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ORIGINAL PAPER

Regional output growth synchronisation with the Euro Area

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Abstract This paper investigates the patterns and determinants of the co-movement of economic activity between regions in the European Union and the Euro Area. We use a panel dataset of 208 regions over the period 1989–2002 and estimate a system of simultaneous equations to analyse the impact of regional trade integration, industry specialisation and exchange rate volatility on regional output growth synchronisation with the Euro Area. We find that deeper trade integration with the Euro Area had a strong direct positive effect on the synchronisation of regional output growth with the Euro Area. Industrial specialisation and exchange rate volatility were sources of cyclical divergence. Industrial specialisation had however an indirect positive effect on regional output growth synchronisation via its positive effect on trade integration, while exchange rate volatility had an indirect additional negative effect on regional output growth synchronisation by reducing trade integration.

Keywords European economic and monetary union · Business cycles · Regional growth

JEL Classification E32 · F33 · F42

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1 Introduction

A common monetary policy has both benefits and costs. The benefits are gains in trade and growth due to the elimination of exchange rate uncertainty and the reduction of transaction costs.The costs are related to the possibility of increased volatility of economic activity due to the loss of independence over monetary and exchange rate policy as stabilisation tools. Since a common monetary policy can only address common shocks to the participating countries and regions, the presence of asymmetric shocks is associated with costs in terms of volatility of economic activity. Thus, the balance between benefits and costs depends on the occurrence of asymmetric shocks. Business cycle synchronisation is taken as an indication of a low probability of asymmetric shocks and a low cost of losing independence over monetary and exchange rate policies (Mundell 1961; McKinnon 1963; Kenen 1969; Bayoumi and Eichengreen 1997; Alesina and Barro 2002).

Increased international economic integration has stimulated a growing academic and policy interest in the analysis of the synchronisation of business cycles and their international transmission. (Stockman 1988; Canova and Marrinan 1998; Kose et al. 2003; Baxter and Kouparitsas 2003; Bordo and Helbling 2003; Imbs 2004). In particular, the impact of monetary integration on the business cycle synchronisation has received increasing attention recently[1] (Frankel and Rose 1998; Artis et al. 2003, 2004; Barrios et al. 2003; Traistaru 2004; Bergman 2005; Schiavo 2008; Giannone et al. 2009).

Furthermore, the economic integration process is likely to have a stronger effect at regional level than at national level. This stronger effect can be expected because regions trade relatively more than countries and specialisation at regional level is higher than at national level (Krugman 1993; Fatás 1997). Thus, fluctuations of economic activity at regional level are expected to be more important than at national level which raises the question about the extent of synchronisation of regional business cycles. Barrios and de Lucio (2003) argue that the dynamics of regional business cycles may condition the adjustment of national economies to economic integration.

To date there are only a few studies which investigate regional output growth synchronisation in Europe. De Nardis et al. (1996) examined the correlation between regional and national output growth in the EU countries. Forni and Reichlin (2001) estimated a factor model of regional GDP growth with a European, national and region-specific component. A number of studies analysed correlations of regional employment growth. Fatás (1997) examined the correlation of regional employment growth with the national and European aggregate. Clark and van Wincoop (2001) found that specialisation in production explains the low correlations of regional employment growth across countries in the EU. Barrios et al. (2003) found that while bilateral correlations of regional cycles within the United Kingdom were high, correlation coefficients between regional cycles and the Euro Area aggregate were insignificant. It appears that sectoral specialisation fostered

[1] See Haan et al. (2008) for a review of recent research on the synchronisation of business cycles in the European Economic and Monetary Union and its underlying factors.

this cyclical divergence. Belke and Heine (2006) provide additional empirical evidence about the negative effect of regional industry specialisation on correlations of employment growth across regions in the EU.

However, the scope of these studies with respect to econometric methods, geographical coverage and explanatory power is limited. To fill this gap, this paper identifies and explains the pattern and determinants of synchronisation of European Union (EU) regional output growth with the Euro Area using improved econometric techniques and a richer data set. In particular, we use data for 208 regions[2] in the EU15 countries[3] over the period 1989–2002 and analyse the effect of trade integration, industrial specialisation and monetary policy co-ordination proxied with exchange rate volatility as determinants of regional output growth synchronisation with the Euro Area. We use annual data which is available for all regions over the analysed period.[4] We examine correlations between the regions' output growth and the Euro Area's output growth rather than correlations between the corresponding cyclical components. This choice is motivated by the fact that filtering the data using de-trending techniques would lead to the loss of data points at the end of the sample.

Our contribution to the literature is threefold. First, in contrast to existing studies that estimate single-equations, we estimate a system of simultaneous equations to test the effect of determinants of regional output growth correlations suggested by theory and account for endogeneity and simultaneity in the underlying relationships. This econometric approach allows us to identify both direct and indirect effects of trade integration, industry specialisation and exchange rate volatility on regional output growth synchronisation with the Euro Area. Second, we go beyond most existing cross-section studies by using panel data and account for time invariant region-specific unobserved characteristics and time-specific common shocks that may affect the regions output growth synchronisation. Third, in comparison to existing studies, we use a richer data set including a higher number of regions and more disaggregated manufacturing data at regional level.

