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A Closer Look at the World Business Cycle Synchronization

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A Closer Look at the World Business Cycle Synchronization[1]

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Abstract

This paper uses the period by period correlation index proposed by Cerqueira and Martins(2009) and two transformations that correct some shortcomings of this index to analyze how business cycle synchronization has changed since 1960. These indexes by distinguishing negative correlations due to episodes in single years, asynchronous behavior in turbulent times and synchronous behavior over stable periods will allow a more detailed analysis than if we used the linear correlation coefficient over time windows.

JEL code: C33, E32, F42

Keywords: Globalization, Business cycle synchronization, Convergence.

1 Introduction

The last decades globalization was characterized, among other aspects, by an increase in world trade[1] and financial integration[2]. However, despite the increase of these linkages across countries, the evolution of cross-country business cycle synchronization (hereafter, BCS) is an open issue, as neither of these channels have a clear effect on international business cycle synchronization.

Theoretically, increased world trade can work either way. It may increment synchronization due to the increase of demand and supply spillovers as described in a wide range of two countries models[3] or, as more trade spurs specialization, sectorial shocks might become dominant decreasing cross-country synchronization[4]. As for financial integration, it may increase synchronization due to wealth effects of external shocks or herd behavior of investors[5], but can, also, decrease it by fostering capital mobility between countries to exploit short term advantages or by increasing the possibilities of international risk sharing reducing income risk and fostering international specialization.

Empirical work on international BCS is generally in favor of direct positive effects of increased trade[6], but the results regarding the effects of financial integration are mixed: Imbs (2004, 2006) and Kose et al. (2003) point to increased synchronization due to higher financial integration, but Heathcote and Perri (2003, 2004), Cerqueira and Martins (2009) and Kalemli-Ozcan et al.(2010) find the opposite and Baxter and Koupiratsas (2004) show that this relationship is not robust. Finally, as the previous linkages might have indirect effects through industrial specialization, empirical work that measures the effects of specialization on cross-country synchronization does not provide a clear cut image: Cerqueira and Martins

[1] The world merchandise trade as percentage of GDP (taken from World Bank Indicators) was 21% in 1970, 32% in 1990, 41% in 2000 and 53% in 2008

[2] For an analysis of the trend evolution of financial openness see Lane and Millesi-Ferreti (2006).

[3] See, for instance, Baxter and Crucini (1995), Kollman (1996) or Ambler et al. (2002).

[4] See Baxter and Kouparitsas (2004).

[5] See Calvo and Mendoza (2000) or Mendoza (2001).who explain the herd behavior of investors and the sudden reversal of capital flows.

[6] See Frankel and Rose (1998), Imbs (2004, 2006), Cálderon et al. (2002) Baxter and Koupiratsas (2005) and Cerqueira and Martins(2009). An important exception is the work of Fidrmuc (2001) which does not find any relation between trade and BCS.

(2009) and Clark and van Wincoop (2001) find that the relationship is not significant and Baxter and Koupiratsas (2004) show that it is not robust to different model specifications. On the contrary, Imbs (2004 and 2006) finds a positive association between specialization and synchronization, but, also, finds that industrial specialization, contrary to expected, decreases when trade increases and that the effects of financial integration on specialization depend on the variable used to measure it. Overall, the literature on the determinants of BCS does not give a clear picture of the impact of globalization on synchronization.

Other branch of the literature studies directly the evolution of BCS by comparing its pattern over different periods, but the different studies made have, also, not provided a clear answer. A number of authors[7] found for the developed countries that the period from the nineties to the earlier years of the 21^{st} century showed a lower synchronization level than any previous period; Kose et al. (2008) show that between the developed countries and the emerging markets groups there was a decrease of worldwide synchronization but an increase within each group and Bordo and Helbling (2003) using a sample of sixteen developed countries found a secular trend towards increased synchronization.

Nevertheless, the methodologies used in most of these studies compute the synchronization estimates for specific time windows. This time aggregation might be problematic if there are outliers in specific years, as they will have a disproportionate impact on the correlation measure and may change the inter-period comparison. To overcome this problem, this paper uses a period-by-period index proposed by Cerqueira and Martins (2009) and two transformations that correct some shortcomings of the original index. These indexes will be used to study the evolution of cross-country BCS since 1960.

The paper structure is the following: the second section presents the period-by-period indexes, the third analyses the evolution of cross-country BCS not only at world level, but also by geographical and income groups and the final one presents the conclusions.

[7] See for instance, Bayoumi and Helbling (2003) who study the correlation coefficients between the United States and the other countries of the G7 group, Heathcote and Perri (2004) who document the correlations of output, consumption, and investment between the United States and an aggregate of Europe, Canada, and Japan or Stock and Watson (2005) who analyze the G-7 countries since 1960 using a structural factor VAR model.

2 The period by period correlation indexes

Cerqueira and Martins (2009) consider that a good period by period correlation index ($\rho_{ij,t}$) should have two characteristics: when averaged over the entire sample should be equal to the linear correlation index (ρ_{ij}) and be based on the Euclidean distance between the standardized variables of the two countries at any given date. So, considering that we have two series (d_i and d_j) measured over T periods being $\overline{d}_i$ and $\overline{d}_j$ their average, they suggest:

$$\rho_{ij,t} = 1 - \frac{1}{2}\left(\frac{\left(d_{i,t} - \overline{d}_i\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t} - \overline{d}_i\right)^2}} - \frac{\left(d_{j,t} - \overline{d}_j\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t} - \overline{d}_j\right)^2}} \right)^2 \tag{1}$$

The main advantages of this index over the correlation index are that it distinguishes negative correlations due to episodes in single years, but also asynchronous behavior in turbulent times and synchronous behavior over stable periods, thus capturing time variability. However, $\rho_{ij,t}$ has one main drawback: it is asymmetric.

