Impact of sub-national synchronization on the behavior of national business cycles in emerging economies with inflation targeting

Received 1 December 2023
Revised 2 February 2024
Accepted 1 March 2024

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Abstract

Purpose – The purpose of this paper is to assess sub-national business cycle (BC) synchronization's impact on national cycles in four emerging markets economies with inflation targeting (IT-EMEs): Brazil, Colombia, South Korea and Mexico.
Design/methodology/approach – The authors use panel data models with fixed-effects and distributed lags.
Findings – The authors disclosed that sub-national synchronization increased national cycle amplitudes during expansion and recession phases. The authors also noticed that South Korea exhibited a more pronounced effect compared to Latin American countries, and this seemed to be associated with differences in the homogeneity of the production structures in the regions of these countries.
Research limitations/implications – The authors cautioned that contrasting the findings with prior research on the effects of regional BC synchronization in IT-EMEs or with studies in different geographical contexts, is not possible due to the absence of prior research endeavors with this specific focus.
Originality/value – This study constitutes a first attempt to explain the impact of subnational cycle synchronization on the magnitude of national cycles in four IT-EMEs.

Keywords Distributed lags, Fixed-effects models, Synchronization regional business cycles, Amplitude of national business cycles, Emerging market economies

Paper type Research paper

1. Introduction

The synchronization of regional business cycles (BC) is the co-movement of the BC at the sub-national level within an economy. Researchers in the field of regional BC of emerging market economies (EMEs) are focusing their studies on this particular feature (Padilla and Quintero, 2022). This literature actively illustrates that economic shocks produce varying effects on sub-national units within a country. While a country experiences a recession, some regions can enter an expansion phase of their BC, namely BCs between regions within a country and between a region and the country may not synchronize.

Existing studies on BCs in EMEs aim to determine how synchronized the regions are with each other (Mejía-Reyes, 2007; Delajara, 2011; Duran, 2013, 2015), with the national BC (Duran, 2013; Díaz González and Mendoza Sánchez, 2012), with developed economies (Mejía-Reyes and Campos-Chávez, 2011; Mejía-Reyes *et al.*, 2018), and with bordering territories (Martincus and Molinari, 2007). Likewise, researchers are interested in studying the effects of recessions in developed economies on regional synchronization in EMEs (Mejía-Reyes and Díaz-Carreño, 2016; Shepherd *et al.*, 2014, 2017). However, in the literature on regional cycles in EMEs there is no study that analyzes the effect of the synchronization of regional cycles on the amplitude of BC in the national aggregate.

Journal of Economic Studies
© Emerald Publishing Limited
0144-3585
DOI 10.1108/JES-12-2023-0682

Anything that increases or decreases the amplitude of expansions or recessions is important for decision-making by investors, private banks, central banks, and policymakers. For example, government size can affect the magnitude of BCs, as demonstrated by Leibrecht and Scharler (2015) in a study involving 18 OECD countries. Also, Belke *et al.* (2017) demonstrate that the common monetary policy of the EU can generate issues regarding the amplitude of the BCs of its members.

Nevertheless, the inherent dynamics of regions can also influence the behavior of the national aggregate cycle. Specifically, it is worth asking whether the synchronization of sub-national cycles has any relationship with the amplitude of the expansion and recession phases of aggregate cycles. Our objective is to provide an answer to this question by estimating how the synchronization of subnational cycles impacts the magnitude of national cycles in four EMEs: Brazil, Colombia, South Korea, and Mexico. This represents one of the main contributions of this study to the existing literature, which has only considered political and macroeconomic variables as determinants of aggregate economic fluctuations.

Another significant contribution of this work is methodological, as it incorporates a distributed lag model and the rolling-window technique to estimate the lagged effects of explanatory variables on the characteristics of aggregate cycles. While distributed lag models are not novel, there is no precedent in the literature for their use in estimating determinants of the characteristics of economic fluctuations.

The selection of the four mentioned economies has various reasons. Firstly, these economies share the common feature of conducting their monetary policy under the inflation targeting (IT) framework, which allows for more comparable results. There is evidence that countries implementing this framework tend to increase the amplitude of real GDP growth volatility compared to countries with other monetary policy frameworks (Stojanovikj, 2022). The second reason is the availability of regional GDP time series data. Among the IT-EMEs, only these countries have extensive sub-national GDP statistical series that enable the calculation of the evolution of regional BCs synchronization over a considerable period of time. A third reason is the economic importance of these four economies within the total of IT-EMEs. This is evident in the fact that, according to World Bank figures for the year 2019 at constant 2015 prices, the combined GDP of these four nations represents 52% of the GDP of IT-EMEs [1].