The main research findings of the paper are as follows. Deeper trade integration with the Euro Area had a strong direct positive effect on the synchronisation of regional output growth with the Euro Area. Industrial specialisation and exchange rate volatility were sources of cyclical divergence. Industrial specialisation had however an indirect positive effect on output growth synchronisation via its positive effect on trade integration, while exchange rate volatility had an indirect additional negative effect on output growth correlations by reducing trade integration.

The remainder of this paper is organized as follows: Section 2 discusses the theoretical framework of our analysis and derives hypotheses to be tested. Section 3 presents our model specification and estimation issues. Section 4 discusses summary statistics of regional output growth synchronisation with the Euro Area

[2] The analysed regions are classified as NUTS 2 regions according to the Nomenclature of Territorial Units for Statistics (NUTS) of the EUROSTAT—the statistical office of the European Union.

[3] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, United Kingdom.

[4] Quarterly data is not available at regional level. Furthermore, as pointed out by Giannone et al. (2009) annual data is less affected by measurement error in comparison to quarterly data.

and the main explanatory variables. Section 5 presents the results of our econometric analysis and Section 6 concludes.

2 Theoretical framework and related literature

Existing theoretical and empirical literature on the international transmission of business cycles suggests complex interactions between trade intensity, sectoral specialisation, similarity of economic policies and business cycle synchronisation (Imbs 2004).

First, it has been suggested that trade integration results in highly correlated business cycles (McKinnon 1963). Frankel and Rose (1998), Artis and Zhang (1997), Clark and van Wincoop (2001) and Imbs (2004), among others, investigated the relationship between trade intensity and business cycle correlation for industrial countries and found that deeper trade integration was associated with higher business cycle correlations. Frankel and Rose (1998) suggest on the basis of their findings that members of a monetary union would fulfil the Optimum Currency Area (OCA) criteria *ex post* since a common currency reduces transaction costs and thus leads to more trade and more business cycle synchronisation. Furthermore, Micco et al. (2003) find evidence of a positive and significant effect of the European Economic and Monetary Union (EMU) on bilateral trade. This conjecture has led to a number of studies on the endogeneity of the OCA criteria (see De Grauwe and Mongelli 2005) confirming that monetary integration results in increased trade.

In this paper, we test the hypothesis that trade integration with the Euro Area had a positive effect on regional output growth synchronisation with the Euro Area aggregate.

Second, following Kenen (1969), business cycle synchronisation is likely to be lower between two economies having different economic structures. If this is the case, an external demand or supply shock will hit the two economies to a different extent. With differences in economic structures, e.g. if one is specialised in agricultural products while the other in manufacturing, a common, sector-specific shock results in asymmetric effects so that business cycles are less correlated. Similarly, if two economies have different energy intensity, then the more intensive energy user will suffer more from an oil price increase that can dampen output.

The empirical evidence about the effect of economic specialisation on business cycle synchronisation is inconclusive. While a number of studies find that similarity of economic structures was significantly related to business cycle synchronisation across countries (Imbs 2004; Traistaru 2004; Calderón et al. 2007; Inklaar et al. 2008) and across regions (Barrios and de Lucio 2003; Barrios et al. 2003; Belke and Heine 2006), Baxter and Kouparitsas (2005) found that sectoral similarity was not a robust explanatory factor of business cycle correlations across countries. Clark and van Wincoop (2001) finds that while similarity of economic structures is significantly related to cross-country correlation of employment growth in the EU, it does not explain cross-country correlations of GDP growth.

Given the theoretical arguments about the role of specialisation on business cycle synchronisation, we test the hypothesis that regions with dissimilar industry structures with respect to the Euro Area aggregate, have a lower growth cycle correlation with the Euro Area. We use an index of industry specialisation at regional level computed on the basis of seven industries[5] which reflects a more precise industry structure in comparison with previous studies.

The third source of business cycle synchronisation which we address here is monetary integration. According to the real business cycle theory, monetary integration is likely to lead to more synchronised business cycles among its members given that asymmetric monetary policies are sources of business cycle fluctuations (Buiter 2000). For example, if central banks had similar inflation targets and followed a similar exchange rate policy the output effect on their economies would be similar and would lead to business cycle convergence. Furthermore, Mundell (1973a, b) suggests that with flexible prices and wages and free capital mobility, exchange rate movements may be a source of macroeconomic volatility, in particular in small open economies. This view is, however, not uncontested, since the inability to conduct an independent monetary policy can enhance asymmetry of business cycle fluctuations (Clark and van Wincoop 2001; Fatás 1997).

Increased monetary policy coordination took place between EU members following the creation of the European Monetary System (EMS) in 1979 and the establishment of the European Exchange Rate Mechanism (ERM) which aimed to reduce exchange rate variability and achieve monetary stability in preparation to the EMU and the introduction of the single currency. As a result of this policy coordination, exchange rate volatility between EU members decreased and eventually exchange rates were fixed between EMU members. Fatás (1997) found that cross-country co-movement of business cycles of twelve EU countries[6] with the corresponding EU aggregate was higher after the establishment of the EMS in comparison to the pre-EMS period. Artis and Zhang (1997) demonstrated that reduced exchange rate volatility was related to more business cycle synchronisation among European countries before the creation of EMU.

