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Business Cycle Synchronisation in a Currency Union: Taking Stock of the Evidence

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Abstract: This paper offers a first systematic evaluation of the evidence on the effects of currency unions on the synchronisation of economic activity. Focusing on Europe, we construct a database of about 3,000 business cycle synchronisation coefficients as well as their design and estimation characteristics. We find that: (1) synchronisation increased from about 0.4 before the introduction of the euro in 1999 to 0.6 afterwards; (2) this increase occurred in both euro and non-euro countries (larger in former); (3) there is evidence of country-specific publication bias; (4) our difference-in-differences estimates suggest the euro accounted for approximately half of the observed increase in synchronisation.

Keywords: business cycles synchronisation, optimum currency areas, EMU, euro, meta-analysis.
JEL classification: E32, F42

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1. Introduction

Sometimes, it seems nobody loves the euro. The single currency has received wide criticism on many fronts. It has been singled out as a major aggravating factor, if not as the root cause, of the global financial crisis (Martin and Philippon, 2017). This is despite the fact that even before the global financial crisis, economists (e.g., De Grauwe, 2006) raised serious concerns about potential flaws in the design of the European Economic and Monetary Union (EMU). Yet it took a severe double-dip crisis to prompt European leaders to announce plans for reforming it into a "Genuine" EMU (Begg, 2014).

The debate about the future of the EMU requires a careful examination of the costs and benefits of the single currency. A fundamental criterion for optimal currency areas is the degree of synchronisation of economic activity. Synchronisation is often measured as the correlation between two data series that capture economic activity in two countries or between one country and a group of countries (e.g. euro area). This paper takes stock of the empirical evidence on synchronisation of business cycles in Europe. It tries to identify whether and by how much synchronisation changed across European countries after the introduction of the euro.

Some argue that economic criticism of the euro is irrelevant because the single currency is essentially a political project (Jespersen, 2016). Even so, it is a political project immersed in the history of economic thought, propelled by economic reasoning and supported by a considerable body of econometric evidence. The 1960s saw the advent of a theory on optimum currency areas (Mundell, 1961) and first plans for a European single currency (e.g. the Werner Report). Although currency-union plans were abandoned after collapse of the Bretton Woods system in the early 1970s (Eichengreen, 2008), they were revived in the late 1980s (e.g. the Delors Committee). The revised plan for a new European currency was accompanied by a flurry of research on the theory of endogenous optimal currency areas (Frankel and Rose, 1998) and econometric evaluation of the effects of currency unions (Silva and Tenreyro, 2010). For a so-called political project, the euro seems to possess a fairly solid economics pedigree.

Distinguishing criticism of the euro project and assessment of its effects also shows deep division over its implications. Critics of the euro project claim the joint achievements are illusory, and predict an eventual collapse of the European single currency (e.g. Feldstein, 2013). Econometric evidence, in contrast, tells a somewhat different story. It suggests the euro has supported significant increases in international trade flows (Glick and Rose, 2016; Glick, 2017), foreign direct investment (De Souza and Lochard, 2011), price convergence and competition (Cavallo et al., 2014), financial integration (Kalemli-Ozcan et al., 2010) and structural reforms (Alesina et al., 2011; Gomes et al., 2013). Thus, while some predict demise of the euro project, the econometric evidence suggests otherwise. How might we reconcile such disparate views? Is our understanding of the econometric evidence biased or incomplete?

One way of reconciling these views is to stress the possibility that while politicians and media commentators may often pessimistic about the single currency, academic economists tend to view it as having generated substantial benefits. The latter also point out that one of the main drawbacks has been the euro’s inability to distribute these benefits across countries, chiefly between core and periphery (Giannone et al., 2011, and Wyplosz, 2016). In other words, the euro created substantial economic benefits (“glass half full”), but failed to distribute them evenly across member states (“glass half empty”). The discussions about lack of convergence in Europe, the persistence of “imbalances” and EMU deepening can also be understood as ways of enhancing those distributive mechanisms.

The objective of this paper is to systematically examine the evidence on the effects of the introduction of the euro on business cycle synchronisation in Europe. The present study complements, updates and extends previous efforts, chiefly Fidrmuc and Korhonen (2006) and De Haan et al. (2008). We conclude that the available evidence suggests a significant increase in synchronisation and we estimate that about half of this increase can be attributed to the euro.

We apply meta-regression analysis to address these issues. Recent concerns about research transparency and reproducibility are handled by the inclusion of new approaches to establishing research credibility (Ioannidis et al., forthcoming). In a review of new techniques, Christensen and Miguel (forthcoming) highlight the efficacy of meta-regression analysis in systematically summarising findings of a body of scientific literature on a given topic. Unlike conventional literature reviews, meta-analysis applies statistical methods that make it less susceptible to reviewer tastes, preferences and biases (Stanley and Doucouliagos, 2012).

This paper uses a unique hand-collected database encompassing results, design and estimation characteristics of 2,979 estimates from 63 studies on business cycle correlations between European (mostly EU) countries over the past six decades. These econometric studies use several variables for synchronisation (e.g. GDP, industrial production and inflation), a variety of ways for calculating correlations (e.g. simple correlations of growth rates and correlation of de-trended variables), as well as multiple econometric methods (e.g. HP filter and structural VAR). In principle, meta-regression analysis should produce a systematic, transparent and rigorous summary of the evidence accounting for these differences.

Our main findings are as follows. First, business cycle correlation coefficients have significantly increased over time from about 0.4 before the introduction of the euro in 1999 to 0.6 afterwards. Second, the increase is observed in all euro zone core countries, euro zone periphery countries and non-euro countries in Europe, but the increase is heterogeneous. Third, multiple factors explain the variation over time and across countries in synchronisation estimates. For example, quarterly data or Blanchard-Quah decomposition systematically lowers synchronisation estimates. Fourth, the evidence of publication bias appears to be restricted to a few countries, most notably Greece, the UK, Bulgaria and Latvia. Finally, using difference-in-differences, we estimate that half of the observed synchronisation increase after 1999 is due to the euro. These results are robust to an extensive battery of sensitivity checks.

This paper is organised as follows. The next section provides a general conceptual framework drawing from the optimal currency areas literature. Section 3 introduces our data and methodology. Section 4 presents our empirical results on the magnitude of the effect of the establishment of the EMU on business-cycle synchronisation. Section 5 discusses our econometric results. Section 6 concludes.

2. Conceptual framework

How co-movement of business cycles of different countries are correlated, or synchronised, is a central issue in research on optimal currency areas (OCAs). A key issue within this discussion involves the costs and benefits of sharing a currency (Alesina and Barro, 2002). This question, unfortunately, often gets light treatment or falls victim to mechanistic approaches such as criteria-listing. Indeed the basic OCA question "Why do different countries use different currencies?" can be rephrased in several ways such as "Why don't all countries use the same currency?" or "Why doesn't the world just use the dollar, pound, renminbi or the euro?" (Mundell, 2005).

On one hand, governments lose seigniorage income and autonomy of domestic monetary and exchange-rate policies.[1] On the other hand, a common currency may still be justified if it generates large benefits such as lower transaction costs, exchange rate certainty, price transparency, increased trade and investment flows, and more competition.

De Grauwe and Mongelli (2005) offer a useful approach to the OCA question that focuses on the interactions of symmetry, flexibility and integration. *Symmetry* is defined as synchronisation of economic activity (business cycles). *Flexibility* is seen mostly as labour mobility. *Integration* is essentially international trade flows. Their main argument is that countries must share some threshold combination of these factors for a currency union to generate positive net benefits. Their thesis proposes that the euro area is an OCA, while the EU as a whole is not. This implies that many countries are integrated to the point where they generate sufficient gains to offset the macroeconomic costs of the monetary union.

De Grauwe and Mongelli (2005) further observe that the degree of economic integration and symmetry can change over time. This formulation is among the earliest to move beyond the traditional stand-alone treatment of OCA criteria and discuss possible complementarities.[2] In particular, the contrast between independent and interdependent OCA criteria is starting to be slowly resolved in favour of the latter. For example, looking at labour mobility, an OCA precondition, Farhi and Werning (2015) develop a model to examine the interaction between trade openness and factor mobility.

It should also be noted that although the original OCA formulation stressed issues such as labour mobility, production diversification, trade openness and the possible endogeneity of

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[1] Rey (2013) argues that such autonomy is illusory for the vast majority of countries.
[2] Frankel and Rose (1998) point out that trade intensity with other potential currency union members and the extent to which domestic business cycles are correlated with those of other countries are not independent (endogenous). Thus, they are not essential criteria in evaluating the readiness of countries to share a common currency. See also Montinari and Stracca (2016) amd references therein.

currency unions (Frankel and Rose, 1998), more recent research deals with the potential role of credibility shocks (Chari et al., 2016). The intuition here is that when different countries have varying degrees of policy commitment that increase time-inconsistency problems, it is advantageous for countries with dissimilar credibility shocks to join a currency union.

Synchronisation of economic activity occupies a central place in the debate about the extent to which monetary unions affect symmetry (Krugman, 1993 and 2013). Specifically, the greater the extent of co-movement, the smaller is the cost of abandoning domestic policy tools. This is a central aspect of currency unions – symmetry lowers the cost of surrendering monetary and exchange-rate policy autonomy.

3. Data and measurement

We apply meta-analysis and meta-regressions using a unique database that encompasses the estimates, design and estimation characteristics of more than 60 studies. We focus on papers that estimate business-cycle correlations between EU countries, but include Norway well.

For the sake of transparency, we follow the general guidelines for meta-analysis (Stanley et al., 2013). We start by searching for papers from the online sources Google Scholar, the Research Papers in Economics (RePEc) bibliographic database and the SSRN online paper repository with the following search string:

> business AND cycle AND (correlation OR synchronization OR synchronisation) AND (EU OR EMU OR "European Union" OR "Euro Area")

This search should capture any paper that estimates business-cycle correlations between two or more European countries. We include only those papers that report correlation coefficients between some economic variables for at least one well-defined time interval. We also note that it is fairly common in this body of literature to only report results in graphic form.

The data set was completed in February 2017 meaning that it should include all papers published in 2016.

Our search procedure yields 63 individual papers published between 1993 and 2016 (Appendix A). Many of these papers have been revised or published elsewhere, so we only include information in our database from the most recent version of the paper. When we have access to working paper version and the version published in an academic journal or book, we only take the estimates from the latter. These 63 papers provide 2,979 individual estimates for up to 25 countries.

We quantify several characteristics related to individual studies (in addition to all reported synchronisation estimates). Specifically, we collect information related to authors (number and affiliations), publication (journal publication, working paper, PhD dissertation), data and sample (frequency; variable used for computing synchronisation; start and end of sample; whether correlations are calculated only against a single country/grouping; whether benchmark country/group is Germany, entire euro area or something else), as well as various features of the econometric methodology (simple correlation, time series models, Blanchard-Quah decomposition, etc.).

The wide fluctuation in publication on the topic is striking. Figure 1 shows changes in the number of papers published on business-cycle correlation over time. Interest seems to peak with the introduction of euro banknotes in 2002, and then spikes several times thereafter as researchers return to the topic with each addition of new members to the euro area.[3] The number

[3] The euro was first introduced in 1999 with eleven members (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Spain and Portugal). Physical euro banknotes and coins were issued in 2002. The euro area thereafter experienced several expansions. Greece joined in 2001, Slovenia in 2007, Cyprus and Malta in 2008, Slovakia in 2009, Estonia in 2011, Latvia in 2014 and Lithuania in 2015. Denmark also maintains a tight peg to the euro.

of publications for each main European region is similar, with the possible exception of Eastern Europe.

{Figure 1 about here}

Our dataset contains hand-collected information on 2,979 estimates from 63 studies, implying that each paper reports an average of 47 estimates. Reported estimates per paper range from a minimum of 8 to a maximum of 384.

The average value of the business cycle synchronisation correlation coefficient over all 2,979 estimates is 0.48, with a relatively high standard deviation of 0.34. To assess how these estimates change over time (especially before and after the euro's introduction in 1999), we use two methods. First, we consider all estimates and separate them into two groups according to the middle year of their estimation window, i.e. one group where the middle year of the sample occurs before 1999 and the other where the middle year is 1999 or later. The two groups overlap. Figure 2 illustrates how average of reported correlation coefficients changes over time for different countries. Darker shades of blue indicate higher correlation.

{Figure 2 about here}

Our second method only includes studies where the estimation window ends before 1999 or starts in or after 1999 (the year the euro was introduced). This second method generates two non-overlapping sets of estimates.

In our overlapping set, we find that the value of the business cycle synchronisation correlation coefficient increases from an average of 0.43 before the euro to an average of 0.60 afterwards. The overlapping set consists of 2,010 pre-euro estimates and 969 euro-era estimates. From our non-overlapping cut (i.e. where we exclude all correlation coefficients with estimation window spanning both before and after 1999), we obtain a more balanced set of 742 before-1999 estimates and 501 estimates for 1999 and after. In the non-overlapping case, the value of the business cycle synchronisation correlation coefficient increases even more starkly from an average of 0.38 before the euro to an average of 0.73 afterwards.