The rest of the document follows this structure. Section 2 reviews the previous empirical literature. Section 3 describes the data and methods used. Section 4 presents the empirical results. Section 5 discusses the role of the homogeneity of the productive structure between the regions of a country in the incidence of greater regional synchronization on the amplitude of national cycles. And Section 6 concludes the document.

2. Previous empirical literature

In the context of IT-IEMEs, literature includes several studies that estimate the determinants of regional synchronization. For Mexico, some of the identified determinants of regional synchronization include the relative importance of international trade, foreign direct investment, 'maquila' production (Mejía-Reyes and Campos-Chávez, 2011); distance and the border effect (Shepherd *et al.*, 2014); and spatial dependence during the Great Recession of 2008–2009 (Kondo, 2022). For Turkish regions, Duran (2015) reveals that bilateral trade intensity, the degree of agglomeration, market size, and urbanization are equally determining factors of synchronization. In the case of Poland, factors influencing regional synchronization with the nation include greater regional participation in sold industrial production (Spychała, 2020). Furthermore, Rabiej *et al.* (2023) identify idiosyncratic components and spatial spillover as determinants of synchronization among Polish NUTS-2 regions, contributing to the limited co-movement observed among its NUTS-3 regions.

However, these determinants of regional synchronization are not exclusive to IT-EMEs countries. Recent literature highlights some of these same determinants and considers others in various geographical contexts. In the case of the United States, empirical evidence indicates that economic cycles are more synchronized among states characterized by strong trade links, similar industrial structures, labor market features, and openness (Cainelli *et al.*, 2021). Likewise, for Chinese regions, the literature identifies determinants of synchronization such as geographical location (Song *et al.*, 2018); industrial connections through the industry value chain (Shao *et al.*, 2018; Beck, 2021; Guisinger *et al.*, 2024); resource scarcity; financial system growth; growth patterns in each region; market liberalization policies (Song *et al.*, 2018; Liu *et al.*, 2020), and the similarity in industrial structure (Wang *et al.*, 2023).

Similarly, in the literature on the amplitude of the national economic cycle in IT-EMEs, various determinants have been identified, such as institutional factors (Calderón and Fuentes, 2010; Altug *et al.*, 2012), terms of trade (Calderón and Fuentes, 2010; Martins and Rugitsky, 2021), US interest rate shocks, inflation, real exchange rate overvaluation, sudden stops, financial depth, trade openness, financial openness, and output diversification (Calderón and Fuentes, 2010); access to international liquidity, and procyclical policies (Martins and Rugitsky, 2021); fiscal stabilization policy, and IT regime (Stojanovikj, 2022); exchange rate flexibility (Kohler and Stockhammer, 2023), and spatial dependence (Rabiej *et al.*, 2023).

Up until now, in this literature on the determinants of national cycle amplitude, researchers have not been evaluating the role of regional synchronization. Much less has there been suggested an explanation on the channels through which the amplitude of aggregate cycles may be connected to the level of synchronization of sub-national units. Nevertheless, it is interesting to note that within this set of determinants of regional cycle synchronization and the amplitude of national cycles, a common element is the productive structure.

For Turkey, while investigating the economic determinants of synchronization among regional BC between 1975 and 2010, Duran (2015) finds that the productive structure is a determining factor in the synchronization of its regional cycles. In the case of Mexican regions, several studies also identify the productive structure as a determinant of synchronization. According to Mejía-Reyes (2007), there appear to be strong links between the synchronization of the BC trajectory in the northern and central states of the country and between states due to similarities in industrialization patterns. In later research, Mejía-Reyes and Campos-Chávez (2011) and Mejía-Reyes and Díaz-Carreño (2016) show a high level of synchronization between the cycles of Mexican regions and those of the United States. This latest study, for instance, observes that as a consequence of the U.S. mortgage crisis (2008–2009), the industrial regions of Mexico experienced a significant decline in their output. Mejía-Reyes *et al.* (2018) argue that when the productive structures between countries and regions are similar, sectoral shocks can generate homogeneous effects on productive activities because they are responding to the same driving forces. Finally, Gómez-Zaldívar and Llanos-Guerrero (2021) are explaining the synchronization of BCs among Mexican states using a single variable that encompasses all characteristics of state-level productive structures, known as economic complexity.

Regarding the role of the productive structure as a determinant of the amplitude of aggregate BCs, Kim *et al.* (2003) discovered that the decrease in the amplitude of economic fluctuations within the Philippines, the so-called ‘Asian Tigers’ (Singapore, Taiwan, and South Korea), and ’newly industrialized countries’ (Malaysia, Thailand, Indonesia) during the 1985–1996 period can be primarily attributed to shifts in their productive structures. These economies witnessed a transformation in which the industrial and service sectors emerged as the foremost drivers of their economic activities. The authors demonstrate that by reducing the participation of the agricultural sector, which is significantly more susceptible to price and productivity shocks, the volatility of economic fluctuations decreases.