Based on these arguments we test whether regions that were subject to increased monetary policy coordination, proxied by exchange rate stability, showed more output growth synchronisation. To this purpose, we relate regional output growth correlations to the volatility of the nominal exchange rates of national currencies vis-à-vis the Ecu/Euro.

3 Model specification and estimation issues

In Section 2 we proposed to explain regional output growth synchronisation in the EU by trade intensity, industry specialisation and exchange rate volatility. Most of the existing studies look at the impact of different determinants of business cycle synchronisation using a single-equation approach. In contrast, we build on and extend

[5] Classified according to NACE at 2 digit level: mining and energy; food, beverages, tobacco; textiles and clothing; fuels, chemicals, rubber and plastic products; electronics; transport equipment; other manufacturing.

[6] The members of the European Union as of 1992: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, United Kingdom.

the model proposed by Imbs (2004) and estimate the direct and indirect effects of these determinants using a system of simultaneous equations. This approach takes into account the complex links between business cycle synchronisation, trade intensity, industry specialisation and exchange rate volatility and controls for simultaneity and endogeneity in the underlying relationships. We expect that a region shows a higher output growth synchronisation with the Euro Area the more it trades with the Euro Area, the more similar is its industry structure with respect to the Euro Area and the less volatile is its exchange rate vis-à-vis the Ecu/Euro.

As mentioned above, it is highly likely that the explanatory factors are interrelated with each other and therefore they have both direct and indirect effects on the synchronisation of business cycles. First, neoclassical trade theory suggests that regions specialise when trading. To the extent that trade leads to more specialisation, the direct positive effect of trade on business cycle correlations would be diminished by its negative indirect effect via specialisation. However, if trade is largely based on intra-industry trade, the positive effect on business cycle synchronisation would dominate (Fidrmuc 2004). Second, the previous literature on the endogeneity of OCA criteria tells us that trade will increase when monetary policies are more coordinated (Frankel and Rose 1998; De Grauwe and Mongelli 2005).[7]

Most of previous empirical studies have estimated cross-section models of business cycle synchronisation. In this paper we estimate time-varying correlations of regional output growth cycles calculated on the basis of five-year rolling windows over the period 1989–2002.[8] Our panel dataset allows us to control for region-specific time invariant unobserved characteristics and common time-specific shocks which may influence the correlations of regional output growth with the Euro Area and thus reduces a potential omitted variable bias.

We use annual output growth rates to measure business cycles. Our choice is motivated by the fact that filtering the data using de-trending techniques would result in losing points at the end of the sample.[9]

We estimate the model for the full sample and two sub-periods corresponding to the pre-EMU (the first six time points) and EMU (the last four time points) period. Further, we estimate the model separately for the Euro Area[10] and non-Euro Area regions.[11] We measure output growth synchronisation between each region and the Euro Area by Pearson correlations.

[7] Trade may also have an effect on the exchange rate volatility since economies which trade intensively with each other have similar consumption baskets and a price increase in a particular product will be passed to the trading partner so that the real exchange rate remains unchanged (Broda and Romalis 2009). Since our trade data refers to the regional level and the exchange rate volatility to the national level we cannot estimate this potentially indirect relationship.

[8] Using averages of output growth over 5 years has the advantage to avoid an incorrect classification of leading or lagging behaviour of outliers as a missed co-movement of economic activity. We thank one anonymous referee for suggesting this point to us.

[9] See Giannone et al. (2009) for a discussion of this argument. They also point out that annual data is less affected by measurement error in comparison to quarterly statistics.

[10] NUTS 2 regions in Austria, Belgium, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

[11] NUTS 2 regions in Denmark, Sweden, and the United Kingdom.

Our model specification contains the following 3 equations to be estimated simultaneously.[12]

$$\mathrm{CORRY}_{it} = \alpha_1 \mathrm{TRADE}_{it} + \alpha_2 \mathrm{SPEC}_{it} + \alpha_3 \mathrm{EVAR}_{it} + R_i + T_t + \varepsilon_{1,it} \tag{1}$$

$$\mathrm{TRADE}_{it} = \beta_1 \mathrm{SPEC}_{it} + \beta_2 \mathrm{EVAR}_{it} + \beta_3 I_{1,it} + \varepsilon_{2,it} \tag{2}$$

$$\mathrm{SPEC}_{it} = \delta_1 \mathrm{TRADE}_{it} + \delta_2 I_{2,it} + \varepsilon_{3,it} \tag{3}$$

$$I_{1,it} \neq I_{2,it}$$

$i = 1,\ldots,208$ is the index of regions in EU15, $t = 1,\ldots,10$ is the time index. CORRY is the Pearson correlation between the regional output growth rate of real gross value added and the Euro Area output growth rate. To account for the fact that the dependent variable takes values between -1 and 1, while the independent variables are not bound in our regressions, we use the following transformed measure of output growth synchronisation: $\mathrm{CORRY}^*_{it} = \frac{1}{2}\ln\left(\frac{1+\mathrm{CORRY}_{it}}{1-\mathrm{CORRY}_{it}}\right)$. TRADE is the share of a region's exports to the Euro Area in the region's total gross value added. It measures the degree of economic integration, the importance of transmission of region-specific shocks through trade linkages. SPEC is an index of dissimilarity (specialisation) of a region's industrial structure with respect to the Euro Area. It measures the importance of industry-specific shocks. EVAR is the exchange rate volatility and captures the importance of monetary policy coordination. Each observation in t relates to a five-year rolling window. Vector R contains dummy variables for the 208 regions and vector T time dummies for the 11 time observations. CORRY, TRADE and SPEC are endogenous variables. $I_{1,it}$, $I_{2,it}$ are vectors that contain the exogenous determinants of Eq. (2) and (3). The definitions of variables and data sources are explained in the Appendix.