Studies of European monetary integration frequently reference the path-setting publication of Bayoumi and Eichengreen (1993). We find that about 52% of these estimates are taken from working papers, while approximately 48% come from published articles (Appendix B contains descriptive statistics tables). Around 75% of authors are affiliated with universities and 35% with central banks or international institutions (overlap indicates dual affiliation).

Almost 60% of the estimates measure synchronisation of economic activity between countries using GDP, while the remainder rely mainly on industrial production, inflation, demand or supply shocks (each accounting for approximately 10% of the estimates). Synchronisation is found in 48% of the estimates with respect to the EU, 38% with respect to Germany and 14% with respect to the euro area. For 52% of the estimates, the frequency of the data is quarterly, while for 38% it is annual, and for about 10% of the cases it is monthly. The most popular methodology remains the Hodrick-Prescott filter (56% of the estimates). The Blanchard-Quah decomposition is used in about 20% of the estimates, simple correlations in 17% and other time-series methods in the remaining 7% of the cases.

Separating the estimates into overlapping and non-overlapping groups before and after the introduction of the euro in 1999 generates some new insights. For example, the reference used for the calculation of synchronicity with respect to Germany is 48% of the estimates before 1999, but only 18% after that year in the overlapping case (compared to 73% and 10% respectively in the non-overlapping case). An interesting change is the surge of academic affiliation of the authors. For the overlapping case before 1999, approximately 70% of the estimates were made by authors affiliated with universities and about 40% by those working at central banks. After 1999, the former share rises to almost 90%, while the latter falls to below 15%. The use of GDP as the synchronicity indicator rises from about 45% before the euro's introduction to nearly 70% after. In terms of data frequency, the share of annual data somewhat surprisingly increases from 34% to 44% of the estimates, while the number of estimates based on simple correlations decreases over time. These suggest our dataset does a good job in capturing and reflecting changes in research practice over the last two decades.

4. Assessing the evidence

We now utilize this unique database to provide a detailed picture of the evolution of business cycle synchronisation across countries and over time. Regarding the time scale, our emphasis is in contrasting the periods before and after the introduction of the euro. For cross-country variation, we report results for individual countries. Given that the literature covers 25 EU members (almost every study on this subject excludes Cyprus, Luxembourg and Malta), we also create artificial groupings to help in carrying out comparisons.[4] Armed with these stylised facts, we present and discuss statistical tests on whether the introduction of the euro significantly

[4] Given the large number of countries, we aggregate them for clearer presentation. Somewhat arbitrarily, but still following many papers on the topic, we group countries as follows: EMU core (Germany, France, Austria, Netherlands, Belgium and Finland); EMU (EMU core plus Estonia, Greece, Portugal, Ireland, Spain, Italy, Latvia, Slovakia and Slovenia); Non-EMU West (Denmark, Sweden, UK and Norway); and the CEECs (countries of Central and Eastern Europe). We also report results for individual countries, so these groupings are only provided for ease of exposition.

changes the level of business cycle synchronisation and whether the econometric evidence is affected by publication bias.

4.1 Evolution of business cycle synchronisation

The creation of the EMU represents a major economic policy event and, as such, can be expected to have a significant influence on the degree of synchronisation of business cycles. To compare the period before and after the introduction of the euro in 1999, analysis of business cycle synchronisation must be carried out for periods of several years to encompass multiple cycles and their variations. Most papers estimate business cycles over a period covering many years before and after the introduction of euro. We consider each study as a moving window for the correlation estimation (Gächter and Riedl, 2014), which we attribute to the middle year of each relevant sample.

The development of moving-window correlations in Figure 3a is relevant to the current debate on business cycle correlation. Note that all groupings show an increasing degree of synchronisation, including the CEECs and Non-EMU West countries.

Figure 3b focuses on individual countries. As before, the degree of business cycle synchronisation increased over time, except for the most recent period of the financial crisis. Variance of these estimates remains large, however. Visual inspection of these figures is insufficient for concluding with certainty that an increase in business cycle synchronisation was statistically significant. This determination requires the appropriate statistical tests, which are laid out in subsection 4.2 below.[5]

[5] Notably, increasing synchronisation of business cycles seems to also increase uncertainty about the estimates. The figures with the standard deviations of estimates for country groups and countries (Appendix C), show heterogeneity increased for all regions, with the possible exception of the core countries of the euro area and heterogeneity reached its peak around the euro introductions years 1999–

{Figures 3a and 3b about here}

4.2 Statistical tests for structural change in business cycle synchronisation

The shifts in business cycle synchronisation in the above figures already suggests that synchronisation of business cycles has increased in the EU in general. At the same time, the descriptive statistics in Table 1 reveal considerable heterogeneity across countries, regions and periods. Therefore, further statistical analysis is needed to obtain a sharp picture of structural changes in EU-wide business cycles.

{Table 1 about here}

Table 1 presents the *t*-tests on whether the mean of the correlation coefficients have changed before and after the euro's introduction. The tests confirm that synchronisation of business cycles has generally increased for all main groupings and nearly all countries. Significant heterogeneity, however, remains at the country level. The level of business cycle synchronisation does not change significantly in some countries (Bulgaria, Estonia, Greece, Latvia, Lithuania, Slovakia and Norway). In addition, the synchronisation of business cycles in Germany, among the highest in our sample, remains relatively stable over time. As the mean equality test draws an incomplete picture, we return to this issue with more rigorous econometrics in subsection 5.5.

2002.

4.3 Publication bias

Economic policy debates that spill out into the wider public discussion are sometimes influenced by cherry-picked academic results (Bruns, 2017). This can lead to publication bias when authors, reviewers and publishers follow their preferences for statistically strong, significant and theoretically expected results that bolster, or at least do not contradict, a preferred hypothesis. Moreover, general expectations of specific results, as well as corresponding publication bias, can differ across countries. In this subsection, we assess whether the publications in our database suffer from publication bias.

Funnel plots are an intuitive way to visualize publication selection bias. A funnel graph is a scatter diagram that plots the precision of the reported effect on the vertical axis against the measured effect size on the horizontal axis (Stanley and Doucouliagos, 2012). In the absence of publication bias, the estimates will normally be distributed around the "true" effect. The plot is expected to resemble an inverted funnel, with the more precise estimates being close to the true effect. In contrast, publication bias may be significant if the funnel plot appears asymmetric.

The precision of published results is usually measured by standard errors. However, standard errors are often unavailable for correlation coefficients, so they are commonly proxied by the inverse of number of observations. The drawback to this approach is that the number of observations tends to be higher for quarterly or monthly data. Therefore, we also present funnel plots for studies using only quarterly data in the sensitivity analysis (Appendix C). Alternatively, we use number of available years (reflecting that quarterly data have four observations and monthly data have 12 observations per year).

The funnel plots for the main European regions are quite symmetrical, despite some observations with large positive numbers. The figures for regions seem to miss the upper part of the inverted funnel. For individual countries, this is mainly because the precise estimates tend to be highly heterogeneous.

The robustness analysis shows that the results are highly similar when the number of available years is used instead of number of observations. Quarterly data shows a more clear-cut picture of the genuine effect and publication bias than funnel plots for data at different frequencies (see Appendix C).

Because funnel plots themselves are inconclusive for detecting asymmetry, we employ a funnel asymmetry test (FAT) based on a simple meta-regression of available effects and corresponding standard errors (Card and Krueger, 1995; Egger et al., 1997), such that

$$\frac{1}{2} ln\left(\frac{1+\rho_{ij}}{1-\rho_{ij}}\right) = \tilde{\rho}_i + \beta SE_{ij} + \varepsilon_{ij} \ , \qquad (1)$$

where we use the Fisher transformation for correlation coefficients, ρ, which is not truncated between -1 and 1. Subscript i signifies country and j publication. Precision of the individual reported correlation coefficient, as usually measured in similar studies, is proxied by the inverse number of observations, $SE = 1/T$. Publication bias can be country-specific for idiosyncratic reasons, so we allow the coefficient of SE to vary across countries to obtain

$$\frac{1}{2} ln\left(\frac{1+\rho_{ij}}{1-\rho_{ij}}\right) = \tilde{\rho}_i + \sum_{i=1}^{N} \beta_i SE_{ij} + \varepsilon_{ij}. \qquad (1')$$

The FAT approach is based on expected symmetry of publications results around the most precise estimates. If estimates are distributed symmetrically, then coefficient β should not significantly differ from zero. By the same token, a significant coefficient β implies a tendency to report certain parameter values or only significant results. Rejection of the null confirms the presence of publication bias (presence of asymmetry).

Our FAT analysis (Table 2 and Figure 4 for country-specific biases) also confirms the asymmetries revealed previously by the funnel plots. However, there is ambiguity in these results. Standard errors as proxied by the inverse of simple number of observations show a positive publication bias in general. In contrast, we can see a negative publication bias when standard errors are proxied by the inverse of number of available years. This is due to studies that rely on extremely short time spans. There is a positive, but insignificant, publication bias when we only include studies covering more than five years, which is approximately the length of a full business cycle. Publication bias is also significant for this proxy variable if we only include studies spanning more than eight years.

{Table 2 about here}

Figure 4 shows that publication bias is highly country-specific. The largest biases are found in the CEECs (Bulgaria and Latvia). They are positive for number of observations used and negative for number of available years. A comparably low, but still significant, bias is found for the UK and Greece.

{Figure 4 about here}

5. Understanding variation of synchronisation estimates through meta-regression

To identify the overall effect of the euro on business cycle synchronisation, we present a detailed study of the main factors that explain cross-country, between-study and over-time variations for reported correlation coefficients. We select a preferred specification that is robust to different estimation strategies, from a version of the specific-to-general approach to Bayesian model averaging analysis. We discuss several sensitivity tests regarding alternative estimation methodologies and subsamples. We end the subsection by asking whether business cycle correlation increased more in euro area countries than in other European countries.

5.1 Meta-regression results

We employ meta-regressions to assess the degree of business cycle synchronisation between the euro area as a whole and eurozone or non-eurozone countries. We control for various characteristics of individual studies in these regressions.

While there are many ways to formulate meta-regressions, we start with a specific-to-general formulation for tractability. (Notably, we obtain quite similar results with a Bayesian model averaging as our alternative modelling strategy). For ease of presentation, we divide our control variables into four groups.

The first group include variables related to each publication. In this group, we construct dummy variables for whether the paper was published in a journal and whether the focus of the publication is on a single country. Moreover, we construct a dummy variable for whether at least one of the authors is affiliated with a central bank. Previous research by Fidrmuc and Korhonen (2006) finds this to be an important variable.

Second, we consider the reference region for synchronisation. Early studies of business cycle correlation in Europe relied on a proxy for the euro area as a reference for synchronisation as the eurozone did not exist yet. Some studies use Germany, while others use broad groups of EU countries (typically core countries or the twelve member states of the European Community).

We empirically distinguish among these possibilities.

Third, we estimate which econometric methodologies are influential. Business cycle correlations can be computed in different ways, so we include dummies for simple correlations in time-series models, Blanchard-Quah decomposition, and filters such as the Hodrick-Prescott filter.

Finally, authors may select from different definitions of variables in estimating business cycle synchronisation. We thus include dummies for GDP, industrial production, supply and demand shocks and inflation. Similarly, we consider different data frequencies (monthly or annual as compared to quarterly frequency, our base category).

Most explanatory variables are dummy variables, taking the value of one if the specified criterion is fulfilled and zero otherwise. All other variables (e.g. publication year, number of observations and number of analysed countries) are demeaned.

Our empirical strategy is to estimate the following equation where the reported, original correlation coefficients, ρ_{ij}, are truncated between -1 and +1. In other words, the reported correlation coefficients have been transformed via Fisher transformation to remove the truncation problem such that

$$\frac{1}{2}\ln\left(\frac{1+\rho_{ij}}{1-\rho_{ij}}\right) = \rho_i + \sum_{k=1}^{K}\beta_{ijk}D_{ijk} + \sum_{i=1}^{N}\gamma_i Trend_{ij} + \varepsilon_{ij}. \qquad (2)$$

Country dummy ρ_i gives the average correlation coefficient for country *i*, controlling for analysed *K* characteristics of publication *j* such as publication year, variable, methodology, sample size, frequency, author affiliation or whether the publication is a journal. We try to use the common best-practice option as our base category (Doucouliagos, 2016). Thus, we can interpret country dummies as the best-practice level estimate of business cycle correlation with the euro area, controlling for all sources of bias mentioned above.

The regression analysis requires several steps. We always include country fixed effects and country-specific time trends (the latter computed as country dummies multiplied by the middle year of the sample). We then add stepwise the groups of explanatory variables. In the regression results reported in Table 3, the first four columns show results for including control variables related to publication, reference country, methodology and specifications, respectively. The final column displays our preferred specification, where we include all the control variables that were significant in the first four specifications.

The main results are as follows. First, we examine the individual group of variables related to the papers. Journals and PhD theses usually report a lower level of business cycle synchronisation than working papers (base category). As in Fidrmuc and Korhonen (2006), authors from central banks report more conservative results for business cycle synchronisation in Europe. In contrast, it is unimportant whether the publication focuses on a particular country (*Single_country*). If a proxy for the euro area has been used (*Reference_EU*), the studies usually show a higher degree of correlation. Correlation coefficients calculated against Germany are not significantly different from the "authentic euro area" (base category).

