Santos Silva and Tenreyro 2006; Martinez-Zarzoso 2013). Also, the dataset was seen very flawed; for example, one reason why Rose et al. (2000) got a three-fold increase in trade lies in the fact that his dataset of 186 countries, included territories, overseas departments, dependencies, political colonies and so forth, resulted in a number of common currency unions consisting of one large and dominating country with a large number of much smaller territories or countries. In addition, in the presence of zero trade flows and unobserved heterogeneity, OLS technique produces biased and inconsistent results.

In the light of above mentioned discussion, the present study sets out the following objectives:

[2] Although adopted in 1999, the euro was physically introduced in 2002.

1. To find out the effect of using the euro as a common currency on the bilateral trade and exports of European Union economies.
2. To confirm whether uncertainty in exchange rate hampers trade flows.
3. To examine the patterns of trade existing in the European Union countries.

In order to fulfill the above-mentioned objectives, this study employs panel econometric techniques of fixed effects and random effects on the gravity model of international trade. The sample dataset consists of 29 European economies covering the period 1994 through 2011. As the euro has successfully completed more than a decade since its physical introduction in 2002, a fresh look at the evidence of the euro's impact on bilateral trade and exports of EU economies is highly relevant. In particular, we determine the effect of using the euro as a common currency on the trade and exports from Eurozone to Eurozone and other EMU economies. Thus, this study carves out a niche of the true effect of mature euro. Our approach is based on 'time effects' embedded term of gravity equation, which is suitable to such an analysis. In addition, we use this modified gravity model comprising a variable for exchange rate variability to analyze the effects of exchange rate uncertainty on bilateral trade flows. Regarding trade patterns, the OCA theory presents two extreme views. On the one extreme, economists believe that existence of high trade within a monetary union can result in higher industrial specialization between countries in the products in which they have comparative advantage, leading to asynchronous business cycles resulting in industry specific shocks (Krugman 1993). The other side is of the opinion that increased trade may result in increased correlation amongst the currency union members' business cycles provided common demand shocks exist or provided intra-industry trade accounts for most of the trade i.e., international trade pattern and international business cycle correlation is endogenous (Frankel and Rose 1998). In the light of this argument, we attempt to investigate the type of trade and the degree of specialization of these sample economies. In other words, we are interested in determining whether the EMU (including the 17 Eurozone)[3] economies are making an intensive use of their abundant factor of production and hence, have flourished an inter-industry trade type, or on the contrary, are on the path of economic convergence via intra-industry trade.

The remainder of the paper is structured as follows. Section 2 describes our estimation methodology. Section 3 exposes the gravity model used in this study. Section 4 gives our sources of data and their measurement. Section 5 presents our estimated results and their analysis. Last, Sect. 6 concludes with final remarks.

2 The econometric methodology

Egger (2000) mentions that the most appropriate methodology dealing with panel data is for disentangling time-invariant and country-specific effects. If we ignore the nature of the panel data and apply pooled OLS, which would assume that

[3] By the joining of Latvia to the Euro-zone on January 1, 2014 and Lithuania on January 1, 2015, the number of countries using the euro as its currency has increased to 19.

$\beta = \beta_j \quad \forall j, i, t$, but that model might be overly restrictive and can have a complicated error process (e.g., heteroskedasticity across panel units, serial correlation within panel units, and so forth). Thus, the POLS solution is not often considered practical. One set of panel data estimators allows for heterogeneity across panel units (and possibly across time) but confines that heterogeneity to the intercept terms of the relationship. They impose restrictions on the above model of $\beta_{jit} = \beta \quad \forall i, t, j > 1$, thereby allowing only the constant to differ over i. This gives rise to such an estimator that controls for bilateral specific effects: the fixed-effects model or the random-effects model.

2.1 Fixed-effects model (FEM) and random-effects model (REM)

These models allow for heterogeneity across units. In particular, we might restrict the slope coefficients to be constant over both units and time and allow for the intercept coefficient that varies by unit or by time. For a given observation, an intercept varying over units results in the structure

$$\begin{aligned} y_{it} = x_{it}\beta + z_i\delta + \mu_i + \varepsilon_{it}, \quad & i = 1, 2, \ldots, N\,individuals; \\ t = 1, 2, \ldots, T\,time\,periods. & \end{aligned} \tag{1}$$

where $\mathbf{x}_{it}$ is a 1 × k vector of variables varying over time and individual, β is the k × 1 vector of coefficients on $\mathbf{x}$, $\mathbf{z}_i$ is a 1 × p vector of time-invariant variables that vary only over individuals, δ is a p × 1 vector of coefficients on $\mathbf{z}$, μ_i is the individual-level effect, and ε_{it} is the disturbance term. μ_i may or may not be correlated with the regressors $\mathbf{x}_{it}$ and $\mathbf{z}_i$. If the μ_i are correlated with the regressors, it gives rise to FE[4] and RE arise in case μ_i are uncorrelated with the regressors. In that case, the individual-level effects become part of the error disturbance ant the sum $(\mu_i + \varepsilon_{it})$ is referred to as composite-error term. ε_{it} is the "usual" residual with the usual properties (mean 0, uncorrelated with itself, uncorrelated with $\mathbf{x}$ and $\mathbf{z}$, uncorrelated with μ_i, and homoscedastic).

If we subtract from (1) the average over time of (1), we obtain the fixed effects transformation as

$$y_{it} - \bar{y}_i = (\mathbf{x}_{it} - \bar{\mathbf{x}}_i)\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)s \tag{2}$$

where $\bar{y}_i = \sum_t \frac{y_{it}}{\mathbf{T}_i}, \bar{\mathbf{x}}_i = \sum_t \frac{\mathbf{x}_{it}}{\mathbf{T}_i}, \quad and \quad \bar{\varepsilon}_i = \sum_t \frac{\varepsilon_{it}}{\mathbf{T}_i}$. A pooled OLS estimator based on Eq. (2), called FE estimator, $\hat{\beta}_{FE}$ or mean-difference estimator or within estimator,

[4] A one-way FEM permits each cross-sectional unit to have its own constant term while the slope estimates of β are constrained across units, as is the σ_ε^2. The estimator is termed as least-squares dummy-variable (LSDV) estimator, since it is equivalent to including N − 1 dummy variables in the OLS regression. More specifically, it can be shown to equal the estimator obtained from OLS estimation of $y_{it} on\, \mathbf{x}_{it} \quad and \quad N$ individual-specific indicator variables $d_{j,it}, \quad j = 1, \ldots, N$, where $d_{j,it}, = 1$ for the ith observation if $j = 1$, and $d_{j,it}, = 0$ otherwise. Then, the fitted model becomes $y_{it} = \left(\sum_{j=1}^{N} \alpha_i d_{j,it}\right) + \mathbf{x}_{it}'\beta + \varepsilon_{it}$. However, this equivalence of LSDV and within estimators does not carry over to nonlinear models. Besides, the name LSDV is fraught with problems because it implies an infinite number of parameters in our estimation. A better way to understand the FE estimator is to see that removing panel-level averages from each side of (1) removes the FE from the model, as shown in the methodology part.

produces unbiased and consistent estimates of β. However, Eq. (2) shows the fixed effects transformation sweeps out the unobserved effect μ_i as well as the time-invariant regressors. This leads to loss of information. Alternative to the within estimator is the random-effects estimator which uses both the within and the between information,[5] thereby producing more efficient results.[6] Under the REM, Eq. (1) becomes

$$y_{it} = \mathbf{x}_{it}\beta + \mathbf{z}_i\delta + (\mu_i + \varepsilon_{it}), \quad i = 1, 2, \ldots, N \text{ individuals}; \quad t = 1, 2, \ldots, T \text{ time periods}. \tag{3}$$