The necessary condition to identify the system (the order condition) requires that the number of exogenous variables excluded in each equation must be equal to or greater than the number of endogeneous variables included in the same equation (Wooldridge 2002). The necessary and sufficient condition (the rank condition) for identification implies that at least one exogenous variable that is omitted from the first equation will be in the reduced form of the second equation and can be used as an instrument for the endogeneous variable in the second equation. Thus, to identify the system $I_{1,it} \neq I_{2,it}$ must hold.

In the primary Eq. (1) α_1, α_2, α_3 capture the direct effects of trade integration, industry specialisation and exchange rate volatility, respectively on regional output growth synchronisation with the Euro Area. Equations (2) and (3) estimate the indirect effects on CORRY working via the endogenous variables. Thus, the indirect effect of industry specialisation via trade integration is equal to $\alpha_1 \cdot \beta_1$; the indirect effect of trade integration via industry specialisation is given by $\alpha_2 \cdot \delta_1$; finally, the indirect effect of exchange rate volatility via trade integration is given by $\alpha_1 \cdot \beta_2$.

[12] Imbs (2004) estimates a model of four simultaneous equations to identify the direct and indirect effects of trade intensity, industrial specialisation and financial integration on business cycle correlations using a cross section of 22 OECD countries. In contrast to Imbs, we use a panel data model allowing for time invariant unobserved region fixed effects and time-specific common shocks.

Equation (2) relates trade integration, industry specialisation and exchange rate volatility. Neoclassical trade theory suggests that economies trading with each other specialise. In contrast, the new trade theory suggests that economies with similar industry structures have intensive intra-industry trade. We expect a positive coefficient β_1 if higher inter-industry specialisation leads to more trade. Exchange rate volatility leads to price changes and increases uncertainty and should therefore reduce trade. This argument was empirically confirmed (see for example, Cushman 1983). If this applies in our context, the coefficient β_2 should have a negative sign.

Finally, trade integration is determined by an exogenous variable contained in the vector I_1.We consider the log of the product of the region's real gross value added per capita and the Euro Area's real gross value added per capita (GDP SUM) as our exogenous variable. The choice of this exogenous variable is suggested by the gravity model, where the income level of two economies is a determinant of their bilateral trade volume. The variable GDP SUM is correlated with TRADE. We expect a positive coefficient of GDP SUM, indicating that richer countries trade more. Gravity models use another important determinant of bilateral trade, namely the distance between two trading partners. Although we find that a region's trade is highly correlated with its distance to the EU centre, we cannot include this variable in our panel data model because it is time invariant.

Equation (3) captures the argument that a region's industry specialisation evolves as it becomes more open to trade. When moving to more coordinated monetary policy, i.e. when the exchange rate volatility decreases, the higher trade integration leads to more industry specialisation. As an exogenous variable we include GDP GAP, the log of the ratio between the per capita regional gross value added and Euro Area's per capita gross value added. Existing trade and growth theories predict a negative relationship between income and sectoral specialisation.[13] In addition, we include a region's population size POP as an exogenous variable, since larger regions are likely to host a full range of industries and thus should be less specialised.

To estimate the system of simultaneous equations, we use a Three-Stage Least Squares (3 SLS) estimator which achieves consistency and efficiency by combining an Instrumental Variables (IV) estimation with an appropriate weighting matrix and a Generalized Least Square (GLS) estimator. The estimation is carried out in three steps (Greene 2000): (1) each equation of the structural model is estimated by OLS and the fitted values for the endogenous variables for each equation are retrieved; (2) each equation of the system is estimated by Two-Stage Least Squares (2SLS) and the covariance matrix of the equations disturbances is then retrieved; (3) using the fitted values of the endogenous variables obtained in the first step and the covariance matrix from the second step, the system is estimated by a GLS estimator.

4 Descriptive empirics

Table 1 presents summary statistics of the considered variables. Over the analysed period, the average regional output growth correlation with the Euro Area was 0.40.

[13] Imbs and Wacziarg (2003) discuss this literature strand.

The average was slightly higher over the pre-EMU sub-period, 0.41, and for the Euro Area regions, 0.51. Regions in the Euro Area were more specialised than non-Euro Area regions. The data also show that the degree of industry specialisation remained rather stable during the 1990s, increasing only slightly. It was highest for the Euro Area regions. This development partly confirms the predictions of Krugman (1993) who argued that specialisation grows with increasing integration. Trade integration with the Euro Area was slightly higher for the Euro Area regions. Exchange rate volatility has decreased and was significantly higher in the non-Euro Area regions compared with the Euro Area regions.

