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Common Baltic-Nordic business cycles: Correlation- versus Markov-switching approaches

Scott W. Hegerty

ABSTRACT

With strong historical ties, and economic linkages that have continued to grow after the fall of the Soviet Union, the Baltic and Nordic regions form a unique economic space. How interconnected are these regions, both to each other and to the rest of the world? Greater connections can help forecast future economic linkages—and also help assess the strength of the Euro as a common currency. This study applies two methods of business-cycle analysis (cross-correlations and Markov-switching approaches) to seven countries in these regions. Both methods find evidence of a single Baltic common cycle for both output and consumption, while a Nordic cycle exists only for output, and there is no single common Baltic-Nordic cycle. Tests of correlation and concordance show there to be relatively strong connections with Germany, the U.S., and Russia—with Nordic-Baltic linkages also quire strong—but that the specific results vary by the method used

KEY WORDS: Baltic region, Nordic region, business cycles, cross-correlations, Markov-switching

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1. Introduction

As Northern European countries that have been members of the European Union for more than a decade, the Baltic nations of Estonia, Latvia, and Lithuania have enjoyed growing trade with their Western neighbors and increasing global economic integration. At the same time, they maintain trade and financial linkages with Russia. Besides the major economic powers to the east and in the EU core, however, the Baltic republics have long enjoyed strong historical, cultural, and

Correspondence concerning this article should be addressed to: **Scott W. Hegerty,** Department of Economics, Northeastern Illinois University, 5500 N St Louis Ave, Chicago, IL 60625. E-mail: s-hegerty@neiu.edu economic ties with the "Nordic" countries along the Baltic Sea. This common history goes back at least as far as the maritime Hanseatic League the expanded to the Baltic territories in the 13th century, followed by incorporation of parts into the Swedish empire in the 16th century. In the modern, post-Soviet era, foreign investment has flowed inward, in particular from Sweden (and Finland, in Estonia's case). It is possible that these economic ties, in particular, may be in some ways stronger than linkages with Germany, Russia, or even the global economy. This may have implications for the stability Eurozone. As Mundell (1961) pointed out, common currency areas must exhibit similar economic behavior for

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a single monetary policy to be effective. Strong linkages between Euro and non-Euro countries might make such a policy unfeasible.

It is this proposition that this paper seeks to test. Applying two statistical methods to isolate the business cycles of the countries of the region and their major neighbors, we then look for common cycles in the Baltics, the Nordic region, and the combined group. We then examine the degree of cyclical co-movements between individual countries and their respective regions, and each region each other and with major partners. This allows us to compare which linkages are the strongest. Overall, we find that the Baltics enjoy common output and consumption cycles, while the four Nordic countries share only a common output cycle, and there is no single joint "Baltic-Nordic" output or consumption cycle. While interconnections are often strongest with Germany or the United States (as a proxy for global factors), specific findings differ depending on the test that is used.

A number of studies in the literature examine business-cycle comovements and their underlying determinants. Many of these were conducted before the onset of the 2008 global financial crisis. Some, like Imbs (2004), focus on the determinants of integration, such as increasing financial linkages among countries. Others conduct empirical tests for specific regions. While Western Europe receives a large share of attention, those studies that examine CEE countries sometimes exclude the Baltics. Artis, Fidrmuc and Scharler (2008), for example, include only Estonia alongside five Central European countries over the period from 1995-2004, calculating contemporaneous correlations among business cycles.

After the 2004 accession of 10 CEE countries to the European Union, the number of studies examining these countries' degree of interconnection to the "core" EU members increased. Darvas and Szapáry (2008), for example, use a dynamic factor model to capture a "common factor" in the region's business cycles and calculate correlations among business-cycle pairs. This study finds little synchronization between the Baltic group and Western Europe. Fadejeva and Melihovs (2008), on the other hand, calculate a common factor for Baltic and European growth rates. Hegerty (2010), mentioned below, finds strong evidence of a Baltic economic region, using data that end in early 2008. Other literature goes into further detail. (See, for example, Babetskii, 2005; Benczúr & Rátfai, 2005; Fidrmuc & Korhonen, 2006; Frankel & Rose, 1999; Hakura, 2009; Horvath & Ratfai, 2004; Inagaki, 2006; Furceri & Karras, 2008. For more on international spillovers, see Bayoumi & Swiston, 2009; Buch, Doepke, & Pierdzioch, 2005; Rafiq, 2011). While these previous studies often arrive at mixed results, we expect that additional years' worth of data, spanning the pre- and post-crisis periods, will allow us to approach the issue with additional clarity.

This study makes use of two methods of determining business cycles using time series data. The first, which filters the data using a variety of methods (the best-known of which is the Hodrick-Prescott filter), was introduced by Backus, Kehoe and Kydland (1994). Hegerty (2010) applies this method using quarterly GDP data and concludes that the three Baltic countries form an integrated region within which connections are stronger than they are with partner countries. He does not, however, include any Nordic countries in his analysis. In fact, there are few specific analyses of the Nordic region using this type of method.

