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Sectoral Business Cycle Synchronization in the European Union

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Abstract

This paper analyses sectoral business cycle synchronization in an enlarged European Union using annual data for the period 1980-2005. In particular, we try to identify which sector for each country is driving the aggregate output business cycle synchronization. Overall, the sectors that provide the most relevant contribution are Industry, Building and Construction, and Agriculture, Fishery and Forestry. In contrast, the Services sector, the largest one in terms of valued added share, shows a relative low business cycle synchronization and volatility, contributing only marginally to the aggregate output business cycle synchronization.

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1. INTRODUCTION

On 1 May 2004 the European Union (EU) welcomed ten new members: the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia. In addition, two other countries, Bulgaria and Romania, joined the EU on January 2007, and other countries are at various stages of EU membership. It is likely that all these countries will benefit from joining in the future the European and Monetary Union (EMU) in terms of inflation bias reduction, higher exchange rate stability, lower interest rates, and higher growth (Cyprus, Malta, Slovakia and Slovenia adopted the euro in the meantime). Therefore, a relevant question is whether these economies should also expect to face high costs from EMU membership. The theory of the Optimum Currency Area, first developed by Mundell (1961), and including the classical contributions of McKinnon (1963) and Kenen (1969), stresses the importance of international linkages between the members of a monetary union to face the loss of the country-independent monetary policy to smooth output fluctuations.[1]

To the extent that monetary policy would have contributed to the stabilization of cyclical fluctuations in the past, the loss of the exchange rate control and of monetary independence can be seen as the stabilisation cost of joining a monetary union. Moreover, it has been shown in the literature that this stabilisation cost is a decreasing function of the correlation between the cyclical output of the member country and the cyclical output of the anchor country (in this case the EMU as a whole). Intuitively, if the business cycle of a country is very highly correlated with the EMU-wide cyclical output, then countercyclical monetary policy conducted by the European Central Bank (ECB) will be a very close substitute for the country independent monetary policy.

The main purpose of this paper is to analyse sectoral business cycle synchronization in an enlarged European Union. In particular, we first ask whether the business cycles of the new EU countries are synchronized and compare them with those of EMU members, using annual data for the period 1980-2005. Second, we analyse how business cycle synchronization evolves over time. Third, we try to identify which sector, in each country, is driving the aggregate output business cycle synchronization.

The results of the paper show that while for some countries (such as Cyprus, Hungary and Malta) EMU membership will be less costly, for the other countries with negative or negligible business cycle synchronization the stabilization cost could be relevant, at least in the short-run. However, business cycle synchronization seems to have increased over time, suggesting that stabilization costs could become less relevant in the future. In terms of sectoral decomposition, the results suggest that, although for each country it is possible to identify which sector is more able to explain the aggregate output business cycle synchronization, overall, Industry, Building and Construction, and Agriculture, Fishery and Forestry sectors provide the most relevant contribution. On the other hand, the Services sector shows relatively low business cycle synchronization.

The remainder of the paper is organized as follows. Section Two provides a brief literature review of the importance of business-cycle synchronization, particularly for the EMU. In Section Three, we present the empirical methodology used to evaluate aggregate and sectoral output business cycle synchronization. Section Four reports the results obtained, and finally, Section Five summarises the paper's main findings.

2. LITERATURE REVIEW

The literature on business-cycle synchronization in Europe (and how it compares to the U.S.) is vast. Bayoumi and Eichengreen (1993) found that demand and supply shocks are more correlated between states in the U.S. than in Europe, and that the U.S. states adjust more

[1] For some recent contributions see Alesina and Barro(2002), Alesina, Barro and Tenreyro (2002), Corsetti and Pesenti (2002).

quickly to economic fluctuations than European countries. Using a different methodology, Wynne and Koo (2000) also found that business cycles are more aligned in the U.S. than in the euro area (of 11 members). Other authors, such as Clark and Shin (1998) and Clark and Van Wincoop (2001), focused on both within-country and cross-country synchronization. They found that average within-country cyclical output correlations are larger than cross-country correlations, for both the U.S. and European countries (and again that business cycles are more synchronized in the U.S. than in Europe). Peiró (2004), examining the existence of asymmetries in industrial production in seven European countries for the period 1957-1998, finds that several of these countries have aligned business cycles.

Other studies have focused on business cycle correlation between the euro area and acceding countries.[2] Boone and Maurel (1998) analyzed unemployment and industrial production and found a high degree of business cycle correlation between acceding countries and Germany. Similarly, Artis et al. (2004) found that business cycles in Hungary and Poland are similar to those of the euro area. Korhoenen (2003) examining the monthly indicator of industrial production in the euro area and in nine accession countries, found that some applicant countries (particularly Hungary) showed a high degree of correlation with the euro area business cycle. In addition, correlation seems to be at least as high as in some smaller EMU members like Portugal and Greece.

Other studies have looked at changes in correlation patterns over time. Angeloni and Dedola (1999) found that the output correlation between Germany and other European countries has clearly increased during 1993-1997. Fatás (1997), using annual employment growth rates for regions of France, Germany, Italy, and the UK, found that the average correlation with aggregate EU-12 employment growth has increased from 1966-1979 to 1979-1992. Furceri and Karras (2008), analyzing cyclical output for the EU-15 countries found that business cycle synchronization has also increased for many countries after the creation of the EMU. In particular, this increase in synchronization is present in all components of aggregate demand, as well as two supply-side variables, but it is more pronounced in the trade components (imports and, particularly, exports). They also showed that the increase in trade within the EMU area is at least partly responsible for the increase in cyclical synchronization.