Figure 1 shows the average output growth correlation of EU regions with the Euro Area for different sub-samples; the full sample of regions, regions in the Euro Area, and regions outside the Euro Area. We note that regional output growth correlations increased in both the Euro Area and the rest of EU15 in the period after

Table 1 Summary statistics for the main variables

	Obs	Mean	Std. Dev.	Min	Max
Output growth correlation[a]					
Full sample	2080	0.400	0.484	−0.982	0.998
Pre-EMU	1248	0.413	0.479	−0.946	0.997
EMU	832	0.381	0.491	−0.981	0.998
Euro area	1600	0.507	0.417	−0.982	0.998
Non-Euro area	480	0.046	0.524	−0.972	0.996
Industrial specialisation index[b]					
Full sample	2080	0.369	0.206	0.100	1.261
Pre-EMU	1248	0.366	0.203	0.100	1.261
EMU	832	0.373	0.210	0.101	1.207
Euro area	1600	0.383	0.221	0.100	1.260
Non-Euro area	480	0.321	0.133	0.108	0.793
Trade share (only trade with Euro Area)					
Full sample	2080	0.152	0.106	0.011	0.859
Pre-EMU	1248	0.144	0.097	0.012	0.686
EMU	832	0.165	0.118	0.011	0.859
Euro area	1600	0.153	0.119	0.011	0.859
Non-Euro area	480	0.150	0.041	0.067	0.265
Exchange rate volatility					
Full sample	2080	0.365	0.234	0.036	0.949
Pre-EMU	1248	0.415	0.210	0.177	0.949
EMU	832	0.290	0.247	0.036	0.757
Euro area	1600	0.270	0.164	0.036	0.949
Non-Euro area	480	0.682	0.124	0.169	0.939

Own calculations based on variables as defined in the Appendix

[a] Pearson correlation of regional output growth with Euro Area

[b] Takes values between 0 and 2

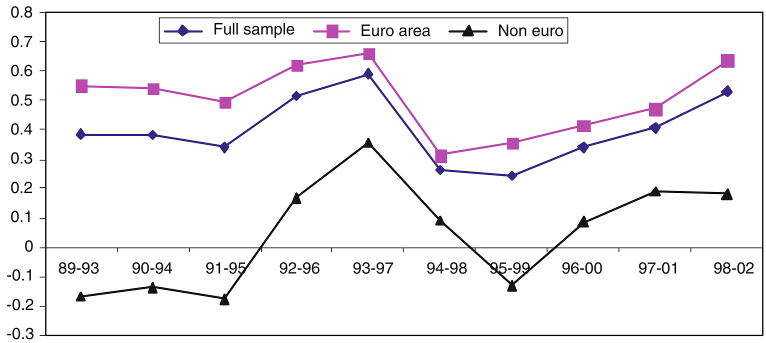

Fig. 1 Average output growth correlations of EU regions with the Euro area

the Maastricht Treaty announcement to create a monetary union, although there was a sharp drop in the mid 1990s. The average correlation for Euro Area regions was higher than that of regions outside the Euro Area. In the latter group the correlation was even negative in the first years of the 1990s and increased only significantly for a short period after the signing of the Maastricht Treaty which led to the creation of the single currency.

Figure 2 shows the regional output growth correlations with the Euro Area at the beginning and the end of the analysed period. In a large number of EU regions output growth was positively correlated with the Euro Area in the beginning and the end of the period (upper right hand quadrant). Only a few initially highly synchronised regions had negative correlations in the end of the period (lower right hand quadrant). In contrast, a number of initially negatively correlated regions have reached high correlations (upper left hand quadrant). It appears that in a small number of regions output growth has remained negatively correlated with the output growth in the Euro Area (lower left hand quadrant).

This analysis suggests that the potential cost of a monetary union is low for the majority of EU regions, as only in a small number of regions, output growth correlations with the Euro Area have declined.[14]

5 Estimation results

We first estimate the model for all regions, over the whole period, 1989–2002 and over two sub-samples corresponding to the pre-EMU and EMU periods[15] (results are shown in Table 2). Further, we investigate whether and to what extent the declining exchange rate volatility in the Euro Area, particularly since the beginning of monetary policy coordination, had affected regional output growth synchronisation

[14] The average regional output growth synchronisation with the Euro Area has increased in all countries with the exception of Greece, Spain, Ireland, Austria and Sweden. Output growth correlations with the Euro Area have decreased in 71 regions, one third of the regions included in our analysis.

[15] The hypothesis of joint equality of time invariant unobserved region characteristics effects in the pre-EMU and EMU periods is rejected by the corresponding F test: $F(208, 6022) = 2.69$, Prob $> F = 0.000$.

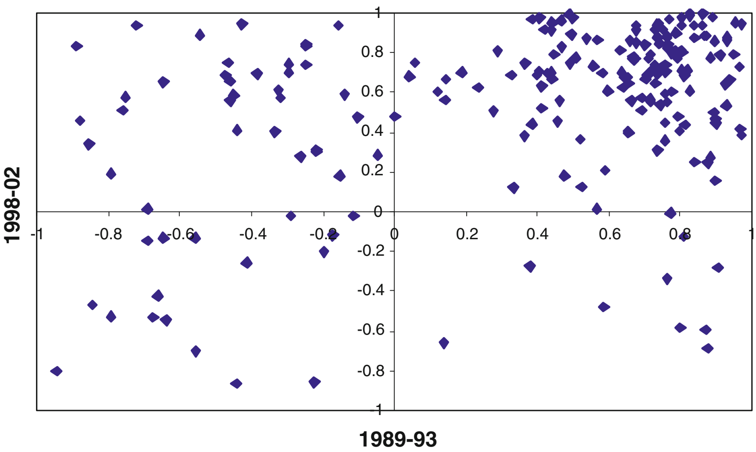

Fig. 2 Correlation of GVA growth rates between the EU regions and the Euro Area

within the area. To this purpose, we estimate the model separately for the Euro Area regions, again over the whole period and over the pre-EMU and EMU periods (results are shown in Table 3). Finally, we estimate the model for the remaining regions in the non-Euro Area.