To implement the one-way REM of Eq. (3), we assume that both μ and ε are mean-zero and constant variance, (homoscedastic) processes, uncorrelated with the regressors as well as with each other, and that there is no correlation over individuals or time. For the T observations belonging to the ith unit of the panel, the composite error process $\eta_{it} = \mu_i + \varepsilon_{it}$ gives rise to the "error-components model." For this model,

$$\begin{aligned}
&\boldsymbol{\eta}_i = [\eta_{i1}, \eta_{i2}, \ldots, \eta_{iT}]',\\
&E\left[\eta_{it}^2|\mathbf{x}^*\right] = \sigma_\mu^2 + \sigma_\varepsilon^2,\\
&E[\eta_{it}\eta_{is}|\mathbf{x}^*] = \sigma_\mu^2, \quad t \neq s\\
&E\left[\eta_{it}\eta_{js}|\mathbf{x}^*\right] = 0 \quad \forall t \text{ and } s \text{ if } i \neq j
\end{aligned}$$

Since observations i and j are uncorrelated, the full covariance matrix of η across the sample is block diagonal in $\sum : \Omega = I_n \otimes \sum$, where $\sum = E[\boldsymbol{\eta}_i \eta'_i|\mathbf{x}^*] = \sigma_\mu^2 \mathbf{i}_T \mathbf{i}'_T + \sigma_\varepsilon^2 \mathbf{I}_T$.

The GLS estimator for the slope parameters of this model is

$$\begin{aligned}
\hat{\beta}_{RE} &= \left(\mathbf{X}^{*\prime}\Omega^{-1}\mathbf{X}^{*\prime}\right)^{-1}\left(\mathbf{X}\Omega^{-1}y\right)\\
&= \left(\sum_i \mathbf{X}_i^{*\prime} \sum^{-1} \mathbf{X}_i^*\right)^{-1} \left(\sum_i \mathbf{X}_i^{*\prime} \sum^{-1} y_i\right)
\end{aligned} \tag{4}$$

Thus, the key to RE estimator is the GLS transform. To compute this estimator, we require $\Omega^{-1/2} = (\mathrm{I}_n \otimes \sum)^{-1/2}$, which involves

$$\sum^{-1/2} = \sigma_\varepsilon^{-1}\left(\mathrm{I} - T^{-1}\theta l_T l'_T\right) \quad \text{where } \theta = 1 - \left(\frac{\sigma_\varepsilon}{\sqrt{\sigma_\varepsilon^2 + T\sigma_\mu^2}}\right)$$

[5] Another type of estimator, the between estimator, is less efficient because it discards the over-time information in the data in favor of simple means, as it is the OLS estimator from the regression of $\bar{y}_i$ *on* $\bar{\mathbf{x}}_i$.

[6] In contrast to the FEM (where inference is conditional on the FE in the sample), inference from the REM pertains to the underlying population of individuals because the REM identifies the population parameters that describes the individual-level heterogeneity. Therefore, a REM is more efficient and allows a broader range of statistical inference. However, the key assumption that μ_i is uncorrelated with the regressors can and should be tested.

The quasi-demeaning transformation defined by $\sum^{-1/2}$ is then $\sigma_{\varepsilon}^{-1}(y_{it} - \theta\bar{y}_i)$; i.e., rather than subtracting the entire individual mean of y from each value, we should subtract some fraction of that mean, as defined by θ.[7]

2.2 Two-way FE and two-way RE

A two-way-effects model allows the intercept to vary both over individuals and over time. In the presence of unobservable time-specific effects as well, Eq. (1) takes the form:

$$y_{it} = \alpha + \mathbf{x}_{it}\beta + \mathbf{z}_i\delta + \mu_i + \lambda_t + \varepsilon_{it} \tag{5}$$

where full N and T effects are included, but with the restrictions $\sum_i \mu_i = \sum_t \lambda_t = \mathbf{0}$. Least squares estimates of the slope coefficients in this model are obtained by regression of $y_{it}^* = y_{it} - \bar{y}_{i.} - \bar{y}_{.t} + \bar{\bar{y}}$ on $\mathbf{x}_{it}^* = \mathbf{x}_{it} - \bar{\mathbf{x}}_{i.} - \bar{\mathbf{x}}_{.t} + \mathbf{x}$, where the period-specific and overall means are $\bar{y}_{.t} = \sum_{i=1}^{N} \frac{y_{it}}{N}$ and $\bar{\bar{y}} = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T} y_{it}$, and likewise for $\bar{\mathbf{x}}_{.t}$ and $\bar{\bar{\mathbf{x}}}$.Once again, the within estimate of the intercept can be deduced from $\tilde{\alpha} = \bar{y}_{..} - \tilde{\beta}\bar{\mathbf{x}}_{..}$ and those of μ_i and λ_t are given by $\tilde{\mu}_i = (y_{i.} - \bar{y}_{..}) - \tilde{\beta}(\bar{\mathbf{x}}_{i.} - \bar{\mathbf{x}}_{..})$ and $\tilde{\lambda}_t = (y_{.t} - \bar{y}_{..}) - \tilde{\beta}(\bar{\mathbf{x}}_{.t} - \bar{\mathbf{x}}_{..})$, respectively. In the case of two-way RE model, the composite error becomes $(\mu_i + \lambda_t + \varepsilon_{it})$, and λ_t satisfies all the properties of a "standard" error (for details, see Baltagi 2008; Cameron and Trivedi 2009).

2.3 Fixed effects versus random effects

The choice of the method (FEM or REM) depends on two important things, its economic and econometric relevance. From an economic point of view, there are unobservable time invariant random variables, difficult to be quantified, which may simultaneously influence some explanatory variables and the trade volume. From an econometric point of view, the inclusion of fixed effects is preferable to random effects because the rejection of the null assumption of no correlation of the unobservable characteristics with some explanatory variables is less plausible (Baier and Bergstrand 2007). Moreover, there have been recent econometric evaluations of the gravity equation with panel data using the Hausman test to make a selection between the FEM and the REM.

[7] As can be seen, RE estimator has pooled OLS ($\theta = 0$) and within estimation ($\theta = 1$) as special cases. The RE estimator approaches the within estimator as T gets large and as σ_{μ}^2 gets large relative to σ_{ε}^2, because in those cases $\theta \to 1$. To the extent that θ differs from 0, pooled OLS will be inefficient, as it will attach too much weight on the between units variation, attributing it all to the variation in $\mathbf{x}$ rather than apportioning some of the variation to the differences in ε_i across units.

3 Gravity framework

The basic specification of the gravity model includes supply side factors of the export country (GDP and Population or per capita GDP), demand side factors of the import country (GDP and Population or per capita GDP),[8] and trade supporting and impeding determinants (proxies for transport costs and geographic, cultural, and historical bilateral linkages, etc.). Exporter effects (Importer effects), treated as fixed, capture the general propensity to export (import) of a country. However, what about the cyclical influences? The answer lies in 'time effects' that account for the business cycle and changes in openness across all economies (Egger and Pfaffermayr 2003). The resulting estimating equation used in this paper to study the determinants of bilateral trade flows is specified as follows:

$$\begin{aligned} Trade_{ijt} = {} & \alpha + \beta_1 PCGDPI_{it} + \beta_2 PCGDPII_{jt} + \beta_3 PCLANDI_{it} + \beta_4 PCLANDII_{jt} \\ & + \beta_5 DPCGDP_{ijt} + \beta_6 DISTW_{ijt} + \beta_7 ERV_{ijt} + \beta_8 CUI_{it} + \beta_9 CUII_{jt} \\ & + \beta_{10} CU_{ijt} + \beta_{11} NumCUI_{it} + \beta_{12} NumCUII_{jt} \\ & + \beta_{13} MinCU_{ijt} + \omega' Z_{ijt} + \mu_i + \lambda_t + \varepsilon_{ijt}. \end{aligned} \tag{6}$$

where

$Trade_{ijt}$: log of volume of trade (i.e., exports plus imports), between country i (reporting country) and country j (partner country) in year t measured in current US dollars at current exchange rates.