The implications of the EMU for fiscal policy have also been considered in the literature. In fact, unlike other monetary unions, the EMU does not have a central fiscal authority, and stabilisation of shocks is left to the responsibility of the domestic fiscal policies of the EMU members. However, the literature has shown that the ability of the EMU members' national fiscal policies to smooth shocks is very modest.[3] As an implication, business-cycle synchronization is extremely important in the EMU not only because it reduces the probability of asymmetric shocks, but also because it makes it plausible to expect the ECB to respond to aggregate shocks and to implement stabilising interventions with greater ease.

The literature is much thinner on the analysis of sectoral business cycle synchronization. We believe that this is an important element which would provide useful policy indications, since it would enable to identify which sector for each country contributes more to synchronize aggregate output with the EMU-wide business cycle. As an example, we can mention the relative importance of the construction sector for some EU countries and its relevance in the context of the 2008-2009 economic crises. Thus, our analysis has the purpose of extending the literature and provides some more insights in understanding business cycle synchronization in the EU.

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[2] See Fidrmuc and Korhonen (2004) for a more comprehnesive review of the literature on business cycle correlation between the euro area and acceding countries.

[3] See, for example, Galì and Perotti (2003), Afonso and Furceri (2008).

3. EMPIRICAL METHODOLOGY

We obtain the output business cycle measures by detrending the series of real GDP. Four different methods are used to detrend the output series of each country *i* and estimate its cyclical component. The first measure is simple differencing (growth rate of the real GDP).

The second and the third method use the Hodrick-Prescott (HP) filter, proposed by Hodrick and Prescott (1980). The second method uses the value recommended by Hodrick and Prescott for annual data for the smoothness parameter (λ) equal to 100. The third method considers the smoothness parameter (λ) equal to 6.25. In this way, as pointed out by Ravn and Uhlig (2002), the Hodrick-Prescott filter produces cyclical components comparable to those obtained by the Band-Pass filter. The fourth method makes use of the Band-Pass (BP) filter proposed by Baxter and King (1999), evaluated by Stock and Watson (1999) and Christiano and Fitzgerald (2003) who also compare its properties to those of the HP filter.[4]

While minor differences among the results obtained by the three filters can be detected (for example, differencing generally produces the most volatile series, while the BP the smoothest), the main characteristics are remarkably similar. This robustness will be formally assessed by the estimations of the empirical section.

In practice, we measure GDP business cycle synchronization for each country as the correlation between the country's cyclical component, c_i, and the EMU's cyclical component, c_{EMU}:

$$corr(c_i, c_{EMU}). \qquad (1)$$

Successively, in order to identify which sector *j* for each country *i* is mainly responsible for the aggregate output business cycle synchronization, we first compute the country's sectoral cyclical components, c_i^j, and then we compute the correlation between these components and the EMU's cyclical component:

$$corr\left(c_i^j, c_{EMU}\right). \qquad (2)$$

Moreover, to determine the relative weight of each sector in the computation of the aggregate output business cycle synchronization, we compute the standard deviations of the country's sectoral cyclical components. In fact, it is clear that the higher is the volatility of a given sector, the more relevant is this sector in the computation of the aggregate output business cycle synchronization. In particular, if we could approximate[5] the country's GDP cyclical component c_i as the weighted sum of the sectoral value added cyclical components (where the weights are given by the sector's share of total value added, γ_i^j)

$$c_i \cong \gamma_i^j \sum\nolimits_j c_i^j \ , \qquad (3)$$

we could decompose the correlation between the country's cyclical component and the EMU's cyclical component, as a weighted average of the correlations between the country's sectoral cyclical components c_i^j and the EMU's cyclical component:

$$corr\left(c_i, c_{EMU}\right) \approx \sum\nolimits_j \gamma_i^j w_i^j \left(c_i^j, c_{EMU}\right). \qquad (4)$$

The weights, w_i^j, are represented by the share of output business cycle volatility (measured by the standard deviation of the cyclical components) attributable to each sector:[6]

$$w_i^j = \frac{\sigma_i^j}{\sigma_i}. \qquad (5)$$

[4] See Appendix 1 for an additional descripion of the filtering methods used in the paper.

[5] This is the case when value added growth rates are considered as cyclical components (differencing filtering) but not in the case of nonlinear filtering methods (HP, BP).

[6] See Appendix 2 for the mathematical derivation.

Therefore, equations (4) and (5) imply that the correlation between the countries's output cyclical component, c_i, and EMU's output cyclical component, c_{EMU}, depends on i) the correlation between the cyclical component of the value added of each sector and EMU's output cyclical component; ii) the share in terms of value added of each sector in the whole economy; and iii) the volatility of each sector's value added.

4. EMPIRICAL ANALYSIS

4.1. Data

We use data from the European Commission *Annual Macro-economic Database* (AMECO).[7] Our dataset covers 28 countries: 13 EMU countries at the time, 3 *old* EU countries which have not adopted the euro, 11 *new* EU members, and one prospective member, Turkey, from 1980 to 2005.

The income variable we use to determine output business cycle synchronization is real GDP at 2000 constant prices.[8] We use data for Gross Value Added for the Industry (not including Building and Construction), Agriculture, Forestry and Fishery, Building and Construction, and Services sectors to decompose output synchronization into sectoral business cycle synchronization.

4.2. Output Business Cycle Synchronization

We compute the correlation coefficient of each country's cyclical component of real GDP with that of EMU, as a whole, using the HP filter with smoothness parameter equal to 6.25. Even though the estimated correlations vary according to the detrending method used, the implied rankings are very similar. Regarding the overall period, the highest Spearman's rank correlation coefficients is 0.936 (BP, HP6.25) and the lowest is 0.776 (Diff, HP100), as can be seen from Table 1.

Table 2 covers three different periods of analysis. The first, from 1980 to 1992, considers the EU15 countries. The second, from 1993 to 2005, considers all 28 countries. The third covers the full period from 1980 to 2005. In relation to the overall period, we can see that for most EMU countries business cycle is relatively well synchronized, even if for some countries (namely Finland) there is an almost zero correlation with the EMU economy as a whole.