Table 2 shows the estimates obtained for all regions, over the whole analysed period and separately for the pre-EMU and EMU periods. The upper part of Table 2 shows the point estimates while the second part reports the corresponding standardised coefficients to compare the size of the effects of trade integration, industrial specialisation and exchange rate volatility on regional output synchronisation with the Euro Area. The point estimates in the primary equation of the simultaneous equations system (Eq. 1) shown in the first column in Table 2 indicate that, *ceteris paribus*, trade integration had a direct positive and significant effect on regional output growth synchronisation with the Euro Area while industrial specialisation and exchange rate volatility were sources of cyclical divergence. It appears that while the effect of trade was stronger in the pre-EMU period, the effects of specialisation and exchange rate volatility were stronger in the EMU period in comparison to the pre-EMU period.

The standardised coefficients suggest that among the analysed determinants regional specialisation had the strongest effect on regional output growth synchronisation. In the EMU period the size of the negative effect of industrial specialisation was twice as large as the positive effect of trade on regional output synchronisation with the Euro Area.

The estimated structural equations for trade and specialisation (Eqs. 2, 3) reveal additional information about the indirect effects of these determinants on regional output growth synchronisation with the Euro Area. Industrial specialisation had a positive and significant impact on trade integration indicating that countries with different industrial structures with respect to the Euro Area export more to the Euro Area. This suggests that industrial specialisation had an indirect positive effect on

Table 2 Estimation results: All regions. Three-stage least squares regressions with region and time fixed effects

	All regions 1989–2002	All regions Pre-EMU	All regions EMU
Correlation (CORRY*)			
TRADE	1.557*** (0.133)	2.127*** (0.187)	1.169*** (0.184)
SPEC	−0.526*** (0.023)	−0.469*** (0.030)	−0.581*** (0.033)
EVAR	−0.768*** (0.056)	−0.672*** (0.075)	−1.050*** (0.089)
N	2080	1248	832
R^2	0.363	0.349	0.404
Trade (TRADE)			
SPEC	0.034*** (0.005)	0.037*** (0.006)	0.029*** (0.008)
EVAR	−0.061*** (0.010)	−0.063*** (0.013)	−0.046*** (0.016)
GDP SUM	0.011*** (0.000)	0.011*** (0.000)	0.011*** (0.001)
N	2080	1248	832
R^2	0.680	0.692	0.668
Specialisation (SPEC)			
TRADE	0.880*** (0.083)	0.978*** (0.115)	0.766*** (0.119)
GDP GAP	−0.514*** (0.022)	−0.476*** (0.028)	−0.573*** (0.036)
POP	−0.188*** (0.002)	−0.189*** (0.003)	−0.186*** (0.003)
N	2080	1248	832
R^2	0.891	0.893	0.889
Standardised coefficients			
Correlation (CORRY*)			
TRADE	0.165	0.206	0.138
SPEC	−0.266	−0.234	−0.299
EVAR	−0.180	−0.141	−0.026
Trade (TRADE)			
SPEC	0.017	0.018	0.014
EVAR	−0.014	−0.013	−0.011
GDP SUM	0.004	0.004	0.004
Specialisation (SPEC)			
TRADE	0.093	0.095	0.090
GDP GAP	−0.199	−0.187	−0.218
POP	−0.165	−0.165	−0.162

Standard errors in parentheses; *** significance at the 1 % level, ** significance at the 5 % level, * significance at the 10 % level. Standardised coefficients are computed using the corresponding standard deviation values reported in Table 1

regional output growth synchronisation via trade. However the standardised coefficients indicate that in comparison to the direct negative effect of specialisation on regional output growth synchronisation, the positive indirect effect of specialisation was limited. For example, over the analysed period the indirect effect of specialisation via trade was equal to 0.003 ($\alpha_1 \cdot \beta_1$).

Table 3 Estimation results: Euro Area regions. Three-stage least squares regressions with region and time fixed effects