$PCGDPI_{it}$: log of reporting country's GDP per capita in year t measured in current US dollars at current exchange rates.

$PCGDPII_{jt}$: log of partner country's GDP per capita in year t measured in current US dollars at current exchange rates.

$PCLANDI_{it}$: arable land per capita in reporting country i in year t expressed in hectares per person.

$PCLANDII_{jt}$: arable land per capita in partner country j in year t expressed in hectares per person.

$DPCGDP_{ijt}$: per capita GDP difference between the two trading partners and serves as a proxy of economic distance or of comparative advantage intensity, $DPCGDP_{ijt} = |PCGDP_{it} - PCGDP_{jt}|$.

$DISTW_{ijt}$: log of distance between the two countries i and j (in kilometers) in year t, measured according to the great circle formula which uses latitudes and longitudes of the most important cities, in terms of population, or of its official capital. The general formula developed by Head and Mayer (2002) and used for calculating this weighted distance (pop-wt, km) between country i and country j is $d_{ij} = \{\sum_{k \in i} (pop_k/pop_i) \sum_{l \in j} (pop_l/pop_j) d_{kl}^{\theta}\}^{\frac{1}{\theta}}$, where pop_k designates the

[8] The modern theory of optimum currency areas has shifted its priority from nature and characteristics of an economy to the level of economic development of an economy in judging optimality. In the light of this argument, we preferred per capita GDP to GDP and, hence, retained only per capita GDP variable in our gravity model.

population of agglomeration k belonging to country i. The parameter θ measures the sensitivity of trade flows to bilateral distance d_{kl}.
ERV_{ijt}: annual bilateral nominal exchange rate volatility between reporting country i and partner country j in year t, where the exchange rates were expressed in relation to the Special Drawing Rights (SDR) of particular countries at the end of the month resulting in 12 observations per year. Following earlier studies, exchange rate volatility was measured using the standard deviation of first differences of logs of monthly values. These differences are equal to zero when the exchange rate does not exist.
CUI_{it}: dummy variable whose value is equal to 1 if country i is a member of currency union and country j is not a member of currency union in year t and 0 otherwise.
$CUII_{jt}$: dummy variable whose value is equal to 1 if country j is a member of currency union and country i is not a member of currency union in year t and 0 otherwise.
CU_{ijt}: dummy variable whose value is equal to 1 if both countries are using the euro as their currency in year t and 0 otherwise.
$NumCUI_{it}$: variable that takes the value of the number of years the country i has been in the currency union when country j is not a member of the currency union.
$NumCUII_{jt}$: variable that takes the value of the number of years the country j has been in the currency union when country i is not a member of the currency union.
$MinCU_{ijt}$: variable that takes the value of minimum from the number of years in the currency union for both the trading countries.
Z_{ijt}: vector of explanatory variables that may affect bilateral trade between the two trading partners in year t. A detailed description of these control variables is given in Appendix.
μ_i: unobservable country-specific effects, treated as fixed.
λ_t: unobservable time specific effect in the period t, treated as fixed in two-way models; otherwise random (affecting all observations in the same way).
α: refers to the constant term and ε_{ijt} is the error term.

4 Data sources and measurement

The study is wholly restricted to the European Union (EU) economies. The sample covers all the 29 EU countries including the 17 countries in the Eurozone (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherland, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom) and Iceland.[9] The period of estimation is from 1994 to 2011. Following De Nardis et al. (2008), 1994 was chosen as the starting year and the CU dummy variable takes the value of 1 since 1998. The permutations of 29 countries into country pairs yields 812 (29*28) bilateral trade flows i.e., cross-sectional units. The total number of observations is 14,185. Table 1 gives the

[9] Iceland and Croatia were included being on Exchange Rate Management (ERM II).

Table 1 Panel summary statistics

Variable	Mean	SD	Min	Max	Observations
ID			1	812	N = 14,616
YEAR			1994	2011	N = 14,616
TRADE					
Overall	19.87936	2.641273	7.083539	26.32026	N = 14,372
Between		2.538054	12.5421	25.67332	n = 812
Within		0.7591676	14.07049	23.75066	T = 18
EXP					
Overall	19.05134	2.831343	2.108425	25.86138	N = 14,340
Between		2.723492	10.10155	25.11763	n = 812
Within		0.850679	8.482338	23.99658	T = 18
PCGDPI					
Overall	9.683752	0.9352137	6.968922	11.64598	N = 14,588
Between		0.8321448	7.89213	11.09893	n = 812
Within		0.4276006	8.66732	10.7889	T = 18
PCGDPII					
Overall	9.683752	0.9352137	6.968922	11.64598	N = 14,588
Between		0.8321448	7.89213	11.09893	n = 812
Within		0.4276006	8.66732	10.7889	T = 18
PCLANDI					
Overall	0.2771352	0.1634296	0.0193241	0.8379116	N = 14,448
Between		0.1588458	0.0225918	0.6455427	n = 812
Within		0.0382052	0.0730834	0.4814881	T = 18
PCLANDII					
Overall	0.2771353	0.1634295	0.0193241	0.8379116	N = 14,448
Between		0.1588457	0.0225918	0.6455427	n = 812
Within		0.0382052	0.0730834	0.4814882	T = 18
DPCGDP					
Overall	9.269597	1.187407	2.222232	11.58011	N = 14,560
Between		1.080742	5.359848	11.05542	n = 812
Within		0.4949321	4.923823	11.4622	T = 18
DISTW					
Overall	7.16291	0.617807	5.080959	9.641174	N = 14,616
Between		0.6181666	5.080959	9.641174	n = 812
Within		1.67E−15	7.16291	7.16291	T = 18
ERV					
Overall	0.0134115	0.0186894	0	0.2319909	N = 14,616
Between		0.0104255	0.0031633	0.046272	n = 812
Within		0.0155154	−0.0256495	0.1991304	T = 18
CNTGTY					
Overall	0.08867	0.2842765	0	1	N = 14,616
Between		0.284442	0	1	n = 812
Within		0	0.08867	0.08867	T = 18