Looking at the period 1993-2005, France shows an almost perfect correlation with the EMU economy. However, comparing the at the time 12 euro area countries with the 3 (*old*) non-euro economies, it is difficult to establish a systematic relationship. In fact, Denmark, Sweden and the UK appear to be more synchronized with the EMU-wide cycle than some euro area members, such as Greece and Finland.

Generally, the *new* EU member states showed higher synchronization with the EMU than the *old* members during the accession period. In particular, there are some *new* EU countries (such as Cyprus, Hungary and Malta) already well synchronized with the EMU, and with correlations comparable to, or even higher than, those of some of the *old* members. On the other hand, several *new* EU countries such as Estonia, Lithuania and Slovakia, exhibit negative correlations, and the same occurred for Romania and Turkey. The other new EU countries (namely, Czech Republic, Latvia, Poland, Slovenia and Bulgaria) show very negligible, even if positive, correlations. Overall, we can argue that while for some countries such as Cyprus, Hungary and Malta, EMU membership will be less costly, for the other countries with negative or negligible business cycle synchronization the stabilisation cost could be relevant, at least in the short-run.

[7] See the Annex for a description of data sources.
[8] We use the GDP deflator to express the variables at 2000 constant prices.

Focusing on the 1980-2005 period is only feasible for the *old* EU members, but this can be used to indicate how the correlations have changed for these countries, and how they could change for the new Member States. The most striking fact to emerge from this exercise is that the degree of synchronization with EMU has remarkably increased for all countries (with the exception of Germany, where it remained broadly similar).[9] This result can be largely attributed to the achievement of a more integrated market since 1992, and to an increase in trade as pointed out by Furceri and Karras (2008). More interestingly, the results show that the increased synchronization has been at least as large in the non-euro area as in the euro area economies.

Finally, given the increase in the intra-EMU share of trade for the new EU members after they joined the European Union, and given the fact that trade is the main factor driving synchronization, it is likely that the new EU members will increase the synchronization of their business cycle with the EMU's one.[10] Thus, as pointed out by Frankel and Rose (1998), Rose and Engel (2002), and Rose (2005), the business cycle synchronization between the candidate countries and the currency union (or the anchor country) is endogenous, and it will tend to increase once the country joins the currency union.

4.3. Sectoral Business Cycle Synchronization

Industry (excluding Building and Construction)

In Table 3, we calculate for each country the correlation coefficient between Industry's value added cyclical component and that of the EMU-wide GDP, as well as the standard deviation of the Industry value added cyclical component (using the HP filter with smoothness parameter equal to 6.25 for consistency). For each country, we also report the share of total value added generated by the Industry sector. We also consider in Table 3, as before, the three periods of analysis.

Looking at the shares of this sector we can see that Industry generated around one fourth of the total valued added (looking at the period where data for all 28 countries are available, it ranges from 13.0 percent for Cyprus to 32.4 percent for Ireland). Moreover, comparing the two sub periods it emerges clearly that this share is diminishing over time (in favour of the service sector as we will see below).

Regarding the overall period, we can see that for some countries such as France, Germany, Ireland, Italy and Spain, the Industry sector synchronization with the EMU-wide GDP is relatively high. Moreover, a sizeable volatility of this sector in these countries contributes to provide a significant contribution to total GDP synchronization. In contrast, for other countries such as Austria, Greece and Netherlands, the industry valued added cyclical component is weakly correlated with the EMU-wide business, and in the case of Greece it is also reduced by the relative high volatility.

However, looking at the two sub periods we can see an increase in the Industry business cycle synchronization for many EMU countries, contributing to the increase in GDP business cycle synchronization found in the previous section.

Finally, analyzing the period 1993-2005 we can see that while the new EU and candidate members show a higher volatility in the Industry sector, there is no particular difference between EU and EMU countries. In fact, while some of them (such as Cyprus and

[9] The increase in syncronizationation may also be related to the decrease in output volatility. However, the results of the next section point out that for most sectors business cycle volatility has not been significantly reduced, which would suggest that the increase in syncronization is likely due to an increase in the co-movements between cycles.

[10] See also Artis and Zhang (1997), Artis et al. (2004), Darvas and Szapary (2004). Baxter, and Kouparitsas (2005), and Inklar et al. (2008).

UK) are more synchronized than most of the EMU members, other countries (Hungary, Slovakia, Czech Republic and Estonia) show a negative correlation.

Building and Construction

In Table 4, we present the results in terms of business cycle synchronization, volatility and share of total value added for the Building and Construction sector. In terms of the shares we can see that the valued added contribution generated by the Building and Construction sector is relatively small and around 6%. Moreover, comparing the two sub periods it emerges that for many EU15 countries (with the exception of Spain, Austria and Portugal) this share is declining over time.

Considering the overall period, we see that for some countries such as Ireland, Belgium and Sweden, the Building and Construction sector synchronization with the EMU-wide GDP is relatively high, and it is also volatile, providing a significant contribution to total GDP synchronization. In contrast, for other countries such as Austria, this sector is negatively synchronized with the EMU-wide GDP, and for many other countries the correlation is negligible.

Regarding the two sub periods we can not observe, as in the case of the Industry sector, a systematic increase in business cycle synchronization (with the exception of Ireland, Spain, the UK, and Portugal). Additionally, analyzing the period 1993-2005, we observe that while the new EU and candidate members show a higher volatility in this sector, they have lower business cycle synchronization. In fact, most of them show a negative or quite negligible correlation.

Furthermore, it seems that for some countries such as Spain and Portugal, characterized by an increasing share and high and increasing business cycle synchronization in Building and Construction, this sector contributes significantly and positively to the computation of total GDP business cycle synchronization.