To summarize, although the literature highlights several key factors in the co-movements of sub-national cyclical fluctuations and the amplitude of aggregate cycles, production structure is a common point among the determinants of both phenomena. Therefore, there may exist a connecting factor between the amplitude and synchronization of regional BCs, with the degree of similarity in the production structure of regions very likely being a key element in this connection.

3. Data and methods

3.1 Data

We primarily select countries and their regions based on the availability of regional data. To ensure economies as similar as possible, we include four emerging countries with IT, of which three are from Latin America (Brazil, Colombia, and Mexico), and one is from Asia (South Korea). These countries and their regions have complete GDP data at constant prices for a long enough period of time (1985–2019) [2], which helps to enhance the accuracy of the estimates. We used data obtained from statistical institutes in Brazil (IBGE, IPEADATA), Colombia (DANE), Korea (KOSIS), and Mexico (INEGI). In the case of Brazil, only Tocantins is excluded from the 27 states. We collected data from 23 of the 32 existing departments in Colombia, in addition to the capital district, for a total of 24 regions. We included 13 of the 17 official regions in South Korea, excluding the provinces of Gwangju, Daejeon, Ulsan, and Sejong. Mexico is the only economy that provides complete GDP statistics by regions, comprising 31 states plus its capital.

3.2 Measurement of regional synchronization, national cycle amplitude and similarity index

3.2.1 Measurement of regional synchronization. To calculate regional synchronization, we start with the annual GDP series for regions in Brazil, Colombia, South Korea, and Mexico for the period 1985–2019. We extract the trend from these series using the Hodrick and Prescott (1997) [3] filter and obtain the turning points applying the Harding and Pagan (2002) [4] algorithm created by Bracke (2012) to each of the series to obtain peaks and troughs for each region [5].

Then, we specifically apply the fixed-size rolling window technique. This technique involves the use of 16-year sub-periods. For the consolidation of the rolling windows, in each new window, we add a new year to the analysis period, and the oldest observation is discarded (pruning), resulting in a total of 20 sub-periods [6]. The first window covers the sub-period 1985–2000; the second window spans from the sub-period 1986–2001, and so on until all 20 sub-periods are completed.

We used the results of the phases of the cycle (expansion or recession) in which each region was in each year as input to calculate the synchronization between two regions. Ultimately, we calculated an average synchronization index among all the regions of the country for each time window. In particular, we constructed the concordance index proposed by Harding and Pagan (2002). This index is a non-parametric measure of co-movement that employs a binary indicator variable for economic expansions and recessions. The concordance index $\widehat{I}$ for a pair of regions i, j is defined as the fraction of times when the cycle of region i, $y_{i,t}$ and region j, $y_{j,t}$ within the same country are in the same phase of the cycle. Formally, the concordance index is defined as:

$$\widehat{I} = \frac{1}{T}\left\{\sum_{t=1}^{T} S_{y_{i,t}} S_{y_{j,t}} + \sum_{t=1}^{T}\left(1 - S_{y_{i,t}}\right)\left(1 - S_{y_{j,t}}\right)\right\} \quad (1)$$

where, $S_{i,t}$; $t = 1, ..., T$; $i = 1, ..., N$ with $S_{i,t} = 1, (S_{i,t} = 1)$ if region $i(j)$ in year t is in an expansion phase and $S_{i,t} = 0, (S_{i,t} = 0)$ if region $i(j)$ in year t is in a recession phase.

Lastly, we compute an index that averages the concordance of all possible combinations between two regions of each country for each year. Finally, after calculating the synchronization indices for each year within the sub-period of analysis, we proceed to compute the window average. We consider this average value as the level of regional synchronization for each sub-period [7].

3.2.2 Measurement of national business cycle amplitude. According to Burns and Mitchell (1946), the amplitude of cyclical oscillations is determined by measuring the increase of a specific cycle from the starting trough to its peak and the decrease from the starting peak to the ending trough. That is, S_t is a binary variable that takes the value of 1 when the series is in an expansion phase and 0 when it is in recession. Once the phase values were obtained, we calculated the national BC amplitude using the equations proposed by Harding and Pagan (2001) and implemented by empirical studies like Altavilla (2004).