Proposition 1 *$\rho_{ij,t}$ is bounded between 3-2T and 1*[8]

Therefore, the distribution of $\rho_{ij,t}$ is more disperse over negative values than over positive values, which may bias the results. One way to counteract this is to apply a sort of Fisher transformation adapted to $\rho_{ij,t}$, let's call this index $\rho^{nb}_{ij,t}$:

$$\rho^{nb}_{ij,t} = \frac{1}{2}\ln\left(\frac{1 + \frac{\rho_{ij,t}}{2T-3}}{1 - \rho_{ij,t}}\right) \tag{2}$$

Proposition 2 *$\rho^{nb}_{ij,t}$ is unbounded*

Proof. :

$$\lim_{\rho_{ij,t}\to 3-2T^-} \rho^{nb}_{ij,t} = \lim_{\rho_{ij,t}\to 3-2T^-} \frac{1}{2}\ln\left(\frac{1+\frac{\rho_{ij,t}}{2T-3}}{1-\rho_{ij,t}}\right) = -\infty$$

$$\lim_{\rho_{ij,t}\to 1^-} \rho^{nb}_{ij,t} = \lim_{\rho_{ij,t}\to 1^-} \frac{1}{2}\ln\left(\frac{1+\frac{\rho_{ij,t}}{2T-3}}{1-\rho_{ij,t}}\right) = +\infty \quad \blacksquare$$

[8] See proof in appendix A

This last index, although it is symmetric, when applied to periods with very high correlation creates large absolute differences in the measure even if the synchronization between two pairs of countries is not that different[9]. Therefore, even if we reduce the negative outliers, we may be introducing positive ones and, once again, bias the results.

A third measure, which is bounded between -1 and 1 ($\rho^{b}_{ij,t}$) is given by:

$$\rho^{b}_{ij,t} = \tanh(\rho^{nb}_{ij,t}) \tag{3}$$

The last transformation presented, the bounded index, is symmetric and does not create large absolute differences when synchronization is very high/low and so is less sensitive to possible outliers. Therefore, the empirical analysis will draw the conclusions, mainly, from the analysis of the bounded index , although it will also present the results from the other indexes as controls and robustness checks.

3 International synchronization evolution

This section analyses the evolution of the BCS across countries at worldwide level, but also, by geographical and income groups. The indexes were constructed from the growth rate of each country, using the Real Gross Domestic Income Adjusted for Terms of Trade Changes taken from the Penn World Tables from 1960 to 2007 for 111 countries[10]

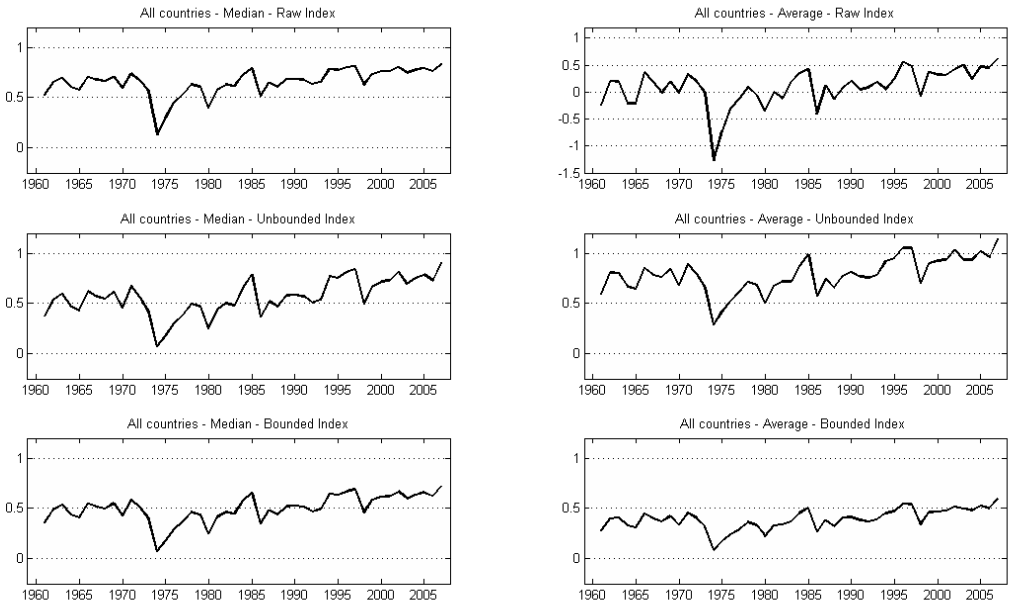
3.1 Worldwide analysis

The evolution of the median and average of the BCS indexes presented in the previous section are illustrated in figure (1). These plots show that, while the median evolution is similar across indexes, the plot of the raw index average is quite different from the remaining. This happens because, as stated before, the raw index ranges from -93 to 1, so negative outliers have a larger impact on its average.

[9] If we have $T = 47$, then if the raw index is 0.99, 0.98, 0.95, the unbounded version is respectively: 2.312, 1.96, 1.50. Therefore , in a regression the unbounded index will give disporportionate importance to periods with high correlation values.

[10] The country list and classification are in appendix B.

Figure 1: The evolution of Business Cycle Synchronization.



Nevertheless, all of these plots show a reduction of cross country BCS around 1974/76, 1980, 1986/89 and 1997. The first two periods are coincident with the first and second oil crises, commonly found as troughs in the business cycle literature; however, the remaining troughs in synchronization, which are much smaller, have no close association with identifiable business cycle recessions[11]. Finally, it seems that overall synchronization is slightly higher at the end of the sample than before. However the observed increase in the plot is quite small to say anything definite, so to test the accuracy of this claim we perform a fixed effects[12] panel estimation of the BCS indexes against a linear trend and its square[13]:

$$sinc_{ij,t} = \alpha_{ij} + \beta_1 time_t + \beta_2 time_t^2 + u_{ij,t} \tag{4}$$

[11] At this point, it should be noted that Helbling and Bayoumi (2003) found a business cycle trough at 1986/89, while other papers estimated a world business cycle stagnation at these years.

[12] Following Baltagi (2005), pp. 12-14 : "The fixed effects model is an appropriate specification if we are focusing on specific set of N firms" as "... the random effects ... if we are drawing N individuals randomly from a large population". In this study, clearly we are not randomly drawing the observations, so the study should be understood as focusing in the synchronization of the observed 111 countries.

[13] The trend variable takes the value 1 in 1961 and 47 in 2007.

As explained in the previous section, the estimations using the raw index or the unbounded index might be biased because the two indexes have distribution frequencies with very long tails, respectively, to the left (negative synchronization) or to the right (positive synchronization). This can be seen in table 1, where the raw index has a sample average of 0.88, an observed maximum close to one, while the minimum is -33.743. The unbounded index has a sample average of 0.785, an observed minimum of -2, while the maximum is 11.762. Finally the bounded index ranges from - 0.964 to 1 with an average of 0.391. This symmetry around zero of the bounded index makes it less susceptible to outliers, so we will focus on the estimations which use this index, keeping the remaining ones for comparison.