Agriculture, Fishery and Forestry

In Table 5, we present the set of results for the Building and Construction sector. In terms of the share of this sector in total added value, we can see that it is quite small (with the exception of Finland, Greece, Portugal, Ireland, and Spain), and decreasing over time.

In relation to the overall period, we can see that for most of the EU15 countries the Agriculture, Fishery and Forestry sector synchronization with the EMU-wide GDP is relatively small. However, it is more than compensated, in terms of relevance in the computation of the aggregate output business cycle synchronization, by a high volatility (compared to the other sectors).

Concerning the two sub periods we can see that while synchronization increased for some countries (for example, Austria and Germany) it decreased for many others (especially Ireland). In contrast business cycle volatility seems to have remained quite stable.

At last, analyzing the period 1993-2005, again we can see that the new EU and candidate members show a higher volatility than in the Industry sector, but there are no major differences between the EU and the EMU countries in terms of business cycle synchronisation. Latvia seems to be an exception, being characterized by significant synchronization and high volatility. Overall, although this sector is characterized by relatively low business cycle synchronization, and it is very volatile, contributing nevertheless to GDP business cycle synchronization.

Services

In Table 6, we present the same set of results for the Services sector. In terms of the share in total valued added, we can observe that the Services sector is the most relevant one in the European Union, around 60 percent, and its share is increasing over time.

Analysing the result in terms of GDP business cycle synchronization, in relation to the overall period, we can see that for Italy, Spain and Sweden the Services sector is well synchronized with the EMU-wide GDP. For the other countries the correlation is either negative (as in the case of Austria, Netherlands and Denmark) or negligible. Volatility is also relatively low compared to the other sectors, implying a low weight contribution to the aggregate output business cycle synchronization.

For the two sub periods we can see that while synchronization increased for some countries (especially France, and the Netherlands), significant decreases were recorded for Greece and Italy. For the period 1992-2005 the new EU and candidate members show an higher volatility in the Services sector (as in the other three sectors), but again there is no particular difference between EU and EMU countries in terms of sectoral synchronization. In fact, while countries such as Cyprus, Malta, and the UK are more synchronized than most of the EMU members, other countries (such as Hungary, Slovakia, Czech Republic and Estonia) show a negative correlation.

Overall, it seems that due to the low business cycle synchronization and the relative low volatility, this sector is the one that (compared to the other three sectors) contributes less to the aggregate output business cycle synchronization.[11]

5. CONCLUSIONS

The new EU member states are expected to join in the future the single currency. It is likely that all these countries will benefit in terms of inflation bias reduction, higher exchange rate stability, lower interest rates, and higher growth from joining the EMU. The theory of the Optimum Currency Area stresses the importance of business cycle synchronization (the business-cycle correlation between the candidate's economy and that of the euro area as a whole) to face the loss of a country-specific monetary policy notably to smooth output fluctuations.

The results of the paper show that there are some *new* EU countries (such as Cyprus, Hungary and Malta) already well synchronized with the EMU, and with correlations comparable to, or even higher than those of some of the *old* members. On the other hand, several *new* EU countries, such as Estonia, Lithuania and Slovakia, exhibit negative correlations, as do Romania and Turkey. However, it is worthwhile mentioning that this analysis can give useful indications in terms of stabilization costs only in the short-medium term. In fact, as it has been shown by Frankel and Rose (1998), business cycle synchronization is likely to increase for the EU countries once they join the EMU, as EU membership could increase intra-EMU trade allowing business cycles to become more synchronized. It is significant that our analysis also shows that business cycle synchronization has increased for all the EU15 countries after the achievement of the Single Market (1991).

Successively, we tried to identify for each country which sector is driving the aggregate output business cycle synchronization. In particular, we considered four sectors: Industry (not including Building and Construction); Agriculture, Forestry and Fishery; Building and Construction; and Services.

For each sector we computed the respective total valued added shares, the sectoral business cycle synchronization and volatility. Overall, while the Services sector is the largest one in terms of valued added share, it shows relative low business cycle synchronization and

[11] Additionally, we report in Appendix 2 results for sectoral business cycle synchronization within country, linked with the EMU-sector synchronization via the EMU-country synchronization.

volatility, implying that it contributes only marginally to the aggregate output business cycle synchronization. In contrast, the other three sectors are overall quite synchronized and relatively volatile, implying a higher and more relevant contribution.

Moreover, for each country is possible to identify which sector is more able to explain the aggregate output business cycle synchronization. For example, for countries like Germany, France, Italy, Cyprus and UK the Industry sector is the one that has the higher business cycle synchronization. For countries like Belgium, Spain (especially in the last decade) and Sweden the Building and Construction sector is the more relevant one. Finally the Agriculture, Fishery and Forestry sector is particularly important for the Czech Republic and Latvia.

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Annex – Data Sources

Original series (from the EC AMECO database)	AMECO codes
Gross domestic product at 2000 market prices - National currency: Data at constant prices.	1.1.0.0.OVGD
Price deflator gross domestic product at market prices - National currency; 2000 = 100. Ratio: Data at current prices/Data at constant prices	3.1.0.0.PVGD
Gross Value Added at current prices; agriculture, forestry and fishery products – National currency: Data at current prices	1.0.99.0.UVG1
Gross value added at current prices; industry excluding building and construction – National Currency: Data at current prices	1.0.99.0.UVG2
Gross value added at current prices; building and construction – National Currency: Data at current prices	1.0.99.0.UVG4
Gross value added at current prices; services – National currency: Data at current prices	1.0.99.0.UVG5

Table 1 – Spearman's rank correlation matrix

	HP6.25	HP100	BP	Diff
HP6.25	1.000			
HP100	0.936***	1.000		
BP	0.847***	0.855***	1.000	
Diff	0.839***	0.776***	0.788***	1.000