Somewhat surprisingly, the use of annual data (*Annual*) yields much higher levels of business cycle synchronisation than other frequencies. Monthly data (*Monthly*) are not significantly different from quarterly data.

{Table 3 about here}

Methodological choices affect the reported correlation coefficients as well. Time series models (*Time_series*) and structural VAR models (*Blanchard-Quah*) yield significantly lower results than standard filters (*Hpfilter*). Similarly, the reported degree of synchronisation is lower if supply shocks and demand shocks are used.

Our preferred specification is presented in the last column. We include only those variables that were statistically significant at least at the 10% level in the previous steps. We then drop one by one the least significant variable and proceed to the final specification, i.e. whether the reported level of business cycle synchronisation is determined mainly by type of publication (journal and PhD thesis), characteristics related to the reference choice (EU), methods (HP filter) or variable definition (supply and demand shocks).

Estimation of equation (2) with the Fisher transformation of published correlation coefficients may make country fixed effects and trends hard to interpret. Therefore, we extricate correlation coefficients from the adjusted fixed effects as follows:

$$\tilde{\rho}_i = \frac{1+\exp(\rho_i)}{1-\exp(\rho_i)}. \tag{3}$$

We report this indicator on the horizontal axis of Figures 5a and 5b. The figures show that there are surprisingly small differences between the individual country effects, which are positive and significant for all countries.[6] As expected, the lowest degree of business cycle synchronisation, after controlling for publication characteristics, is found for countries in the euro area periphery (Lithuania) and Eastern European EU members outside the euro (Bulgaria and Romania).

[6] Note that, due to the Fisher transformation, a country fixed effect of, for example, 0.98, corresponds to a correlation coefficient of 0.67.

Unsurprisingly, we find highest business cycle correlation levels for the core countries of the euro area with Germany and France in the lead and Belgium, Austria, Netherlands and Italy close behind.

{Figures 5a and 5b about here}

The speed of convergence (displayed on the vertical axis of Figures 5a and 5b) is defined as the change of implied correlation coefficient after one year when evaluated using the country fixed effect:

$$speed_i = \frac{1+\exp(\rho_i+\gamma_i)}{1-\exp(\rho_i+\gamma_i)} - \frac{1+\exp(\rho_i)}{1-\exp(\rho_i)}. , \qquad (4)$$

where country-specific trends, γ, are estimated in equation (2).

All countries except Norway show a positive and significant trend in terms of business cycle synchronisation, while overall the speed of convergence is slow. The degree of business cycle correlation increases by just 0.03 in the case of Greece and 0.05 in the case of the UK. Both countries exhibit low levels of adjusted business cycle synchronisation and speed of convergence. The comparable high estimated coefficients for country-specific trends do not imply a higher speed of convergence for the core countries of the euro area because of the Fisher transformation. Thus, if evaluated at the estimated country effect, the correlation say for the Netherlands increases only by 0.04 (e.g. from 0.73 to 0.77). A few countries in Central and Eastern Europe show high speeds of convergence, albeit from lower initial levels.

5.2 Bayesian model averaging

As an alternative model selection strategy, we use Bayesian model averaging (BMA) methodology to identify those variables capable to explain the distribution of business cycle correlation coefficients. BMA has become an important tool for dealing with model uncertainty in meta-analysis in economics (Havránek and Rusnák, 2013; Havránek et al., 2015). The BMA approach has the advantage of considering all possible combinations of explanatory variables and weighting them according to model fit. BMA results are robust to model uncertainty when the correct set of explanatory variables is largely unknown. Thus, we consider all possible specifications where business-cycle correlation is explained by all possible combinations of explanatory variables.

Our data set consists of 67 possible explanatory variables. This number includes variables such as country fixed effects and country-specific trends (a total of 50 variables), which should be included in all estimated models to reflect the underlying data heterogeneity. As our *focus* variables (De Luca and Magnus, 2011), we always include these so that we then concentrate on which of the remaining 17 auxiliary regressors should be included in the final models. This gives us a model space with $2^{17} = 131{,}072$ possible models.

We compare the BMA results with a weighted-average least-squares (WALS) estimator that relies on the Laplace priors to select important auxiliary regressors.[7] The key BMA statistic (Table 4) is the posterior inclusion probability (PIP) which reflects the importance of each variable. Using it as a criterion, a PIP above 0.5, or even 0.75, gives a similar specification to the one we selected previously.[8] The most important explanatory variables are: journal, Germany as

[7] These are implemented using *Stata* commands *bma* and *wals* from De Luca and Magnus (2011).
[8] Following the definitions of Kass and Raftery (1995), the significance of each indicator is weak, positive, strong or decisive if the PIP lies above 0.5, 0.75, 0.95 or 0.99, respectively.

a reference country (instead of EU), simple correlations, HP filter, demand or supply shocks, inflation and annual data. The WALS results concur, but give slightly more weight to GDP.

{Table 4 about here}

5.3 Robustness analysis: Alternative estimation methods

Using our preferred specification, confirmed by Bayesian model averaging analysis, we perform further robustness checks. In Table 5, we report these results for our various estimation methods.

The first method is weighted regression. We experiment with the number of observations in the underlying studies as weights. The idea is that studies with more observations are somewhat more reliable, *ceteris paribus*. However, this would put more weight on studies using monthly data, even if their quality is not necessarily better. Therefore, we compute the number of available years in the sample as the alternative weight.

We then use median regression as an alternative estimation methodology. Instead of minimizing the sum of squared residuals as in ordinary least squares regression, median regression minimizes the sum of absolute residuals to reduce the effect of large outliers on the estimated coefficients. The robust regression which uses Cook's distance to offset the largest outliers provides an alternative way to deal with outliers.

Our third method is random effects for individual studies. This analysis accounts for possible remaining cross-sectional dependence between observations in the same study. Alternatively, we use the two-way clustering of standard errors as proposed by Cameron et al. (2006) using country (as in the preferred specification) and study clustering dimensions. The results are very similar to the random effect model specification although more variables (especially dummy for journals) become less significant.[9]

Finally, our meta-regressions use a representative year of the analysis (middle year of the analysed sample), which cannot be measured exactly. For example, different publications may have the same middle year of the sample while covering periods of different lengths. Similarly, some periods may be more influential than others, or authors' preferences for some results (publication bias) can be influenced by the developments in particular sub-periods. Therefore, we also estimate an errors-in-variable regression reported in the last column of Table 5.

Overall, the explanatory variables remain like those in our preferred specification in all alternative estimation methods above. The main differences are that the dummy variables for journal publication, annual data and time-series methods become insignificant in the random effects model. Country fixed effects and country-specific trends change only slightly with respect to the preferred specification. The correlation for country fixed effects and country-specific trends is always over 0.90 for the former and above 0.60 for the latter (individual results are available upon request).

{Table 5 about here}

5.4 Robustness analysis using various subsamples

In this sensitivity exercise, we compare our preferred specification estimated for the full sample, reported again in column (1) of Table 6, with results from selected subsamples. First, as business cycles may differ with different indicators of economic activity, we use only results based on GDP data (including decomposition of GDP into supply and demand shocks) in column (2).

[9] Detailed results are available from authors on request.

Thus, the dummy for inflation is dropped in this specification. The main change is that coefficients for journal and simple correlation become insignificant in this subsample.

As the use of annual or monthly data may lead to different levels of business cycle synchronisation, we include only quarterly data in column (3) and drop the dummy for annual data from the specification. The coefficient for journal publications becomes again insignificant in this robustness test. Moreover, the coefficient for reference country is also insignificant.

The robustness test in column (4) excludes studies using Germany as a reference country. The coefficient for EU as reference country (base category is EMU) is now only marginally significant.

Our next subsample only includes the euro area countries as of 2017. Column (5) shows that this specification yields the most clear-cut results, although the differences to our selected specification in column (1) remain small.

{Table 6 about here}

For our fifth subsample, we drop studies published after the outbreak of the financial crisis. Column (6) shows the coefficients on inflation and annual data have become insignificant.

Finally, we exclude possible outliers identified as correlations in the lowest and highest percentile of the entire sample. These results are similar to the preferred specification also in this sensitivity test. We also compare these results with various outlier definitions (e.g. top and bottom 5%) to check the robustness of our results without yielding major changes.

All these robustness analyses confirm our main results with regard to both explanatory variables and regarding country effects and country-specific trends.

5.5 Did business cycle correlation increase more for countries in the euro area?

To sum up the previous discussion, we see that the degree of business cycle synchronisation has increased in both the euro area and in non-euro countries. This could be the result of monetary integration, spillovers of shocks from the euro area to other regions, or both. The past two decades have also been affected by globalization, financial and economic integration and EU enlargement – all of which are likely to influence business cycles similarly across Europe. To differentiate between genuine euro effects and the effects of other factors, we apply a difference-in-differences approach (Donald and Lang, 2007), in which the euro's adoption is considered as the treatment, while the other countries are the non-treatment group. The treatment effect is defined as the difference between the mean of the outcome variable (business cycle synchronisation) after treatment (euro introduction) and the corresponding increase in the outcome variable for the non-treated group, $(\bar{\rho}^{eur}_{post99} - \bar{\rho}^{eur}_{pre99}) - (\bar{\rho}^{noneur}_{post99} - \bar{\rho}^{noneur}_{pre99})$. We can estimate the treatment effects, δ, as

$$\frac{1}{2}\ln\left(\frac{1+\rho_{ij}}{1-\rho_{ij}}\right) = \delta euro_{ijt} \times post99_{ijt} + \omega_1 euro_{ijt} + \omega_2 post99_{ijt} + \varepsilon_{ij}. \qquad (5)$$

Because we have multiple periods before and after the introduction of the euro, year effects are preferable to a dummy for the period after 1999 (Imbens and Wooldridge, 2009, Lechner, 2010). Similarly, we replace the euro dummy by country fixed effects in some specifications. We also include the variables from the preferred specification including country-specific trends (country dummies multiplied by the middle year of the sample).

After the euro introduction in 1999 in ten countries (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal and Spain), the euro was adopted in Greece (2001), Slovenia (2006), Slovakia (2009) and Estonia (2011).[10] Thus, the euro treatment occurred in multiple periods. Alternatively, we can consider the euro creation and the later enlargements as separate treatments.[11] The final difference-in-difference specification is thus

$$\frac{1}{2}\ln\left(\frac{1+\rho_{ij}}{1-\rho_{ij}}\right) = \sum_{m=1}^{M} \delta_m euro_{ijt}^{m} \times post_{ijt}^{m} + \omega_1 euro_{ijt} + \tau_{ijt} + \cdots + \varepsilon_{ij}. \qquad (5')$$

where $euro^m \times post^m$ is a dummy variable for the euro membership considering a particular group of countries, m, and τ are time effects (based on the middle year of the analysed sample).

The difference-in-differences approach may have some limitation with respect to the euro's introduction. First, the selection of the countries was not random, having been determined by meeting the Maastricht convergence criteria. Second, euro states followed a policy of fixed exchange rates before joining the euro. Thus, the euro's introduction was an event on the continuum of convergence. Third, the euro area continues to play an increasingly important role in Europe, meaning that non-euro countries are also subject to treatment effects from euro area policy. With these caveats in mind, the results provide an interesting benchmark for possible effects from the euro's introduction.

The results for equations (5) in column (1) and (5') in the remaining columns of Table 7 show that the euro introduction has a statistically significant effect on increasing business-cycle

[10] Luxembourg was a founding member of the eurozone. Cyprus and Malta adopted the euro in 2008, Latvia in 2014 and Lithuania in 2015. For these countries, we do not have yet any observations for the euro era.
[11] Because the number of observations is too low for later entrants, we include all these countries as one group. For example, the results for the euro adoption in Greece are negative, but insignificant. These results are available from the authors on request.

correlation in the euro area members. The magnitude of the effect[12] seems to be between 0.1 and 0.15, which is at least half of the overall increase in business-cycle correlation observed earlier. This effect remains robust when we include country fixed effects and other explanatory variables. They become smaller and insignificant when country-specific time trends are added. The implication here is that euro effects are highly country-specific, a finding which would show similarities to trade effects of the euro (Baldwin, 2006). Obviously, country-specific trends can also pick up increasing effect of the euro on business-cycle correlation for countries that joined the euro.

{Table 7 here}

The euro's introduction has insignificant (possibly negative) effects for countries that joined later. Of course, this can be due to country-specific factors, the very short time span since the euro was adopted, or both. In any case, the number of observations for these countries is very small.

6. Conclusions

The objective of this paper was to take stock, in a systematic and quantitative manner, of the body of econometric evidence on the effects of the euro on synchronisation of business cycles within Europe. Several findings deserve mention. First, business cycle correlation coefficients have significantly increased over time, from an average of 0.4 before the introduction of the euro in 1999 to 0.6 during the euro era. Second, this increase happened in the core and periphery euro countries, as well as in the non-euro countries of Western Europe such as Sweden and the UK.