The use of the Hodrick-Prescott filter has been criticized for its suboptimal statistical properties (See Hamilton, 2017, for example, who notes that this filter can generate "spurious" dynamic relations that are unrelated to the underlying time series). This has led to the increasing use of alternative filtering methods, such as those of Baxter and King (1999) and of Christiano and Fitzgerald (1999). In addition, Markovswitching models, which incorporate a change in state between a high-growth and a low-growth regime, have been growing in popularity. Introduced by Hamilton (1989), this method has been applied to the CEE region to some extent. The Baltic and Nordic regions, however, are often omitted. Jiménez-Rodríguez, Morales-Zumaquero and Égert (2013) examine five CEE and eight Western European countries from 1995 to 2011, finding a high degree of synchronization in this subregion. Di Giorgio (2016) examines seven CEE countries from 1993 to 2014, including Latvia and Lithuania, but not Estonia, because the country joined the Euro during the study period. The study finds that Central Europe demonstrates the highest degree of business-cycle synchronization, particularly in the cases of Hungary and Poland, and more often during recessionary periods. While Aastveit, Jore and Ravazzolo (2016) focus entirely on the case of Finland, the rest of the Nordic region does not receive similar attention in the literature.

The purpose of this study, then, is to focus entirely on this under-analyzed part of the world, both for individual countries and as common regions. We find diverging patterns that show each country to exhibit its own unique characteristics, while at the same time uncovering common cycles that are interlinked both across Europe and with the world. This paper proceeds as follows: Section II explains the econometric methodology. Section III presents the results. Section IV concludes.

2. Methodology

For this study, we use quarterly data from the International Financial Statistics (IFS) for four Nordic and three Baltic countries, as well as the "partner" countries of the United States (a proxy for the global economy), Germany, and Russia. The data span from 1995q1 to 2014q4. Real GDP is calculated from nominal using the GDP deflator, and real consumption using the Consumer Price Index. Domestic currencies are converted to Euros where necessary, and in one case (Latvian consumption) the Euro transition created an "outlier" data point that was smoothed by taking the average of the two surrounding values. The natural logarithms of these series are then seasonally adjusted using the Census-X12 method. In all, we have 20 time series.

Using these series, we first select an appropriate filter to remove the cycles from the trend series. In this "traditional" approach, we choose from three: those of Hodrick and Prescott (1997), Baxter and King (1999), and Christiano and Fitzgerald (1999), which will be referred to as *HP*, *BK*, and *CF*, respectively. We extract each type of filtered cycle from our output and consumption series, and for each, we compare their timeseries properties. Since, for the most part, the members of each trio are highly correlated with one another, we choose the Christiano-Fitzgerald method because recent studies in the literature prefer this method over the Hodrick-Prescott filter, and because it retains more observations at the beginning and the end of the resulting series than does the Baxter-King filter. With one output and one consumption cycle for each of our ten countries, we next test for and extract their common component(s) for the Baltic and Nordic regional groups. We also do this for the combined Nordic-Baltic region. We generate combined regional series using Principal Components Analysis (PCA), which extracts the component(s) of the cycles that contribute the majority of their common variance. Following this well-known procedure, we create principal components in those cases where the resulting eigenvalue is greater than one, labeling each a regional output or consumption cycle.

We then calculate cross-correlation functions (CCFs) for various pairs of individual countries and regions. Because 10 countries, plus numerous regional cycles, allows for an impossibly large number of pairs, we take only a cursory look at connections between individual countries and their respective region. The majority of our analysis is between regions and other regions or with each of the three partner economies.

Following Hegerty (2010), the CCF is calculated as follows, with a maximum of -k = 4 lags and k = 4 leads:

$$\rho_{t+k} = \frac{\sum (X_t - \overline{X}) (Y_{t+k} - \overline{Y})}{\sqrt{\sum (X_t - \overline{X})^2 \sum (Y_{t+k} - \overline{Y})^2}}$$
(1)

Here, contemporaneous correlation occurs where k = 0. If k > 0, X in a previous period is correlated with Y in the current period, or X "leads" Y. Likewise, if k < 0, X in the current period is correlated with Y in a previous period, so X "lags" Y. These can be tabulated over the range k = [-4, 4] for multiple pairs, to see which contemporaneous correlations are strongest, and for which country pair. This will allow us to test the strength of Baltic-Nordic linkages versus those with other partner countries.

Our second method makes use of the Markov-Switching (MSM) approach of Hamilton (1989). Here, an economy can "switch" between two states: growth and contraction. The probability of such a change is calculated as:

$$p_{i,j} = \Pr(s = j \mid s_{i-1} = 1), \qquad \sum_{j=1}^{2} p_{i,j} = 1 \forall i, \qquad j \in \{1, 2\}$$
(2)

We can estimate these probabilities based on an underlying AR(1) function of log changes in output or consumption, and then graph these probabilities as a measure of each cycle. We then test for linkages by calculating concordances, or the fraction of the time peri-

