Business, Management and Education
ISSN 2029-7491 / eISSN 2029-6169
2020 Volume 18 Issue 1: 127–141
https://doi.org/10.3846/bme.2020.12254

BUSINESS CYCLES SYNCHRONISATIONS IN THE BALTIC COUNTRIES

Arvydas KREGŽDĖ *

Institute of Applied Mathematics, Faculty of Mathematics and Informatics, Vilnius University, Vilnius, Lithuania

Received 10 March 2020; accepted 30 March 2020

Abstract. *Purpose* – The purpose of the paper is to investigate the level of real business cycles synchronisation between the Baltic and the Nordic countries and between the Baltic countries and the euro area.

Research methodology – Wavelet analysis was employed to evaluate the level of synchronisation for different periods and time. Quarterly data from 1995 Q2 to 2019 Q4 was used.

Findings – We discover the influence of several essential events in economies of the Baltic countries on the synchronisation: accession to the EU in 2004, the introduction of the euro in the Baltic countries and some external shocks.

Research limitation – A lack of reliable long-term data from the Baltic countries does not allow performing calculation for other important financial variables.

Practical implications – Results of the research are important for forecasting and implementing flexible economic policies of the Baltic countries.

Originality/Value – Business cycles synchronisation between the Baltic countries themselves and between the Baltic countries, the Nordic countries and the euro area countries across time and various frequency dimensions was investigated for the first time.

Keywords: synchronisation, business cycle, wavelet, Baltic, Nordic, the euro area.

JEL Classification: C32, E30, E32.

Introduction

During 30 years of independence, the Baltic states were focusing their economic policy on catch up with the developed Nordic and other West European countries. One of the main indicators of the development of the country is GDP and GDP per capita. In order to converge towards the West European countries, the real GDP growth of the Baltic countries should be significantly higher.

*Corresponding author. E-mail: *arvydas.kregzde@mif.vu.lt*

During the early years of sovereignty, economic links of the Baltic countries with the Eastern countries were powerful. The task to reorient economies towards the West became crucial in the light of the Russian crisis in 1998. Increasing links to the Western countries made the Baltic countries exposed to the economic cycles of these countries. Currently, real economies and especially financial sectors of the Baltic countries are connected to the West and particularly to the Nordic countries very closely. Therefore, events in Western countries have a spillover effect on the Baltic countries. Due to the membership in the EU since 1 May 2004 and participation in the common market, the relationship of the economic cycles of the Baltic countries with the economic cycles of the EU is of great interest. Currently, after joining the Eurozone, the Baltic countries run a unanimous monetary policy and synchronisation of the real business cycle with the Eurozone countries has become crucial. Sweden and Denmark, not members of the Eurozone, are critical business partners and investments from these countries to the Baltic states are growing. Therefore, synchronisation of the economies of the Baltic countries in the light of the catch up is of great interest.

Economic cycles and synchronisation of the cycles are analysed by a number of authors. Introduction of the common currency, the euro, in 1999/2002 increased the importance of studies on financial and real cycles of economies in the Eurozone. The monetary policy of ECB is based on a prediction of economic indicators for all the countries of the Eurozone. In order to accept the right decision, which is suitable for the majority of the countries, GDP cycles should be in the same trend. Estimations of cyclical commonalities provide essential input for the conduct of monetary policy and are also relevant for macroprudential policy. Therefore, research on the business cycles of the Eurozone countries receives continuous attention. A number of mathematical models have been used for this analysis. We chose the wavelet analysis for our analysis of business cycles synchronisation. The reason for it was an intention to find changes in synchronisation not only in time but also in the frequency dimension. We had the interest to understand the length of periods of synchronised (or not synchronised) behaviours of the real economic changes.

The scientific papers analysing the Baltic GDP cycles are mostly based on the classical econometric approach. Nekhili et al. (2002) stress that widely used parametric models like the random walk with GARCH, random walk with stochastic volatility, jump-diffusion processes, etc. have been found insufficient in explicating the underlying dynamics of the financial variables across all frequency levels. Berdiev and Chang (2015) emphasize the importance of examining the strength of business cycle synchronisation by using a time-frequency framework. They demonstrate that the synchronisation of growth cycles may be high at long-run developments. In contrast, there may be a low degree of co-movement at short-run fluctuations for a particular sample period.

We contribute to the existing literature in several ways. Business cycles synchronisation between the Baltic countries themselves and between the Baltic countries, the Nordic countries and the euro area countries across time and various frequency dimensions have been investigated for the first time. The frequency dimension added enables us to discover the time when the coherence changes and to find the frequencies at which the co-movements are concentrated. In addition, we discover the influence of several essential events in economies of the Baltic countries on the synchronisation: accession to the EU in 2004, the introduction of the euro in the Baltic countries and some external shocks.

1. Literature review

Globalization or the world itself affects various aspects of economic activity. Increasing trade links, financial relations, international investments and other kinds of cooperation have an impact on the country's development. Financial markets react immediately to the events in any country and a spillover effect on the global financial market has been determined by a number of researches (e.g. Gallegati et al., 2014; Syllignakis & Kouretas, 2011; Kregzde, 2018; Adam & Merkel, 2019). Dependence of the country's output on external events is not evident, and there are different views on it. For example, Akin, 2012 studied real GDP correlations for 51 countries including 27 emerging markets for the periods of 1970–2008 and concluded that "On average, global financial integration has no significant effect on output synchronisation. However, for developed country pairs and developed and emerging market pairs, financial integration lowers business cycle synchronisation, whereas, for emerging markets, financial integration increases synchronisation". Bordo and Helbling (2011), investigated 16 industrial countries over 120 years. They stated that business synchronisation was increasing, and shocks and crises made the most significant impact on synchronisation. Artis and Okubo (2009) generally found a high level of cross-correlations for the industrial countries in the period from 1960 to 2001. Beirne (2020) stated that business cycles were partially synchronised globally. The result was based on analysis of 38 advanced and emerging economies in Latin America, Asia and Eastern Europe. Beck, 2019 investigated 43 possible determinants of business cycles synchronisation.