	Euro area 1989–2002	Euro area Pre-EMU	Euro area EMU
Correlation (CORR*)			
TRADE	1.184*** (0.127)	1.447*** (0.178)	1.061*** (0.179)
SPEC	−0.469*** (0.022)	−0.371*** (0.029)	−0.595*** (0.033)
EVAR	0.030 (0.078)	0.328*** (0.096)	−0.890*** (0.158)
N	1600	960	640
R^2	0.520	0.542	0.509
Trade (TRADE)			
SPEC	0.050*** 0.006)	0.050*** (0.007)	0.056*** (0.010)
EVAR	−0.168*** (0.018)	−0.147*** (0.023)	−0.264*** (0.039)
GDP SUM	0.014*** (0.000)	0.013*** (0.001)	0.014*** (0.001)
N	1600	960	640
R^2	0.644	0.655	0.635
Specialisation (SPEC)			
TRADE	0.946*** (0.084)	0.969*** (0.116)	0.920*** (0.120)
GDP GAP	−0.637*** (0.024)	−0.602*** (0.030)	−0.694*** (0.039)
POP	−0.187*** (0.002)	−0.186*** (0.003)	−0.187*** (0.004)
N	1600	960	640
R^2	0.893	0.895	0.891
Standardised Coefficients			
Correlation (CORRY*)			
TRADE	0.141	0.158	0.140
SPEC	−0.249	−0.194	−0.323
EVAR	0.005	0.050	−0.118
Trade (TRADE)			
SPEC	0.026	0.026	0.030
EVAR	−0.028	−0.022	−0.035
GDP SUM	0.006	0.005	0.006
Specialisation (SPEC)			
TRADE	0.112	0.106	0.121
GDP GAP	−0.262	−0.251	−0.278
POP	−0.177	−0.177	−0.177

Standard errors in parentheses; *** significance at the 1 % level, ** significance at the 5 % level, * significance at the 10 % level. Standardised coefficients are computed using the corresponding standard deviation values reported in Table 1

Exchange rate volatility had a significantly negative effect on trade, which could be explained by price variations and price uncertainty. This indicates that regions in countries which did not follow the tight margins of the ERM or which were not members of EMU had lower trade with the EU. Over the analysed period, the indirect effect of the exchange rate volatility on regional output growth synchronisation via trade was equal to −0.002 ($\alpha_1 \cdot \beta_2$). Another interesting, although less strong result is that richer regions in the EU traded more. Again, these results remain stable for the two sub-periods.

The equation of specialisation indicates that *ceteris paribus* specialisation was negatively related with the income gap. Regions with a lower income relative to the Euro Area appear more specialised. Also, as expected, smaller regions appear to be more specialised. The results show again a positive relationship between trade and specialisation. Higher trade integration results in higher regional industry specialisation consistent with Krugman (1993). Over the full period, the indirect effect of trade on regional output growth synchronisation via specialisation was equal to -0.025 ($\alpha_2 \cdot \delta_1$). The signs and significance of the coefficients in the specialisation equation are the same in the pre-EMU and EMU periods.

Further we tested the equality of regression coefficients between the Euro Area and non-Euro Area regions. On the basis of the result of the F test we reject the hypothesis of homogeneous slopes for the two groups of regions.[16] In the next step, we estimated the model for different groups of EU regions, namely for regions in the Euro Area and for those not participating in the EMU. We also distinguish between the pre-EMU and EMU period. Since the estimates for the non-Euro Area have very little explanatory power we report the results for the Euro Area regions only (see Table 3).

The results for the group of Euro Area regions are fairly similar to the results obtained for the full sample. For Eqs. (2), (3) the significant coefficients are of the same sign and quantitatively similar in most cases. In the primary equation, the sign of the exchange rate volatility coefficient is positive but not significant. The effect of the exchange rate volatility appears positive and significant in the pre-EMU period and negative and significant in the EMU period. The positive and significant coefficient for exchange rate volatility in the pre-EMU period indicates that over this period, *ceteris paribus*, country-specific exchange rate fluctuations acted as shock absorbers and contributed to cyclical synchronisation. In addition, while trade integration was the main source of regional output growth synchronisation with the Euro Area, specialisation was the main source of cyclical divergence.

6 Conclusions

In this paper we investigated the patterns and determinants of the output growth synchronisation between EU regions and the Euro Area. Using a panel dataset covering the period 1989–2002, we estimated a system of three simultaneous equations and analysed the role of trade integration, industrial specialisation and exchange rate volatility in explaining regional output growth synchronisation with the Euro Area.

Over the analysed period, regional output growth correlations with the Euro Area were on average 0.40. They were slightly higher over the pre-EMU period of the sample, 0.41, and relatively higher for the Euro Area regions, 0.51. Industrial specialisation—relative to the Euro Area average—has become more pronounced in

[16] $F(12, 8294) = 56.95$, Prob $> F = 0.0000$.

the Euro Area regions than in the rest of the EU regions. Over the analysed period trade integration of EU regions with the Euro Area increased with the Euro Area regions achieving slightly higher trade integration than other regions. Exchange rate volatility has generally decreased in the EU but was higher in the non-Euro Area regions compared with the Euro Area regions.

Figure 3 summarises the main results of our econometric analysis of regional output growth synchronisation between EU regions and the Euro Area. Deeper trade integration with the Euro Area had a strong direct positive effect on the synchronisation of regional output growth with the Euro Area. Industrial specialisation and exchange rate volatility were sources of cyclical divergence. Industrial specialisation had however an indirect positive effect on output growth synchronisation via its positive effect on trade integration, while exchange rate volatility had an indirect additional negative effect on regional output growth synchronisation by reducing trade with the Euro Area. On average, income differentials between regions and the Euro Area as well as regions' size were negatively related to industry specialisation. Higher income regions traded more intensively with the Euro Area.

While the direct positive effect of trade on regional output synchronisation with the Euro Area was stronger in the pre-EMU period, the negative effects of industry specialisation were stronger in the EMU period.