Baltic Y	Eigenvalues	Loadings	PC1	Baltic C	Eigenvalues	Loadings	PC1		
PC1	1.279	EE	0.572	PC1	1.296	EE	0.578		
PC2	0.681	LT	0.570	PC2	0.584	LT	0.572		
PC3	0.569	LV	0.590	PC3	0.500	LV	0.582		
Nordic Y	Eigenvalues	Loadings	PC1	Nordic C	Eigenvalues	Loadings	PC1	PC2	
PC1	1.296	DK	0.514	PC1	1.206	DK	0.589	-0.150	
PC2	0.903	FI	0.549	PC2	1.051	FI	-0.518	0.431	
PC3	0.751	NO	0.409	PC3	0.799	NO	0.597	0.284	
PC4	0.665	SW	0.517	PC4	0.714	SW	0.168	0.844	
Nordic- Baltic Y	Eigenvalues	Loadings	PC1	PC2	Nordic- Baltic C	Eigenvalues	Loadings	PC1	PC2
PC1	1.443	EE	0.422	-0.262	PC1	1.432	EE	0.464	-0.104
PC2	1.075	LT	0.384	-0.416	PC2	1.066	LT	0.439	-0.149
PC3	0.876	LV	0.394	-0.436	PC3	0.959	LV	0.446	-0.073
PC4	0.750	DK	0.318	0.545	PC4	0.753	DK	0.418	0.037
PC5	0.678	FI	0.410	0.303	PC5	0.657	FI	-0.292	0.129
PC6	0.591	NO	0.347	-0.023	PC6	0.562	NO	0.364	0.462
PC7	0.554	SW	0.360	0.424	PC7	0.466	SW	0.000	0.854

Table 1. Principal component analysis, filtered cycles

Table 2. Correlations between Christiano-Fitzgerald filtered cycles and alternatives

	EEY	LTC	LTY	LVC	LVY	
ВК	0.962	0.967	0.964	0.969	0.960	0.967
HP	0.971	0.971	0.964	0.969	0.963	0.972
	DKC	DKY	FIC	FIY	NOC	NOY
BK	0.961	0.956	0.822	0.942	0.918	0.952
HP	0.958	0.949	0.898	0.958	0.936	0.947
	DEC	DEY	RUC	RUY	USC	USY
ВК	0.967	0.978	0.934	0.947	0.947	0.966
HP	0.937	0.977	0.941	0.951	0.925	0.943



Figure 1. Selected filtered business cycles..

ods in which the members of each pair are simultaneously in the same state. Higher fractions mean stronger linkages. These concordances can be written as:

$$I_{jr} = T^{-1} \left\{ \sum_{t=1}^{T} S_{jt} S_{rt} + \sum_{t=1}^{T} \left(1 - S_{jt} \right) \left(1 - S_{rt} \right) \right\}$$
(3)

Applying these two methods, we can then test our main hypothesis. While both sets of tests show the presence of some Baltic and Nordic regional cycles, they differ when assessing the relative strength of integration among country pairs. Our results are provided below.

3. Results

In the interest of space, Figure 1 depicts the CF-, HP-, and BK-filtered cycles for selected output and consumption series. All three appear to behave quite similarly, which is confirmed by the contemporaneous correlations in Table 1. Taking into account the abovementioned criticisms of the HP filter, as well as the fact that the BK filter truncates the first and last few observations, we proceed with the CF filter for the rest of this study. All Baltic and Nordic series are plotted individually in Figure 2. We see that Estonia, Latvia, and Lithuania share a common "boom" and "bust" before and after the 2008 financial crisis, but that the Nordic countries—particularly Finnish consumption and Norwegian output—appear to follow different patterns. We suspect that our visual clues will be reflected in our formal analysis.

Table 2 provides the results of our Principal Components Analysis. Based on the eigenvalues, we see that there are single Baltic output and consumption cycles, as well as only one Nordic output cycle, but there are two Nordic consumption cycles. The three Baltic countries load equally on their first principal component (labeled *PC1* in the PCA summary and *BALY* and *BALC* elsewhere), but Norway loads relatively less on the Nordic output principal component *NORY*. The Nordic *PC1* for consumption (*NORC1*) has a rather small factor loading for Sweden and a negative loading for Finland. The Nordic consumption PC2 cycle (*NORC2*) has a small loading for Norway and a negative loading for Denmark. We therefore surmise that there are in fact two "Nordic" pairs rather than a single region.

Following the same approach to extract common Nordic-Baltic cycles, we isolate two principal components for output and consumption. While PC1 (*NBY1*)



Figure 2. Filtered country output and consumption cycles



Figure 3. Multiple PCA consumption cycles.

EEY - BALY	LTY - BALY	LVY - BALY	EEC - BALC	LTC - BALC	LVC - BALC
0.937	0.933	0.965	0.971	0.961	0.978
DKY - NORY	FIY - NORY	NOY - NORY	SWY - NORY	DKC - NORC1	DKC - NORC2
0.864	0.922	0.688	0.868	0.856	-0.166
FIC - NORC1	FIC - NORC2	NOC - NORC1	NOC - NORC2	SWC - NORC1	SWC - NORC2
-0.753	0.475	0.869	0.313	0.245	0.931

Table 3. Correlations between country cycles and regional cycles



Figure 4. Regional output and consumption cycles.

does not present any issues for output, PC2 (*NBY2*) has the Baltics' factor loadings opposite from Denmark, Sweden, and Finland; Norway's factor loading is rather small. For the first consumption principal component (*NBC1*), Finland's loading is negative and Sweden does not load at all. For *NBC2*, the Baltics' factor loadings are negative and small. Sweden loads heavily on this component, as does Finland to a lesser extent.