We measure the amplitude A of the expansion and contraction phases using equations (2) and (3), respectively. This variable generally measures the percentage change in economic activity in each phase of the economy.

$$\widehat{A}_{\exp} = \frac{\sum_{t=1}^{T} S_t \Delta y_t}{\sum_{t=1}^{T-1} (1 - S_{t+1}) S_t} \tag{2}$$

$$\widehat{A}_{rec} = \frac{\sum_{t=1}^{T} (1 - S_t) \Delta y_t}{\sum_{t=1}^{T-1} (1 - S_t) S_{t+1}} \tag{3}$$

where $\sum_{t=1}^{T} S_t \Delta y_t$ measures the total change in economic activity during expansion or contraction. Since $S_t = 1$ when there is an expansion, $\sum_{t=1}^{T} S_t$ measures the total time of expansions, $\sum_{t=1}^{T} (1 - S_t)$ measures the total time of recessions, $\sum_{t=1}^{T-1} (1 - S_{t+1}) S_t$ measures the number of peaks during expansions, $\sum_{t=1}^{T-1} (1 - S_t) S_{t+1}$ measures the number of troughs during recessions.

This measure of the amplitude of the expansion and recession phases of the national BC is calculated for the same sub-periods considered in the measurement of regional synchronization described in the previous section.

3.2.3 Measurement of similarity index. To explore the potential link between the amplitude and the synchronization of regional BCs, we suggest quantifying the level of similarity in the productive structure among pairs of regions. We will employ the similarity index proposed by Chen *et al.* (2021), as expressed in the following formula:

$$SI_{AB} = \frac{\left(\sum_{i=1}^{n} X_{Ai} * X_{Bi} \right)}{\sqrt{\left(\sum_{i=1}^{n} X_{Ai}^2 * \sum_{i=1}^{n} X_{Bi}^2 \right)}}; \; 0 \leq SI_{AB} \leq 1 \tag{4}$$

where X_{Ai} and X_{Bi} represent the proportion of the value added of sector i in regions A and B, respectively, in the total production value of these regions. If the index $SI_{AB} \geq 0.9$, the production structures are similar (Chen *et al.*, 2021).

3.3 Econometric strategy

In this study, we estimate the effects of the synchronization of sub-national BC on the amplitude of national BCs in IT-EMEs. Since data on these cycle characteristics are collected over time, it is possible to estimate the dynamic causal effect. Including only a contemporary measure of regional cycle synchronization does not capture the persistent effects that regional co-movements can have on the amplitude of the expansion or recession of aggregated cycles over time. To capture these effects, it is necessary to consider the impact on the phases of the amplitude of national cycles, both contemporary and lagged from regional synchronization. Therefore, we estimate dynamic causal effects using distributed lag panel data models (DL) with fixed effects, where amplitude is expressed as a function of current and lagged values of regional cycle synchronization. In other words, because dynamic causal effects occur over time, we incorporated lags in the model to assess the existence of non-contemporary effects of regional synchronization on the amplitude of aggregated economic cycles (Stock and Watson, 2020). In particular, we estimate the following equation:

$$A_{i,t} = \beta(L)Syn_{i,t-h} + \gamma_i + \mu_{i,t} \tag{5}$$

where $A_{i,t}$, as the dependent variable, represents the level variable of aggregate cycle amplitudes, and $Syn_{i,t-h}$ constitutes the regional cycle synchronization index and represents the independent variables. Additionally, the subscript i refers to the 4 countries studied, and the subscript t corresponds to the 20 sub-periods studied, for a total of 80 observations. In the panel model, unobservable factors specific to each country and time-constant constants, represented as γ_i [8], are included, along with an error term $\mu_{ij,t}$, which is assumed to be uncorrelated with the explanatory variables.

Furthermore, the number of lags to consider, denoted as (L), is an empirical element to be determined. The parameters of these lags, (β), represent the amplitude responses of the national cycle phases to a change in regional synchronization, (h) years after the impact of synchronization. For this reason, the number of lags for $Syn_{i,t}$ becomes significant. In this regard, the time horizon with which you work is crucial.

As this study has 20 sub-periods as temporal data, including a large number of lags results in a loss of degrees of freedom and a reduction in the precision of the estimators. Therefore, we decided to estimate different finite distributed lag models with the synchronization variable of regional BCs lagged up to 4 periods ($h = 1, \ldots, 4$). In the case of 4 lags, the equation above looks like this:

$$A_{i,t} = \alpha + \beta_0 Syn_t + \beta_1 Syn_{t-1} + \beta_2 Syn_{t-2} + \beta_3 Syn_{t-3} + \beta_4 Syn_{t-4} + \gamma_i + \mu_{i,t} \tag{6}$$

Following Stock and Watson (2020), it is possible to rewrite the previous regression as shown in equation (7) to obtain cumulative dynamic multipliers.

$$A_{i,t} = \alpha + \eta_i + \phi_0(\Delta Syn_{i,t}) + \phi_1(\Delta Syn_{i,t-1}) + \phi_2(\Delta Syn_{i,t-2}) + \phi_3(\Delta Syn_{i,t-3}) + \phi_4(Syn_{i,t-4}) + \mu_t \tag{7}$$