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[12] The actual treatment effects are slightly lower than the reported coefficients because these are estimated for the Fisher transformation of correlation coefficients, e.g. between 0.074 for specification (1) and 0.120 for specification (2).

However, the increase was larger for countries in the euro area, showing the importance of the single currency in fostering economic convergence. Third, our analysis identified a set of robust factors that account for the variation over time and across countries in the reported correlation coefficients. For example, the use of quarterly data or Blanchard-Quah decomposition (i.e. demand and supply shocks) systematically lowered correlation estimates, while the affiliation of article authors (university or central bank) had no effect on the estimated correlation coefficients. Fourth, country-specific publication bias was found for several countries. Finally, using difference-in-differences, we estimate that the single currency was responsible for about half of the documented increase in business cycle synchronisation.

The main policy lesson that emerges from this exercise is that business cycle synchronisation in Europe has increased with the introduction of the euro. This increase is significant statistically and economically. The heterogeneity of the effects is of particular interest as our results suggest that increases in synchronisation are substantially more pronounced in core euro countries than in the euro periphery.

Our results also suggest various avenues for future research. A theoretical framework that relates synchronicity to other relevant features (e.g. trade openness and factor mobility) of endogenous currency unions is lacking. Moreover, future work should better consider the dynamics of different groupings of countries, ideally starting with the simple core and periphery groupings used here before going further. Finally, individual country studies will doubtless remain valuable in the future, but authors need to make substantial efforts at understanding the robustness of their key findings by considering alternative statistical methodologies. This could be done through more direct comparisons between HP filters and Blanchard-Quah results, or choice of variables (e.g. GDP vs. industrial production).

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Table 1. Descriptive statistics (by region and period)

	Before 1999			*After 1999*			t-test	
	Obs.	Mean	Std. dev.	Obs.	Mean	Std. dev.		
All Countries	2011	0.427	0.323	968	0.601	0.357	-13.306	***
EMU	592	0.419	0.303	279	0.608	0.349	-8.177	***
EMU core	674	0.552	0.287	302	0.735	0.264	-9.43	***
Non-EMU West	339	0.334	0.309	96	0.62	0.327	-7.907	***
CEECs	406	0.308	0.347	291	0.449	0.399	-3.655	***
Austria	117	0.58	0.254	50	0.752	0.23	-4.127	***
Belgium	121	0.625	0.23	48	0.72	0.257	-2.338	**
Bulgaria	5	-0.012	0.427	3	0.347	0.526	-1.061	
Czech Rep.	52	0.236	0.344	35	0.499	0.358	-3.439	***
Denmark	88	0.401	0.275	33	0.59	0.36	-3.082	***
Estonia	46	0.347	0.352	30	0.484	0.406	-1.56	
Finland	116	0.312	0.288	46	0.693	0.299	-7.518	***
France	135	0.61	0.235	60	0.771	0.25	-4.348	***
Germany	61	0.73	0.212	44	0.79	0.244	-1.352	
Greece	102	0.355	0.287	56	0.362	0.386	-0.129	
Hungary	55	0.439	0.304	35	0.586	0.318	-2.204	**
Ireland	109	0.335	0.317	55	0.632	0.299	-5.765	***
Italy	133	0.518	0.285	59	0.749	0.293	-5.13	***
Latvia	44	0.346	0.365	29	0.488	0.423	-1.522	
Lithuania	5	-0.071	0.34	13	0.179	0.377	-1.289	
Netherlands	124	0.528	0.312	54	0.682	0.295	-3.062	***
Norway	29	0.107	0.245	4	0.224	0.257	-0.891	
Poland	53	0.334	0.284	37	0.44	0.293	-1.714	*
Portugal	119	0.378	0.301	54	0.587	0.314	-4.167	***
Romania	39	0.165	0.373	25	0.343	0.434	-1.752	*
Slovakia	53	0.257	0.352	43	0.254	0.498	0.032	
Slovenia	54	0.375	0.326	41	0.608	0.295	-3.603	***
Spain	129	0.477	0.287	55	0.706	0.318	-4.786	***
Sweden	102	0.378	0.266	25	0.806	0.165	-7.677	***
UK	120	0.303	0.35	34	0.56	0.326	-3.824	***

Note: Own calculations. ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Table 2. Funnel Asymmetry Test

	(1)	(2)	(3)
proxy for standard errors	observation	years	years (>5)
publication bias	7.691***	-0.451**	0.172
	(0.410)	(0.162)	(0.430)
Observations	2979	2979	2765
R^2	0.120	0.003	0.000

Note: Standard errors clustered for countries in parentheses. ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Table 3. Meta-regressions of business cycle synchronisation

	(1)	(2)	(3)	(4)	(5)	(6)
Phd thesis	-0.382***					-0.217***
	(0.054)					(0.058)
Journal	-0.244***					-0.072***
	(0.015)					(0.021)
Single_country	-0.065					
	(0.315)					
Central_bank	-0.216***					
	(0.017)					
Refc_Germany		-0.134**				
		(0.062)				
Refc_EU		0.204***				0.147***
		(0.039)				(0.032)
Correlation			0.048			0.108***
			(0.034)			(0.034)
Time series			-0.216***			-0.131***
			(0.032)			(0.035)
Blanch-Quah			-0.337***			
			(0.028)			
HP filter			0.288***			0.155***
			(0.021)			(0.023)
GDP				0.123**		
				(0.052)		
Industrial prod				-0.130*		
				(0.070)		
Demand shocks				-0.503***		-0.390***
				(0.074)		(0.041)
Supply shocks				-0.412***		-0.316***
				(0.062)		(0.035)
Inflation				-0.223***		-0.188***
				(0.066)		(0.046)
Monthly					0.033	
					(0.038)	
Annual					0.398***	0.168***
					(0.032)	(0.032)
No. of obs.	2979	2979	2979	2979	2979	2979
adjusted R^2	0.695	0.691	0.735	0.733	0.704	0.760

Note: Standard errors clustered by countries in parentheses. ***, **, and * denote significance at 1%, 5%, and 10% level, respectively.

Table 4. Bayesian Model Averaging and Weighted-Average Least Squares

	BMA			WALS		
	post mean	std. error	PIP	coefficient	std. error	t-stat
Phd_thesis	-0.006	0.036	0.05	-0.158	0.096	-1.65*
Journal	-0.084	0.019	1.00+++	-0.081	0.017	-4.74***
Single_country	-0.001	0.044	0.02	-0.052	0.293	-0.18
Central_bank	0.000	0.003	0.02	0.006	0.021	0.30
Refc_Germany	-0.208	0.021	1.00+++	-0.184	0.028	-6.50***
Refc_EU	0.000	0.004	0.02	0.026	0.026	1.00
Correlation	0.090	0.046	0.86+	0.086	0.028	3.06***
Time_series	-0.106	0.045	0.91++	-0.084	0.032	-2.61***
Blanch-Quah	0.010	0.041	0.08	0.072	0.074	0.98
HP filter	0.154	0.034	1.00+++	0.147	0.024	6.07***
GDP	0.008	0.030	0.09	0.093	0.035	2.67***
Industrial prod	0.010	0.039	0.09	0.062	0.045	1.36
Demand shocks	-0.398	0.060	1.00+++	-0.359	0.078	-4.57***
Supply shocks	-0.324	0.058	1.00+++	-0.299	0.074	-4.03***
Inflation	-0.162	0.051	0.95++	-0.087	0.044	-2.00**
Monthly	0.003	0.014	0.06	0.046	0.033	1.37
Annual	0.176	0.021	1.00++	0.168	0.022	7.52***

Note: ***, ** and * denote significance at 1%, 5% and 10% level, respectively. +++, ++ + denote whether PIP indicates: positive significance (PIP above 0.75), strong significance (0.95) and decisive significance (0.99).

Table 5. Sensitivity analysis: estimation methods

	(1) preferred	(2) WLS	(3) WLSY	(4) MEDREG	(5) COOKR	(6) REM	(7) EIV
Phd_thesis	-0.217***	-0.292***	-0.187***	-0.243**	-0.166*	-0.267***	-0.225**
	(0.058)	(0.076)	(0.055)	(0.106)	(0.097)	(0.084)	(0.101)
Journal	-0.072***	-0.087***	-0.069***	-0.095***	-0.073***	-0.004	-0.073***
	(0.021)	(0.024)	(0.018)	(0.019)	(0.018)	(0.065)	(0.018)
Refc_EU	0.147***	0.108***	0.182***	0.142***	0.154***	0.076*	0.144***
	(0.032)	(0.033)	(0.036)	(0.020)	(0.018)	(0.041)	(0.018)
Correlation	0.108***	0.149***	0.030	0.118***	0.094***	0.141**	0.110***
	(0.034)	(0.040)	(0.035)	(0.033)	(0.029)	(0.056)	(0.031)
Time series	-0.131***	-0.113***	-0.106***	-0.096***	-0.122***	-0.090	-0.132***
	(0.035)	(0.032)	(0.030)	(0.033)	(0.030)	(0.057)	(0.031)
HP filter	0.155***	0.083***	0.068***	0.178***	0.158***	0.101*	0.156***
	(0.023)	(0.024)	(0.021)	(0.029)	(0.026)	(0.053)	(0.027)
Demand shocks	-0.390***	-0.369***	-0.434***	-0.359***	-0.383***	-0.377***	-0.388***
	(0.041)	(0.041)	(0.039)	(0.037)	(0.033)	(0.063)	(0.034)
Supply shocks	-0.316***	-0.319***	-0.352***	-0.279***	-0.303***	-0.287***	-0.315***
	(0.035)	(0.037)	(0.032)	(0.035)	(0.032)	(0.057)	(0.033)
Inflation	-0.188***	-0.243***	-0.181***	-0.178***	-0.179***	-0.155**	-0.186***
	(0.046)	(0.049)	(0.040)	(0.036)	(0.033)	(0.076)	(0.034)
Annual	0.168***	0.119***	0.116***	0.188***	0.174***	0.049	0.171***
	(0.032)	(0.035)	(0.027)	(0.022)	(0.020)	(0.093)	(0.021)
No. of obs.	2979	2979	2979	2979	2979	2979	2979
R^2/Pseudo-R^2	0.760	0.763	0.793	0.2927	0.465	0.417	0.462

Note: preferred = preferred estimation (OLS with standard errors clustered by countries), WLS = weighted (number of observations) least squares, WLSY = weighted (number of years) least squares, MEDREG = median regression, COOKR = Cook's Distance Robust Regression, REM = random effects model, EIV = errors-in-variables regression. Robust standard errors (homoscedastic standard errors for EIV) in parentheses. ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Table 6. Sensitivity analysis: selected subsamples

	(1) preferred	(2) gdp	(3) quarterly	(4) noger	(5) emu	(6) pre2008	(7) outlier
Phd_thesis	-0.217***	-0.124**	-0.210***		-0.257***		-0.204***
	(0.058)	(0.055)	(0.058)		(0.059)		(0.055)
Journal	-0.072***	-0.007	0.013	-0.069**	-0.081***	-0.101***	-0.074***
	(0.021)	(0.025)	(0.035)	(0.027)	(0.018)	(0.030)	(0.021)
Refc_EU	0.147***	0.174***	0.057	0.050*	0.169***	0.105**	0.146***
	(0.032)	(0.033)	(0.036)	(0.026)	(0.040)	(0.039)	(0.029)
Correlation	0.108***	0.046	0.199***	0.098*	0.172***	0.162***	0.114***
	(0.034)	(0.038)	(0.038)	(0.048)	(0.035)	(0.034)	(0.032)
Time series	-0.131***	-0.177***	-0.071*	-0.237***	-0.172***	0.299***	-0.132***
	(0.035)	(0.039)	(0.040)	(0.066)	(0.046)	(0.054)	(0.031)
HP filter	0.155***	0.179***	0.217***	0.077**	0.190***	0.158***	0.163***
	(0.023)	(0.028)	(0.030)	(0.037)	(0.022)	(0.037)	(0.020)
Demand shocks	-0.390***	-0.387***	-0.318***	-0.558***	-0.419***	-0.241***	-0.375***
	(0.041)	(0.046)	(0.055)	(0.090)	(0.047)	(0.045)	(0.038)
Supply shocks	-0.316***	-0.313***	-0.240***	-0.437***	-0.327***	-0.182***	-0.302***
	(0.035)	(0.040)	(0.050)	(0.074)	(0.044)	(0.044)	(0.033)
Inflation	-0.188***		-0.209***	-0.439***	-0.200***	-0.075	-0.152***
	(0.046)		(0.053)	(0.098)	(0.057)	(0.046)	(0.046)
Annual	0.168***	0.197***		0.261***	0.155***	0.039	0.149***
	(0.032)	(0.036)		(0.059)	(0.037)	(0.037)	(0.032)
no of obs.	2979	2227	1532	1836	2187	1507	2932
R^2	0.765	0.795	0.722	0.822	0.790	0.693	0.782