The cycles that include the Nordic countries, which in three of the four cases have two principal components, are depicted in in Figure 3. In these cases, they are clearly out of sync with one another. We can conclude that not only is there no single "Nordic" consumption cycle or any "Nordic-Baltic" cycle in any sense, there are instead three axes: the Baltics, Denmark-Norway, and Sweden-Finland. These findings help drive our regional analysis. Our final cycles for the Baltic, Nordic, and Baltic-Nordic combined series are presented in Figure 4.

"Partner" business cycles are depicted in Figure 5. We see that Germany, Russia, and the United States often follow similar patterns, but that certain periods (such as the 1998 Russian default) lead to distinctive individual patterns. We expect there to be differences in the interregional connections between the Baltics, Nordic countries, and the rest of the world.

	BALY-DEY	BALY-RUY	BALY-USY	BALY- BALC	BALY -NORY	BALY- NBY1	BALY- NBY2	BALY- NBC1	BALY- NBC2
-4	0.120	0.228	0.277	0.682	0.272	0.478	-0.37	0.676	-0.159
-3	0.221	0.322	0.379	0.801	0.378	0.621	-0.396	0.775	-0.194
-2	0.325	0.423	0.478	0.890	0.471	0.747	-0.425	0.860	-0.193
-1	0.414	0.510	0.566	0.947	0.532	0.832	-0.438	0.916	-0.170
0	0.454	0.560	0.619	0.951	0.565	0.881	-0.454	0.928	-0.116
1	0.422	0.566	0.619	0.895	0.515	0.824	-0.437	0.876	-0.092
2	0.338	0.521	0.575	0.796	0.416	0.717	-0.432	0.787	-0.068
3	0.208	0.443	0.497	0.663	0.285	0.570	-0.426	0.657	-0.065
4	0.066	0.340	0.408	0.501	0.151	0.410	-0.409	0.502	-0.063
	BALC-DEC	BALC-RUC	BALC-USC	BALC- NORC1	BALC- NORC2	BALC- NBY1	BALC- NBY2	BALC- NBC1	BALC- NBC2
-4	-0.395	0.417	0.101	0.461	-0.262	0.392	-0.383	0.608	-0.193
-3	-0.306	0.540	0.226	0.544	-0.268	0.544	-0.428	0.736	-0.201
-2	-0.182	0.639	0.350	0.600	-0.249	0.674	-0.452	0.837	-0.191
-1	-0.072	0.696	0.466	0.648	-0.220	0.769	-0.467	0.912	-0.166
0	0.027	0.724	0.546	0.676	-0.176	0.817	-0.479	0.951	-0.127
1	0.099	0.701	0.580	0.663	-0.153	0.803	-0.483	0.916	-0.099
2	0.172	0.650	0.579	0.613	-0.133	0.728	-0.481	0.841	-0.081
3	0.229	0.591	0.548	0.528	-0.140	0.612	-0.490	0.728	-0.093
4	0.245	0.516	0.493	0.418	-0.146	0.481	-0.480	0.589	-0.109
	NORY-DEY	NORY-RUY	NORY-USY	NORY- NORC1	NORY – NORC2	NORY- NBY1	NORY- NBY2	NORY- NBC1	NORY- NBC2
-4	0.399	0.142	0.266	0.020	0.246	0.280	0.222	0.112	0.169
-3	0.546	0.161	0.420	0.138	0.255	0.473	0.310	0.235	0.203
-2	0.688	0.193	0.565	0.322	0.312	0.640	0.354	0.388	0.307
-1	0.794	0.227	0.711	0.457	0.345	0.767	0.399	0.492	0.381
0	0.811	0.211	0.806	0.608	0.438	0.888	0.451	0.569	0.530
1	0.699	0.156	0.802	0.639	0.433	0.780	0.359	0.562	0.553
2	0.524	0.034	0.711	0.639	0.386	0.674	0.282	0.517	0.536
3	0.306	-0.111	0.600	0.612	0.326	0.529	0.194	0.444	0.502
4	0.084	-0.249	0.485	0.528	0.189	0.351	0.086	0.344	0.377

Table 4. Cross-correlation functions between regional cycles and partners

	NORC1- DEC	NORC1- RUC	NORC1- USC	NORC1- BALC	NORC1- NORC2	NORC1- NBY1	NORC1- NBY2	NORC1- NBC1	NORC1- NBC2
-4	0.339	0.089	0.298	0.418	0.084	0.516	0.108	0.478	0.194
-3	0.378	0.193	0.377	0.528	0.064	0.629	0.081	0.606	0.209
-2	0.384	0.269	0.437	0.613	0.029	0.702	-0.005	0.714	0.212
-1	0.360	0.332	0.457	0.663	-0.011	0.733	-0.059	0.786	0.208
0	0.279	0.366	0.496	0.676	0.000	0.738	-0.150	0.868	0.293
1	0.161	0.398	0.454	0.648	-0.113	0.637	-0.269	0.781	0.125
2	0.024	0.432	0.358	0.600	-0.208	0.537	-0.381	0.718	0.009
3	-0.098	0.421	0.253	0.544	-0.311	0.396	-0.482	0.638	-0.122
4	-0.193	0.409	0.160	0.461	-0.423	0.303	-0.551	0.534	-0.263
	NORC2-	NORC2-	NORC2-	NORC2-		NORC2-	NORC2-	NORC2-	NORC2-
	DEC	RUC	USC	BALC		NB12	NBAJ	NBC1	NBC2
-4	0.598	-0.155	0.267	-0.118		0.038	0.404	-0.293	0.186
-3	0.641	-0.240	0.368	-0.129		0.111	0.550	-0.248	0.390
-2	0.645	-0.315	0.466	-0.140		0.139	0.626	-0.207	0.579
-1	0.595	-0.422	0.546	-0.164		0.153	0.686	-0.186	0.744
0	0.586	-0.526	0.596	-0.189		0.143	0.690	-0.159	0.928
1	0.474	-0.619	0.540	-0.239		0.059	0.652	-0.190	0.824
2	0.368	-0.654	0.464	-0.260		0.029	0.625	-0.188	0.745
3	0.298	-0.646	0.359	-0.259		-0.004	0.565	-0.180	0.630
4	0.174	-0.600	0.269	-0.233		0.006	0.521	-0.160	0.488