The parameter ϕ_0 represents the contemporaneous or short-run effect of a unit change in $Syn_{i,t}$ on $A_{i,t}$. This coefficient is equivalent to β_0 in the level equation (equation 5). The parameters ϕ_1 to ϕ_4 represent the cumulative impacts between 1 and 4 years of increased regional synchronization on the amplitude of the national cycle. The coefficient ϕ_1 is the cumulative effect on $A_{i,t}$ 1 year later following a unit change in $Syn_{i,t}$. This coefficient is equivalent to $\beta_0 + \beta_1$ in the level equations. The coefficient ϕ_2, equivalent to the cumulative value of $\beta_0 + \beta_1 + \beta_2$ from the level model, represents the cumulative effect of a unit change in the regional synchronization index on the amplitude of national BC two periods later, and so forth.

One of the main advantages of estimating equation (7) is that by differencing the $Syn_{i,t}$ variable, the series is theoretically made stationary, correcting for potential multicollinearity. However, we applied various statistical tests to test for the absence of a unit root in the series and the non-collinearity of the model coefficients. We describe the various tests and their results in the following section.

4. Results

4.1 Unit root tests

Table 1 presents Pesaran's (2007) second-generation unit root test results. We opted for this test due to its basis on the assumption of heterogeneous cross-sections. Considering our analysis involves diverse countries and regions, we addressed potential cross-sectional dependence. The Pesaran (2007) unit root test revealed that amplitude variables of national expansion and recession cycles, both with and without trend, in levels and first differences, were stationary at the 5% significance level. Similarly, first differences of regional synchronization, with and without trends, were stationary at the 1% significance level.

4.2 Effect of regional synchronization on aggregate cycle amplitude

We estimated models with 1, 2, 3, and 4 lags of the explanatory variable. According to the AIC and BIC information criteria, models with 1 lag of the explanatory variable, both for the expansion and recession of the aggregate cycle, provide the best fit. When we include more than 4 lags in the models, the statistical significance of the explanatory variables is significantly affected due to a substantial decrease in the number of observations in the estimated models. For this reason, and given that a higher number of lags allows estimating the cumulative effect of the regional synchronization index on the amplitude of expansions and recessions in IT-EMEs over a longer time horizon, in this study, we have chosen the model with 4 lags as the baseline model. Therefore, initially, in Table 2, we present the results of the DL models estimated with 4 lags of the explanatory variable, in which we assess the impact of regional synchronization on the amplitude of national cycles.

The estimates show a positive and statistically significant effect of regional synchronization on the amplitude of the expansion phase of national cycles. In other words, the more synchronized the regions of the IT-EMEs are, the economic activities of Brazil, Colombia, South Korea, and Mexico experience greater growth during the expansion phase of the cycle.

	(B) Pesaran (2007) panel unit root test (CIPS)	
Variables	Without trend	With trend
Level variable		
Amplitude country		
Expansion	−1.908**	−3.072***
Recession	−3.955***	−3.964***
Regional synchronization	−1.532*	−0.960
Variables in first differences		
Amplitude country		
Expansion	−7.476***	−6.659***
Recession	−8.076***	−8.140***
Regional synchronization	−5.777***	−5.389***

Note(s): ***, **, * statistically significant at the 1%, 5% and the 10% level, respectively
Source(s): Authors' own creation

Table 1. Panel unit root test

Table 2.
Effect of regional synchronization on cycle amplitude aggregate in IT-EMs. DL baseline model

Accumulated impact	Amplitude Expansion	b/se	Amplitude Recession
ϕ_0	0.076*		−0.171***
	(0.04)		(0.05)
ϕ_1	0.146***		−0.196***
	(0.05)		(0.06)
ϕ_2	0.209***		−0.215***
	(0.05)		(0.06)
ϕ_3	0.185***		−0.195***
	(0.05)		(0.05)
ϕ_4	0.121***		−0.205***
	(0.04)		(0.04)
Constant	−0.043*		0.095***
	(0.02)		(0.03)
N	64		64
R2	0.315		0.364

Note(s): Fixed-effects panel estimates. ***, **, * statistically significant at the 1%, 5% and the 10% level, respectively
Source(s): Authors' own creation

Specifically, an increase of one unit in the average regional synchronization index of an emerging economy over 20 years (i.e. going from an average of 0.63 to 0.64) is reflected in an average increase in the amplitude of the expansion phase of the cycles by 0.08 percentage points (p.p.) during that same period. As expressed in previous lines, cumulative impacts allow us to determine the non-contemporary effects of regional synchronization on the amplitude of national cycles. After the first year, the effect of regional synchronization on the amplitude of expansion is 0.15 p.p., with this cumulative impact increasing to 0.21 p.p., the following year. In the two subsequent years, the cumulative impact decreases, stabilizing at approximately 0.12 p.p., four years after the increase in regional synchronization.