Table 1: Summary Statistics of the correlation indexes

	Raw Index	Unbounded Index	Bounded Index
Average	0.88	0.785	0.391
Standard dev.	1,6293	1,1635	0,52598
Maximum	1[14]	11.762	1
Minimum	-33.743	-2.000	-0,964
Skewness	-4.4276	1.3338	-0.6023
Excess Kurtosis	31,986	3,3069	-0,82748

Table 2 shows the estimated values of equation (4). These estimates[15] predict that the indexes have a downward trend from the sixties until 1974/75, when they reach a minimum, and an increasing trend afterwards. These results also show that the synchronization level in the 21^{st} century is higher than in the sixties. This leads to the conclusion that the world has become more synchronous during the globalization era . Nevertheless, we should take into account that not all the synchronization increase in the latter years is due to the globalization, as part of it is the backlash from the synchronization decrease found in the seventies and early eighties.

However, the question of whether this is a worldwide pattern or just the reflex of some country groups remains open. The next section will address this issue, analyzing the evolution of BCS for different sets of countries, grouped either by geographical location or by

[15] With $trend^3$ the results were qualitatively equal, and from the $trend^4$ onwards some of the variables lose signficance.

Table 2: Synchronization Evolution - Panel Results; 1961-2007

Dep. Variable	Raw Index	Unbounded Index	Bounded Index
	Fixed Eff.	Fixed Eff.	Fixed Eff.
time	-0.0196^{***}	-0.0114^{***}	-0.0067^{***}
	(0.001)	(0.001)	(0.000)
$time^2$	0.00065^{***}	0.00039^{***}	0.00023^{***}
	(0.000)	(0.000)	(0.000)
Minimum^{+}	1975	1974.5	1974.7
$^{+}$As the trend takes the value 1 in 1961, the minimum is reached at $1960+\left(-\frac{\widehat{\beta}_1}{2\widehat{\beta}_2}\right)$			
N=6105;T=47			
Between brackets Arellano robust standard errors.			
*,**,*** - Significant at 10%, 5% and 1%, respectively			

development level.

3.2 Inter and Intra Group analysis

This section analyses the evolution of business cycle synchronization for different country groups, either divided by geographic location or by income level.

3.2.1 Geographical groups

The countries were divided into six groups, using the geographical division of the World Bank: East Asia and Pacific (EAP), Europe and Central Asia (ECA), Latin America and Caribbean (LAC), Middle East and North Africa (MENA), South Asia (SA), Sub-Saharan Africa (SSAf) and North America (NA)[16]. The following equation was estimated using fixed effects:.

$$sinc_{ij,t} = \alpha_{ij} + \beta_1 time_t + \beta_2 time_t^2 + \sum_k \left(\beta_{1k}.\left(d_k.time_t\right) + \beta_{2k}.\left(d_k.time_t^2\right)\right) + u_{ij,t}$$

where d_k is a dummy variable which takes the value 1

if both countries belong to group k and 0 otherwise

$$k = EAP, ECA; LAC, MENA, SSAf, SA, NA \tag{5}$$

Table 3 reports the results using the three synchronization indexes, as well as restricted

[16] See the groups composition in appendix B.

models and the respective joint tests significance of the omitted variables using the model with the bounded index. This last index (regressions 3, 3.1 and 3.2) is the one we will focus because as said before it is less sensible to outliers. Regression 3 shows that most geographical regions have different synchronization patterns when compared with the base (in this case the base case is the synchronization between countries of different groups), being apparent exceptions the ECA and MENA group.

The restricted model 3.1 and respective Wald test on the restrictions show that we cannot omit all the variables for which the coefficients are not individually significant . However, if we keep the time squared variable associated with the MENA group[17], the joint test on the restrictions (regression 3.2) does not reject the null, and so, only the synchronicity pattern of the ECA group is similar to the one of the base case.

Figure (2) shows the adjusted group averages using regression 3.2. It reveals that the synchronization pattern of the base case (which depicts synchronization between countries of different regions) is similar to the one found in the previous section for the world as whole, this is, a U shape, with a synchronization trough around 1975 reaching higher synchronism in the sample end than in the beginning.

As for the regions, four have a U shape pattern (NA, LAC, SSAf, MENA) like the base case, being the differences on the trough date, the curvature of the U shape and the recover strength. As for the trough date, it happened earlier for the MENA region and latter for the LAC, SSAf and NA (in this case much later - around 1986). In terms of curvature the MENAs and SSAfs are almost inexistent, but that of the MENA region seems to have a first phase of no changes until 1975 and a large increase afterwards, while the SSAf synchronicity hardly changes through all sample. Finally, the synchronicity increase from mid-eighties onward is different, as LAC and MENA regions reach higher values of synchronicity in the end of the sample than in the beginning; SSAf, as said, hardly moves, and NA does not recover to the levels reached in the sixties.

Two other regions have a different pattern when compared with the base case: SA and

[17] It should be noted that all the other joint tests that ommited all but one of the non-individual significant variables rejected the null at least at 10% signifcance level.