Table 4. Cross-correlation functions between regional cycles and partners (Continued)

Bold: Highest positive value for each pair (if one exists)

Before testing these interregional connections, we first examine the contemporaneous correlations between the individual Baltic and Nordic cycles and their respective regional cycles. These values are reported in Table 3. While all three Baltic countries enjoy strong correlations (above 0.9) with both regional output and consumption cycles, this is not the case for the four Nordic countries. In all cases, even the highest Nordic value (0.922) is lower that the Baltic correlations, and in particular, Norway's output correlation with the Nordic cycle (0.688) is only two-thirds of the typical Baltic value. While we expect correlations to differ widely for the two Nordic consumption cycles, we find Norway and Denmark to be highly correlated with *NORC1* and Sweden to be highly correlated with *NORC2*. Finland is an outlier, with a negative correlation with *NORC1* that is larger in absolute value than its positive correlation with *NORC2*. This supports our conjecture that the Baltics represent a more coherent economic space than do the four Nordic countries.

How strong are the inter-regional connections? Table 4 presents the CCFs for the Nordic and Baltic common cycles, with each other and with their three major partners. We note the largest correlation over each cycle's



Figure 5. Partner output and consumption cycles.



Figure 6. Individual Baltic expansion phase probabilities (black) and growth rates (grey).

lead and lags, and consider the strongest linkages to occur when the highest correlation is found at a lead/lag of zero.

According to this criterion, we see in Table 4 that, for the three partner countries, the common Baltic output cycle has the highest correlation vis-à-vis the United States (0.619). The correlation is nearly as strong (0.565) between the Baltic and the Nordic region, underlying this important link. Both Baltic output and consumption also have a strong connection to the *NBC1* (Denmark-Norway) consumption cycle. At the same time, Baltic consumption is much more synchronized with Russia (0.724) than with Germany (which is strongly asynchronous). Within the Nordic-Baltic combined

	NBY1 - DEY	NBY1 - RUY	NBY1 – USY	NBY1 - NBC1	NBY1 - NBC2		NBC1 - DEC	NBC1 - RUC	NBC1 - USC
-4	0.291	0.199	0.306	0.441	0.006	-4	-0.324	0.321	0.180
-3	0.432	0.264	0.450	0.567	0.005	-3	-0.266	0.449	0.291
-2	0.572	0.343	0.588	0.703	0.067	-2	-0.186	0.549	0.394
-1	0.684	0.414	0.721	0.794	0.121	-1	-0.119	0.618	0.475
0	0.717	0.434	0.805	0.845	0.238	0	-0.059	0.656	0.544
1	0.634	0.407	0.802	0.810	0.262	1	-0.013	0.656	0.550
2	0.487	0.312	0.723	0.735	0.265	2	0.036	0.639	0.512
3	0.291	0.186	0.616	0.620	0.247	3	0.095	0.595	0.452
4	0.085	0.049	0.501	0.476	0.175	4	0.100	0.538	0.379
	NBY2 -	NBY2 -	NBY2 -	NBY2 -	NBY2 -		NBC2 -	NBC2 -	NBC2 -
	DEY	RUY	USY	NBC1	NBC2		DEC	RUC	USC
-4	0.329	0.021	0.017	-0.572	0.330	-4	0.598	-0.220	0.356
-3	0.383	-0.068	0.073	-0.553	0.407	-3	0.611	-0.281	0.444
-2	0.425	-0.173	0.126	-0.506	0.506	-2	0.575	-0.340	0.521
-1	0.438	-0.250	0.175	-0.461	0.586	-1	0.490	-0.420	0.566
0	0.411	-0.346	0.222	-0.409	0.676	0	0.444	-0.504	0.599
1	0.329	-0.428	0.219	-0.362	0.715	1	0.319	-0.561	0.516
2	0.224	-0.519	0.182	-0.329	0.688	2	0.201	-0.558	0.402
3	0.115	-0.603	0.141	-0.273	0.658	3	0.141	-0.540	0.267
4	0.012	-0.652	0.099	-0.229	0.535	4	0.015	-0.482	0.158

Table 5. Cross-correlation functions between Nordic-Baltic cycles and partners

region, Baltic output and consumption are much more synchronized with their corresponding first principal components than with the second.