According to Martinez-Martin et al. (2018), after the introduction of the euro in 1999/2002, studies on the synchronisation of financial and business cycles of the Eurozone countries became a pertinent research question. Aguiar-Conraria and Soares (2011) studied business cycle synchronisation across EU-15 and EU-12 countries. Their research revealed that Germany and France were the most synchronised with the rest of the European countries. The authors used wavelet analysis in their research. A number of studies have been performed on the impact of the common currency, the euro, on the synchronisation of economies. Grigoraş and Stanciu (2016) concluded that "previous to the World Financial Crisis the European business cycle has been constantly enforced by formal or informal cohesion between EU member states, but in the post-crisis period show signs of a great disconnect, both within Europe and between Europe and the US". Montoya and de Haan (2008) investigated regional business cycles of the Eurozone countries. They indicated that on the average, regional business cycles synchronisation increased for the period of 30 years (1975–2005) for the countries. Furceri and Karras (2011) found that the EU countries were better synchronised with the EMU-wide economy in the post-EMU period than they were before the euro. Lehwald (2013) compared the pre-Euro period (1991–1998) to the Euro period (2000–2010) and discovered that co-movement of the key macroeconomic variables increased for the core Eurozone countries from the first to the second period, while it decreased for the most peripheral economies. Oman (2019) found that financial cycles were less synchronised than business cycles, and business cycle synchronisation had increased while financial cycle synchronisation had decreased in the Eurozone.

There is a number of papers studying financial cycles within the countries dimension. Scharnagl and Mandler (2019) focused on the analysis of credit and house price cycles. They revealed that these cycles were closely linked to domestic cycles in real activity, showing financial and real economic cycles as interconnected phenomena. Germany was an exception. Rünstler and Vlekke (2018) estimated trend and cyclical components in GDP, credit volumes and house prices for the U.S. and the five largest European economies. Kurowski and Rogowicz (2018) suggested that the pre-crisis period was one of the internal synchronisations between financial and output cycles across countries, while the post-crisis period had been marked by international synchronisation. Balfoussia et al. (2018) stated that GDP appeared to be subject to fluctuations at both business-cycle and medium-term frequencies, and GDP fluctuations at medium-term frequencies were strongly correlated with the cycles in credit and house prices. Miles and Vijverberg (2018) investigated changes of synchronisation since the euro adoption. They made a conclusion that adopting the common currency might increase synchronisation for the nations ready for the common currency, but it could lower synchronisation for the nations that were far from synchronised before the monetary unification. Loannou (2018) analysed features of credit, housing price, and output cycles in Lithuania during 1995–2017.

A number of authors analysed synchronisation of Central and Eastern Europe and the Eurozone countries. Darvas and Szapary (2008) analysed synchronisation of business cycles between new and old EU member states. They discovered that Hungary, Poland and Slovenia had achieved a high degree of synchronisation for GDP, industry and exports, but not for consumption and services. Njegić et al. (2017) indicated that the business cycles of CEEC's were generally synchronised with the EU-15 business cycles. In contrast, distinct differences existed before, during, and after the financial crisis (2008–2009) and during the European sovereign debt crisis (2010–2011). They demonstrated that powerful business cycles synchronisation occurred in almost all CEECs during crisis periods and at higher wavelet scales, while only moderate synchronisation was recorded in relatively tranquil periods at higher frequencies. Hanus and Vacha (2018) indicated an increasing co-movement of the Visegrad Four countries with the European Union after the countries had accessed the European Union. Heller and Warzala (2019) compared the major economic indicators of relatively new EU member states who had joined the Eurozone with the Polish macroeconomic indicators. They discovered that macroeconomic indicators of stabilization could be observed after their accession to the Eurozone.

A few papers investigated synchronisation of business cycles focusing on the Baltic and EU countries. Valentinaitė and Snieška (2005), revealed that symmetry among the business cycles in the Baltic States and other EU countries was low, while Lithuania had the highest correlation with the EU 'core' and the entire Eurozone. Di Giorgio (2016) noted that the indications of business cycle synchronisation between CEECs (Central and Eastern European countries) were quite high in the recession regime, but lower in normal and high growth regimes. Hegerty (2017) investigated common cycles and Baltic-Nordic economic integration. His key result revealed that each of the Baltic countries behaved differently from one another. While regional differences were quite considerable, they made it harder to describe the Baltic region as a single unit.

2. Methodology

We apply wavelet transform analysis for the time series of quarterly GDP changes. Wavelet transform analysis uses little wavelike functions known as wavelets (see Addison, 2017). A family of wavelets $\psi_{\tau,s}(t)$ is defined by using the basic wavelet functions $\psi(t)$, called a mother wavelet, in the following way:

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right),$$

where, variable *s* (dilation parameter) is the scale and τ (translation parameter) is the time. The scale s is proportional to the inverse of the frequency.