The close monetary policy co-ordination in the ERM and common monetary policy after the adoption of the euro justify the analysis of the regional output growth synchronisation with the Euro Area separately. In the case of the Euro Area regions the only distinct result in comparison with the analysis for the full sample is the direct positive and significant effect of exchange rate volatility on output growth correlations in the pre-EMU period. Evidently, the currency devaluations which

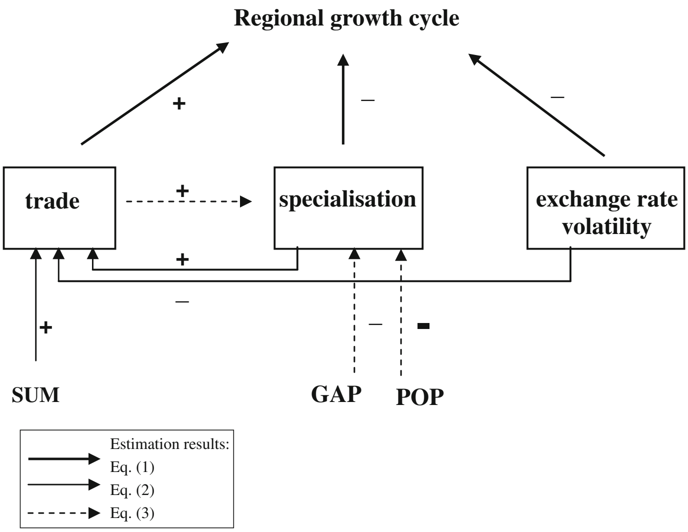

Fig. 3 Estimation results: direct and indirect effects on regions output growth synchronisation (full sample)

were carried out by some later EMU-members in the early 1990s acted as shock absorbers.

Our results suggest a number of relevant policy implications for the EMU and EMU enlargement. First and foremost, promoting trade integration with the Euro Area is likely to foster regional output growth synchronisation and thus lower the probability of regions' exposure to asymmetric shocks. Real income convergence with the Euro Area average is expected to increase trade integration and at the same time affect the pattern of industry specialisation towards more similarity which in turn will increase regional output growth correlation with the Euro Area. Furthermore, as suggested by the OCA literature, in addition to reducing exposure to asymmetric shocks, policy makers should focus on increasing labour and product market flexibility as adjustment mechanisms and financial integration as risk-sharing mechanism to insure against asymmetric shocks.

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Appendix: Variable definitions and data sources

CORRY: regional output growth synchronisation with the Euro Area

Pearson correlations of annual growth rates of real regional gross value added and Euro Area real gross value added computed over 5-year rolling windows. Data on real gross value added is taken from the European Regional Database, Cambridge Econometrics. To account for the fact that while this variable takes values between -1 and 1, the independent variables are not bound, we use in regressions the following transformed variable: $\mathrm{CORRY}^{*}_{it} = \frac{1}{2}\ln\left(\frac{1+\mathrm{CORRY}_{it}}{1-\mathrm{CORRY}_{it}}\right)$ as suggested by Inklaar et al. (2008).

SPEC: industrial specialisation index

The industrial specialisation index is computed using regional gross value added disaggregated on the following seven NACE 2 digit industry sectors: mining and energy; food, beverages and tobacco; textiles and clothing; fuels, chemicals, rubber and plastic products; electronics; transport equipment; other manufacturing. The specialisation index for region i is defined as follows: $\mathrm{SPEC}_i = \sum_{j=0}^{N} |s_{ij} - s_{\mathrm{Euro},j}|$. s_{ij} is the share of sector j in region i and $s_{\mathrm{Euro},j}$ is the share of sector j in the Euro Area. This index takes values from 0 to 2. A value equal to 0 indicates complete similarity of industrial structure, and a value equal to 2 indicates total specialisation. The variable is included in regressions in logs. Data is taken from the European Regional Database, Cambridge Econometrics.

TRADE: regional exports to the Euro Area as share of gross value added

Total exports of each region to the Euro Area are estimated using NACE two-digit national exports provided by the WIFO-World Trade Databank (based on UN Trade Statistics) and NACE two-digit regional gross value added from the European Regional Database, Cambridge Econometrics. National exports of a product sector j are allocated to regions using the share of each region in the gross value added of sector j in total national gross value added. Total regional exports is then the sum of exports in all sectors $j,\ldots,N$.

EVAR: exchange rate volatility

Exchange rate volatility is proxied by the standard deviation of the first difference of the log of the exchange rate index over five years corresponding to the rolling windows of the growth cycles. We use monthly nominal market exchange rates of national currencies per unit of Ecu/Euro from the IMF's International Financial Statistics.

GDP SUM: log of product of per capita real regional value added and per capita Euro Area real gross value added

Regional real gross value added per capita from the European Regional Database, Cambridge Econometrics.

GDP GAP: log of the ratio of a region's per capita real gross value added and Euro Area per capita real gross value added

Regional real gross value added per capita is taken from the European Regional Database, Cambridge Econometrics. Cambridge Econometrics**.** $GAP > 0$ for regions with per capita gross value added greater than the Euro Area aggregate; $GAP < 0$ for regions with per capita gross value added lower than the Euro Area aggregate.

POP: log of regional population in persons

Population in thousand persons from the European Regional Database, Cambridge Econometrics.

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