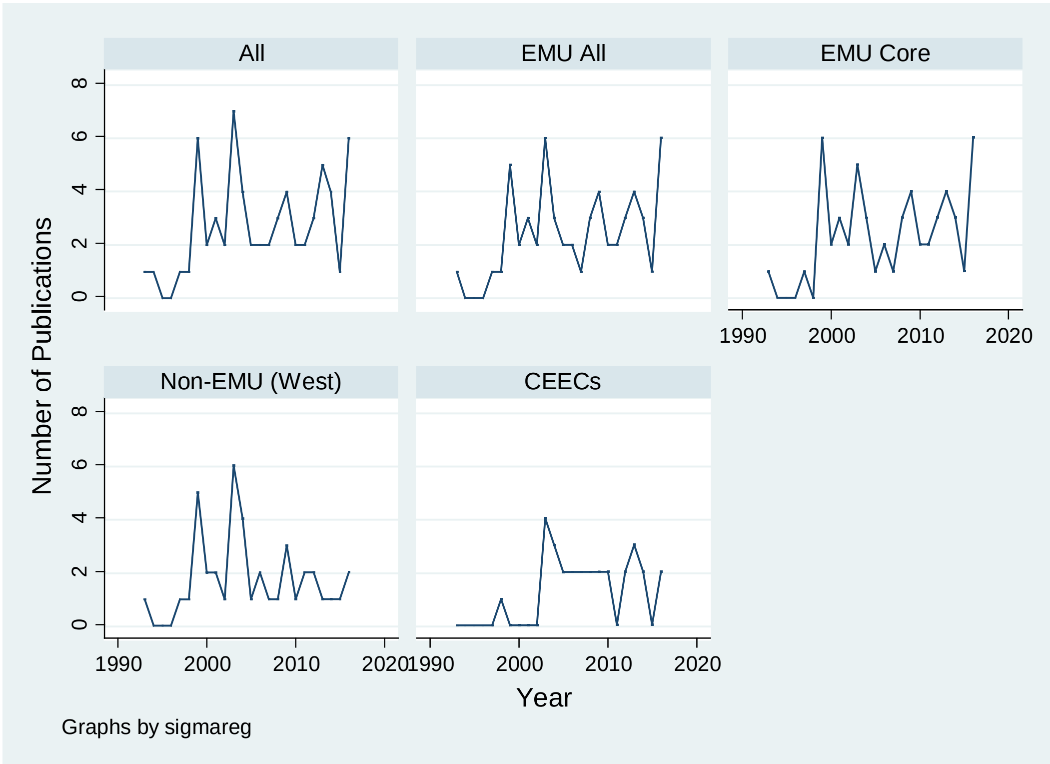
Note: preferred = preferred estimation (full sample), gdp = only GDP data, quarterly = only quarterly data, noger = excluding studies using Germany as a reference country, emu = including only euro area countries (as of 2017), pre2008 = excluding studies that were published after the financial crisis (2008 or later), outlier = excluding observations in the lowest and highest percentiles. Standard errors clustered by countries in parentheses. ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Table 7. Increase in business cycle correlation in the euro area (difference-in-differences estimation)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
D-i-D (all euro countries)	0.109***	0.155***	0.181**	0.165**	0.093				
	(0.041)	(0.037)	(0.069)	(0.063)	(0.080)				
D-i-D (founding members)						0.255***	0.211**	0.193**	0.107
						(0.041)	(0.076)	(0.070)	(0.094)
D-i-D (new members)						-0.022	-0.077	-0.065	0.065
						(0.074)	(0.064)	(0.065)	(0.066)
Dummy for euro (all countries)[a]	0.195***	0.212***							
	(0.022)	(0.020)							
Dummy for euro (founding members)[a]						0.283***			
						(0.022)			
Dummy for euro (new members)[a]						-0.034			
						(0.024)			
Dummy for post 1999 period[a]	0.318***								
	(0.034)								
country fixed effects	no	No	yes	yes	yes	no	yes	yes	yes
time effects	no	yes	yes	yes	yes	yes	yes	yes	yes
control variables	no	No	no	yes	yes	no	no	yes	yes
country specific trends	no	No	no	no	yes	no	no	no	yes
No. of observations	2,979	2,97Ó9	2,979	2,979	2,979	2,979	2,979	2,979	2,979
R^2	0.128	0.344	0.384	0.458	0.479	0.412	0.387	0.461	0.479

Note: [a] is a dummy for euro countries and for post treatment period are not included in specifications with country fixed effects and time effects, respectively. Standard errors clustered by countries in parentheses. ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Figure 1. Number of publications per year by selected regions.



Source: Own calculations.

Figure 2. Reported correlation coefficients for European countries (overlapping samples).

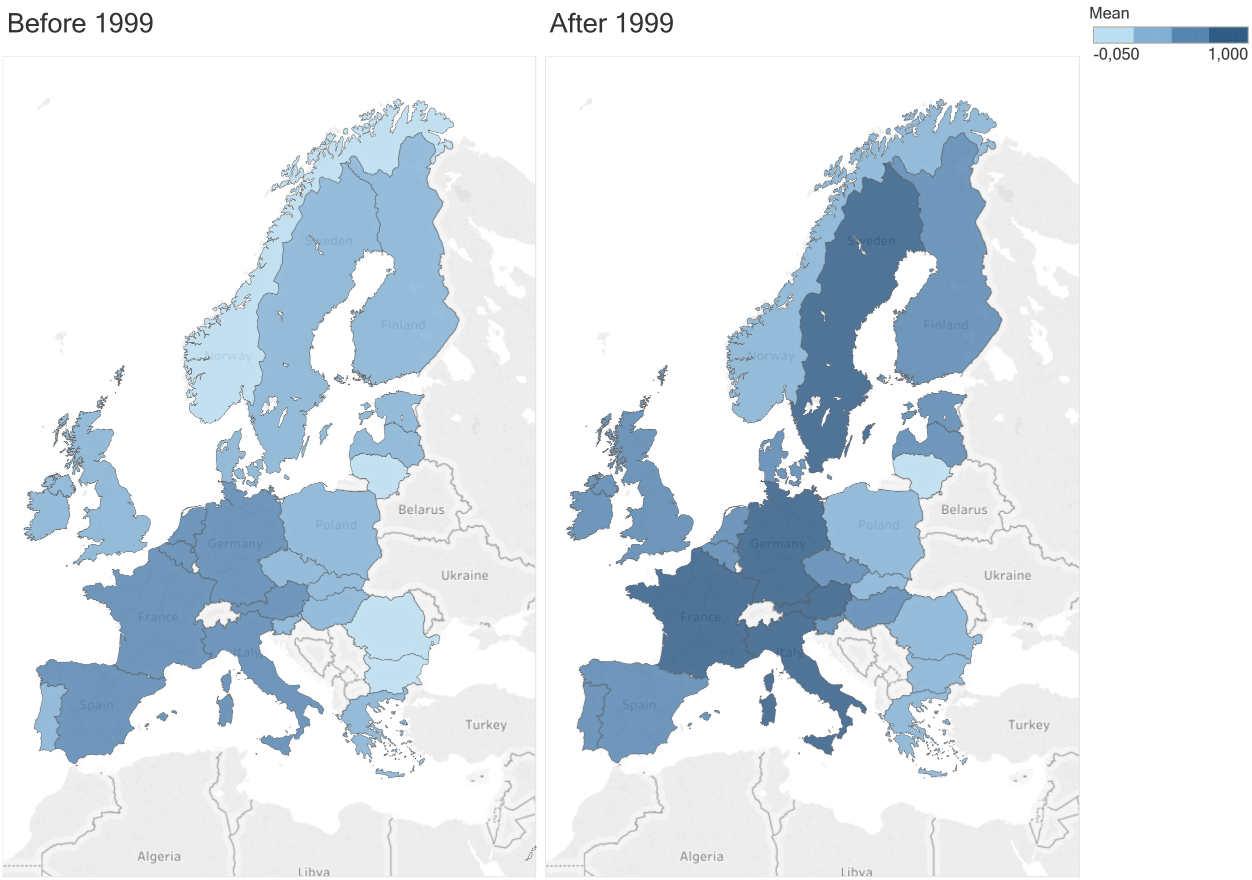


Figure 3a. Development of business cycle synchronisation estimates over time (selected regions).

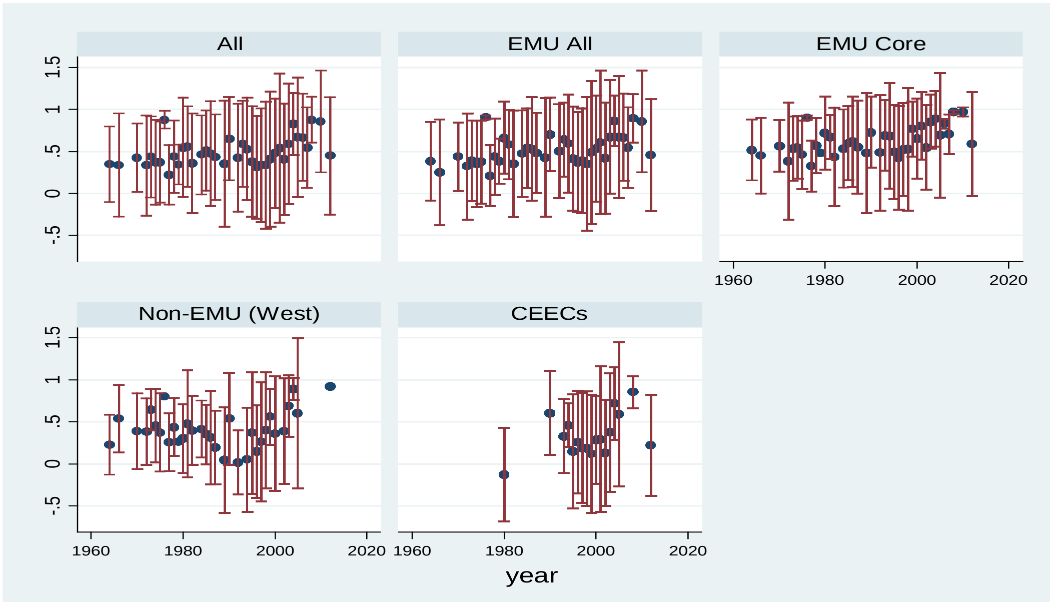


Figure 3b. Development of business cycle synchronisation estimates over time (by country).

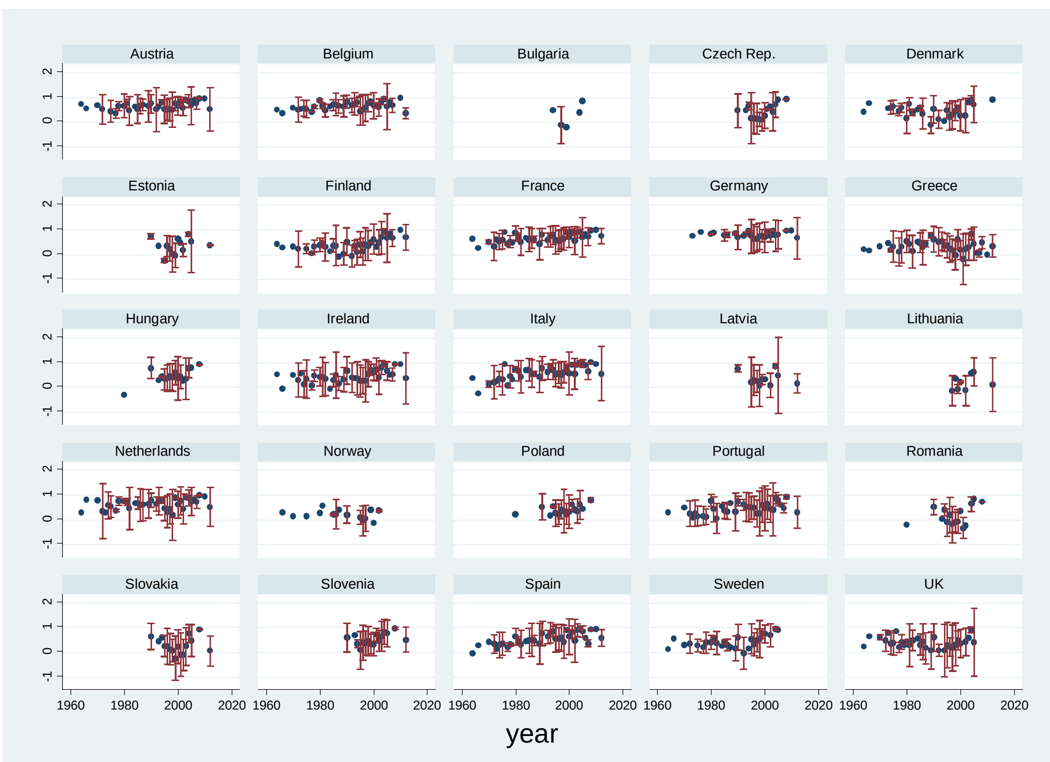
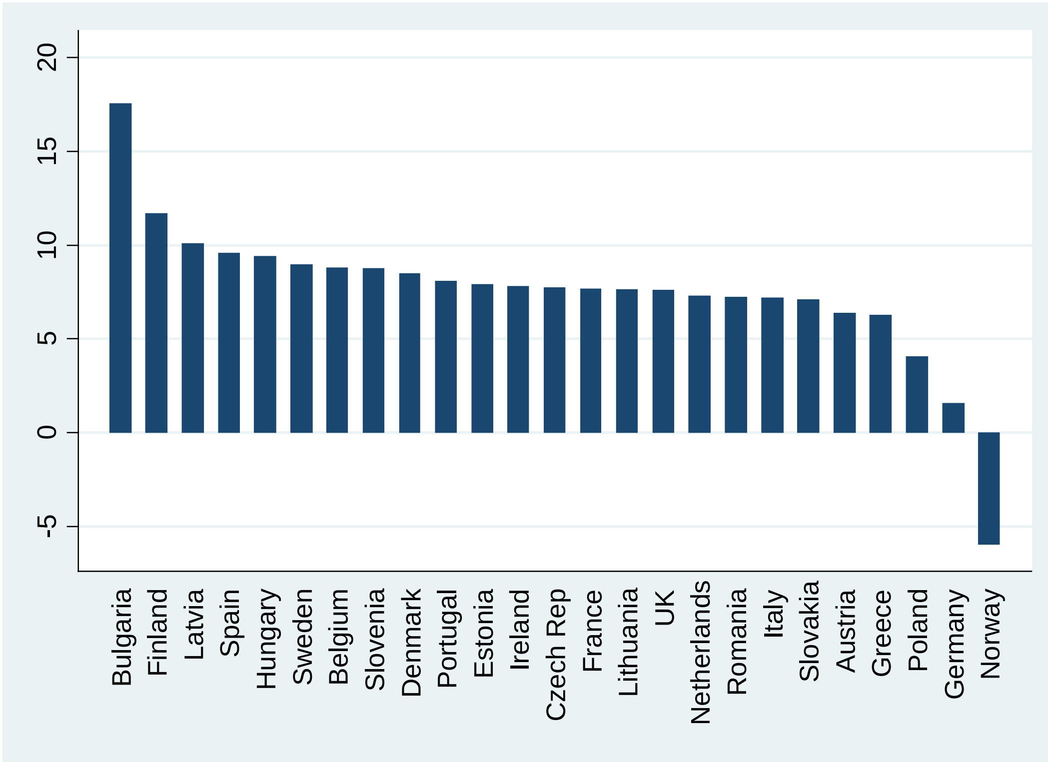