The continuous wavelet transformation (CWT) of a time series $x(t)$ is defined through the following formula:

$$W_x(\tau,s) = \int_{-\infty}^{\infty} x(t)\psi^*_{\tau,s}(t)dt,$$

where ψ^* denotes the complex conjugate of ψ. We face discreet time series $x(t)$, therefore for t = 1,…N CWT is calculated as follows:

$$W_x(\tau,s) = \sum_{t=1}^{N} x(t)\psi^*_{\tau,s}(t).$$

CWT is used to transform the initial time series x(t) into another representation, separating time τ and scale (frequency) *s*.

The cross-wavelet spectrum of two-time series x(t) and y(t) with wavelet transforms $W_x(\tau,s)$ and $W_y(\tau,s)$ is defined as $W_{xy}(\tau,s) = W_x(\tau,s)W_y^*(\tau,s)$. It captures the covariance between two-time series in the time-frequency space.

We define the wavelet transformation squared coherence coefficient (WTC) or simply coherency of two-time series *x(t)* and *y(t)* in the way as it is described by Torrence & Compo, 1998 by the following formula:

$$R^2(\tau,s) = \frac{|\,S\left(s^{-1}W_{xy}(\tau,s)\right)|^2}{S\left(s^{-1}|\,W_x(\tau,s)|^2\right)S\left(s^{-1}|\,W_y(\tau,s)|^2\right)},$$

where S(•) is a smoothed (see Torrence & Compo, 1998) operator and s is the wavelet scale. It allows us to estimate the presence of a simple cause-effect relationship between the phenomena recorded in the time series. Coherency is the analogy of the correlation coefficient. A value of the coherence close to zero shows a weak correlation, while values close to one indicate a strong correlation.

Noteworthy, $R^2(\tau, s)$ is always nonnegative; therefore, positive and negative correlation could have the same value. Following Torrence and Compo (1998), we introduce the coherence phase difference, which is defined as follows:

$$\varphi_{x,y}(\tau,s) = tan^{-1}\left\{\frac{Im\left[S\left(s^{-1}W_{xy}(\tau,s)\right)\right]}{Re\left[S\left(s^{-1}W_{xy}(\tau,s)\right)\right]}\right\},$$

where *Re* and *Im* are real and imaginary parts of the complex number. The sign of phase difference together with the sign of *Im* indicates whether the series are positively or negatively correlated.

We use a complex Morlet as mother wavelet, which is defined as follows:

$$\psi(t) = \pi^{-\frac{1}{4}} e^{i\omega_0 t} e^{-\frac{t^2}{2}}.$$

This way, the Morlet wavelet mother function consists of the multiplier $e^{i\omega_0 t} = \cos(\omega_0 t) + i\sin(\omega_0 t)$ which is a periodic function with a period of $\frac{2\pi}{\omega_0}$ and the Gaussian envelope $e^{-\frac{t^2}{2}}$ Which tends to zero as $t \to \pm\infty$. We fix $\omega_0 = 6$, because it provides for a good balance of time and frequency (see Grinsted et al., 2004).

3. Research findings

3.1. Descriptive statistics

We use Eurostat data for seasonally and calendar adjusted quarterly GDP from the first quarter (Q1) of 1995 to the fourth quarter (Q4) of 2019. The data is recalculated for real GDP growth from Q2 of 1995 to Q4 of 2019. The starting date of 1995 is taken based on the fact that the Baltic data is reliable from this year only.

During the period from 1995 Q2 to 2019 Q4 real GDP growth was variable from country to country. The data on GDP growth is presented in Table 1.

Table 1. Change of real GDP from 1995 Q2 to 2019 Q4

	Estonia	Latvia	Lithuania	Eurozone	Denmark	Finland	Sweden
	164%	153%	172%	49%	48%	71%	82%
Annual average	6.7%	6.4%	6.9%	2.7%	2.6%	3.7%	4.1%

As we see from Table 1, the average GDP growth rate of the Baltic countries is about two times higher than that of Finland and Sweden and almost three times higher than the rate of the eurozone and Denmark. The higher growth rate in the Baltic countries is the consequence of a significantly lower GDP in 1995 and a catch-up process during the later years. GDP growth rate has not been uniform for all the countries. A standard deviation of the quarterly growth of real GDP is presented in Table 2.

Table 2. Standard deviation of quarterly GDP growth.

Estonia	Latvia	Lithuania	Eurozone	Denmark	Finland	Sweden
1.9%	2.2%	1.8%	0.5%	0.8%	1.2%	0.8%

Table 2 shows that volatility of the quarterly GDP growth in the Baltic countries is almost twice as high as that in the rest of the countries. One of the main reasons thereof is described by Almansour et al. (2015). They note that emerging markets are more sensitive to external shocks than developed markets are. In addition to the influence from outside, during the period of consideration, the Baltic countries faced some political challenges and important

changes in their monetary policy. First of all, the Baltic countries joined the EU in 2004 and introduced the euro (Estonia in 2011, Latvia in 2014 and Lithuania in 2015). Before joining the Eurozone, Lithuania re-pegged its national currency from the US dollar in 2002 and Latvia re-pegged its national currency from SDR basket to the euro in 2004. The changes in political and economic policy had an impact on the economy and real GDP growth as well.

3.2. Interconnection of GDP growth in the Baltic countries

Because the growth rate is changing in time and the length of cycles is different, we investigate the GDP growth rate in time and frequency scales. The wavelet approach is a very suitable instrument for this purpose.

We convert frequency into time units (years), ranging from the highest frequency, which corresponds to the period of 0.25 years to the lowest frequency corresponding to the period of 5 years. The minimal scale of 0.25 corresponds to 0.25 years or a quarter, and the maximum scale corresponds to 5 years or 20 quarters. The phase differences for the coherences greater than 0.5 are illustrated by arrows. The arrow in the 1 or 4 (2 or 3) quadrants indicates that the series is positively (negatively) correlated.