Table 3: Synchronization Evolution by Geographic Region- Panel Results 1960-2007

Dep. Variable	Raw	Unbounded	Bounded		
Model/Test	(1)	(2)	(3)	(3.1)	(3.2)
time	-0,0195***	-0,012***	-0,007***	-0,007***	-0,007***
	(0,001)	(0,001)	(0,000)	(0,000)	(0,000)
time^2	0,00067***	0,00041***	0.00023***	0.00023***	0.00023***
	(0,000)	(0,000)	(0.000)	(0.000)	(0.000)
EAP*time	0,0634***	0,042***	0.022***	0.022***	0.022***
	(0,009)	(0,005)	(0.003)	(0.003)	(0.003)
EAP*time^2	-0,0012***	-0,00087***	-0.00046***	-0.00046***	-0.00046***
	(0,000)	(0,000)	(0.000)	(0.000)	(0.000)
ECA*time	0,007*	0,008**	0.002	—	—
	(0,004)	(0,004)	(0.002)		
ECA*time^2	-0,00016**	-0,00013*	-0.00002	—	—
	(0,000)	(0,00008)	(0.00003)		
LAC*time	-0,029***	0,020***	-0.011***	-0.011***	-0.011***
	(0,005)	(0,004)	(0.002)	(0.002)	(0.002)
LAC*time^2	-0,0005***	0,00034***	0.00019***	0.00019***	0.00019***
	(0,000)	(0,000)	(0.000)	(0.000)	(0.000)
MENA*time	-0,0383	-0,007	0.004	—	0.006***
	(0,033)	(0,013)	(0.007)		(0.0009)
MENA*time^2	-0,00046	0,00038	0.00004	—	—
	(0,00062)	(0,00028)	(0.00014)		
SSAf*time	-0,00067	0,002	0.001	—	—
	(0,00339)	(0,002)	(0.001)		
SSAf*time^2	-0,00017**	-0,00015***	-0.00008***	-0.00005***	-0.00005***
	(0,000)	(0,000)	(0.00002)	(0.00002)	(0.00006)
SA*time	0,050***	0,030***	0.013**	0.006***	0.006***
	(0,017)	(0,000)	(0.0054)	(0.017)	(0.017)
SA*time^2	-0,0007**	-0,00044***	-0.00015	—	—
	(0,00029)	(0,000)	(0.00012)		
NA*time	-0,017***	-0,130***	-0.030***	-0.030	-0.030***
	(0,001)	(0,001)	(0.00040)	(0.023)	(0.00040)
NA*time^2	0,0006**	0,00213***	0.00043***	0.00043	0.00043***
	(0,0012)	(0,000)	(0.000)	(0.0004)	(0.000)
Wald Test	—	—	—	46,68	5,40
$[p-value]$				[0.000]	[0,369]
N=6105;T=47					
Test columns - Joint significance test of the variables coefficients marked with 0.					
Between curved brackets Arellano robust standard errors.					
Between squared brackets p.-value of Wald Test					
*,**,*** - Significant at 10%, 5% and 1%, respectively					

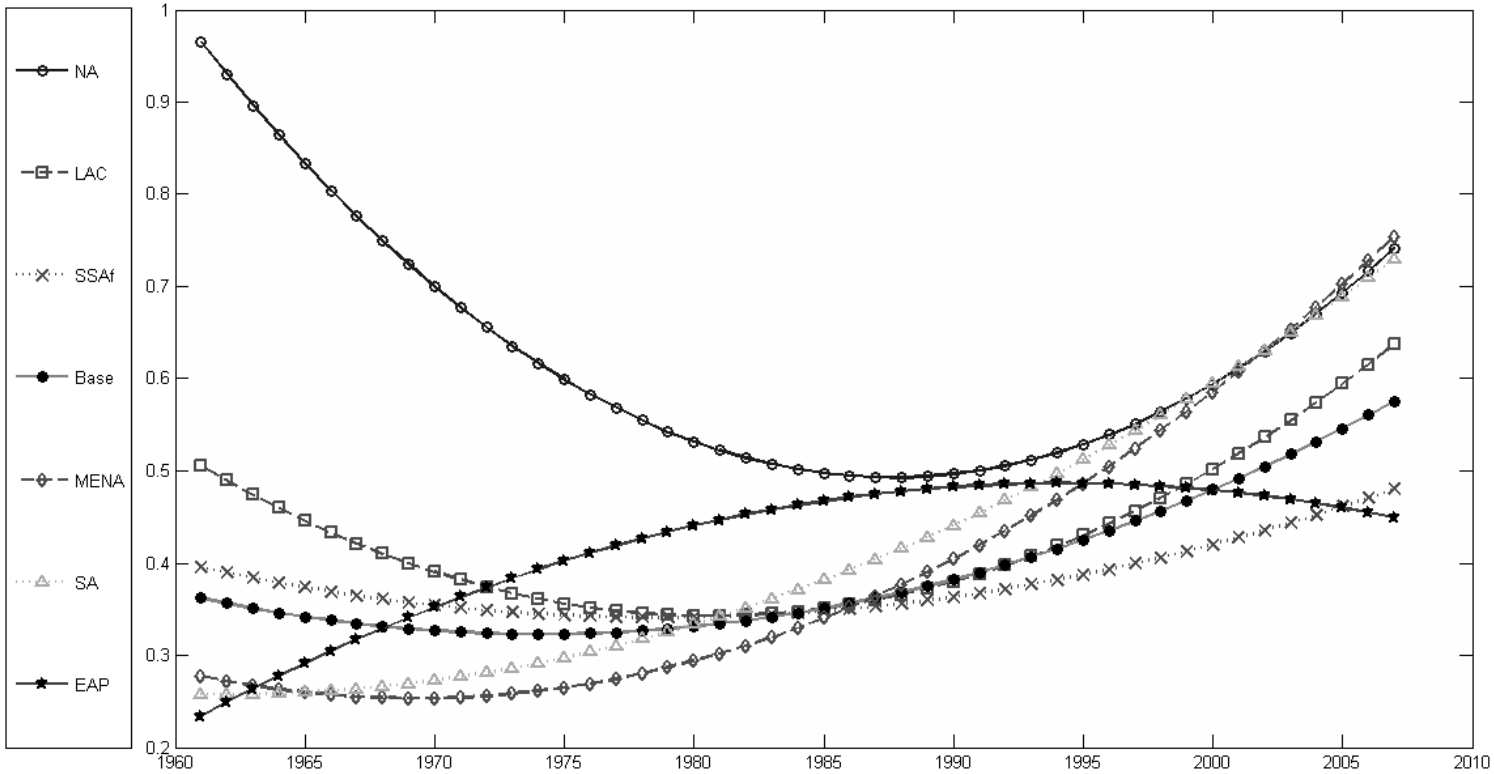


Figure 2: The evolution of Business Cycle Synchronization by geograpical groups

EAP. Both start with very low values of intra-group synchronicity, but while SA has a continuous increase over the whole period, reaching high values in the sample end, EAP synchronicity increases rapidly from 1960 until 1990 and afterwards it stagnates or even decreases.

3.2.2 Income level groups

The countries were divided into four groups, using the income level classification of the World Bank: Low-Income (LIC), Lower-Middle Income (LMIC), Upper-Middle Income (UMIC) and High Income (HIC).[18] First it was analyzed the intra-group evolution to check if synchronization within groups is different. Afterwards the same analysis was made for the synchronization between the high income and developing countries.