Table 1 continued

Variable	Mean	SD	Min	Max	Observations
COMLANGE					
Overall	0.0320197	0.1760584	0	1	N = 14,616
Between		0.1761609	0	1	n = 812
Within		0	0.0320197	0.0320197	T = 18
LANDLKDI					
Overall	0.1724138	0.3777526	0	1	N = 14,616
Between		0.3779725	0	1	n = 812
Within		0	0.1724138	0.1724138	T = 18
LANDLKDII					
Overall	0.1699507	0.3756024	0	1	N = 14,616
Between		0.375821	0	1	n = 812
Within		0	0.1699507	0.1699507	T = 18
LANDLKD					
Overall	0.3423645	0.5238615	0	2	N = 14,616
Between		0.5241665	0	2	n = 812
Within		0	0.3423645	0.3423645	T = 18
CUI					
Overall	0.1954023	0.3965236	0	1	N = 14,616
Between		0.3072572	0	0.7777778	n = 812
Within		0.2508661	−0.5823755	1.139847	T = 18
CUII					
Overall	0.1953339	0.3964711	0	1	N = 14,616
Between		0.3071335	0	0.7777778	n = 812
Within		0.2509343	−0.5824439	1.139778	T = 18
CU					
Overall	0.1532567	0.3602471	0	1	N = 14,616
Between		0.2745649	0	0.7777778	n = 812
Within		0.2334091	−0.6245211	1.097701	T = 18
NumCUI					
Overall	3.517241	5.527412	0	14	N = 14,616
Between		5.53063	0	14	n = 812
Within		0	3.517241	3.517241	T = 18
NumCUII					
Overall	3.517241	5.527412	0	14	N = 14,616
Between		5.53063	0	14	n = 812
Within		0	3.517241	3.517241	T = 18
MinCU					
Overall	2.758621	4.939292	0	14	N = 14,616
Between		4.942167	0	14	n = 812
Within		0	2.758621	2.758621	T = 18

summary statistics of the panel data set. Time-invariant regressors have zero within variation, so the variables CNTGTY, COMLANGO, COMLANGE, LANDLKDI, LANDLKDII, LANDLKD, NumCUI, NumCUII, and MinCU are time-invariant. Individual-invariant regressors have zero between variations. The only individual invariant variable in our study is YEAR. The Min and Max columns represent the minimums and maximums of say, x_{it} for overall, $\bar{x}_i$ for between, and $x_{it} - \bar{x}_i + \bar{x}$ for within. In addition, it can be found out that there is more variation across individuals (between variation) than over time (within variation) for all the variables. This suggests that within estimation may lead to considerable efficiency loss (Cameron and Trivedi 2009).

Annual Export and Import data measured in current US dollars at current exchange rates are retrieved from the International Monetary Fund (IMF) Direction of Trade Statistics (DOTS). Hence, bilateral trade (Trade_{ij}) data is obtained by adding the exports and imports of a country with the partner country. We have used the log of the sum of exports and imports in the final estimation. Data on the variables of Per Capita GDP and Per Capita arable land are taken from the World Development Indicators database of the World Bank. Distance and control variables were collected from the *Centre d'Etudes Prospectives et d'Informations Internationales (CEPII)* database, while monthly nominal exchange rate data was retrieved from the International Financial Statistics (IFS) CD_ROM of the IMF.

5 Estimation results and empirical analysis

In this section, we first present (in Table 2) the results of estimating Eq. (6) on the complete dataset of 29 EMU economies described above using the FEM and the REM by taking into account the country-specific effects and time effects and outline their implications for the hypotheses of interest. We carry out several panel data estimations in order to compare the results across several specifications and to identify the most robust one. Then, in Table 3 we estimate the same gravity equation for bilateral trade and bilateral exports on a smaller dataset using one-way fixed effects estimator instead of two-way fixed effects estimator. In the beginning, preliminary analysis regarding the presence of unobservable heterogeneity due to bilateral country-specific effects in the sample data is done with the help of two-way scatter plots. Figure 1 shows the presence of heterogeneity across the countries used in the analysis. The presence of unobservable country-specific fixed effects is also confirmed by the effect test given at the end of Table 2. Hence, running a simple OLS regression is invalidated by the dataset. However, the OLS regression estimates are also presented (column 1, Table 2) in order to make comparisons. We also test the presence of time effects in which case the null hypothesis of no time effects is rejected, although marginally at 5 % level of significance. This presence of time-specific effects is shown in Fig. 2.

We have retained both one-way and two-way estimates because of the presence of small time-specific effects. The χ^2 value of the Hausman test (through the value of χ^2 this test indicates whether the specific effects are correlated or not with the

Table 2 Estimates of bilateral trade using the gravity model

Variable	OLS	Fixed effect	Random effect	Two_way FE	Two_way RE
PCGDPI	0.774***	0.813***	0.812***	1.043***	1.021***
	(0.021)	(0.032)	(0.031)	(0.043)	(0.041)
PCGDPII	0.703***	0.685***	0.690***	0.910***	0.894***
	(0.021)	(0.033)	(0.031)	(0.045)	(0.043)
PCLANDI	0.888***	−0.329*	−0.255	0.011	0.081
	(0.119)	(0.194)	(0.188)	(0.201)	(0.194)
PCLANDII	0.428***	−0.699***	−0.636***	−0.344**	−0.287
	(0.114)	(0.187)	(0.181)	(0.185)	(0.179)
DPCGDP	−0.101***	−0.042***	−0.045***	−0.026**	−0.028***
	(0.015)	(0.010)	(0.010)	(0.011)	(0.010)
DISTW	−2.320***	–	−2.300***	–	−2.340***
	(0.039)		(0.159)		(0.161)
ERV	9.400***	0.589*	0.612*	1.280***	1.280***
	(1.020)	(0.352)	(0.350)	(0.374)	(0.371)
CNTGTY	0.416***	–	0.647***	–	0.686***
	(0.059)		(0.253)		(0.256)
COMLANGE	1.080***	–	1.280***	–	1.500***
	(0.091)		(0.348)		(0.350)
LANDLKDI	0.039	–	−0.988***	–	−1.020***
	(0.060)		(0.180)		(0.185)
LANDLKDII	–	–	−1.040***	–	−1.070***
			(0.194)		(0.199)
LANDLKD	−0.836***	–	–	–	–
	(0.046)				
CUI	0.139**	0.128***	0.129***	0.065**	0.060*
	(0.061)	(0.025)	(0.025)	(0.033)	(0.033)
CUII	0.075	0.168***	0.170***	0.096***	0.092***
	(0.059)	(0.025)	(0.025)	(0.032)	(0.032)
CU	0.035	0.111***	0.112***	0.136***	0.125***
	(0.063)	(0.025)	(0.025)	(0.037)	(0.037)
NumCUI	0.107***	–	0.072***	–	0.064***
	(0.005)		(0.014)		(0.014)
NumCUII	0.104***	–	0.079***	–	0.072***
	(0.005)		(0.014)		(0.014)
MinCU	0.186***	–	0.133***	–	0.111***
	(0.005)		(0.014)		(0.015)
Constant	21.600***	6.000***	21.800***	1.400**	18.000***
	(0.372)	(0.241)	(1.140)	(0.614)	(1.280)
No. of groups	812	812	812	812	812
No. of observations	14185	14185	14,185	14,185	14,185
r2	0.557	0.737		0.753	

Table 2 continued

Variable	OLS	Fixed effect	Random effect	Two_way FE	Two_way RE
Root MSE	1.75	0.383	0.399	0.371	0.387
r2_o		0.214	0.544	0.212	0.540
r2_b		0.149	0.510	0.147	0.504
r2_w		0.737	0.737	0.753	0.753
Sigma_u		2.330	1.500	2.340	1.480
Sigma_e		0.394	0.394	0.382	0.382
Rho		0.972	0.936	0.974	0.937
F test/Wald test (model)	988.93***	735.07***	7519.65***	372.05***	10376.81***
Effect test(*F* test/BP LM test)		554.92***	96696.54***	236.95***	96696.54***
Hausman test (prob > chi^2)		24.15 (0.115)		59.02 (0.0002)	

Time dummies were included in columns 4 and 5 (Table 2). The F-statistic for significance of time dummies is $F(17, 14{,}149) = 1.62$ which is significant at 5 % level. The corresponding F-statistic for the significance of country dummies is $F\ (811, 13384) = 554.92$***. Combined F-statistic for the significance of both the effects is $F(43, 14123) = 236.95$***. Hausman test for (Two_way FE-Two_way RE) is $\chi^2(26) = 59.02$ with a *p* value of 0.0002

Values in the parenthesis report robust standard errors

***, ** and * Denote significance at 1, 5 and 10 % level, respectively

explanatory variables) rejects the two-way REM in favor of the two-way FEM (columns 4 and 5, Table 2). However, FEM eliminates the unobserved heterogeneity and, therefore, estimates of the time-invariant variables are not obtained under this model. Inference about the possible impact of time-invariant variables on the dependent variable can be made from one-way REM estimates because in the absence of time effects (columns 2 and 3, Table 2) the Hausman test does not reject the null hypothesis of country-specific effects being uncorrelated with explanatory variables against the alternative hypothesis that unobservable country-specific effects are correlated with explanatory variables.