Figure 1 presents coherence (WTC) of the GDP growth rate in the Baltic countries. The x-axis refers to time, and the y-axis refers to period or frequency. Light colour shows high coherence between the variables and dark colour represents low coherence.

When looking at the time scales in Figure 1, we can find an obvious commonality between the Baltic GDP growth rates (the white colour is dominant). The interdependence of the economies is exceptionally high for Lithuania and Estonia. For the periods exceeding two

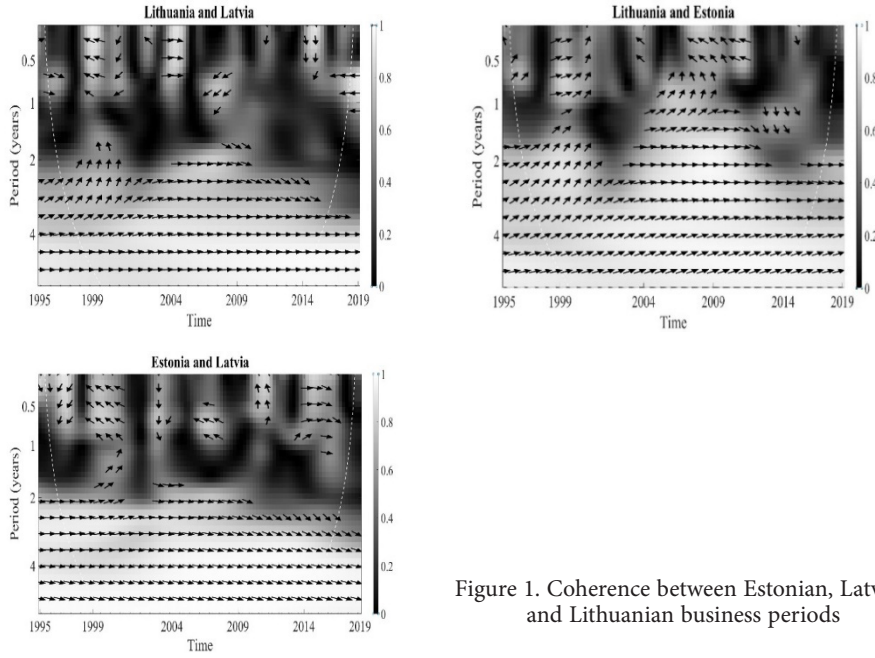

Figure 1. Coherence between Estonian, Latvian and Lithuanian business periods

years, the coherence between Lithuania and Estonia is very high during all the time intervals under consideration, except for the years of 2001–2003 and 2012–2016. The coherence of GDP growth is increased for the highest frequencies (periods of 0.25 years) during 1997–1999 and 2008–2010. The first period coincides with the Russian crisis, which has resulted in the Russian government and the Russian Central Bank devaluing the national currency and defaulting on its debt in 1998. The second period is related to the global financial crisis, which started in the USA and then spread across the world later on (hereinafter the World Financial Crisis). The period of the financial crisis in the USA started in December 2007 and lasted until June 2009, as defined by the National Bureau of Economic Research (NBER). The arrows indicate that correlation between Lithuania and Estonia for the periods of 0.25 and 0.5 years is negative during 2008–2012.

The behaviour of Latvian GDP growth is slightly different from the situation in Lithuania and Estonia. Figure 1 shows that coherence between Latvian and Estonian as well as Latvian and Lithuanian GDP growth is different from the coherence of Lithuania and Estonia. We do not see any higher synchronisation during the crisis period as it was in the case of Lithuania and Estonia. Synchronisation appears to be slightly increased only for the periods exceeding two years and is high for the periods exceeding 3.5 years. The different behaviour is also mentioned by Njegić et al. (2017). They raise a hypothesis that Latvian economy has a higher resistance to external systematic shocks. Our view is that this hypothesis is valid in the case of the Russian crisis. Our analysis reveals that correlation between Latvia and Lithuania as well as between Latvia and Estonia is negative for short periods during the Russian crisis (arrows appear in the second quadrant). In our opinion, Latvian economy has faced even a higher effect of the World Financial Crisis and thus the cycle to rebound is longer. Therefore, GDP cycles in Latvia are less synchronised with the other Baltic countries during the crisis.

Noteworthy, decreased commonalities are observed between the Baltic countries for the periods of 2 years and longer during 2012–2016. The above can be explained by the fact that economies react quickly to a crisis, yet recovery cycles are different and synchronisation during the recovery period is weak. We do not find any impact of the accession to the EU or to the Eurozone on synchronisation between the Baltic countries. The reason for it can be the same date as the accession to the EU for all the Baltic countries and close dates for joining the Eurozone.

3.3. Interconnection between Lithuania and the Nordic countries and between Lithuania and the euro area

Figure 2 presents coherence (WTC) of the GDP growth rate of Lithuania and the Nordic countries and Lithuania and the euro area.

When looking at the time scales in Figure 2, we can find that similarities between Lithuanian and Finnish business cycles have changed dramatically after Lithuania had joined the EU. The business cycles are highly synchronised for business periods exceeding 2 years. During the World Financial Crisis, the interdependence of the growth cycles of the economies became close even for a very short period exceeding 0.25 year. Starting from 2009 to 2014, coherence between Lithuanian and Finnish economies remains high for the periods exceeding two years. For shorter periods, coherence is not high and returns to the level of 2004.