The single Nordic output cycle is about equally synchronized (with high cross-correlation values at zero lags) with Germany and with the United States (the corresponding coefficients are 0.811 and 0.806, respectively). This connection is larger than that of the corresponding *BALY-NORY* contemporaneous correlation (0.565), suggesting a "one way street" where the Nordic countries are more influential to the Baltics than the other way around. The link with the Russian output cycle is much weaker. This cycle is also more closely connected with the first principal component of the common Nordic-Baltic cycle.

The two Nordic consumption cycles behave differently from one another as well. The first (which represents Denmark-Norway) is most closely synchronized with the United States and least synchronized with Russia. It is also highly correlated with the combined cycle *NBC1*, suggesting a great degree of consumption smoothing within this common region—but not as high as was the case for Baltic consumption. The second principal component (*NORC2*), which mainly represents Sweden and Finland, is more closely connected to U.S. consumption than is *NORC1*, and is also out of sync with Germany. This series also is highly

Baltic Y	Eigenvalues	Loadings	PC1	Baltic C	Eigenvalues	Loadings	PC1			
PC1	1.158	EE	0.621	PC1	1.146	EE	-0.587			
PC2	0.915	LT	0.555	PC2	0.913	LT	-0.545			
PC3	0.840	LV	0.553	PC3	0.873	LV	-0.598			
Nordic Y	Eigenvalues	Loadings	PC1	Nordic C	Eigenvalues	Loadings	PC1	PC2		
PC1	1.178	DK	0.409	PC1	1.165	DK	0.552	-0.108		
PC2	0.954	FI	0.499	PC2	1.005	FI	-0.172	0.926		
PC3	0.934	NO	0.483	PC3	0.897	NO	0.613	0.040		
PC4	0.835	SW	0.592	PC4	0.836	SW	0.538	0.360		
Nord- Balt Y	Eigenvalues	Loadings	PC1	PC2	Nord-Balt C	Eigenvalues	Loadings	PC1	PC2	PC3
PC1	1.305	EE	0.486	-0.177	PC1	1.207	EE	-0.398	0.396	-0.052
PC2	1.041	LT	0.313	-0.547	PC2	1.109	LT	-0.259	0.531	0.038
PC3	0.970	LV	0.372	-0.188	PC3	1.006	LV	-0.425	0.389	0.174
PC4	0.898	DK	0.221	0.530	PC4	0.930	DK	-0.414	-0.330	-0.161
PC5	0.884	FI	0.451	-0.152	PC5	0.895	FI	0.151	0.043	0.918
PC6	0.812	NO	0.296	0.481	PC6	0.867	NO	-0.522	-0.292	0.063
PC7	0.769	SW	0.432	0.316	PC7	0.791	SW	-0.357	-0.463	0.306

Table 6. Principal component analysis, log differences

Table 7. Percentages of quarters that are expansion phases

EEC	EEY	LTC	LTY	LVC	LVY		
50.0	91.0	35.9	6.4	67.9	78.2		
DKC	DKY	FIC	FIY	NOC	NOY	SWC	SWY
82.1	7.7	59.0	17.9	55.1	20.5	34.6	92.3
BY1	BC1	NY1	NC1	NC2			
83.3	16.7	85.9	30.8	79.5			
DEY	RUY	USY	DEC	RUC	USC		
88.5	73.1	84.6	12.8	75.6	42.3		
NBY1	NBY2	NBC1	NBC2	NBC3			
67.9	94.9	15.4	69.2	21.8			



Figure 8. Individual Nordic expansion phase probabilities (black) and growth rates (grey).

synchronized with the second principal components for Nordic-Baltic output and consumption (*NBY1* and *NBC1*), respectively. For the Baltic region in particular, output and consumption are highly synchronized, highlighting the major role that this component plays in regional GDP.

While the presence of two common cycles for both output and consumption suggests that this combined region does not form a single unified economic space, we still examine cross-correlations vis-à-vis our set of major trading partners in Table 5. The first pan-regional output cycle is much more synchronized with partner output, and also with local consumption, than is the second principal component. The second consumption cycle is more closely linked to U.S. and German consumption, while the first consumption-cycle principal component is linked to Russia. This suggests that the regional split (particularly regarding Finland) might drive these trade linkages.

In summary, the traditional cross-correlation approach to business-cycle synchronization shows that of the common Baltic output and consumption cycles, the common Nordic output cycle, and the two Nordic consumption cycles, linkages to the German and U.S. business cycles are often stronger than are those with Russia. Baltic-Nordic cycle synchronization lies somewhere in between. Synchronization between individual country cycles and the common cycle is often quite strong as well. There is limited evidence, however, of a common Baltic-Nordic output or consumption cycle.

We next test for these connections using Markov-Switching approaches and concordance analysis. We begin by performing PCA on the log changes of each output or consumption series, the results of which are presented in Table 6. We find that there is one principal component with an eigenvalue above one for Baltic output and consumption, as well as for Nordic output. As was the case with PCA using the CF cycles, there are two Nordic consumption cycles. Here, however, the differences in the factor loadings seem to be dominated by Finland. This suggests that the lone Euro member in the group, with close proximity to Russia, is an "outlier" in the Nordic region. PCA also shows even less evidence for a combined Nordic-Baltic economic region, with two common output growth series and three common consumption series. We can still, however, examine the properties of the resulting cycles.