One point that the theory of Optimum Currency Areas suggests is the real convergence of macro variables among countries using the same currency. In terms of convergence hypothesis, this means estimating the effect that currency union has, via trade, on output per capita. In other words, bilateral trade will be very high between the countries using the same currency than those countries that are not part of currency union (Fig. 3). This also means more the number of years the two countries have been using the same currency, higher will be the trade between them and lesser will be the divergence or dispersion of trade (Fig. 4).

Coming to the estimated results of Table 2, the expected signs for the estimators associated with the variables are based on the traditional gravity arguments. Theoretically, we expect a positive impact of the variables like such as the per capita GDP, the currency union agreement, the number of years in the currency union, the common language, and the common border on trade flows; but a negative

Table 3 The gravity results of sub-sample data using the fixed effects model

Variable	Eurozone-EMU		Eurozone–Eurozone	
	Bilateral trade	Exports	Bilateral trade	Exports
PCGDPI	0.552***	0.558***	0.643***	0.673***
	(0.065)	(0.086)	(0.091)	(0.112)
PCGDPII	0.791***	0.843***	0.686***	0.643***
	(0.046)	(0.062)	(0.083)	(0.110)
PCLANDII	−0.695***	−0.813**	−1.100	−2.250*
	(0.240)	(0.354)	(0.679)	(1.240)
PCLANDI	−0.300	−0.389	0.183	0.063
	(0.379)	(0.531)	(0.412)	(0.622)
DPCGDP	−0.042***	−0.069***	−0.059***	−0.071***
	(0.015)	(0.018)	(0.020)	(0.024)
ERV	−1.530	−0.606	−1.030	0.339
	(0.986)	(1.840)	(1.040)	(1.390)
CUI	0.138***	0.136***	0.130***	0.094*
	(0.026)	(0.034)	(0.043)	(0.052)
CUII	0.205***	0.196***	0.209***	0.196***
	(0.032)	(0.054)	(0.031)	(0.054)
CU	0.170***	0.123***	0.187***	0.150***
	(0.027)	(0.037)	(0.027)	(0.033)
_cons	7.500***	6.440***	7.760***	7.430***
	(0.396)	(0.528)	(0.645)	(0.931)
No. of observations	8252	8238	4673	4665
r2	0.692	0.562	0.658	0.542
Root MSE	0.376	0.508	0.363	0.462
r2_o	0.208	0.170	0.246	0.193
r2_b	0.160	0.126	0.220	0.160
r2_w	0.692	0.562	0.658	0.542
sigma_u	2.450	2.660	2.470	2.700
sigma_e	0.387	0.523	0.374	0.476
Rho	0.976	0.963	0.978	0.970

Time-invariant variables (distance, common border, common language, landlockedness, and number of years a country has been in the currency union) get omitted in the fixed effects estimation

Values in the parenthesis report robust standard errors

***, ** and * Denote significance at the level of 1, 5 and 10 %, respectively

effect of geographical distance and landlockedness on bilateral trade flows. The exchange rate variable can have either the positive sign or the negative sign. While a negative sign implies a depreciation of the exporter currency with respect to the partner's currency resulting in improved export competitiveness, a positive sign implies higher returns associated with higher risk. It should be noted that bilateral trade is a risky activity in our study because of the "sunk costs" associated with

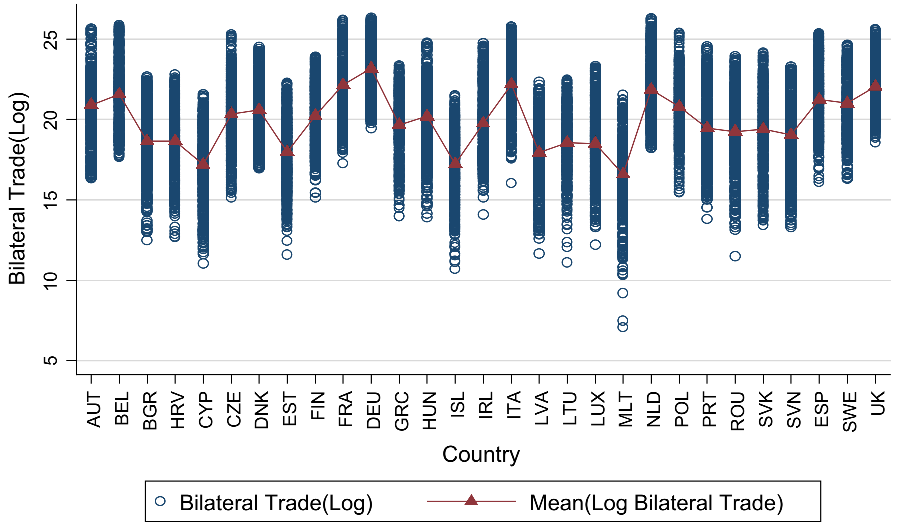

Fig. 1 Fixed effects: heterogeneity across countries

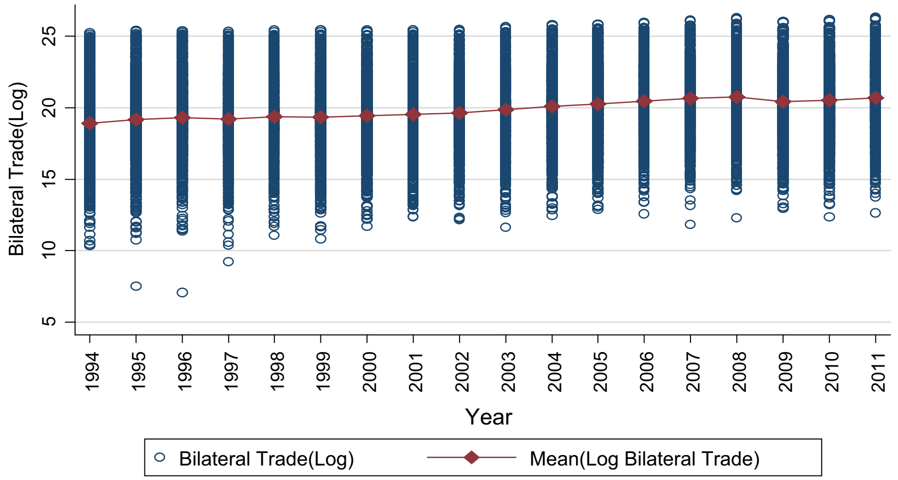

Fig. 2 Fixed effects: heterogeneity across years

export and import of goods across borders. Regarding the sign of the absolute difference of per capita GDP, it is positive if the Heckscher–Ohlin (H–O) assumptions are confirmed. Countries very different in factors endowments and thus, in comparative advantages would exchange more goods of inter-industry nature between them. On the contrary, according to the new trade theory explaining intra-industry trade, the difference of income per capita variable between countries is expected to have a negative impact on bilateral trade flows. Also, geographical distance, being a proxy of transport costs, has always a negative impact theoretically.