Intra-group analysis For the intra-group analysis we estimated the following equation:

$$sinc_{ij,t} = \alpha_{ij} + \beta_1 time_t + \beta_2 time_t^2 + \sum_k \left(\beta_{1k}.\left(d_k.time_t\right) + \beta_{2k}.\left(d_k.time_t^2\right)\right) + u_{ij,t}$$

where d_k is a dummy variable which takes the value1

if both countries belong to group k and 0 otherwise

$$k = LIC, LMIC, UMIC, HIC \tag{6}$$

Table (4) shows that LIC and UMIC may be equal to the base case. From the restricted models 3.1 to 3.4 we realize that we cannot omit simultaneously the two variables associated to the UMIC group, as the Wald test always reject that hypothesis. Therefore, it can be said that only the LIC group is not different from the base case.

Figure (3) depicts the estimated value for each group using regression 3.4. It shows that the LMIC and the UMIC groups have a similar synchronization pattern to the one of the base case. The difference between these groups is the fact that the UMIC group synchronization starts higher than the base case and ends,roughly, at the same level, while the LMIC synchronization is in the sixties similar to the base case but in the sample end this

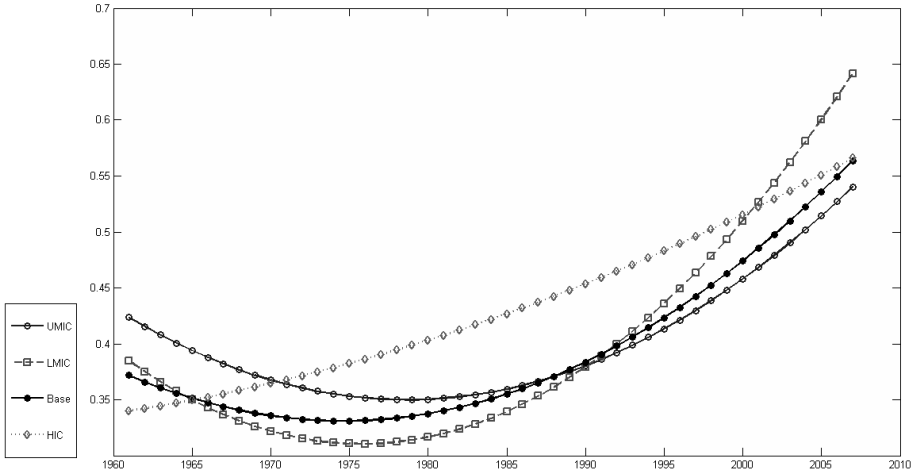
[18] Groups composition in appendix B.

Table 4: Evolution of BCS by Income Level - Intra Group - Panel Results 1960-2007

Dep. Variable	Raw	Unbounded	Bounded				
Model/Test	(1)	(2)	(3)	(3.1)	(3.2)	(3.3)	(3.4)
time	-0,021***	-0,012***	-0,0072***	-0,0072***	-0,0072***	-0,0072***	-0,0072***
	(0,0012)	(0,001)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
$time^2$	0,0006***	0,0004***	0,0002***	0,0002***	0,0002***	0,0002***	0,0002***
	(0,0012)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
LIC*time	-0,0024	-0,0004	-0,0012	–	–	-0,0012	–
	(0,004)	(0,0025)	(0,0011)			(0,0011)	
LIC*$time^2$	0,00006	0,00002	0,00001	–	–	0,00001	–
	(0,0007)	(0,0005)	(0,00002)			(0,00002)	
LMIC*time	-0,001	-0,009**	-0,004**	-0,003***	-0,004***	-0,004***	-0,004***
	(0,005)	(0,004)	(0,002)	(0,001)	(0,001)	(0,001)	(0,001)
LMIC*$time^2$	0,0001	0,0002***	0,0001***	0,0001***	0,0001***	0,0001***	0,0001***
	(0,0001)	(0,0007)	(0,00003)	(0,00003)	(0,00003)	(0,00003)	(0,000)
UMIC*time	-0,002	-0,001	-0,001	–	-0,001	–	-0,0017***
	(0,005)	(0,003)	(0,002)		(0,001)		(0,0003)
UMIC*$time^2$	-0,00009	-0,00004	-0,00002	–	-0,00002	–	—
	(0,0001)	(0,00007)	(0,00003)		(0,00003)		
HIC*time	0,024***	0,019***	0,009***	0,009***	0,009***	0,009***	0,009***
	(0,003)	(0,003)	(0,001)	(0,001)	(0,001)	(0,001)	(0,001)
HIC*$time^2$	-0,0004***	-0,0004***	-0,0002***	-0,0002***	-0,0002***	-0,0002***	-0,0002***
	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
Wald Test	—	—	—	22.35	4.43	19.2	4.95
$[p-value]$				[0.0001]	[0.105]	[0.0001]	[0.175]
N=6105;T=47							
Test columns - Joint significance test of the variables coefficients marked with 0							
Between curved brackets Arellano robust standard errors.;							
Between squared brackets p.-value of Wald Test							
*,**,*** - Significant at 10%, 5% and 1%, respectively							

group is the most synchronous of all. Finally, the HIC group shows a continuous increase in synchronization through all the sample, not showing any synchronization decrease due to the first or second oil crisis.

Figure 3: Evolution of Business Cycle Synchronization by income level (Intra-group)



Inter-group analysis This section studies the BCS evolution between developing countries, grouped as before, and the high income countries. The estimated equation is:

$$sinc_{ij,t} = \alpha_{ij} + \beta_1 time_t + \beta_2 time_t^2 + \sum_k \left(\beta_{1k}.\left(d_{HIC,k}.time_t\right) + \beta_{2k}.\left(d_{HIC,k}.time_t^2\right)\right) + u_{ij,t}$$

where $d_{HIC,k}$ is a dummy variable which takes the value 1 if one country belongs to the HIC group and the other to group k and 0 otherwise.