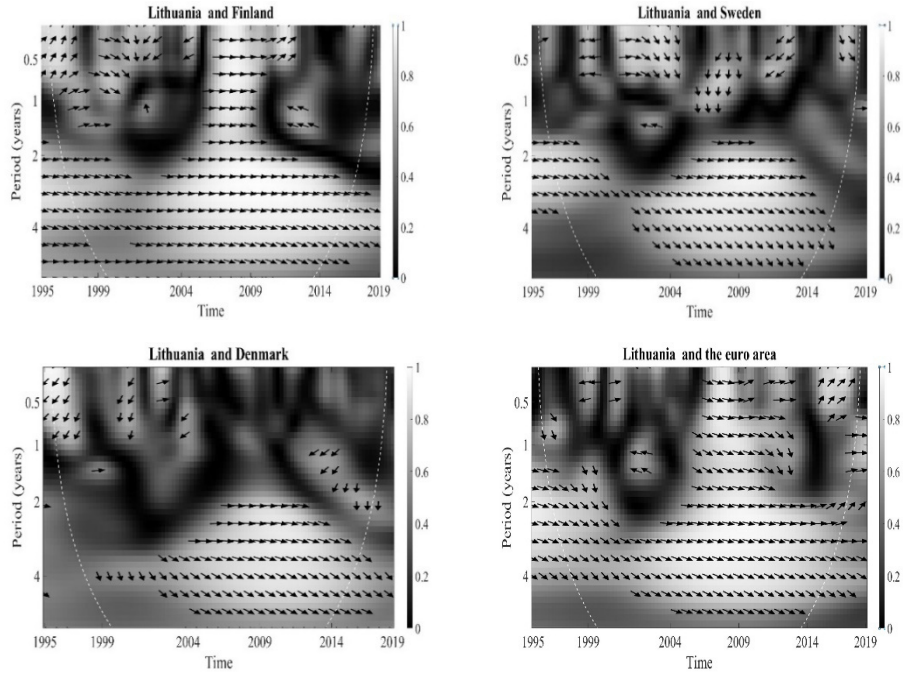

Figure 2. Coherence between business periods of Lithuania and Finland, Sweden, Denmark and the euro area

The Pierson correlation coefficient between Lithuanian and Finish GDP growth is equal to 0.65, which is higher than the correlation coefficients between Lithuanian and Swedish and Lithuanian and Danish GDP growths.

Coherence between the business cycles of Lithuania and the euro area are similar to those between Lithuania and Finland. Coherence is lower between Lithuania and Sweden and between Lithuania and Denmark. For the periods shorter than 3 years, coherences between Lithuanian and Swedish as well as Lithuanian and Danish business cycles remain weak, except for the years during the World Financial Crisis. Noteworthy, the effect of the World Financial Crisis is not so deeply reflected as in the case of Finland and the euro area. The Pierson correlation coefficient between Lithuanian and Swedish GDP growth is equal to 0.31, which is twice lower than the one between Lithuania and Finland.

3.4. Interconnection between Estonia and the Nordic countries and between Estonia and the euro area

Figure 3 presents coherence of the GDP growth rate of Estonia and the Nordic countries and of Estonia and the euro area region.

From Figure 3 we do not see any essential difference of interdependence between Lithuania and Finland and between Estonia and Finland, except that the business cycle during the World Financial Crisis is very close for Lithuania and Finland even for short periods.

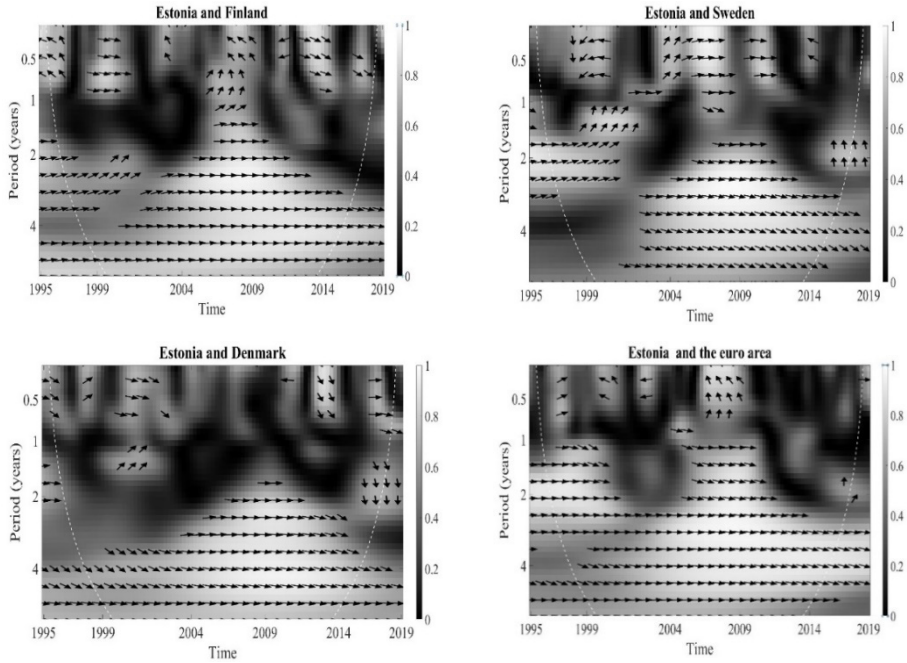

Figure 3. Coherence between business periods of Estonia and Finland, Sweden, Denmark and the euro area

Noteworthy, Estonia was not affected by the European sovereign debt crisis in 2010, which to some extent had an impact on Lithuania and Finland, and the correlation between Estonia and Finland for short periods around 2010 is negative (arrows appear in the second quadrant). For Estonia, similarly, as for Lithuania, interdependence with the Nordic countries and the euro area gradually decreased from 2010 to 2014 in the periods from 2 to 3–3.5 years. It can be explained by the fact that recovery from the World Financial Crisis depends on individual circumstances in the country, which have reduced interdependence. For the periods exceeding four years, coherence between growth rate cycles remains high after the Crisis. Coherence between the GDP growth of Estonia and Sweden as well as of Estonia and Denmark is higher than that of Lithuania.