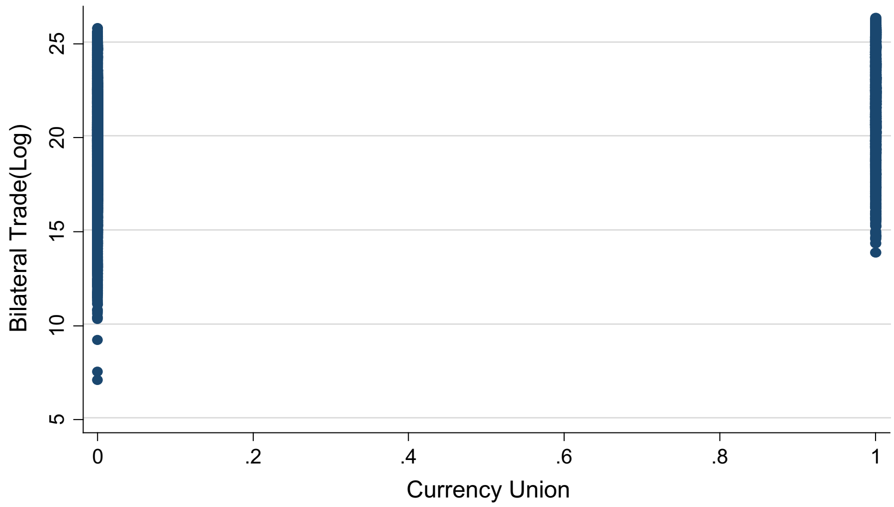

Fig. 3 Impact of currency union participation on bilateral trade

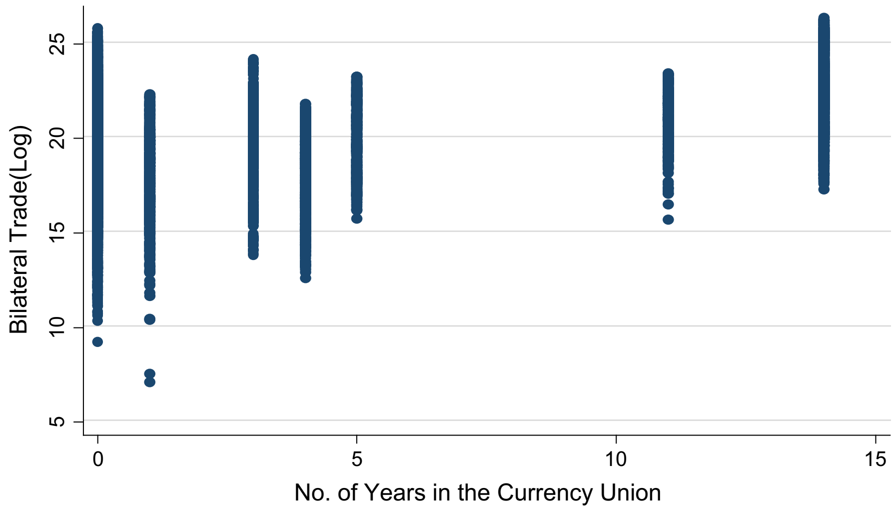

Fig. 4 Impact of currency union participation on bilateral trade

In all estimations, we can notice that the variable of income per capita has the expected positive sign for both the reporting country and the partner country. This is in accordance with the modern trade theory, i.e., countries with similar economic structure tend to have higher volumes of trade between them. On the contrary, the distance variable (proxy for the transportation costs) with negative value represents an obstacle for trade. It should be noted that the distance between countries have a negative elasticity of 2.34 and hence, have an important explanatory capacity. Land per capita as factor endowment variable has a very fragile impact on trade flows as one would expect in the case of these developed European Union economies (Cieslik et al. 2012). Contiguity and common language have expected signs while a country which is not having access to sea will trade less. Exchange rate variability influence on bilateral trade has always been a matter of controversy (De Grauwe and Skudelny 2000). In this study it has a positive and significant effect on bilateral trade. This implies that one should not expect that the removal of exchange rate volatility as a result of the adoption of the euro currency would stimulate trade flows. Further, the reported results show the significantly negative impact of per capita income differences variable on bilateral trade flows, which implies that intra-industry trade is taking place among these economies. In terms of implication to trade theory, this result is in line with the arguments for intra-industry trade.

Coming to our variable of interest i.e., currency union, the two-way fixed effects (colum 4, Table 2) model shows that countries using the same currency will increase their bilateral trade by 14.57 %.[10] This impact is higher than the impact when only the reporting country or the partner country is using the euro as its currency. In the former case, it is 6.18 % while in the latter case the euro effect is 10.07 %. Contrary to this, when time effects are dropped, the euro effect on trade flows gets reduced to 11.85 % in the case of both countries using the euro currency. The duration (number of years) by which the two countries are using the euro as its currency has also a favourable impact on bilateral trade. This is suggested by the positive and significant coefficients of MinCU, NumCUI and NumCUII variables at 1 % level of significance.

In Table 3, the euro effect on both bilateral trade and exports is estimated using a smaller dataset (columns 1 and 2 are estimated using 17 Eurozone economies as reporting countries and all the 29 EMU economies as partner countries; columns 3 and 4 make estimations on the Euro club economies only). Except exchange rate volatility variable and the reporting country's per capita arable land variable, the results of other variables (such as per capita GDPs, partner country per capita arable land, currency union variables, absolute GDP difference variable) are same (in terms of sign and significance) as that obtained in Table 2. While columns 1 and 3 (Table 3) show the estimates of Eq. (6), columns 2 and 4 of Table 3 report corresponding estimated results when bilateral exports replace bilateral trade as the dependent variable in Eq. (6). It is clear from Table 3 that the euro effect on both trade and exports is highest when both the countries belong to the Eurozone (parameter coefficient of CU variable is larger in columns 3 and 4 of Table 3 than in columns 1 and 2 of Table 3). More specially, the euro adoption increases trade and exports by 20.56 and 16.18 % when the Eurozone economies trade with themselves, while the corresponding results for columns 1 and 2 (Table 3) are 18.53 and 13.09 %, respectively.

[10] Column 4 (two-way FEM) of Table 2 gives the parameter of CU dummy equal to 0.136. Therefore, the increase in bilateral trade induced by the adoption of the euro by euro member countries is $[\{e^{0.136\times 1} - e^{0.136\times 0}\} \times 100] = 14.57$ %.

6 Conclusion and final remarks

The main purpose of this study was to investigate the trade implications of the euro adoption for the intra-EMU and intra-Eurozone economies using the generalized gravity model on a panel dataset of 29 EMU countries from the period 1994 to 2011. A motivation for this study was that with more than a decade of euro adoption, the euro impact on trade will now be more discernible. Recent research suggests that the introduction of the euro has a sizeable and statistically significant effect on trade among EMU members (see, Bun and Klaassen 2007; Cieslik et al. 2012, among others). Earlier studies imply that EMU has increased trade by about 10 % in the first few years of its existence (see, for example, Micco et al. 2003). In our study, we find out that the euro adoption has a positive and statistically significant impact on bilateral trade. Our reported results show that the adoption of the euro has increased intra-EMU trade by about 14 % and the intra-Eurozone trade by about 20 %, thereby suggesting a higher economic integration of the Euro-club economies. This finding has an important policy implication for the countries that are considering joining the euro.