$$k = LIC, LMIC, UMIC \tag{7}$$

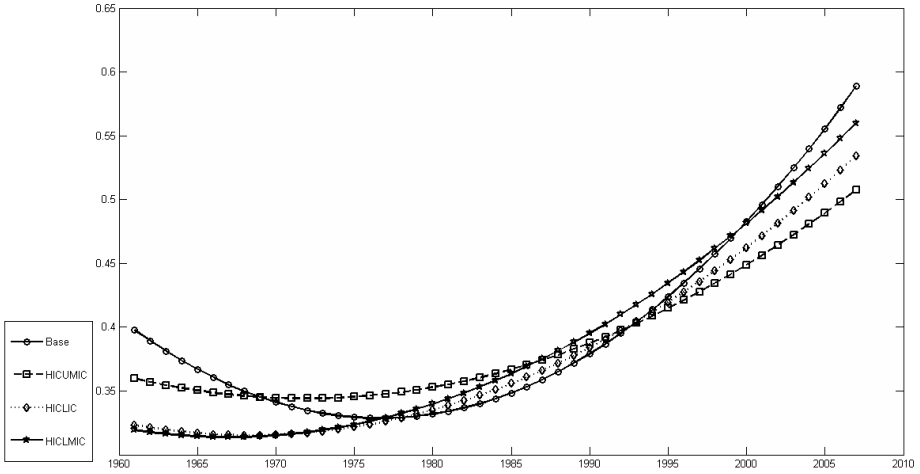
Table 5 shows that the synchronization pattern between any group of developing countries with the high income countries is always significantly different from the one of the remaining world. Also, the synchronization evolution between the HIC and LIC countries is not significantly different from the one between HIC and LMIC countries[19]. This means

[19] The joint test $\beta_{1,LIC} = \beta_{1,LIMC}$ and $\beta_{2,LIC} = \beta_{2,LIMC}$ does not reject the null for the unbounded and

Table 5: Evolution of BCS by Income Level - Inter Group - Panel Results 1960-2007

Dep. Variable	Raw	Unbounded	Bounded
Model/Test	(1)	(2)	(3)
time	-0,0256***	-0,0164***	-0,0094***
	(0,0014)	(0,0009)	(0,0004)
time^2	0,0008***	0,0005***	0,0003***
	(0,0000)	(0,0000)	(0,0000)
HIC,LIC*time	0,0173***	0,0130***	0,0067***
	(0,0028)	(0,0019)	(0,0009)
HIC,LIC*time^2	-0,0003***	-0,0003***	-0,0001***
	(0,0000)	(0,0000)	(0,0000)
HIC,LMIC*time	0,0144***	0,0133***	0,0072***
	(0,0034)	(0,0023)	(0,0011)
HIC,LMIC*time^2	-0,0002***	-0,0002***	-0,0001***
	(0,0000)	(0,0000)	(0,0000)
HIC,UMIC*time	0,0129***	0,0113***	0,0060***
	(0,0032)	(0,0022)	(0,0011)
HIC,UMIC*time^2	-0,0003***	-0,0003***	-0,0001***
	(0,0000)	(0,0000)	(0,0000)
N=6216; T=47			

Figure 4: Business cycle synchronization evolution by income groups.(Inter-group)



that among the developing countries in terms of synchronization with the HIC countries we can split the countries into two groups: the UMIC and the LMIC/LIC group.

Anyway the evolution pattern, as figure (4) shows, is similar to any cross-group considered. Synchronization was stable until mid-seventies and increases afterwards, showing that the developing world was getting more synchronous with the developed world even before the nineties.

4 Conclusion

This paper using period by period synchronization indexes shows that worldwide BCS decreased until the mid-seventies and increased afterwards. Furthermore, the increase in later years was so strong that the levels reached in the early years of the 21st century were higher than the ones observed in the sixties.

This worldwide behavior is replicated for most of the inter and intra group analysis, showing that in most cases the only change observed was the strength of the synchronization increase in the last three decades and the dating of the trough. However there are two exceptions: first, the high income countries group shows an increasing synchronization level since the sixties without suffering any effect from the oil crisis in the seventies and early eighties. Other exception is the East Asia and Pacific group that had a continuos increasing synchronization until the eighties, but from then onward it has stabilized or even decreased.

On conclusion, it can be said that since the seventies the business cycle synchronization at world level has increased continuously. This increase cannot be explained only by the recover from the trough, so, we suspect that the globalization process is a relevant factor of this rise.

bounded index at 5% level of significance.

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APPENDIX

A Proof of Proposition 1

Proposition 1 *$\rho_{ij,t}$ is bounded between 3-2T and 1.*

Proof. *$Max(\rho_{ij,t}) = 1$*

As the second component in equation (1) is always non-negative, when it is zero we get $\rho_{ij,t} = 1$.

$Min(\rho_{ij,t}) = 3 - 2T$

To find the extreme values of a specific value of $\rho_{ij,t}$ (let's say the 1^{st}), we analyze the function:

$$f_1(d_{i,t}, d_{j,t}) = \left(\frac{\left(d_{i,1} - \overline{d}_i\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t} - \overline{d}_i\right)^2}} - \frac{\left(d_{j,1} - \overline{d}_j\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t} - \overline{d}_j\right)^2}} \right)^2$$

From the derivatives to obtain the stationary points we get:

$$\overbrace{2\left(\frac{\left(d_{i,t} - \overline{d}_i\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t} - \overline{d}_i\right)^2}} - \frac{\left(d_{j,1} - \overline{d}_j\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t} - \overline{d}_j\right)^2}} \right) \frac{C_1(T)}{D_1 i(d_{i,t}, d_{j,t})} \sum_{t=2}^{T}\sum_{s=t+1}^{T}(d_{i,t} - d_{i,s})^2}^{\frac{\partial f}{\partial d_{i,1}}} = 0,$$

$$\overbrace{2\left(\frac{\left(d_{i,t} - \overline{d}_i\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t} - \overline{d}_i\right)^2}} - \frac{\left(d_{j,1} - \overline{d}_j\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t} - \overline{d}_j\right)^2}} \right) \frac{C_1(T)}{D_1 j(d_{i,t}, d_{j,t})} \sum_{t=2}^{T}\sum_{s=t+1}^{T}(d_{j,t} - d_{j,s})^2}^{\frac{\partial f_1}{\partial d_{j,1}}} = 0$$

(At this point we do not need to know the remaining 2T-2 derivatives)

where C_1 is a constant that depends on T, $D_{1i} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t}-\overline{d}_i\right)^2}^3$ and $D_{1j} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t}-\overline{d}_j\right)^2}^3$.