***,**,* denote significance respectively at 1%, 5%, and 10%.

Table 2 – Business cycle synchronisation (vis-à-vis EMU)

	1980-1992	1993-2005	1980-2005
		EMU countries	
Austria	0.534*	0.793***	0.647**
Belgium	0.692***	0.832***	0.762***
Finland	0.582**^	0.478*	0.509*^
France	0.615***	0.977***	0.786***
Germany	0.763***	0.678***	0.696***
Greece	0.601***	0.441	0.554**
Ireland	0.285	0.645***	0.465*
Italy	0.539**	0.810***	0.674***
Luxembourg	0.419	0.745***	0.570*
Netherlands	0.542*	0.875***	0.692***
Portugal	0.341	0.733***	0.507*
Spain	0.506*	0.871***	0.662**
		Other EU	
Czech Republic		0.031	
Denmark	0.043	0.569**	0.258
Estonia		-0.220	
Cyprus		0.541*	
Latvia		0.238	
Lithuania		-0.032	
Hungary		0.789***	
Malta		0.698***	
Poland		0.247	
Slovenia		0.412	
Slovakia		-0.673***	
Sweden	0.164	0.695***	0.443
UK	-0.137	0.594**	0.042
		Candidate countries	
Bulgaria		0.342	
Romania		-0.242	
Turkey		-0.273	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.

Table 3 – Industry (excluding Building and Construction) contribution to business cycle synchronisation (vis-à-vis EMU)

	Business Cycle Synchronization			Volatility			Sector share in the country added value (%)		
	80-92	93-05	80-05	80-92	93-05	80-05	80-92	93-05	80-05
					EMU countries				
Austria	-0.169	0.706***	0.284	0.014	0.017	0.015	26.054	22.612	24.402
Belgium	0.174	0.453*	0.349	0.025	0.023	0.023	26.333	21.970	24.239
Finland	0.464^	0.430	0.447^	0.055^	0.061	0.058^	27.361	26.628	27.009
France	0.569**	0.815***	0.679***	0.020	0.016	0.018	22.311	17.704	20.100
Germany	0.501*	0.801***	0.668*	0.017	0.016	0.016	32.747	25.135	29.093
Greece	0.418	-0.185	0.175	0.047	0.021	0.036	20.119	14.690	17.513
Ireland		0.527**			0.040			32.428	
Italy	0.669***	0.342	0.547**	0.027	0.031	0.030	27.434	23.518	25.554
Luxembourg	0.135	0.592**	0.313	0.035	0.028	0.031		13.624	
Netherlands	-0.001	0.490*	0.196	0.023	0.019	0.020	24.459	19.825	22.235
Portugal	0.585**	0.233	0.379	0.047	0.027	0.039	22.116	20.033	21.116
Spain	0.617	0.442	0.563**	0.041	0.030	0.037	26.578	20.909	23.857
Minimum	-0.169	-0.185	0.175	0.014	0.016	0.015	20.119	14.690	17.513
Maximum	0.669***	0.815***	0.679***	0.055	0.061	0.058	32.747	32.428	29.093
					Other EU				
Cyprus		0.656***			0.007			13.003	
Czech Republic		-0.108			0.052			31.315	
Denmark	0.021	0.586**	0.325	0.025	0.023	0.024	20.831	20.257	20.556
Estonia		-0.060			0.028			21.908	
Hungary		-0.193			0.081			26.623	
Latvia		0.173			0.054			21.002	
Lithuania		0.428			0.109			25.239	
Malta		0.510*			0.049			23.080	
Poland		0.009			0.088			25.704	
Slovakia		-0.122			0.031			28.767	
Slovenia		0.350			0.080			30.468	
Sweden	0.393	0.349	0.374	0.039	0.062	0.051	24.841	24.093	24.482
UK	0.043	0.633**	0.303	0.036	0.047	0.041	30.831	22.660	26.909
Minimum	0.021	-0.193		0.025	0.007	0.024	20.831	13.003	20.556
Maximum	0.393	0.656***		0.039	0.109	0.051	30.831	31.315	26.909
					Candidate countries				
Bulgaria		-0.005			0.384			24.757	
Romania		-0.070			0.114			30.783	
Turkey		-0.201			0.124			23.740	
Minimum		-0.201			0.114			23.740	
Maximum		-0.005			0.34			30.783	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.

Table 4 – Building and Construction contribution to business cycle synchronisation (vis-à-vis EMU)