Exchange rate volatility shows a favorable effect on bilateral trade in a two-way FEM (Table 2) but insignificant effect in case of one-way FEM (Table 3). This result, though converse to most of the studies, is not a surprising one. Evidence on the impact of exchange rate variability on trade and exports is mixed: some studies finding no significant influence of exchange rate volatility on trade, others find significantly negative or positive effects. Still, others find a negligible impact of the exchange rate volatility on trade flows. In the literature, these mixed results about exchange rate volatility resulted in the renewal of the theoretical analysis by progressively relaxing the restrictive assumptions. While Hooper and Kohlhagen (1978) assume constant absolute risk aversion so that an increase in the exchange rate risk leads to a reduction of the risky activity (trade), De Grauwe (1988) argues that the effects of an exchange rate risk may be different once this assumption is relaxed. This makes, in general, the effect of exchange rate uncertainty on international trade flows to be very ambiguous.

From the international trade theories point of view, developing countries or two sets of heterogeneous economies that are at different levels of economic development will have inter-industry and vertical intra-industry trade. While inter-industry trade will arise because of the differences in relative factor endowments among them and hence better utilized comparative advantages (H–O theory); the vertical intra-industry trade, stimulated by multinational corporations, arises because of the labor intensive production segments in developing countries due to their less expensive labor costs and comparative advantage in these activities than the developed countries. This hypothesis is tested by a positive coefficient of absolute differences in per capita GDP variable. A negative sign of this coefficient is associated with horizontal intra-industry trade structure, which assumes the existence of simultaneous export and import trade flows of comparable sizes on the same lines of production, i.e., similar products of same quality and of same technology. The economies in our study show a negative coefficient of per capita

GDP differences variable, which implies that horizontal intra-industry trade, is taking place among these sample economies. Thus, the reported results favor the New Trade theory over Heckscher–Ohlin theory. However, the low value of this coefficient suggests that, over the period, the type of trade among these economies has transited from inter-industry trade to horizontal intra-industry trade. That is, these economies have already moved on the path of economic convergence.

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Appendix: List of control dummy variables used in the model

All the economic variables that affect trade between the two trading partners are explicitly included in the model. Besides these standard set of gravity variables, there exist a set of control variables that may affect the bilateral trade (such as geographic location, contiguity, landlockedness, historical ties, regional trading agreements and customs union, colonial ties, similarity in cultural, political, and legal institutions, etc.). These variables are classified as economic geography and historical ties variables. Economic geography variables include contiguity and landlocked location. Contiguity may stimulate cross-border trade, while landlocked location may discourage trade between two countries due to lack of sea access. Historical ties variables include common colonial past, common official language, etc. Since our dataset includes only European Union countries, therefore inclusion of variables like colonial ties variable is not required. The included control variables are

$CONTGTY_{ijt}$: dummy variable whose value is equal to 1 if countries i and j share common border in year t and 0 otherwise.
$COMLANGO_{ijt}$: 1 for the common official primary language between country i and country j in year t; 0 otherwise.
$COMLANGE_{ijt}$: 1 if a language is spoken by at least 9 % of the population in both the countries in year t; 0 otherwise.
$LANDLKDI_{it}$: dummy variable whose value is equal to 1 if reporting country i is a landlocked country and partner country j is not in year t and 0 otherwise.
$LANDLKDII_{jt}$: dummy variable whose value is equal to 1 if country i is not a landlocked country but country j is a landlocked country in year t; 0 otherwise.
$LANDLKD_{ijt}$: dummy variable whose value is equal to 1 if both the countries are landlocked in year t and 0 otherwise.

References

Aitken ND (1973) The effect of the EEC and EFTA on European trade: a temporal cross-section analysis. Am Econ Rev 63:881–892

Alesina A, Barro RJ (2002) Currency unions. Q J Econ 117(2):409–436

Anderson JE (1979) A theoretical foundation for the gravity equation. Am Econ Rev 69(1):106–116

Anderson JE, Wincoop E (2003) Gravity with gravitas: a solution to the Border puzzle. Am Econ Rev 93(1):170–192

Anderson JE (2010) The gravity model. NBER Working Paper 16576

Anderson JE, Vesselovsky M, Yotov YV (2013) Gravity, Scale and Exchange Rates. NBER Working Paper 18807

Baier SL, Bergstrand JH (2007) Do free trade agreements actually increase members' international trade? J Int Econ 71(1):72–95

Baldwin RE, Skudelny F, Taglioni D (2005) Trade effects of the euro: evidence from sectoral data. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=668246

Baldwin R, Taglioni D (2006) Gravity for dummies and dummies for gravity equations. NBER Working Paper 12516

Baldwin R, DiNino V, Fontagne L, De Santis RA, Taglioni D (2008) Study on the impact of the euro on trade and foreign direct investment. Economic Paper 321. Directorate General Economic and Monetary Affairs (DG ECFIN), European Commission

Baltagi B (2008) Econometric analysis of panel data. Wiley, London

Barr D, Breedon F, Miles D (2003) Life on the outside: economic conditions and prospects outside euroland. Econ Policy 18(37):573–613

Barro RJ, Gordon DB (1983) Rules, discretion and reputation in a model of monetary policy. J Monet Econ 12(1):101–121

Barro R, Tenreyro S (2007) Economic effects of currency unions. Econ Inq 45(1):1–23

Berger H, Nitsch V (2008) Zooming out: the trade effect of the Euro in historical perspective. J Int Money Finance 27(8):1244–1260

Bergin PR, Lin CY (2012) The dynamic effects of a currency union on trade. J Int Econ 87(2):191–204

Bergstrand JH (1985) The gravity equation in international trade: some microeconomic foundations and empirical evidence. Rev Econ Stat 67(3):474–481

Blanchard O, Wolfers J (2000) The role of shocks and institutions in the rise of European unemployment: the aggregate evidence. Econ J 110(462):1–33

Broz T (2005) The theory of optimum currency areas: a literature review. Privredna Kretanja I Ekonomska Politika 104:53–78

Buiter WH (1995) Macroeconomic policy during a transition to monetary union. CEPR Working Paper No. 1222

Buiter WH (2000) Optimal currency areas: Why does the exchange rate regime matter? (with an Application to UK Membership in EMU). Centre for Economic Performance, London School of Economics and Political Science

Bun MJG, Klaassen FJGM (2002) The importance of dynamics in panel gravity models of trade. Retrieved from http://dare.uva.nl/record/393045

Bun MJG, Klaassen FJGM (2007) The Euro effect on trade is not as large as commonly thought*. Oxford Bull Econ Stat 69(4):473–496

Buti M, Suardy M (2000) Cyclical convergence or differentiation? Insights from the first year of EMU. Revue de La Banque 64(2/3):164–172

Cafiso G (2008) The Euro's influence upon trade: Rose effect versus Border effect. European Central Bank. http://www.suomenpankki.fi/pdf/160530.pdf

Calvo GA, Reinhart CM (2002) Fear of floating. Q J Econ 117(2):379–408

Camarero M, Gómez E, Tamarit C (2014) Is the "euro effect"on trade so small after all? New evidence using gravity equations with panel cointegration techniques. Econ Lett 124(1):140–142

Cameron AC, Trivedi PK (2009) Microeconometrics using stata, vol 5. Stata Press, College Station