3.5. Interconnection between Latvia and the Nordic countries and between Latvia and the euro area

Figure 4 presents coherence of the GDP growth rate of Latvia and the Nordic countries and Latvia and the euro area.

Our calculations reveal that Latvian synchronisation with the other Nordic countries is not as high as Lithuanian and Estonian. When looking at Figure four, we see that synchronisation of Latvian GDP growth with the euro area is a bit higher than that with the Nordic countries, but remains low. Noteworthy, even during the World Financial Crisis, synchronisation of Latvia with other countries in the periods shorter than two years is very low.

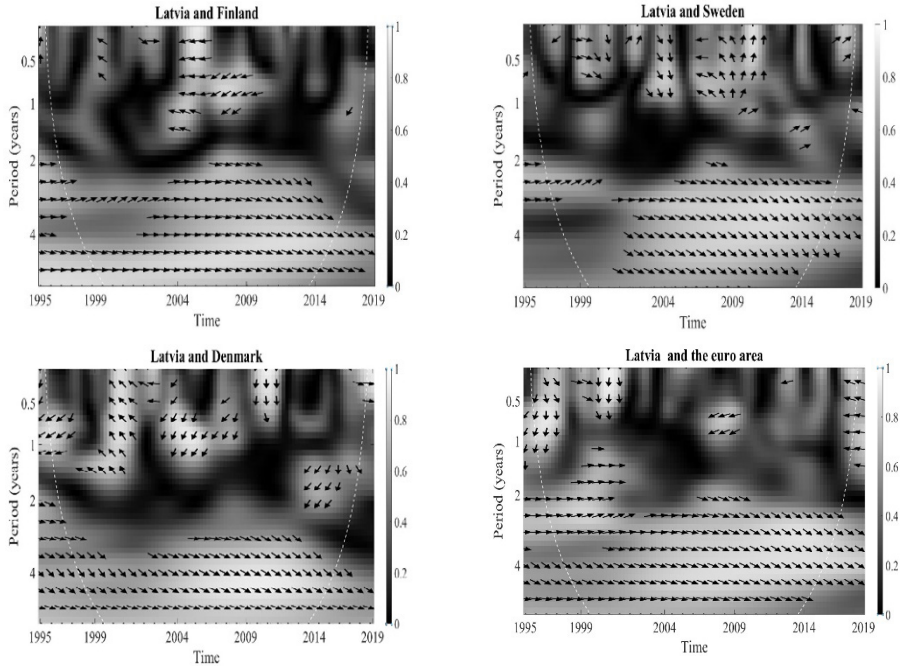

Figure 4. Coherence between business periods of Latvia and Finland, Sweden, Denmark and the euro area.

The above indicates that the Latvian economy is somewhat dependent on internal conditions and is out of synchronisation with the other countries. The difference of Latvia from the other Baltic countries is also noted by Hegerty (2017) and Njegić et al. (2017). Nonetheless, we see a slightly positive impact of the accession to the EU on synchronisation with the Nordic countries and the euro area. For Lithuania and Estonia, the impact of the accession to the EU is far more significant. Latvian economy is more related to Finnish economy than to Swedish and Danish economies, but not as strongly as Estonian and Lithuanian economies are related. The synchronisation of the Latvian economy with the Danish economy is quite low.

3.6. Main outcomes from the analysis

There is an apparent commonality between Lithuanian, Latvian and Estonian GDP growth rates. The interdependence of business cycles is exceptionally high for Lithuania and Estonia. For the periods exceeding two years, the interconnection between GDP growth of Lithuania and Estonia is very high, except for the years of 2001–2003 and 2012–2016. The coherence of GDP growth increased for the highest frequencies (periods of 0.25 years) during 1997–1999 and 2008–2010, which coincide with the Russian crisis and the World Financial Crisis. Commonalities of GDP growth between Lithuania and Latvia as well as between Lithuania and Estonia are lower. We do not see any strong explicit synchronic reaction to the crises for these economies, as it is in the case of Lithuania and Estonia. The synchronisation is slightly increased only for the periods exceeding two years. Noteworthy, decreased commonalities

are observed between Lithuania and Latvia as well as Estonia and Latvia for the periods of 2 years and longer during 2010–2016. The above can be explained by the fact that economies react quickly to a crisis, yet recovery cycles are different and synchronisation during the recovery period is weak. We do not find any impact of the accession to the EU or to the Eurozone on synchronisation between the Baltic countries. The reason for it can be the same date as the accession to the EU for all the Baltic countries and close dates for joining the Eurozone.