Regarding the effects on the amplitude of recessions, we also found that an increase in the regional synchronization index increases the amplitude of this phase. Since the amplitude of recessions takes on negative values (indicating the loss of production generated during the phase), the estimated coefficient ϕ_0 of -0.171 implies that the amplitude of the recession phase increases by 0.17 p.p., with a one-unit increase in the average regional synchronization index of an economy during the same period. This effect increases to 0.20 p.p., one year later, maintaining similar levels of impact in the subsequent years while retaining statistical significance (Table 2).

These results suggest that a driver for the deepening of BCs in IT-EMEs is the heightened synchronization of regional economic cycles. Moreover, the effects of synchronization on the amplitude of expansion and recession phases appear to be relatively symmetrical in the sampled IT-EMEs. These findings may have significant economic implications in terms of the economic stability of countries, as shown by empirical evidence for an emerging economy like South Africa in which the greater amplitude of BCs led to increased economic instability in this nation during the period 1970–2017 (Laubscher, 2020).

4.3 Robustness tests

As a first robustness test, we compared the effects of the baseline model estimates with 4 lags of the explanatory variable with models featuring 1, 2, and 3 lags. As can be observed in Table 3, the magnitude of the contemporaneous and lagged impacts of regional

Table 3. Effect of regional synchronization on the amplitude of the aggregate cycle in IT-EMEs

Accumulated impact	Expansion	Recession	Expansion	Recession	Expansion	Recession	Expansion	Recession
				b/se				
ϕ_0	0.102**	−0.168***	0.084*	−0.161***	0.091**	−0.170***	0.076*	−0.171***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)
ϕ_1	0.093***	−0.122***	0.117***	−0.161***	0.139***	−0.195***	0.146***	−0.196***
	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
ϕ_2			0.119***	−0.150***	0.171***	−0.219***	0.209***	−0.215***
			(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.06)
ϕ_3					0.124***	−0.184***	0.185***	−0.195***
					(0.03)	(0.04)	(0.05)	(0.05)
ϕ_4							0.121***	0.095***
							(0.04)	(0.03)
Constant	−0.027	0.044**	−0.043**	0.061***	−0.046**	0.082***	−0.043*	−0.205***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)
N	76	76	72	72	68	68	64	64
AIC	−509	−497	−491	−477	−467	−456	−445	−426
BIC	−502	−490	−482	−468	−456	−445	−432	−413

Note(s): Fixed-effects panel estimates. ***, **, * statistically significant at the 1%, 5% and the 10% level, respectively
Source(s): Authors' own creation

synchronization on cycle amplitude obtained from estimation of different models up to 4 lags is consistent with each other.

As a second robustness test, we considered to estimate a panel vector autoregression model to account for possible endogeneity. However, when performing the Panel VAR-Granger causality Wald test, we found empirical evidence of a one-way causality, indicating that synchronization significantly influences the amplitude of expansion (or recession) of national cycles, but the amplitude of expansion (or recession) does not cause synchronization in the Granger sense at the 99% confidence level (Table 4). This one-way relationship between synchronization and amplitude of BC helps eliminate any potential endogeneity issues in the baseline model [9].

As a third robustness test, we estimated models by excluding one country in each estimation (Table 5). By excluding any of the EMEs, the models remain consistent, and the amplitude of the expansion and recession phases of national cycles increases (decreases) with increases (decreases) in sub-national synchronization. However, when excluding South Korea, it can be observed that the influence of synchronization on the amplitude of BCs, while still positive, diminishes its impact, particularly in the expansion phase. The most significant decrease (95%) is observed in the parameter ϕ_0, which captures the impact in the same period of the change in regional synchronization [0.004 vs 0.076]. In contrast, when excluding any of the Latin American countries, the effect of regional synchronization on the amplitude of BCs does not change significantly, although in most cases, there is a slight increase in the magnitude of the impacts.

Based on the above findings, we can infer that in South Korea, a higher degree of regional synchronization has a more significant impact on the amplitude of both the expansion and recession phases of the BC, compared to the Latin American countries.