	Business Cycle Synchronization			Volatility			Sector share in the country added value (%)		
	80-92	93-05	80-05	80-92	93-05	80-05	80-92	93-05	80-05
					EMU countries				
Austria	-0.295	-0.131	-0.237	0.026	0.018	0.022	7.235	7.829	7.520
Belgium	0.621**	0.602**	0.622**	0.037	0.024	0.031	5.504	4.944	5.235
Finland	0.567**^	0.407	0.472^	0.107^	0.102	0.105^	7.245	5.114	6.222
France	0.476*	0.433	0.477*	0.029	0.029	0.029	6.894	5.562	6.255
Germany	0.391	0.088	0.248	0.044	0.034	0.039	5.935	5.571	5.760
Greece	0.231	-0.130	0.108	0.056	0.036	0.047	7.583	7.443	7.516
Ireland		0.795***			0.041			6.657	
Italy	0.782***	0.091	0.493*	0.043	0.036	0.040	6.520	5.354	5.960
Luxembourg	0.343	0.114	0.218	0.023	0.036	0.029		6.327	
Netherlands	0.012	0.765***	0.358	0.032	0.023	0.028	5.751	5.463	5.613
Portugal	0.104	0.696***	0.152	0.113	0.041	0.085	5.664	6.691	6.157
Spain	0.463*	0.658**	0.516*	0.077	0.036	0.062	7.348	8.258	7.785
Minimum	-0.295	-0.185	0.175	0.023	0.018	0.015	5.504	4.944	5.235
Maximum	0.782***	0.815***	0.679**	0.113	0.102	0.058	7.583	8.258	7.7875
					Other EU				
Cyprus		-0.639**			0.015			7.738	
Czech Republic		-0.348			0.070			7.474	
Denmark	-0.171	0.344	0.108	0.066	0.042	0.055	5.461	5.068	5.272
Estonia		-0.287			0.039			6.056	
Hungary		0.016			0.118			4.917	
Latvia		0.459			0.129			5.292	
Lithuania		-0.084			0.124			6.888	
Malta		0.233			0.024			4.678	
Poland		0.339			0.086			6.898	
Slovakia		-0.511*			0.119			5.804	
Slovenia		0.244			0.090			5.669	
Sweden	0.726***	0.436	0.601**	0.075	0.061	0.071	6.112	4.356	5.269
UK	0.094	0.611**	0.296	0.059	0.048	0.054	6.070	5.251	5.677
Minimum	-0.171	-0.639	0.108	0.059	0.015	0.054	5.461	4.356	5.269
Maximum	0.726***	0.611**	0.601**	0.075	0.129	0.071	6.112	7.738	5.677
					Candidate countries				
Bulgaria		0.025			0.471			4.442	
Romania		-0.207			0.124			6.162	
Turkey		-0.132			0.162			5.325	
Minimum		-0.207			0.124			4.442	
Maximum		0.025			0.471			6.162	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.

Table 5 – Agriculture, Fishery and Forestry contribution to business cycle synchronisation (vis-à-vis EMU)

	Business Cycle Synchronization			Volatility			Sector share in the country added value (%)		
	80-92	93-05	80-05	80-92	93-05	80-05	80-92	93-05	80-05
				EMU countries					
Austria	-0.139	0.546**	0.183	0.032	0.024	0.028	4.412	2.335	3.415
Belgium	0.239	0.430	0.290	0.038	0.035	0.036	2.283	1.409	1.863
Finland	0.635**	0.431	0.507*^	0.090*	0.057	0.074^	6.731	3.957	5.399
France	-0.023	0.305	0.083	0.035	0.026	0.030	4.176	3.001	3.612
Germany	0.196	0.530*	0.295	0.056	0.046	0.050	1.706	1.233	1.479
Greece	0.150	-0.179	0.032	0.112	0.042	0.084	12.396	8.054	10.312
Ireland		-0.010			0.034			4.697	
Italy	0.461	0.040	0.316	0.033	0.035	0.035	4.545	2.970	3.789
Luxembourg	0.001	0.220	0.080	0.049	0.045	0.046		0.812	
Netherlands	0.124	0.455	0.236	0.030	0.033	0.031	4.079	2.823	3.476
Portugal	-0.071	-0.006	-0.054	0.047	0.035	0.041	12.871	4.751	8.974
Spain	0.197	0.052	0.205	0.053	0.041	0.048	5.926	4.422	5.204
Minimum	-0.139	-0.179	-0.054	0.032	0.024	0.028	1.706	2.335	1.863
Maximum	0.635**	0.546**	0.507*	0.112	0.057	0.084	12.871	1.409	10.312
				Other EU					
Cyprus		0.222			0.039			3.992	
Czech Republic		0.054			0.054			4.041	
Denmark	-0.026	0.386	0.180	0.050	0.083	0.066	4.584	2.755	3.706
Estonia		-0.061			0.029			6.580	
Hungary		-0.173			0.084			5.209	
Latvia		0.565			0.111			5.992	
Lithuania		0.090			0.131			9.361	
Malta		0.113			0.037			2.570	
Poland		0.055			0.097			6.146	
Slovakia		-0.092			0.060			5.136	
Slovenia		0.251			0.090			3.622	
Sweden	0.446	0.188	0.293	0.042	0.058	0.050	3.780	2.189	3.016
UK	0.055	0.073	0.037	0.044	0.028	0.036	1.867	1.298	1.594
Minimum	-0.026	-0.173	0.037	0.042	0.028	0.036	1.867	1.298	3.706
Maximum	0.446	0.386	0.293	0.050	0.131	0.066	4.584	9.361	1.594
				Candidate countries					
Bulgaria		-0.064			0.270			15.367	
Romania		-0.307			0.116			15.823	
Turkey		-0.274			0.165			13.945	
Minimum		-0.307			0.116			13.945	
Maximum		-0.064			0.270			15.823	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.

Table 6 – Services contribution to business cycle synchronisation (vis-à-vis EMU)