We next plot the expansion probabilities for each individual country. The Baltic nations are presented in Fig-



Figure 9. Nordic-Baltic expansion phase probabilities (black) and growth rates (grey).



Figure 10. Partner expansion phase probabilities (black) and growth rates (grey).

	BY1	BC1	NY1	NC1	NC2
EEC	0.564	0.333	0.564	0.551	0.449
EEY	0.872	0.077	0.897	0.269	0.705
LTC	0.423	0.731	0.372	0.487	0.462
LTY	0.154	0.795	0.179	0.654	0.244
LVC	0.641	0.205	0.692	0.500	0.526
LVY	0.795	0.179	0.846	0.397	0.577
DKC	0.731	0.269	0.782	0.333	0.744
DKY	0.141	0.859	0.115	0.692	0.256
FIC	0.603	0.551	0.526	0.487	0.385
FIY	0.269	0.731	0.218	0.615	0.308
NOC	0.564	0.436	0.538	0.449	0.449
NOY	0.244	0.679	0.346	0.641	0.385
SWC	0.359	0.615	0.359	0.577	0.449
SWY	0.885	0.141	0.910	0.308	0.718

Table 8. Local concordances between Markov-switching expansion phases.

Bold = larger concordances

Table 9. Concordances between Markov-switching regional expansion phases.

	BY1	BC1	NY1	NC1	NC2
BY1	1	0.205	0.821	0.295	0.654
BC1		1	0.179	0.654	0.321
NY1			1	0.346	0.654
NC1				1	0.359
NC2					1
	NBY1	NBY2	NBC1	NBC2	NBC3
NBY1	1	0.654	0.321	0.603	0.436
NBY2		1	0.205	0.641	0.218
NBC1			1	0.308	0.731
NBC2				1	0.295

Bold = larger concordances

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	BY1	BC1	NY1	NC1	NC2
DEY	0.769	0.205	0.821	0.679	0.218
RUY	0.718	0.359	0.692	0.577	0.423
USY	0.731	0.244	0.782	0.667	0.359
DEC	0.269	0.782	0.269	0.333	0.692
RUC	0.769	0.308	0.718	0.500	0.397
USC	0.436	0.487	0.538	0.654	0.526

Table 10. Concordances between Markov-switching regional expansion phases.

Bold = larger concordances

Table 11. Summary of especially high correlations.

	CF-Filtered Cycles		Markov-Switching Approach		
	Output	Consumption	Output	Consump-tion	
Baltic	USY, BALC, NBY1	RUC, NBY1, NBC1	DEY, RUC, NY1	DEC	
Nordic (1)	DEY, USY, NBY1	BALC, NBY1, NBC1	DEY, USY, NC1	DEY, USY	
Nordic (2)		USC, NBY1, NBC1		DEC	
Nordic-Baltic (1)	USY, NBC1	RUC	NBY1	NBC3	
Nordic-Baltic (2)	DEY	USC	NBY2	NBC2	

ure 6. The 2008 recession is clearly depicted in the plots for Estonian and Latvian output; Latvian consumption declines both in 2008 and 2014. Lithuania, however, is more likely to exhibit growth "spikes" throughout the study period. The Nordic phase probabilities are depicted in Figure 7. Danish output shows a "boom" prior to 2010, with Swedish output and consumption following more of an oscillating pattern. Again, Finland follows its own unique pattern, with consumption reaching its lowest point after 2010.

Table 7 presents the percentages of quarters during which each cycle is predicted to be in an expansion phase. Estonian output is shown to be high (91.0%), with Lithuanian output's value very low (6.4%). This is likely due to the properties of the model itself rather than because of any failure of the Lithuanian economy.

This gives reason to be suspicious of over-relying on one specific modeling method. Likewise, Danish consumption is in an expansion phase during 82.1% of the quarters, while output is in this phase only 7.7% of the time. While we treat these results with caution, we are able to arrive at some interesting conclusions, particularly involving the common Nordic-Baltic series. The second principal components of both output and consumption growth rates, in which Norway, Denmark, and Sweden appear to form a common grouping, are in expansion a larger percentage of the time than is the case for the other principal components.

The regional cycles, created using our Markovswitching models, are depicted in Figure 8. There are clear "booms" and "busts" surrounding the 2008 crisis; this is particularly clear for the case of Baltic consumption. Baltic output also shows strong fluctuations during the early- and mid-2000s. Nordic cycles exhibit additional fluctuations, particularly after 2010 for output and during the early 2000s for consumption (*NC1*). As might be surmised given the earlier results, the phase probabilities for the common cycles (provided in Figure 9) show limited evidence for common Nordic-Baltic cycles. *NBY1* oscillates more than would be expected, and *NBY2* registers a drop around 2005 that precedes the actual crisis. Only *NBC1* (which captures all countries except Finland in its factor loadings) shows the pre-crisis "boom" for the entire region. This provides further evidence that examining a common Baltic cycle, and perhaps one or two common Nordic cycles, is more appropriate for future analyses.

Partner phase probabilities, depicted in Figure 10, show the expected patterns, with particularly clear cycles for Russian output and Russian and U.S. output and consumption. Russia, in addition, shows contractionary periods around the time of the 1998 default and the economic sanctions following the 2014 invasion of Ukraine.