The picture of commonality of the Lithuanian GDP growth rate and that of the Nordic countries and the euro area is different. We see a significant impact of the accession to the European Union in 2004. Before the accession to the EU, synchronisation between Lithuania and Sweden and between Lithuania and Denmark is almost absent even for more extended periods (4–5 years). After the accession, commonality of the GDP growth cycles becomes higher. During the World Financial Crisis, synchronisation becomes strong for the periods shorter than two years. An unusually high level of synchronisation is observed between Lithuania and Finland and between Lithuania and the euro area countries during the World Financial Crisis. Commonality is observed even between the cycles in very short periods (0.25 years). After the crisis, Lithuanian and Finish GDP growth rates remain synchronised for the periods exceeding two years. Commonalities between Lithuania and Denmark as well as between Lithuania and Sweden decrease after the crisis. Weak synchronisation reached its peak in 2014. Later on, the synchronisation becomes higher. The above can be explained by different policies and circumstances to overcome consequences of the crisis. Noteworthy, the Russian crisis has increased synchronisation of Lithuanian GDP growth with the Nordic and the euro area GDP growths. This is particularly evident for Finland and the euro area.

The synchronisation of Estonia with the Nordic region and the euro area countries is similar to that of Lithuania. Interestingly, Estonian and Finnish synchronisation is lower than Lithuanian and Finish synchronisation despite very strong relations between Estonia and Finland. We observe that during the World Financial Crisis and afterwards, synchronisation between Lithuania and Finland is stronger than between Estonia and Finland. The reason for the above can be the fact that Estonia was not affected by the European sovereign debt crisis in 2010, which to some extent had an impact on Lithuania and Finland. Coherence between the GDP growth of Estonia and Sweden as well as of Estonia and Denmark is higher than that of Lithuania.

Our calculations reveal that Latvian synchronisation with the other Nordic countries is not as high as Lithuanian and Estonian. The highest synchronisation of Latvian GDP growth is observed with the euro area countries. Noteworthy, even during the World Financial Crisis, synchronisation of Latvia with other countries in the periods shorter than 2 years is very low. The above indicates that Latvian output is rather dependent on internal conditions, and the level of synchronisation with the other countries is low.

We do not see any impact of the introduction of the euro on the synchronisation of business cycles between the Baltic countries and between the Baltic and the Nordic countries. Accession to the EU has had no impact on the synchronisation of business cycles between the Baltic countries. Nevertheless, it has had a tremendous impact on synchronisation between the Baltic countries and the Nordic countries and between the Baltic countries and the euro area. Business cycles during the period of recovery from the World Financial Crisis are very different for all the countries.

Conclusions

Business cycles synchronisation between the Baltic countries themselves and between the Baltic countries, the Nordic countries and the euro area countries across time and various frequency dimensions was investigated for the first time. The five main findings were discovered in the current study. First, the study revealed no impact of the introduction of the euro on the synchronisation of business cycles between the Baltic countries themselves, between the Baltic countries and the Nordic countries, and between the Baltic countries and the euro area. Second, accession to the EU had no impact on the synchronisation of business cycles between the Baltic countries themselves. However, it had a significant impact on synchronisation between the Baltic countries and the Nordic countries and between the Baltic countries and the euro area. Third, synchronisation of the Baltic countries, the Nordic countries and the euro area increased during the World Financial Crisis. In contrast, synchronisation between the Baltic countries themselves increased to a lesser extent. Fourth, business cycles in the period of recovery from the World Financial Crisis were very different for all the countries. Fifth, the Latvian synchronisation with the other countries was not as high as the Lithuanian and the Estonian.

A lack of reliable long data from the Baltic countries does not allow performing a calculation on synchronisation for other important financial variables. Calculations were made by applying Morlet wavelet functions as the mother wavelet, as used by researches in analysing business cycles. Performing analysis with some other mother functions would be useful for further research.

References

Adam, K., & Merkel, S. (2019). *Stock price cycle and business cycle* (ECB Working Paper No. 2316). European Central Bank.

Addison, P. S. (2017). *The illustrated wavelet transform handbook: Introductory theory and applications in science, engineering, medicine and finance*. CRC Press.

Aguiar-Conraria, L., & Soares, M. J. (2011). Business cycle synchronisation and the Euro: A wavelet analysis. *Journal of Macroeconomics*, *33*(3), 477–489. https://doi.org/10.1016/j.jmacro.2011.02.005

Akin, C. (2012). *Multiple determinants of business cycle synchronisation*. https://doi.org/10.2139/ssrn.1022648

Almansour, A., Aqib, A., Bluedorn, J., & Duttagupta, R. (2015). How vulnerable are emerging markets to external shocks. *Journal of Policy Modelling*, *37*(3), 460–483. https://doi.org/10.1016/j.jpolmod.2015.03.009

Artis, M., & Okubo, T. (2009). Globalization and business cycle transmission. *The North American Journal of Economics and Finance*, *20*(2), 91–99. https://doi.org/10.1016/j.najef.2009.03.002

Balfoussia, H., Burlon, L., Buss, G., Comunale, M., De Backer, B., Dewachter, H., Guarda, P., Haavio, M., Hindrayanto, I., Iskrev, N. V., Jaccard, I., Kulikov, D., Kunovac, D., Lenarcic, C., Lequien, M., Lozej, M., Mandler, M., Papageorgiou, D., Pedersen, J., Perez-Quiros, G., Rannenberg, A., Rots, E., Rünstler, G., Scharnagl, M., & Wel, P. (2018). *Real and financial cycles in EU Countries: stylised facts and modelling implications* (ECB Occasional Paper No. 205). European Central Bank.