	Business Cycle Synchronization			Volatility			Sector share in the country added value (%)		
	80-92	93-05	80-05	80-92	93-05	80-05	80-92	93-05	80-05
					EMU countries				
Austria	-0.338	0.286	-0.074	0.017	0.016	0.016	63.614	66.748	65.119
Belgium	0.092	0.370	0.203	0.021	0.014	0.018	65.842	71.675	68.642
Finland	0.464^	0.303	0.368^	0.041*	0.051	0.046^	59.543	65.516	62.410
France	0.254	0.507*	0.360	0.012	0.010	0.011	66.619	73.732	70.034
Germany	0.197	0.170	0.171	0.019	0.015	0.017	59.807	69.222	64.326
Greece	0.226	-0.235	0.039	0.049	0.018	0.037	60.036	69.839	64.741
Ireland		-0.127			0.029			56.218	
Italy	0.787***	0.217	0.527**	0.026	0.031	0.029	61.502	68.159	64.697
Luxembourg	-0.236	0.250	0.012	0.018	0.024	0.020		80.403	
Netherlands	-0.414	0.444	-0.019	0.020	0.014	0.017	65.270	71.813	68.410
Portugal	0.428	0.550	0.311	0.066	0.022	0.049	60.686	68.554	64.463
Spain	0.643*	0.586**	0.576**	0.044	0.019	0.036	61.480	62.045	61.752
Minimum	-0.414	-0.235	-0.074	0.017	0.010	0.011	59.543	56.218	61.752
Maximum	0.787**	0.586**	0.576**	0.066	0.051	0.049	65.270	80.403	70.034
					Other EU				
Cyprus		0.840***			0.015			75.267	
Czech Republic		-0.235			0.035			57.159	
Denmark	-0.292	0.152	-0.062	0.016	0.008	0.013	69.093	71.921	70.450
Estonia		-0.102			0.018			60.771	
Hungary		-0.225			0.106			58.816	
Latvia		0.520*			0.062			66.786	
Lithuania		0.432			0.110			58.635	
Malta		0.647**			0.034			66.745	
Poland		0.073			0.077			58.814	
Slovakia		-0.402			0.049			60.293	
Slovenia		0.297			0.073			60.225	
Sweden	0.797	0.325	0.535**	0.041	0.049	0.045	65.268	69.361	67.233
UK	0.340	0.568**	0.411	0.034	0.046	0.040	61.231	70.219	65.546
Minimum	-0.292	-0.402	-0.062	0.016	0.008	0.024	61.231	58.814	65.546
Maximum	0.797	0.840***	0.535**	0.041	0.110	0.051	69.093	75.267	70.450
					Candidate countries				
Bulgaria		0.027			0.426			55.109	
Romania		-0.140			0.089			47.233	
Turkey		-0.196			0.147			56.956	
Minimum		-0.196			0.089			47.233	
Maximum		0.027			0.426			55.109	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.

Appendix 1 – Filtering Methods

Letting $y_{i,t} = \ln(Y_{i,t})$, the first measure is simple differencing (growth rate of real GDP):

$$c_{i,t} = y_{i,t} - y_{i,t-1}\,. \qquad \text{(A1.1)}$$

The second and the third method used in the empirical analysis make use of the Hodrick-Prescott (HP) filter, proposed by Hodrick and Prescott (1980). The filter decomposes the series into a cyclical $(c_{i,t})$ and a trend $(g_{i,t})$ component, by minimizing with respect to $g_{i,t}$, for the smoothness parameter $\lambda > 0$ the following quantity:

$$\sum_{t=1}^{T}(y_{i,t} - g_{i,t})^2 + \lambda\sum_{t=2}^{T-1}(g_{i,t+1} - g_{i,t-1})^2\,. \qquad \text{(A1.2)}$$

The fourth method makes use of the recently very popular Band-Pass (BP) filter proposed by Baxter and King (1995), and evaluated by Stock and Watson (1998) and Christiano and Fitzgerald (1999) that also compares its properties to those of the HP filter. The low pass (LP) filter $\alpha(L)$, which forms the basis for the band pass filter, selects a finite number of moving average weights α_h to minimize:

$$Q = \int_{-\pi}^{\pi}\left|\delta(\omega)\right|^2 d\omega\,,$$

where $\alpha(L) = \sum_{h=-K}^{K}\alpha_h L^h$ and $\alpha_K(\omega) = \sum_{h=-K}^{K}\alpha_h e^{-i\omega h}$.

The LP filter uses $\alpha_K(\omega)$ to approximate the infinite MA filter $\beta(\omega)$. Defining $\delta(\omega) \equiv \beta(\omega) - \alpha(\omega)$, and then minimizing *Q*, we minimize the discrepancy between the ideal LP filter $\beta(\omega)$ and its finite representation $\alpha_K(\omega)$ at frequency ω. The main objective of the BP filter as implemented by Baxter and King (1995) is to remove both the high frequency and low frequency component of a series, leaving the business-cycle frequencies. This is obtained by subtracting the weights of two low pass filters. We define ω_L and ω_H, the lower and upper frequencies of two low pass filters as respectively eight and two for annual data. We therefore remove all fluctuations shorter than two or longer than eight years. The frequency representation of the band pass weights becomes $\alpha_K(\omega_H) - \alpha_K(\omega_L)$, and forms the basis of the Baxter-King filter, which provides an alternative estimate of the trend and of the cyclical component.

Appendix 2 – Country Sectoral Synchronization

If we approximate the country's GDP cyclical component c_i as the weighted sum of the sectoral value added cyclical components, $c_i \cong \gamma_i^j \sum_j c_i^j$, then,

$$corr(c_i, c_{EMU}) = corr\left(\sum_j \gamma_i^j c_i^j, c_{EMU}\right) = \frac{cov\left(\sum_j \gamma_i^j c_i^j, c_{EMU}\right)}{\sigma_i \sigma_{EMU}}. \quad \text{(A2.1)}$$

After that we can re-write the last term of the equality above as

$$\frac{cov\left(\sum_j \gamma_i^j c_i^j, c_{EMU}\right)}{\sigma_i \sigma_{EMU}} = \frac{\sum_j \gamma_i^j cov\left(c_i^j, c_{EMU}\right)}{\sigma_i \sigma_{EMU}}. \quad \text{(A2.2)}$$

Finally, multiplying and dividing by $w_i^j = \frac{\sigma_i^j}{\sigma_i}$ the term on the left-hand side of equation (A2.2), we get:

$$\frac{\sum_j \gamma_i^j cov\left(c_i^j, c_{EMU}\right)}{\sigma_i \sigma_{EMU}} = \frac{\sum_j \gamma_i^j w_i^j cov\left(c_i^j, c_{EMU}\right)}{\sigma_i^j \sigma_{EMU}} = \sum_j \gamma_i^j w_i^j corr\left(c_i^j, c_{EMU}\right). \quad \text{(A2.3)}$$