So or the first factor is zero, which implies that $f_1 = 0$ and $\rho_{ij,1} = 1$,(which is the result for the maximum) or, as the last factor is a sum of squares, each component of the sum is zero. Therefore all observations but the first in each series are equal. Also, the restrictions $D_{1i} \neq 0$ and $D_{1j} \neq 0$ imply the the first observation is different from the others.

With the last result, and considering that all observation of series $d_{i,t}$ and $d_{j,t}$ for $t \geq 2$ are α and β, respectively, the problem simplifies to :

$$\max f_1^*(d_{i,t}, d_{j,t}) = \left(\frac{\left(d_{i,1} - \frac{d_{i,1}}{T} - \frac{\alpha(T-1)}{T}\right)}{\sqrt{\frac{1}{T}\left(\left(d_{i,1} - \frac{d_{i,1}}{T} - \frac{\alpha(T-1)}{T}\right)^2 + \left(\alpha - \frac{d_{i,1}}{T} - \frac{\alpha(T-1)}{T}\right)^2 (T-1)\right)}} - \frac{\left(d_{j,1} - \frac{d_{j,1}}{T} - \frac{\beta(T-1)}{T}\right)}{\sqrt{\frac{1}{T}\left(\left(d_{j,1} - \frac{d_{j,1}}{T} - \frac{\beta(T-1)}{T}\right)^2 + \left(\alpha - \frac{d_{j,1}}{T} - \frac{\beta(T-1)}{T}\right)^2 (T-1)\right)}} \right)^2$$

Where $\frac{\partial f_1^*}{\partial \alpha} = 0$, $\frac{\partial f_1^*}{\partial \beta} = 0$.

Which means that we just have to optimize with respect to the 1^{st} observation of each series ($d_{i,1}$ and $d_{j,1}$).

As the proposed period-by-period index is invariable if we add to all elements of either series a constant (see proof below), we will work onwards with two series,observed over T periods (d_i and d_j),such as all observations but the first are zero. In this case the problem is:

$$f_1^{**}(d_{i,t}, d_{j,t}) = \left(\frac{\left(d_{i,1} - \frac{d_{i,1}}{T}\right)}{\sqrt{\frac{1}{T}\left(\left(d_{i,1} - \frac{d_{i,1}}{T}\right)^2 + \left(\frac{d_{i,1}}{T}\right)^2 (T-1)\right)}} - \frac{\left(d_{j,1} - \frac{d_{j,1}}{T}\right)}{\sqrt{\frac{1}{T}\left(\left(d_{j,1} - \frac{d_{j,1}}{T}\right)^2 + \left(\frac{d_{j,1}}{T}\right)^2 (T-1)\right)}} \right)^2$$

Now notice that:

$$f_{t\geq 2}^{**}(d_{i,t}, d_{j,t}) = \left(\frac{\left(-\frac{d_{i,1}}{T}\right)}{\sqrt{\frac{1}{T}\left(\left(d_{i,1} - \frac{d_{i,1}}{T}\right)^2 + \left(\frac{d_{i,1}}{T}\right)^2 (T-1)\right)}} - \frac{\left(-\frac{d_{j,1}}{T}\right)}{\sqrt{\frac{1}{T}\left(\left(d_{j,1} - \frac{d_{j,1}}{T}\right)^2 + \left(\frac{d_{j,1}}{T}\right)^2 (T-1)\right)}} \right)^2$$

Which simplifies to

$$f^{**}_{t\geq 2}(d_{i,t},d_{j,t}) = \frac{T^2}{(T-1)^2}\frac{\left(\sqrt{\frac{1}{T^2}(T-1)\,d^2_{j,1}}d_{i,1}-\sqrt{\frac{1}{T^2}(T-1)\,d^2_{i,1}}d_{j,1}\right)^2}{d^2_{i,1}d^2_{j,1}} =$$
$$= \frac{T^2}{(T-1)^2}\frac{\left(\sqrt{\frac{1}{T^2}(T-1)}|d_{j,1}|d_{i,1}-\sqrt{\frac{1}{T^2}(T-1)}|d_{i,1}|d_{j,1}\right)^2}{d^2_{i,1}d^2_{j,1}} =$$
$$= \begin{cases} 0 \quad if\, d_{i,1}d_{j,1} > 0 \\ \frac{4}{T-1}\, if\, d_{i,1}d_{j,1} < 0 \end{cases}$$

If $d_{i,1}d_{j,1} > 0$, the linear correlation index is equal to 1. This means that:

$$\rho_{ij,t\geq 2} = 1 - \frac{1}{2}f^{**}_{t\geq 2}(d_{j,t},d_{i,t}) = 1$$

So as $\rho_{ij} = 1$ and $\rho_{ij} = \frac{\sum_{t=1}^{T}\rho_{ij,t}}{T} = \frac{\rho_{ij,1}+\sum_{t\geq 2}^{T}\rho_{ij,t}}{T} = \frac{\rho_{ij,1}+(T-1)}{T}$,implies that:

$$\frac{\rho_{ij,1}+(T-1)}{T} = 1 \Longleftrightarrow \rho_{ij,1} = 1$$

Which is the maximum value as argued before.
But if $d_{i,1}d_{j,1} < 0$ then the linear correlation index is equal to -1 and

$$\rho_{ij,t\geq 2} = 1 - \frac{1}{2}f^{**}_{t\geq 2}(d_{i,t},d_{j,t}) = \frac{T-3}{T-1}$$

Then $\rho_{ij} = \frac{\sum_{t=1}^{T}\rho_{ij,t}}{T} = \frac{\rho_{ij,1}+\sum_{t\geq 2}^{T}\rho_{ij,t}}{T} = \frac{\rho_{ij,1}+(T-1)\frac{T-3}{T-1}}{T}$, which implies that:

$$\frac{\rho_{ij,1}+(T-3)}{T} = -1 \Leftrightarrow \rho_{ij,1} = 3-2T$$

So over the stationary points $\rho_{ij,1}$, takes either the value 1 or $3-2T$.
The first is the maximum as seen before, and the second the potential minimum.

But a stationary point is just a necessary condition to reach a minimum/maximum in a point (its not sufficient). But this also means that if there is global minimum/maximum as the function is continuously differentiable over a open set the maximum/minimum cannot be obtained outside the set of stationary points.