Figure 4. Country-specific publication bias.



Note: Country-specific coefficients for funnel asymmetry test estimated according to equation (1'). Standard errors are proxied by the inverse number of observations reported by studies. All coefficients are significant at 1% level.

Figure 5a. Adjusted country fixed effects and speed of convergence.

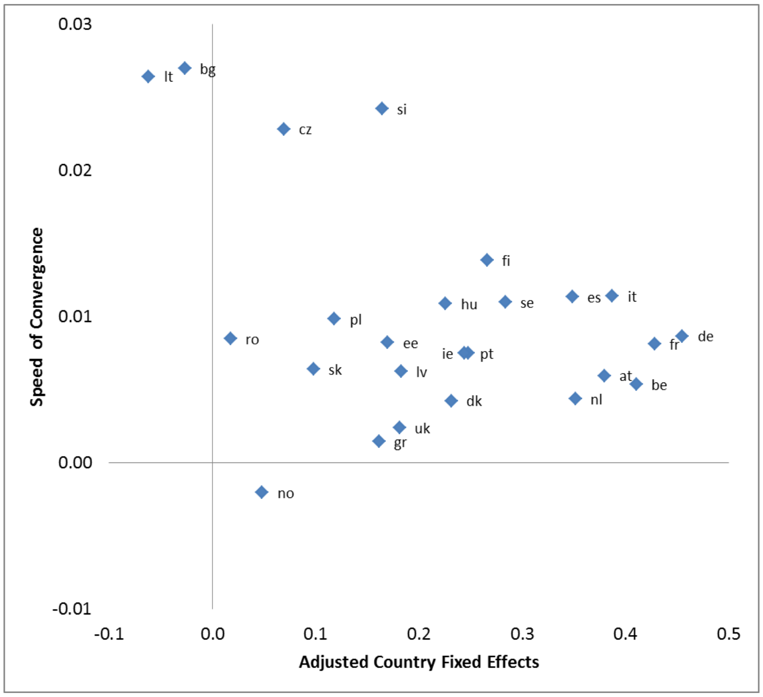
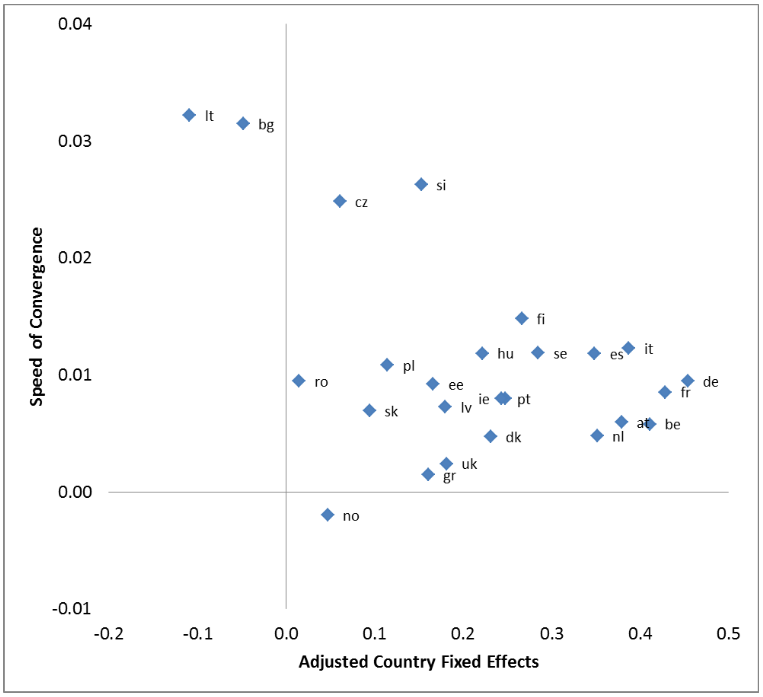


Figure 5b. Adjusted Country Fixed Effects and Speed of Convergence, Errors-in-Variable Regression



Appendix A. Empirical studies included in database (listed by publication year and alphabetically by author)

Authors	Title	Year
Bayoumi, T. and B.Eichengreen	Shocking aspecs of European Monetary Unification	1993
Fatas, Antonio	EMU: Countries or regions? Lessons from the EMS experience	1997
Boone, Laurence, and Mathilde Maurel	Economic convergence of the CEECs with the EU	1998
Angeloni, I., and L.Dedola	From the ERM to the euro: New evidence on economic and policy convergence among EU countries	1999
Artis, Michael, and Wenda Zhang	ERM: Is there a European business cycle?	1999
Buscher, Herbert S.	Business Cycles in EU Member States	1999
Caporale, Guglielmo Maria, Nikitas Pittis and Kyprianos Prodromidis	Is Europe and Optimum Currency Area?	1999
Cheung, Yin-Wong, and Frank Westermann	An Analysis of German Effects on the Austrian Business Cycle	1999
Dueker, Michael, and Katrin Assenmacher	European business cycles: New indices and analyses of their synchronicity	1999
Kontolemis, Zenon G., and Hossein Samiei	The U.K. Business Cycle, Monetary Policy, and EMU Entry	2000
Wynne, Mark A., and Jahyeong Koo	Business cycles in under monetary union: A comparison of the EU and US	2000
Agresti, Anna-Maria, and Benoît Mojo	Some stylised facts on the euro area business cycle	2001
Belo, Frederico	Some facts about the cyclical convergence in the euro zone	2001
Inklaar, Robert, and Jakob de Haan	Is there really a European business cycle?	2001
Lenain, Patrick, and Alan Serrais	Is the euro area converging or diverging?	2002
Valle e Azevedo, João	Business Cycles: Cyclical Comovement Within the European Union in the Period 1960-1999. A frequency domain approach	2002
Artis, Michael	Is there a European business cycle	2003
Boreiko, Dmitri	EMU and accession countries: Fuzzy cluster analysis of membership	2003
Duarte, Agustin, and Ken Holden	The business cycle in the G-7 countries	2003
Fidrmuc, Jarko, and Iikka Korhonen	Similarity of supply and demand shocks between the euro area and the CEECs	2003
Mahlberg, Bernhard, and Ralf Kronberger	Eastern Enlargement of the European Monetary Union: An Optimal Currency Area Theory View	2003
Süppel, Ralph	Comparing economic dynamics in the EU and CEE accession countries	2003
Verhoef, Bastiaan A.	The (A)symmetry of Shocks in the emu	2003
Demyanyk, Yuliya, and Vadym Volosovych	Asymmetry of Output Shocks in the European Union: The Difference Between Acceding and Current Members.	2004
Fidrmuc, Jarko	The Endogeneity of the Optimum Currency Area Criteria,	2004
Fidrmuc, Jarko, and Iikka Korhonen	The euro goes east: Implications of the 2000-2002 economic slowdown for synchronisation of business cycles between the euro area and the CEECs	2004
Moser, Gabriel, Wolfgang Pointer and Gerhard Reitschuler	Economic growth in Denmark, Sweden and the United Kingdom since the start of the monetary union	2004
Babetskii, Ian	Trade integration and synchronization of shocks	2005
Frenkel, Michael, and Christina Nickel	How Symmetric are the Shocks and the Shock Adjustment Dynamics between the Euro Area and Central and Eastern European Countries?	2005
Furceri, Davide, and Georgios Karras	Business Cycles: Cyclical Comovement Within the European Union in the Period 1960-1999. A frequency domain approach	2005
Gilson, Natacha	How to be well shod to absorb shocks? Shock synchronization and joining the euro zone	2006
Afonso, Antonio, and Davide Furceri	Business Cycle Synchronization and Insurance Mechanisms in the EU	2007
Hall, S.G., and G.Hondroyiannis	Measuring the correlation of shocks between the European Union and the accession countries	2007
Crowley, Patrick M.	One money, several cycles? Evaluation of European business cycles using model-based cluster analysis	2008
Sofia Gouveia, Leonida Correia	Business cycle synchronisation in the Euro area: the case of small countries	2008
Tesar, Linda L.	Production Sharing and Business Cycle Synchronization in the Accession Countries	2008

António Afonso, Davide Furceri	Sectoral Business Cycle Synchronization in the European Union	2009
Ferreira-Lopes, Alexandra, and Álvaro M. Pina	Business Cycles, Core, and Periphery in Monetary Unions: Comparing Europe and North America	2009
Periklis Gogas, Georgios Kothroulas	Two Speed Europe and Business Cycle Synchronization in the European Union: The Effect of the Common Currency	2009
Savva, Christos S., Kyriakos C. Neanidis and Denise R. Osborn	Business cycle synchronization of the euro area with the new and negotiating member countries	2009
Afonso, António, and Ana Sequeira	Revisiting business cycle synchronisation in the European Union	2010
Siedschlag, Iulia	Patterns and determinants of business cycle synchronization in the enlarged European Economic and Monetary Union	2010
Artis, Michael, George Chouliarakis, and P.K.G. Harischandra	Business cycle synchronization since 1880	2011
Weyerstrass, Klaus, Bas van Aarle, Marcus Kappler and Atilim Seymen	Business Cycle Synchronisation with(in) the Euro Area: in Search of a 'Euro Effect'	2011
Akın, Çiğdem	Multiple Determinants of Business Cycle Synchronization	2012
Mink, Mark, Jan P.A.M. Jacobs and Jakob de Haan	with an application to the euro area	2012
Bourdon	Revisiting the core-periphery view of EMU	2012
Djennas, Mustapha, Mohamed Benbouziane, Meriem Djennas	Business cycle synchronization in euro area and GCC countries: A wavelets-approach	2013
Gogas, Periklis	Business cycle synchronisation in the European Union - The Effect of the Common Curency	2013
Kolasa, Marcin	Business cycles in EU new member states: How and why are they different	2013
Marius-Corneliu, Marinaş	Business Cycles Synchronization with the Euro Area. The Case of CEE Countries	2013
Tatomir, Cristina-Flavia, and Oana Cristina Popovici	Business cycles synchronization in the European Union: truth or challenge?	2013
Filis, George, and Steve Letza	Business Cycles Synchronisation between the European Monetary Union and Poland	2014
He, Zhang	The Sustainability of European Monetary Union	2014
Iossifov, Plamen	Cross-Border Production Chains and Business Cycle Co-Movement between Central and Eastern European Countries and Euro Area Member States	2014
Konstantakopouloua, Ioanna and Efthymios G. Tsionasb	Half a century of empirical evidence of business cycles in OECD countries	2014
Bekiros, Stelios, Duc Khuong Nguyen, Gazi Salah Uddin and Bo Sjo	Business Cycle (De)Synchronization in the Aftermath of the Global Financial Crisis: Implications for the Euro Area	2015
Belke, Ansgar, Clemens Domnick and Daniel Gros	Business Cycle Synchronization in the EMU: Core vs. Periphery	2016
Campos, Nauro, and Corrado Macchiarelli	Core and Periphery in the European Monetary Union: Bayoumi-Eichengreen 25 Years Later	2016
De Grauwe, Paul, and Yuemei Ji	Flexibility versus Stability: A difficult tradeoff in the Eurozone	2016
Duran, Hasan Engin, and Alexandra Ferreira-Lopes	Determinants of co-movement and of lead and lag behavior of business cycles in the Eurozone	2016
Gouveia, Sofia Helena	Export specialisation and output synchronisation in the euro area: The case of southern countries	2016