5. Discussion

In South Korea, the positive effects of an expansion and the contagion effect between regions during a recession are more pronounced compared to what happens in Latin American

Panel VAR-Granger causality Wald test Excluded	Chi-sq	df	Prob > χ^2
Null hypothesis: no causality			
Dependent variable: amplitude expansion			
synchronization	10.594***	1	0.001
ALL	10.594***	1	0.001
Dependent variable: synchronization			
Amplitude expansion	1.879	1	0.170
ALL	1.879	1	0.170
Null hypothesis: no causality			
Dependent variable: amplitude recession			
synchronization	22.633***	1	0.000
ALL	22.633***	1	0.000
Dependent variable: synchronization			
Amplitude recession	5.249**	1	0.022
ALL	5.249**	1	0.022

Note(s): ***, **, * statistically significant at the 1%, 5% and the 10% level, respectively
Source(s): Authors' own creation

Table 4.
Causality test

Table 5. Effect of regional synchronization on the amplitude of the aggregate cycle in IT-EMEs. Excluding one economy

Accumulated impact	All's	Excluding Brazil	Colombia b/se	South Korea	Mexico
Amplitude of the expansion					
ϕ_0	0.076*	0.084**	0.071	0.004	0.096*
	(0.04)	(0.04)	(0.07)	(0.06)	(0.05)
ϕ_1	0.146***	0.151***	0.133*	0.051	0.169***
	(0.05)	(0.04)	(0.07)	(0.07)	(0.06)
ϕ_2	0.209***	0.209***	0.299***	0.080	0.222***
	(0.05)	(0.04)	(0.07)	(0.07)	(0.06)
ϕ_3	0.185***	0.183***	0.162***	0.134**	0.194***
	(0.05)	(0.04)	(0.07)	(0.06)	(0.06)
ϕ_4	0.121***	0.119***	0.127**	0.058	0.147***
	(0.04)	(0.03)	(0.04)	(0.05)	(0.06)
Constants	−0.043*	−0.046**	−0.045*	−0.004	−0.057*
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Amplitude of the recession					
ϕ_0	−0.171***	−0.159***	−0.239***	−0.104	−0.189**
	(0.05)	(0.05)	(0.08)	(0.07)	(0.06)
ϕ_1	−0.196***	−0.200***	−0.203**	−0.146*	−0.196**
	(0.06)	(0.05)	(0.08)	(0.08)	(0.06)
ϕ_2	−0.215***	−0.222***	−0.222***	−0.158*	−0.215**
	(0.06)	(0.05)	(0.08)	(0.09)	(0.06)
ϕ_3	−0.195***	−0.202***	−0.187**	−0.162**	−0.198**
	(0.05)	(0.05)	(0.08)	(0.08)	(0.06)
ϕ_4	−0.205***	−0.201***	−0.217***	−0.163***	−0.233***
	(0.04)	(0.04)	(0.05)	(0.06)	(0.06)
Constants	0.095***	0.098***	0.102***	0.069*	0.108**
	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)

Note(s): Fixed-effects panel estimates. ***, **, * statistically significant at the 1%, 5% and the 10% level, respectively
Source(s): Authors' own creation

Table 6. Index of similarity in productive structure

Countries	Productive structure similarity coefficient
Brazil	0.794
Colombia	0.761
South Korea	0.939
Mexico	0.852

Source(s): Authors' own creation

countries. One possible explanation for this result is related to the similarities or heterogeneities in the productive structure among regions in these countries, a factor that empirical literature has shown to be determinant for both regional synchronization and the amplitude of national BC.

A straightforward exercise that supports the hypothesis that the higher incidence of regional synchronization on the amplitude of aggregate cycles in South Korea compared to Latin American countries is related to greater homogeneity in the country's production structure is the calculation of a similarity index for the production structure of the four countries. We applied the index by Chen *et al.* (2021), which was referred to in equation (4), using subnational GDP data from 2018 obtained from each of the statistical institutes of the sampled EMEs (IPEADATA, Brazil; DANE, Colombia; KOSIS, South Korea; INEGI, Mexico) for the subsectors of agriculture, forestry and fishing; mining and manufacturing; supply of electricity, gas, steam, and air conditioning; and construction. By calculating an average of the obtained indices for each possible combination of 2 regions, we obtained the results shown in Table 6 [10].

As observed, South Korea is the economy that displays the highest homogeneity in the productive structures among its sub-national units, while in Latin American countries there is greater heterogeneity in productive structures between regions. Therefore, taking into account the results presented in Table 6, greater regional synchronization generates a greater effect on the amplitude of national BC when the similarity of sub-national productive structures is greater. This implies that although a country's regions become more synchronized in terms of the phase of the cycle they are in, this does not necessarily significantly amplify the expansion and recession phases of national cycles. This scenario occurs when there is greater homogeneity in the productive structures.

When such homogeneity does not exist, although the regions may be more synchronized as a result of greater impact from common positive or negative shocks, the effects on the amplitude of national BC would not be as significant. In other words, this heterogeneity generates that when the economies of these countries are in an expansionary phase, the strong economic performance of a region specialized in a particular sector does not manage to spill over its high economic growth to other regions specialized in different sectors, as a result of the existing disconnect between them. The positive aspect is that, during the recession phases of the cycle, crises originating in one sector do not strongly transmit to the rest of the economy's sectors. Certainly, if these are crises associated with global or external phenomena or national macroeconomic situations, they end up affecting the different regions of these countries in a homogeneous manner.