Cieślik A, Michalek JJ, Mycielski J (2012) Measuring the trade effects of the Euro in Central and Eastern Europe. J Int Trade Econ Dev 21(1):25–49

Collins SM (1996) On becoming more flexible: exchange rate regimes in Latin America and the Caribbean. J Dev Econ 51(1):117–138

Cordon WM (1972) Monetary integration. International Finance Section, Princeton University. http://www.getcited.org/pub/101321427
De Grauwe P (1996) The economics of convergence: towards monetary union in Europe. Weltwirtschaftliches Arch 132(1):1–27
De Grauwe P (1988) Exchange rate variability and the slowdown in growth of international trade. Staff Pap Int Monet Fund 35:63–84
De Grauwe P (2006) What have we learnt about monetary integration since the maastricht treaty? J Common Mark Stud 44(4):711–730
De Grauwe P, Skudelny F (2000) The impact of EMU on trade flows. Weltwirtschaftliches Arch 136(3):381–402
De Grauwe P, Mongelli FP (2005) Endogeneities of optimum CURRENCY AREAs: What brings countries sharing a single currency closer Together? Departamento de Economia, Gestão e Engenharia Industrial, Universidade de Aveiro
De Grauwe P (2014) Economics of monetary union. Oxford University Press, Oxford
De Nardis S, Vicarelli C (2003) Currency unions and trade: the special case of EMU. Rev World Econ 139(4):625–649
De Nardis S, De Santis R, Vicarelli C (2008) The Euro's effects on trade in a dynamic setting. Eur J Comp Econ 5(1):73–85
De Sousa J (2012) The currency union effect on trade is decreasing over time. Econ Lett 117(3):917–920
Deardorff A (1998) Determinants of bilateral trade: Does gravity work in a neoclassical world? In: Frankel JA (ed) The regionalization of the world economy. University of Chicago, Chicago, pp 7–32
Dellas H, Tavlas GS (2009) An optimum-currency-area odyssey. J Int Money Finance 28(7):1117–1137
Edwards S (1996) Exchange rates and the political economy of macroeconomic discipline. Am Econ Rev 86(2):159–163
Egger P (2000) A note on the proper econometric specification of the gravity equation. Econ Lett 66(1):25–31
Egger P, Pfaffermayr M (2003) The proper panel econometric specification of the gravity equation: a three-way model with bilateral interaction effects. Empir Econ 28(3):571–580
Engel C, Rose AK (2000) Currency Unions and International Integration. NBER Working Paper 7872
Faruqee H (2004) Measuring the trade effects of EMU. IMF Working Paper 04/154, International Monetary Fund, Washington
Fidrmuc J (2004) The endogeneity of the optimum currency area criteria, intra-industry trade, and EMU enlargement. Contemp Econ Policy 22(1):1–12
Fidrmuc J, Fidrmuc J (2003) Disintegration and trade. Rev Int Econ 11(5):811–829
Flam H, Nordström H (2003) Trade volume effects of the Euro: aggregate and sector estimates. IIES Seminar Paper 746. Institute for International Economic Studies, Stockholm
Fidrmuc J (2009) Gravity models in integrated panels. Empir Econ 37(2):435–446
Frankel JA, Rose AK (1997) Is EMU more justifiable ex post than ex ante? Euro Econ Rev 41(3):753–760
Frankel JA, Rose AK (1998) The endogeneity of the optimum currency area criteria. Econ J 108(449):1009–1025
Gandolfo G (1992) Monetary unions. In: Newman P, Milgate M, Eatwell J (eds) The new palgrave dictionary of money and finance, vol 3. MacMillan, London, pp 765–770
Geldi HK (2012) Trade effects of regional integration: a panel cointegration analysis. Econ Model 29(5):1566–1570
Glick R, Rose AK (2002) Does a currency union affect trade? The time-series evidence. Euro Econ Rev 46(6):1125–1151
Grubel HG (1970) The theory of optimum currency areas. Can J Econ 3(2):318–324
Havránek T (2010) Rose effect and the euro: Is the magic gone? Rev World Econ 146(2):241–261
Head K, Mayer T (2002) Illusory border effects: distance mismeasurement inflates estimates of home bias in trade, vol 1. CEPII, Paris
Helpman E, Melitz M, Rubinstein Y (2008) Estimating trade flows: trading partners and trading volumes. Q J Econ 123(2):441–487
Hooper P, Kohlhagen SW (1978) The effect of exchange rate uncertainty on the prices and volume of international trade. J Int Econ 8(4):483–511
Ishiyama Y (1975) The theory of optimum currency areas: a survey. Staff Papers-IMF, pp 344–83
Issing O (2001) Monetary policy in the Euro area: strategy and decision-making at the European Central Bank. Cambridge University Press, Cambridge

Kenen PB (1969) The optimum currency area: an eclectic view. In: Mundell R, Swoboda AK (eds) Monetary problems of the international economy. University of Chicago Press, Chicago, pp 41–60
Krugman PR (1993) What do we need to know about the international monetary system? International Economics Section, Department of Economics, Princeton University
Krugman PR (2001) Lessons of Massachusetts for EMU. Int Libr Crit Writ Econ 134:41–61
Kydland FE, Prescott EC (1977) Rules rather than discretion: the inconsistency of optimal plans. J Political Econ 85(3):473–491
Linnemann H (1966) An econometric study of international trade flows. North-Holland Publishing Company, Amsterdam. http://library.wur.nl/WebQuery/clc/457015
Martinez-Zarzoso I (2013) The log of gravity revisited. Appl Econ 45(3):311–327
McKinnon R (1963) Optimum currency areas. Amer Econ Rev 717–25
Melitz J (1991) Brussels on a single money. Open Econ Rev 2(3):323–336
Micco A, Stein E, Ordoñez G (2003) The currency union effect on trade: early evidence from EMU. Econ Policy 18(37):315–356
Mundell RA (1961) A theory of optimum currency areas. Am Econ Rev 51:657–665
Mundell RA (1973) Uncommon arguments for common currencies. In: The economics of common currencies: proceedings of the Madrid conference on optimum currency areas. Allen & Unwin, pp 114–32
Nitsch V (2002) Honey, I shrunk the currency union effect on trade. World Econ 25(4):457–474
Obstfeld M, Rogoff K (1996) Exchange rate dynamics redux. NBER Working Paper 4693
Pöyhönen P (1963) A Tentative model for the volume of trade between countries. Weltwirtschaftliches Arch 90(1):93–100
Rault C, Sova R, Sova AM (2009) modelling international trade flows between CEEC and OECD countries. Appl Econ Lett 16(15):1547–1554
Rose AK et al (2000) One money, one market: the effect of common currencies on trade. Econ Policy 15(30):7–46
Roy J (2014) On the robustness of the trade-inducing effects of trade agreements and currency unions. Empir Econ 47(1):253–304
Siliverstovs B, Schumacher D (2009) Estimating gravity equations: To log or not to log? Empirical Econ 36(3):645–669
Santos Silva JMC, Tenreyro S (2006) The log of gravity. Rev Econ Stat 88(4):641–658
Tavlas GS (1993) The 'new' theory of optimum currency areas. World Econ 16(6):663–685
Tinbergen J (1962) Shaping the world economy: suggestions for an international economic policy. Twentieth Century Fund, New York
Tower E, Willett TD (1976) The theory of optimum currency areas and exchange-rate flexibility. International Finance Section, Department of Economics, Princeton University
Westerlund J, Wilhelmsson F (2011) Estimating the gravity model without gravity using panel data. Appl Econ 43(6):641–649