Appendix B. Descriptive statistics

Table B.1. Whole sample

Variable	Observations	Mean	Std. dev.	Minimum	Maximum
Bc	2979	.4836367	.3442487	-.901	.996
Fbc	2979	.6710754	.5863312	-1.477508	3.106302
Ypub	2979	2006.789	5.401981	1993	2016
Year	2979	1993.986	9.303703	1964	2012
Phd	2979	.0067137		0	1
Journal	2979	.4800269	.4996848	0	1
Wp	2979	.5132595	.4999081	0	1
Single	2979	.0006714	.0259064	0	1
Uni	2979	.7502518	.4329399	0	1
Cbank	2979	.3541457	.4783339	0	1
refc_de	2979	.3836858	.4863645	0	1
refc_eu	2979	.4652568	.4988752	0	1
refc_euro	2979	.1510574	.3581649	0	1
Yfirst	2979	1985.602	13.35409	1950	2010
Ylast	2979	2001.903	8.433562	1971	2015
Monthly	2979	.1111111	.3143224	0	1
Quarterly	2979	.5142665	.4998803	0	1
Annual	2979	.3746224	.4841065	0	1
Noobs	2979	47.30279	48.19931	8	384
Correl	2979	.1893253	.3918326	0	1
Timeser	2979	.0832494	.2763052	0	1
Bandq	2979	2024169	.4018688	0	1
Hpfilter	2979	.5612622	.4963161	0	1
Gdp	2979	.530715	.4991395	0	1
Indprod	2979	.0926485	.289988	0	1
Demand	2979	.1047331	.3062607	0	1
Supply	2979	.1121182	.3155647	0	1
Inflation	2979	.0731789	.2604737	0	1
Otherind	2979	.224572	.4173702	0	1

Table B.2. Sample with data midpoint in or before 1998

Variable	Observations	Mean	Std. dev.	Minimum	Maximum
Bc	2011	.4270602	.3230926	-.901	.996
Fbc	2011	.5441462	.4799294	-1.477508	3.106302
Ypub	2011	2004.569	4.699374	1993	2016
Year	2011	1989.545	7.953553	1964	1998
Phd	2011	.0049727	.070359	0	1
Journal	2011	.5280955	.4993342	0	1
Wp	2011	.4669319	.4949029	0	1
Single	2011	.0004973	.0222994	0	1
Uni	2011	.6837394	.4651316	0	1
Cbank	2011	.4674291	.4990621	0	1
refc_de	2011	.4823471	.4998126	0	1
refc_eu	2011	.437096	.4961507	0	1
refc_euro	2011	.0805569	.2722212	0	1
Yfirst	2011	1979.931	12.45492	1950	1996
Ylast	2011	1998.595	8.09946	1971	2012
Monthly	2011	.11636	.3207359	0	1
Quarterly	2011	.5410244	.4984381	0	1
Annual	2011	.3426156	.4747022	0	1
Noobs	2011	.4747022	51.52079	8	384
Correl	2011	.215813	.4114875	0	1
Timeser	2011	.065639	.2477116	0	1
Bandq	2011	.2103431	.4076537	0	1
Hpfilter	2011	.5146693	.4999091	0	1
Gdp	2011	.4599702	.498519	0	1
Indprod	2011	.1228245	.3283173	0	1
Demand	2011	.1103928	.3134567	0	1
Supply	2011	.1213327	.3265947	0	1
Inflation	2011	.0954749	.2939428	0	1
Otherind	2011	.1929388	.3947036	0	1

Table B.3. Sample with data midpoint after 1998

Variable	Observations	Mean	Std. dev.	Minimum	Maximum
Bc	968	.601173	.3570578	-.69	.994
Fbc	968	.9347682	.690543	-.8479558	2.903071
Ypub	968	2011.4	3.526569	2002	2016
Year	968	2003.21	2.984695	1999	2012
Phd	968	.0103306	.1011654	0	1
Journal	968	.3801653	.4856782	0	1
Wp	968	.6095041	.4881137	0	1
Single	968	.0010331	.4856782	0	1
Uni	968	.8884298	.3149997	0	1
Cbank	968	.1188017	.3237222	0	1
	968				
refc_de	968	.178719	.3833149	0	1
refc_eu	968	.5237603	.4996933	0	1
refc_euro	968	.2975207	.4574038	0	1
Yfirst	968	1997.383	4.574649	1988	2010
Ylast	968	2008.776	3.555492	2001	2015
Monthly	968	.1002066	.3004305	0	1
Quarterly	968	.4586777	.4985471	0	1
Annual	968	.4411157	.4967772	0	1
Noobs	968	38.45971	39.00188	10	219
Correl	968	.1342975	.341148	0	1
Timeser	968	.1198347	.324936	0	1
Bandq	968	.1859504	.3892678	0	1
Hpfilter	968	.6580579	.4746055	0	1
Gdp	968	.677686	.4676041	0	1
Indprod	968	.0299587	.1705614	0	1
Demand	968	.0929752	.2905478	0	1
Supply	968	.0929752	.2905478	0	1
Inflation	968	.0268595	.1617563	0	1
Otherind	968	.2902893	.4541304	0	1

Table B.4. Sample with data ending during or before 1998

Variable	Observations	Mean	Std. dev.	Minimum	Maximum
Bc	742	.385779	.3250495	-.901	.99
Fbc	742	.4904333	.4889724	-1.477508	2.646653
Ypub	742	2002.248	5.483674	1993	2016
Year	742	1984.504	9.124087	1964	1997
Phd	742	.0134771	.1153837	0	1
Journal	742	.4420485	.4969653	0	1
Wp	742	.5444744	.498354	0	1
Single	742	.0013477	.0367112	0	1
Uni	742	.4770889	.4998117	0	1
Cbank	742	.5229111	.4998117	0	1
refc_de	742	.7318059	.443318	0	1
refc_eu	742	.1832884	.3871638	0	1
refc_euro	742	.0849057	.2789293	0	1
Yfirst	742	1978.137	12.72018	1950	1996
Ylast	742	1990.588	6.996414	1971	1998
Monthly	742	.2506739	.4336934	0	1
Quarterly	742	.4541779	.4982318	0	1
Annual	742	.2951482	.456417	0	1
Noobs	742	45.77089	43.7704	8	384
Correl	742	.3490566	.4769934	0	1
Timeser	742	.0148248	.1209328	0	1
Bandq	742	.2371968	.4256508	0	1
Hpfilter	742	.4191375	.4937508	0	1
Gdp	742	.2924528	.455196	0	1
Indprod	742	.2237197	.4170175	0	1
Demand	742	.1320755	.3388012	0	1
Supply	742	.1630728	.3696813	0	1
Inflation	742	.0889488	.2848618	0	1
Otherind	742	.0983827	.2980324	0	1

Table B.5. Sample with data ending after 1998

Variable	Observations	Mean	Std. dev.	Minimum	Maximum
Bc	501	.7543034	.2637298	-.388	.994
Fbc	501	1.255244	.6381066	-.4094434	2.903071
	501				
Ypub	501	2011.192	3.057321	2002	2016
Year	501	2004.99	2.754251	2000	2012
Phd	501	.0199601	.1400029	0	1
Journal	501	.2754491	.4471868	0	1
Wp	501	.7045908	.4566825	0	1
Single	501	0	0	0	0
Uni	501	.9281437	.2585079	0	1
Cbank	501	.0718563	.2585079	0	1
refc_de	501	.0958084	.2946225	0	1
refc_eu	501	.6866267	.4643283	0	1
refc_euro	501	.2175649	.4130022	0	1
Yfirst	501	2000.517	3.351748	1999	2010
Ylast	501	2009.327	2.765616	2001	2015
Monthly	501	.0159681	.1254771	0	1
Quarterly	501	.3692615	.4830872	0	1
Annual	501	.6147705	.4871359	0	1
Noobs	501	17.64271	10.96148	10	54
Correl	501	.0479042	.213777	0	1
Timeser	501	.0638723	.2447696	0	1
Bandq	501	.0638723	.2447696	0	1
Hpfilter	501	.8662675	.3407049	0	1
Gdp	501	.8982036	.3026826	0	1
Indprod	501	.0159681	.1254771	0	1
Demand	501	.0319361	.1760058	0	1
Supply	501	.0319361	.1760058	0	1
Inflation	501	0	0	0	0
Otherind	501	.4171657	.4935836	0	1

Appendix C

Figure C.1. Variance of business-cycle synchronisation estimates (sigma convergence by region)**.**

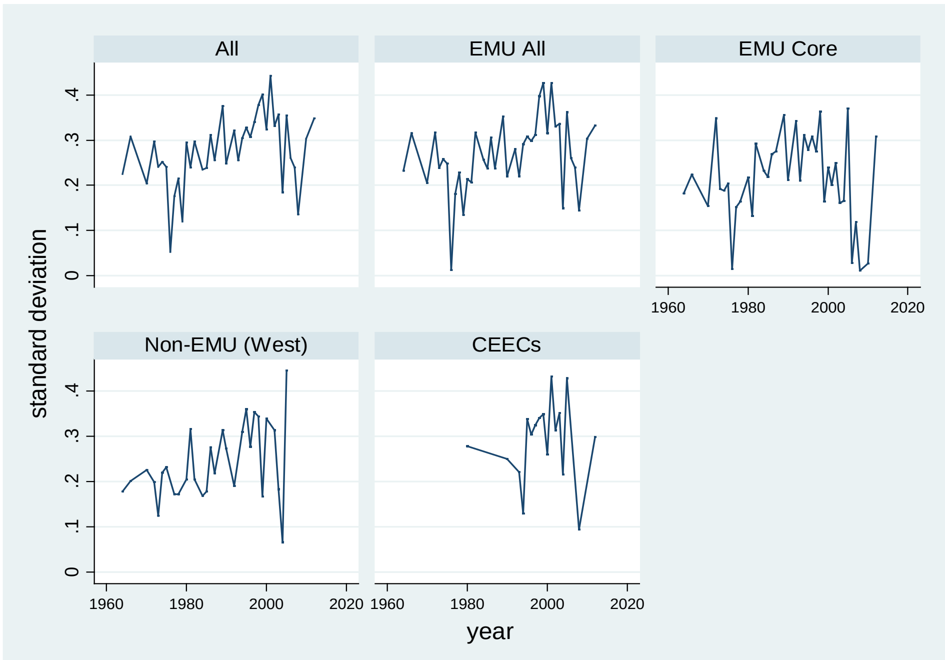


Figure C.2. Variance of business-cycle synchronisation estimates (sigma convergence by country).

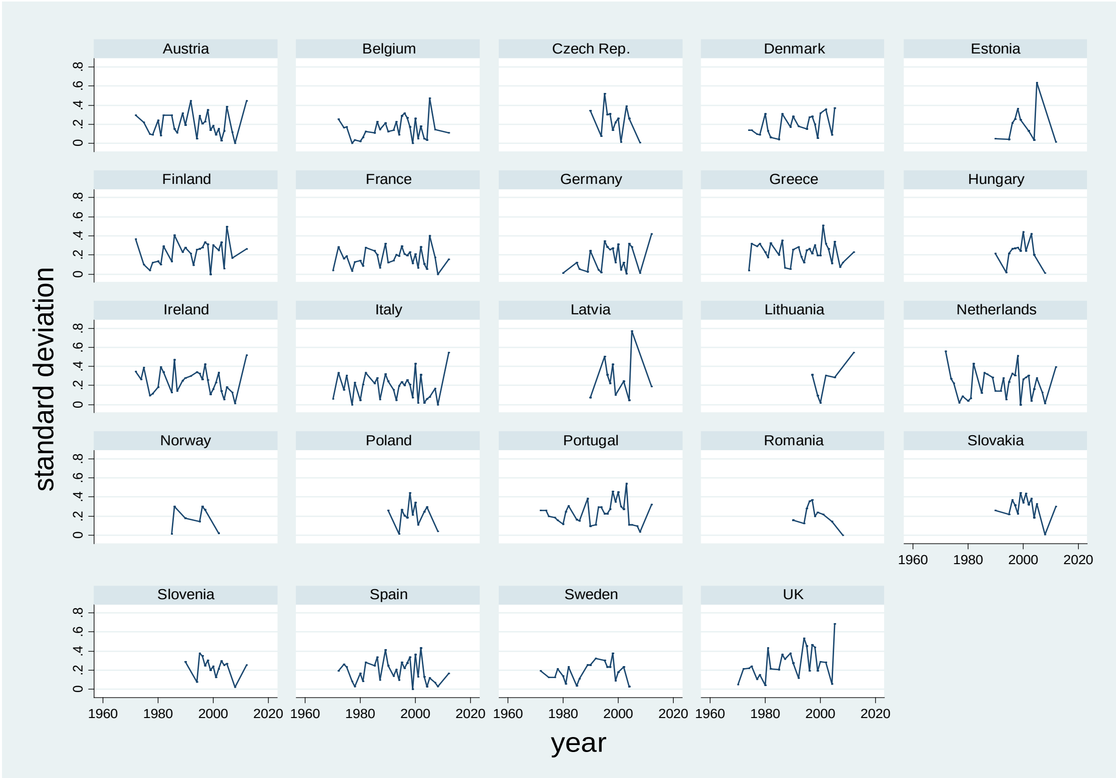


Figure C.3. Funnel plots by region (precision proxied by number of observations).