Are these expansionary and contractionary periods linked to those in the Nordic and Baltic regions? We examine this question in Tables 8, 9, and 10. First, in Table 8 (which shows the highest proportions in the darkest text) we depict concordances between individual countries and their respective regional cycles. We find that of the three Baltic countries, Estonian output is most strongly linked to the Baltic cycle (with concordances during 87.2% of quarters)-but that it is even more closely linked to the Nordic cycle (89.7%). The same is true, to a lesser extent, for Latvian output (with 79.5% concordance with the Baltic cycle, and 84.6% with the Nordic cycle). Lithuanian output, on the other hand, is more closely tied to Baltic consumption. Perhaps historic links, particularly regarding Lithuania's ties to Poland and Estonia's connections to Finland, might help explain these differences. Of the Nordic countries, only Sweden exhibits a strong connection to its own regional cycle, perhaps because it is the main driver of the principal component.

Concordances among the regional cycles are presented in Table 9. The Baltic and Nordic output cycles are highly correlated, with a concordance rate of 82.1 percent. Baltic and Nordic consumption (*NC1*) are also in the same phase probability during 65.4 percent of quarters. The second Nordic consumption cycle (which is primarily represented by Finland, and to a lesser extent, Sweden) has the same proportion of concordant quarters vis-à-vis Baltic and Nordic output. The other concordances, however, are quite low. Among the combined Nordic-Baltic sample, we see that output and consumption are more closely connected with their own principal components—i.e., *NBY1* and *NBY2* have a high concordance, as do *NBC1* and *NBC3*.

To assess the relative strength of the economic connections between the Nordic and Baltic regions and their major neighbors, we examine the business-cycle concordances that are presented in Table 10. While Baltic output is in concordance with all three partners' GDP roughly 70 to 80 percent of the time, the value is highest vis-à-vis Germany (and lowest versus Russia). Interestingly, Baltic output is closely linked to Russian consumption, suggesting a possible role for exports in driving the Baltic cycle. Interestingly, the proportion of concordances is higher between the Baltic and Nordic cycles than between the Baltic cycle and that of any major partner.

Baltic consumption is much more tightly connected to German consumption than with Russia or the United States. His differs from the CCF results, which showed the strongest link between Baltic consumption and Russia. Nordic output is tied to German GDP as well, as is the second consumption cycle. The first consumption cycle, on the other hand, is connected most strongly to German output as well as U.S. consumption.

Comparing and contrasting these results with those provided via the cross-correlation functions, we conclude that the relative strength of economic integration differs for the two tests. A summary of the findings using these two approaches is provided in Table 11. The CCF method shows Baltic output to be linked to the U.S. (Global) cycle, while consumption is most correlated with Russia. Nordic GDP is connected to German output using both tests, but while the CCF method shows the same links to Germany, the MSM has the largest proportion of concordances vis-à-vis the United States. We are therefore wary when rejecting the CCF model because of its use of filtered data. In fact, we suspect (based on the phase probabilities) that the MSM only models accurate cycles in certain cases. We therefore evaluate our findings-regarding common cycles or a lack thereof, along with the relative strength of regional synchronization—using the CCF method as well as Markov-Switching Models.

4. Conclusion

While many studies have been conducted, applying a variety of statistical tests, to examine the degree of synchronization between EU business cycles and those of the bloc's most recent entrants, relatively little has been written regarding the Baltic nations as a single economic region in this process—and even less research has been done on the Nordic economic region. This study applies two time-series methods to extract common Baltic, Nordic, and joint Baltic-Nordic output and consumption cycles, before examining connections between each country and its regional cycles, between the regional cycles themselves, and between the regional cycles and a set of neighboring economies.

Using Principal Components Analysis, we find evidence of common Baltic output and consumption cycles, which is the case whether we use filtered data or growth rates. The Nordic region, however, has only a single common output cycle; consumption is often driven by a Danish-Norwegian grouping, as well as a separate Finnish (and Swedish) grouping. As a combined, seven-country "Nordic-Baltic" region, there is no single common cycle for either output or consumption. We then test for economic integration using two methods, which often provide differing results.

For example, when we generate cross-correlation functions for pairs of filtered cycles, we find all three individual Baltic countries to be highly synchronized with their respective cycles. We also find that Baltic output cycles are most closely correlated to the U.S. (Global) cycle, and consumption cycles to be correlated with Russia. Our Markov-Switching models, however, show Lithuanian output to share an expansion or contraction phase with the Baltic cycle a relatively low percentage of the time, and that both Baltic output and consumption have the largest proportion of concordances vis-à-vis Germany. While Nordic output exhibits linkages to Germany via both methods, differences persist in terms of consumption.

This leads us to conclude that, while recent trends in the literature have been to prefer Markov-switching models over simpler methods, these models should be treated with care. The resulting business cycles do not necessarily correspond with actual events, and the cycles, as well as the results they produce, differ compared to those given by other techniques. For this reason, we consider both CCF and MSM models simultaneously.

Our results show strong evidence that the three Baltic countries represent a common economic space, which is also tied strongly to Western cycles. While the common Baltic cycle is shown to be more closely connected to the Nordic cycle than to that of Germany, the U.S., or Russia, there is no evidence that the Nordic and Baltic regions together share a common cycle. Instead, different cycles exist, one for Denmark and Norway and one for Finland, which suggest that there is only a limited "Nordic" cycle.

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