6. Conclusions

This study aims to determine the impact of sub-national synchronization effects on the amplitude of aggregate cycles in four IT-EMEs: Brazil, Colombia, South Korea, and Mexico. The main results obtained show that greater regional synchronization increases the amplitude of the expansion and recession phases of national BCs in the analyzed countries, with this impact becoming more pronounced 2 years after increasing regional synchronization.

Another important result is that in South Korea, the impact of greater regional synchronization on the amplitude of the expansion and recession phases of the cycle is greater than in the three Latin American countries analyzed. This situation may be related to the similarities or heterogeneities in the productive structures among regions in these countries, a factor that empirical literature has shown to be determinant in both regional synchronization and the amplitude of national BC. Specifically, in South Korea, greater similarity between regions in their productive structures leads to more synchronized regional BC, with direct effects on the amplitude of cycles at the national aggregate level.

These results highlight the importance of regional economic dynamics in the fluctuations of national economies and confirm the existence of other factors that can affect the likelihood of national economies growing more during expansion periods or experiencing deeper crises during recessions. In particular, this study has identified a new determinant of the amplitude of national BC: regional synchronization.

For economic policymakers who seek to stabilize the economy during times of crisis and smooth out BC phases, the results of this study imply that they should focus on implementing differential regional development policies. These policies should aim to promote specific sectors in each region, leveraging their comparative and competitive advantages. By doing so, they can facilitate the enhancement of national economic activity during periods when certain sectors and regions experience a decline in their productive dynamics. The practice of differentiated policies, therefore, plays a crucial role in the development of both regions and the overall country.

Nonetheless, it is important to acknowledge the limitations of this study. It is not possible to contrast the findings with prior research on the effects of regional BC synchronization in IT-EMEs or with other studies in different geographical contexts, as there are no prior research endeavors with this specific focus. Additionally, while four countries were selected, and these economies are representative of IT-EMEs due to their significance, the consistency of the results should be further tested by including other economies such as Indonesia, Israel, the Philippines, Thailand, to the extent that regional-level economic activity data for a sufficiently long time period becomes available. Other potential research avenues could delve into analyzing the effects of regional synchronization on regional cycle characteristics and explore additional aspects of aggregate cycles such as duration and steepness.

Notes

1. Kim and Yim (2020) identify 19 countries with IT, with 14 of them being EMEs, including Brazil, Chile, Colombia, South Korea, the Philippines, Hungary, Indonesia, Israel, Mexico, Peru, Poland, the Czech Republic, Thailand and Turkey.
2. We chose the boundaries for these series for two reasons. Firstly, before 1985, regional data are unavailable for some of these countries. Secondly, we do not extend the series beyond 2019 to avoid potential biases introduced by the pandemic.
3. Researchers in EMEs commonly use Hodrick and Prescott (1997) filtering for regional BC (Padilla and Quintero, 2022). Additional arguments for its use include ease of implementation, resulting in cyclical residues akin to the band-pass filter without altering statistical significance (Panteladis and Tsiapa, 2014). It is also an intuitive and manageable methodology (Mejía-Reyes and Campos-Chávez, 2011; Duran, 2013, 2015).
4. Given the study's goal of identifying turning points in historical real GDP series to characterize the BC of regions and national aggregates in select EMEs, and acknowledging that comparing dating methods exceeds the article's scope, we choose Harding and Pagan's (2002) BBQ algorithm. The simplicity and transparency, along with a common criterion for BC phase identification across countries, guide our methodology selection in this research.
5. The number of rolling window periods is determined arbitrarily by the researcher, but with the aim of having a considerable number of sub-periods of an appropriate length that allows for the observation of different phases of the business cycles.
6. The number of rolling window periods is determined arbitrarily by the researcher, but with the aim of having a considerable number of sub-periods of an appropriate length that allows for the observation of different phases of the business cycles.
7. We calculate both simple averages and weighted averages. In the case of the weighted averages, we take into account the contribution of the evaluated regions' GDP to the national total. However, both types of measures do not substantially differ, so in this study, unweighted calculations were used.
8. These country dummy variables help control for unobservable and time-constant components specific to each country that may affect the dependent variables. Therefore, fixed-effects analyses are more robust than random-effects analyses in the presence of time-constant omitted variables (Wooldridge, 2010).
9. The details about the estimates, impulse responses and statistical tests used in the Panel VAR model are available upon request.
10. We excluded the services sector because, despite being composed of very diverse activities, the available information in some countries was presented in an aggregated form.

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