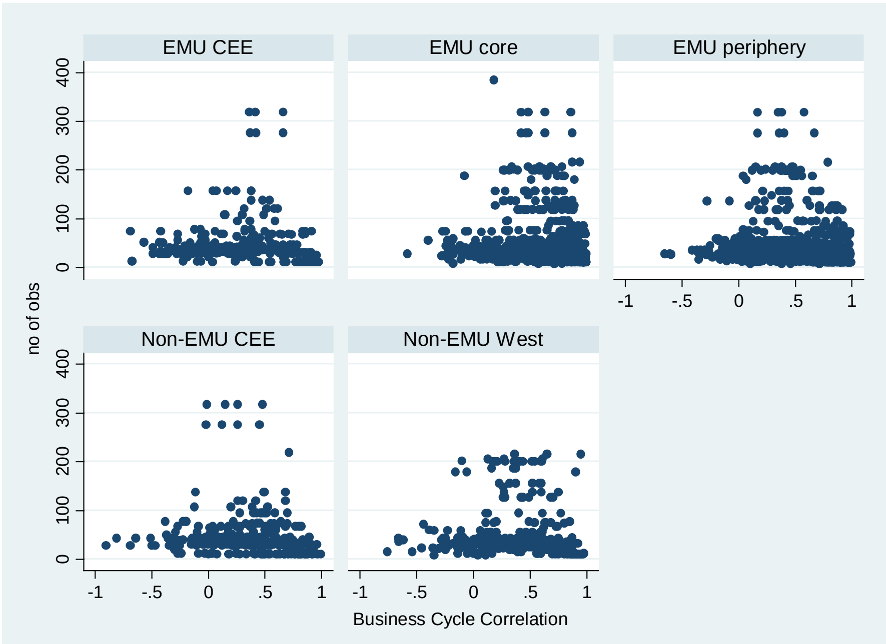


Figure C.4. Funnel plots by country (precision proxied by number of observations).

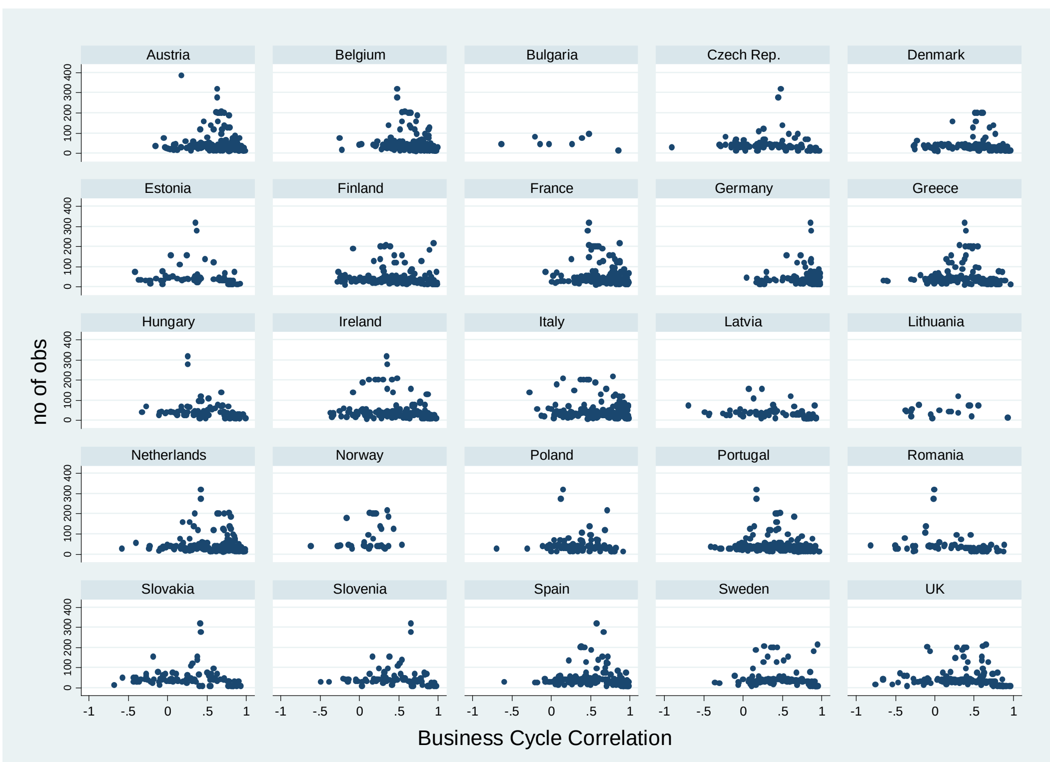


Figure C.5. Funnel plots by region (precision proxied by number of available years).

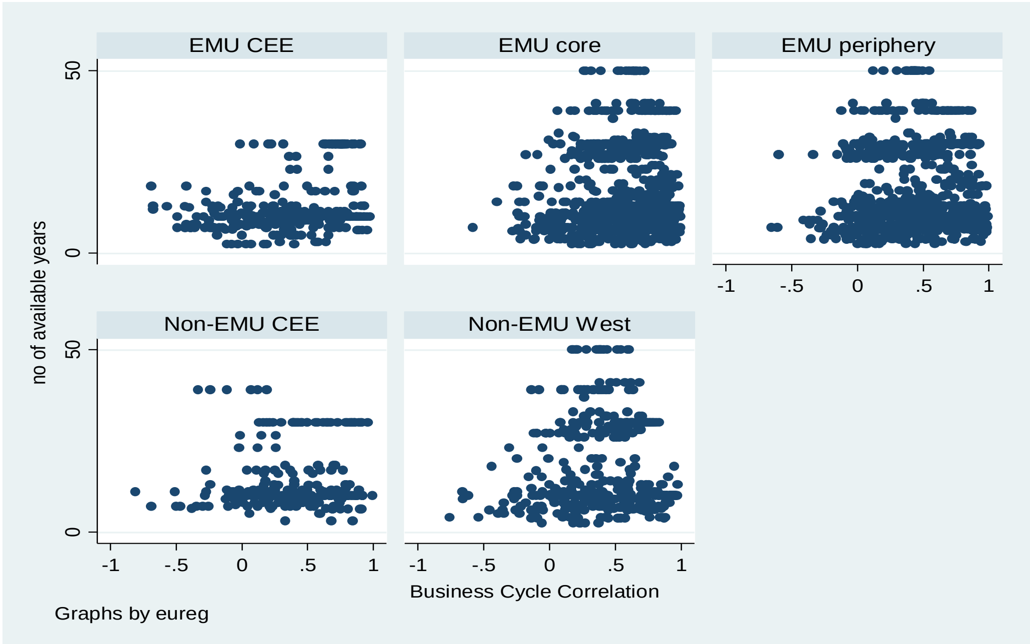


Figure C.6. Funnel plots by country, precision proxied by number of available years.

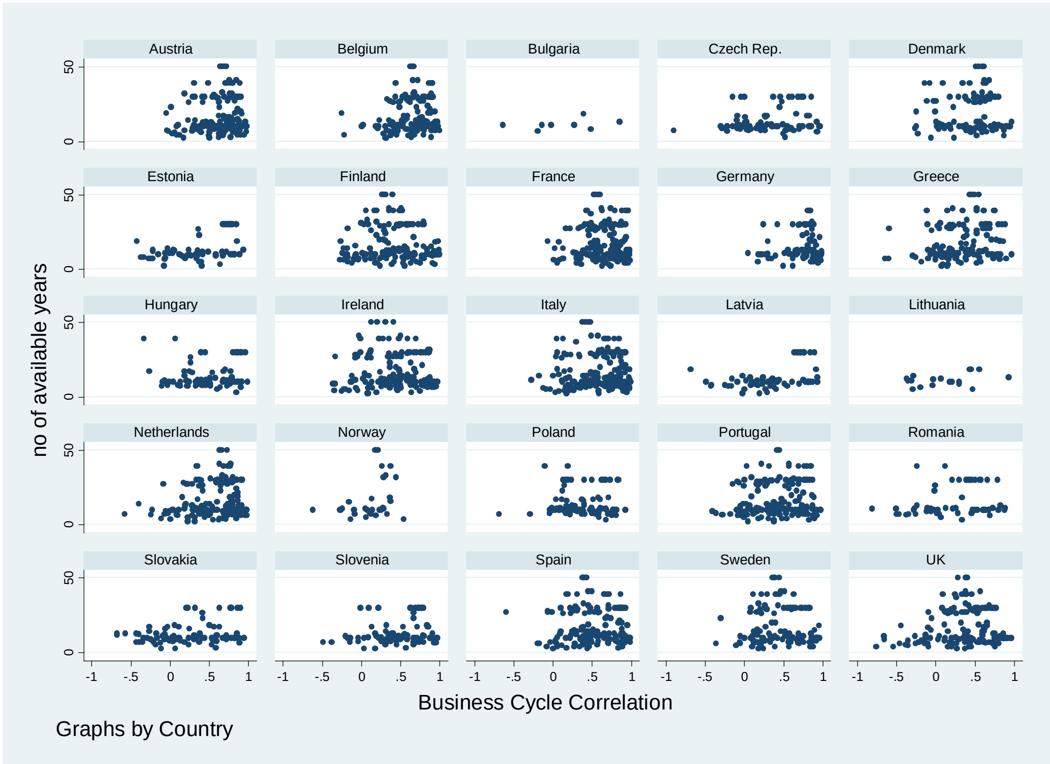
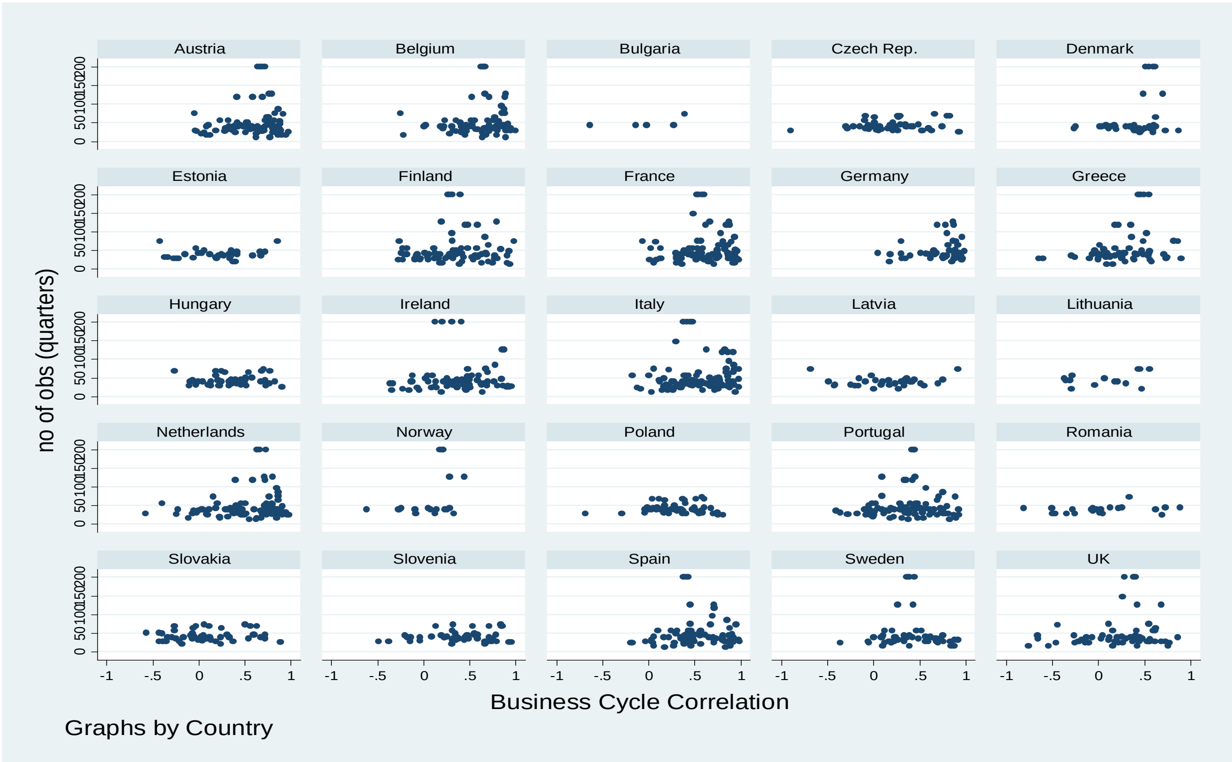


Figure C.7. Funnel plots by country, quarterly data (precision proxied by number of observations).



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