Appendix 3 – Within Country Sectoral Synchronization

It is easy to show that the sectoral business cycle synchronization within country is linked with the EMU-sector (*j*) synchronization via the EMU-country (*i*) synchronization. Indeed, we computed $corr(c_{EMU}, c_i) = \frac{\sigma(c_{EMU}, c_i)}{\sigma_{c_{EMU}} \sigma_{c_i}}$ and $corr(c_{EMU}, c_i^j) = \frac{\sigma(c_{EMU}, c_i^j)}{\sigma_{c_{EMU}} \sigma_{c_i^j}}$, but we can also disaggregate $corr(c_{EMU}, c_i^j)$ as follows:

$$corr(c_{EMU}, c_i^j) = \frac{\sigma(c_{EMU}, c_i^j)}{\frac{\sigma(c_{EMU}, c_i)}{\sigma_{c_i} corr(c_{EMU}, c_i)} \frac{\sigma(c_i, c_i^j)}{\sigma_{c_i} corr(c_i, c_i^j)}} \quad \text{(A3.1)}$$

which allows highlighting the contributions of both $corr(c_i, c_i^j)$ and of $corr(c_{EMU}, c_i)$ to $corr(c_{EMU}, c_i^j)$. Therefore, we also computed the within country sectoral business cycle synchronization, $corr(c_i, c_i^j)$, which we report below.

Table A1 – Within Country Sectoral Synchronization: Industry; Building and Construction

	Industry			Building and Construction		
	80-92	93-05	80-05	80-92	93-05	80-05
	EMU countries					
Austria	0.611	0.617	0.605	0.352	0.301	0.310
Belgium	0.543	0.707	0.614	0.693	0.599	0.644
Finland	0.922*	0.742	0.839*	0.769*	0.900	0.813*
France	0.193	0.865	0.495	0.172	0.407	0.300
Germany	0.505	0.427	0.453	0.754	0.598	0.680
Greece	0.517	0.271	0.490	0.593	0.121	0.495
Ireland		0.831			0.789	
Italy	0.848	0.390	0.618	0.358	0.096	0.271
Luxembourg	0.450	0.334	0.398	0.213	0.236	0.233
Netherlands	0.471	0.214	0.356	0.163	0.592	0.320
Portugal	0.611	0.713	0.647	0.773	0.887	0.760
Spain	0.647	0.737	0.702	0.801	0.835	0.805
Minimum	0.193	0.21	0.36	0.163	0.10	0.23
Maximum	0.922	0.86	0.84	0.801	0.0	0.81
	Other EU					
Cyprus		0.437			-0.276	
Czech Republic		0.752			0.442	
Denmark	0.837	0.670	0.763	0.743	0.498	0.658
Estonia		0.646			0.635	
Hungary		-0.193			-0.012	
Latvia		0.195			0.223	
Lithuania		0.829			0.658	
Malta		0.830			0.229	
Poland		-0.344			-0.149	
Slovakia		0.323			0.755	
Slovenia		0.852			0.784	
Sweden	0.667	0.841	0.783	0.351	0.688	0.529
UK	0.189	0.536	0.262	0.519	0.576	0.504
Minimum	0.189	-0.344	0.26	0.351	-0.276	0.504
Maximum	0.837	0.852	0.78	0.743	0.784	0.658
	Candidate countries					
Bulgaria		0.345			0.370	
Romania		0.677			0.640	
Turkey		0.668			0.676	
Minimum		0.345			0.370	
Maximum		0.677			0.676	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.

Table A2 – Within Country Sectoral Synchronization: Agriculture; Services

	Agriculture, Fishery and Forestry			Services		
	80-92	93-05	80-05	80-92	93-05	80-05
			EMU countries			
Austria	0.056	0.218	0.124	0.220	0.199	0.186
Belgium	0.336	0.356	0.346	0.038	0.242	0.107
Finland	0.719***^	0.584**	0.682***^	0.611^	0.791	0.677*
France	0.286	0.412	0.328	0.050	0.432	0.202
Germany	-0.004	0.412	0.087	0.696	0.664	0.649
Greece	0.499	0.350	0.483*	0.212	0.506	0.253
Ireland		-0.089			0.465	
Italy	0.186	0.113	0.185	0.570	0.174	0.383
Luxembourg	-0.146	0.191	0.009	0.072	0.006	0.037
Netherlands	0.122	0.296	0.223	-0.134	0.314	0.018
Portugal	0.442	0.172	0.363	0.691	0.801	0.684
Spain	0.664**	0.284	0.545**	0.532	0.773	0.595
Minimum	-0.146	-0.08	0.009	-0.134	0.006	0.018
Maximum	0.719***	0.584**	0.682***	0.696	0.801	0.684
			Other EU			
Cyprus		0.441			0.470	
Czech Republic		0.632**			0.165	
Denmark	0.079	0.459	0.273	0.805	0.342	0.641
Estonia		0.627**			0.664	
Hungary		-0.196			-0.256	
Latvia		0.195			0.027	
Lithuania		0.887***			0.658	
Malta		0.160			0.652	
Poland		-0.338			-0.634	
Slovakia		0.464			0.514	
Slovenia		0.628**			0.798	
Sweden	0.487*	0.760***	0.669	0.144	0.639	0.458
UK	0.443	0.466*	0.441	-0.030	0.212	0.045
Minimum	0.079	-0.338	0.273	-0.030	-0.634	0.641
Maximum	0.487*	0.887***	0.669	0.805	0.798	0.045
			Candidate countries			
Bulgaria		0.302			0.355	
Romania		0.703			0.431	
Turkey		0.749			0.716	
Minimum		0.302			0.355	
Maximum		0.749			0.716	

Note: Hodrick-Prescott Filter with smoothness parameter equal to 6.25.
^We did not consider the years 1991 and 1992 to take into account the Finland crisis in the early 1990s.
***,**,* denote significance respectively at 1%, 5%, and 10%.