Beck, K. (2019). What drives business cycle synchronisation? BMA results from the European Union. *Baltic Journal of Economics*, *19*(2), 248–275. https://doi.org/10.1080/1406099X.2019.1652393

Beirne, J. (2020). Financial cycles in asset market and regions. *Economic Modelling* https://doi.org/10.1016/j.econmod.2020.01.015

Berdiev, A. N., & Chang, C. P. (2015). Business cycle synchronisation in Asia-Pacific: New evidence from wavelet analysis. *Journal of Asian Economics*, *37*, 20–33. https://doi.org/10.1016/j.asieco.2015.01.004

Bordo, M., & Helbling, T. (2011). International business cycle synchronisation in historical perspective. *The Manchester School*, *79*(2), 208–238. https://doi.org/10.1111/j.1467-9957.2010.02236.x

Darvas, Z., & Szapáry, G. (2008). Business cycle synchronisation in the enlarged EU. *Open Economies Review*, *19*(1), 1–19. https://doi.org/10.1007/s11079-007-9027-7

Di Giorgio, C. (2016). Business cycle synchronisation of CEECs with the Euro Area: Regime switching approach. *Journal of Common Market Studies*, *54*(2), 284–300. https://doi.org/10.1111/jcms.12302

Furceri, D., & Karras, G. (2011). Business-cycle synchronisation in the EMU. *Applied Economics*, *40* (12), 1491–1501. https://doi.org/10.1080/00036840600843954

Gallegati, M., Ramsey, J., & Semmler, W. (2014). Interest rate spreads and output: A time scale decomposition analysis using wavelets. *Computational Statistics & Data Analysis*, *76*(C), 283–290. https://doi.org/10.1016/j.csda.2014.02.024

Grigoraș, V., & Stanciu, I. E. (2016). New evidence on the (de)synchronisation of business cycles: Reshaping the European business cycle. *International Economics*, *147*, 27–52. https://doi.org/10.1016/j.inteco.2016.03.002

Grinsted, A., Moore, J., & Jevrejeva, S. (2004). Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Processes in Geophysics*, 11(5/6), 561–566. https://doi.org/10.5194/npg-11-561-2004

Hanus, L., & Vacha, L. (2018). Growth cycle synchronisation of the Visegrad Four and the European Union. *Empirical Economics*, 1–17.

Hegerty, S. W. (2017). Common cycles and Baltic-Nordic economic integration. *Economics and Business*, *31*(1), 70–81. https://doi.org/10.1515/eb-2017-0019

Heller, J., & Warzala, R. (2019). The effects of entering the Eurozone on other Central and Eastern European Countries in relation to Poland. *Journal of Competitiveness*, *11*(1), 5–21. https://doi.org/10.7441/joc.2019.01.01

Kregzde, A. (2018). Wavelets analysis of the Baltic equity market: Risk and co-movement with the European market. *Engineering Economics*, *29*(5), 507–515. https://doi.org/10.5755/j01.ee.29.5.19330

Kurowski, L., & Rogowicz, K. (2018). Are business and credit cycles synchronised internally or externally? *Economic Modelling*, *74*(C), 124–141. https://doi.org/10.1016/j.econmod.2018.05.009

Loannou, L. (2018). *Housing price, credit, and output cycles: How domestic and external shocks impact Lithuania's credit* (IMF working papers 2018/160). International Monetary Fund. https://doi.org/10.5089/9781484367513.001

Lehwald, S. (2013). Has the Euro changed business cycle synchronisation? Evidence from the core and the periphery. *Empirica*, *40*(4), 655–684. https://doi.org/10.1007/s10663-012-9205-8

Martinez-Martin, J., Saiz, L., & Stoevsky, G. (2018). Growth synchronisation in euro area countries. In *Economic Bulletin Boxes* (vol. 5). European Central Bank.

Miles, W. & Vijverberg, C. C. (2018). Did the euro common currency increase or decrease business cycle synchronisation for its member countries? *Economica*, *85*(339), 558–580. https://doi.org/10.1111/ecca.12201

Montoya, L. A., & de Haan, D. (2008). Regional business cycle synchronisation in Europe? *International Economics and Economic Policy*, *5*(1–2), 123–137. https://doi.org/10.1007/s10368-008-0106-z

Nekhili, R., Aslihan, A.-S., & Gençay, R. (2002). Exploring exchange rate returns at different time horizons. *Physica A*, *313*, 671–682. https://doi.org/10.1016/S0378-4371(02)00986-X

Njegić, J., Živkov, D., & Damnjanović, J. (2017). Business cycles synchronisation between EU-15 and selected Eastern European Countries – The wavelet coherence approach. *Acta Oeconomica*, *67*(4), 539–556. https://doi.org/10.1556/032.2017.67.4.3

Oman, W. (2019). The synchronisation of business cycles and financial cycles in the euro area. *International Journal of Central Banking*, *15*(1), 327–362.

Rünstler, G., & Vlekke, M. (2018). Business, housing and credit cycles. *Journal of Applied Econometrics*, *33*(2), 212–226. https://doi.org/10.1002/jae.2604

Scharnagl, M., & Mandler, M. (2019). Real and financial cycles in Euro Area economies: Results from wavelet analysis. *Journal of Economics and Statistics*, *239*(5–6), 895–916. https://doi.org/10.1515/jbnst-2019-0035

Syllignakis, M. N., & Kouretas, G. P. (2011). Dynamic correlation analysis of financial contagion: Evidence from the Central and Eastern European markets. *International Review of Economics and Finance*, (20), 717–732. https://doi.org/10.1016/j.iref.2011.01.006

Torrence, C., & Compo, G. (1998). A practical guide to wavelet analysis. *Bulletin of the American Meteorological Society*, (79), 61–78. https://doi.org/10.1175/1520-0477(1998)079<0061:APGTWA>2.0.CO;2

Valentinaitė, M., & Snieška, V. (2005). Baltic States business cycle symmetry: Shock correlation approach. *Engineering Economics*, *44*(4), 24–30.