So assuming that the global minimum/maximum exists the maximum/minimum value the function takes over the set of stationary points is the maximum/minimum of the function. As it only takes two values, the biggest is the maximum and the smallest is the

minimum. So in fact:

$Max(\rho_{ij,t}) = 1$ and $Min(\rho_{ij,t}) = 3 - 2T$ ■

Proposition 3 *The purposed period-by-period index is invariable if we add to all elements of either series a constant, being them equal or different across the series*

Proof. Lets define the constants by δ and ϵ, then we get:

$$f_1(d_{i,t}+\epsilon, d_{j,t}+\delta) = \left(\frac{\left(d_{i,1}+\epsilon-\overline{d_i+\epsilon}\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t}+\epsilon-\overline{d_i+\epsilon}\right)^2}} - \frac{\left(d_{j,1}+\delta-\overline{d_j+\delta}\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t}+\delta-\overline{d_j+\delta}\right)^2}} \right)^2 =$$

$$= \left(\frac{\left(d_{i,1}+\epsilon-\overline{d}_i-\epsilon\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t}+\epsilon-\overline{d}_i-\epsilon\right)^2}} - \frac{\left(d_{j,1}+\delta-\overline{d_j}-\delta\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t}+\delta-\overline{d_j}-\delta\right)^2}} \right)^2 =$$

$$\left(\frac{\left(d_{i,1}-\overline{d}_i\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{i,t}-\overline{d}_i\right)^2}} - \frac{\left(d_{j,1}-\overline{d}_j\right)}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(d_{j,t}-\overline{d}_j\right)^2}} \right)^2 = f_1(d_{i,t}, d_{j,t})$$

$$, t = 1, 2, ..., T$$

■

B Country list and Classification

Country list and Classification

Algeria$^{(4*),+++}$	Dom.Rep.$^{***,+++}$	Japan$^{*,(4+)}$	Philippines$^{*,++}$
Argentina***,	Ecuador$^{***,++}$	Jordan$^{(4*),++}$	Portugal$^{**,(4+)}$
Australia$^{*,(4+)}$	Egypt$^{(4*),++}$	Kenya$^{(6*),+}$	PuertoRico$^{***,(4+)}$
Austria**,	ElSalvador$^{***,++}$	Korea,Rep.$^{*,(4+).}$	Romania$^{**,+++}$
Bangladesh$^{(5*),+}$	Eq.Guinea$^{(6*),(4+)}$	Lesotho$^{(6*),++}$	Rwanda$^{(6*),+}$
Barbados$^{***,(4+)}$	Ethiopia$^{(6*),+}$	Luxemb.$^{**,(4+)}$	Senegal$^{(6*),+}$
Belgium$^{**,(4+)}$	Fiji$^{*,+++}$	Madag.$^{(6*),+}$	Seychelles$^{(6*),+++}$
Benin$^{(6*),+}$	Finland$^{**,(4+)}$	Malawi$^{(6*),+}$	Singapore$^{*,(4+)}$
Bolivia$^{***,++}$	France$^{**,(4+)}$	Malaysia$^{*,+++}$	SouthAfrica$^{(6*),+++}$
Botswana$^{(6*),}$	Gabon$^{(6*),+++}$	Mali$^{(6*),+}$	Spain$^{**,(4+)}$
Brazil$^{***,+++}$	Gambia$^{(6*),+}$	Mauritania$^{(6*),+}$	SriLanka$^{(5*),++}$
BurkinaFaso$^{(6*),+}$	Ghana$^{(6*),+}$	Mauritius$^{(6*),+}$	Sweden$^{**,(4+)}$
Burundi$^{(6*),+}$	Greece$^{**,(4+)}$	Mexico$^{***,+++}$	Switzerland$^{**,(4+)}$
Cameroon$^{(6*),++}$	Guatemala$^{***,++}$	Morocco$^{(4*),++}$	Syria$^{(4*),++}$
Canada$^{(7*),(4+)}$	Guinea$^{(6*),+}$	Mozambique$^{(6*),+}$	Taiwan$^{*,(4+)}$
CapeVerde$^{(6*),++}$	Guinea-Biss.$^{(6*),+}$	Namibia$^{(6*),+++}$	Tanzania$^{(6*),+}$
CentralAfr.Rep.$^{(6*),+}$	Guyana$^{***,++}$	Nepal$^{(5*),+}$	Thailand$^{*,++}$
Chad$^{(6*),+}$	Haiti$^{***,+}$	Netherlands$^{**,(4+)}$	Togo$^{(6*),+}$
Chile$^{***,+++}$	Honduras$^{***,++}$	NewZealand$^{*,(4+)}$	Trinid.&Tob$^{***,+++}$.
China$^{*,++}$	HongKong$^{*,(4+)}$	Nicaragua$^{***,++}$	Turkey$^{**,+++}$
Colombia$^{***,+++}$	Iceland$^{**,(4+)}$	Niger$^{(6*),+}$	Uganda$^{(6*),+}$
Comoros$^{(6*),+}$	India$^{(5*),++}$	Nigeria$^{(6*),++}$	UK$^{**,(4+)}$
CongoD.Rep.$^{(6*),+}$	Indonesia$^{*,++}$	Norway$^{**,(4+)}$	USA$^{(7*),(4+)}$
Congo,Rep$^{(6*),++}$	Iran$^{(4*),++}$	Pakistan$^{(5*),++}$	Uruguay$^{***,+++}$
CostaRica$^{***,+++}$	Ireland$^{**,(4+)}$	Panama$^{***,+++}$	Venezuela$^{***,+++}$
Coted'Ivoire$^{(6*),++}$	Israel$^{**,(4+)}$	P.N.Guinea$^{*,++}$	Zambia$^{(6*),+}$
Cyprus$^{**,(4+)}$	Italy$^{**,(4+)}$	Paraguay$^{***,++}$	Zimbabwe$^{(6*),+}$
Denmark$^{**,(4+)}$	Jamaica$^{***,+++}$	Peru$^{***,(4+)}$	

Legend:

* East Asia and Pacific (EAP); ** Europe and Central Asia (ECA); *** Latin America and Caribbean (LAC); (4*) Middle East and North Africa (MENA); (5*) South Asia (SA); (6*) Sub-Saharan Africa (SSAf) ; (7*) and North America (NA)

+ Low-Income (LIC); ++ Lower-Middle Income (LMIC); +++ Upper-Middle Income (UMIC); (4+) High Income (HIC).

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