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Optimum Currency Area and Business Cycle Synchronization Across U.S. States[1]

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Abstract

We use wavelet analysis to investigate to what extent individual U.S. states' business cycles are synchronized. The results show that the U.S. states are remarkably well synchronized compared to the previous findings w.r.t. the Euro Area. There is also a strong and significant correlation between business cycle dissimilitudes and the distance between each pair of states, consistent to gravity type mechanisms where distance affects trade. Trade, in turn, increases business cycle synchronization. Finally we show that a higher degree of industry specialization is associated with a higher dissimilitude of the state cycle with the aggregate economy.

Keywords: Optimum currency areas, business cycle synchronization, continuous wavelet transform, trade
JEL: E37, E52, R11

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1. Introduction

The introduction of the euro caused a surge in the literature on optimal currency areas. An area of focus was the criteria for an optimum currency area and how well suited countries are for entering into a monetary union. One such condition is synchronization of economic activity because it is a necessary condition for the optimality of a single monetary policy — De Haan et al. (2008). This point will be the focus of this paper.

Countries sharing the same currency but with asymmetric business cycles will incur costs associated with the monetary authority making decisions which benefit not all countries within the monetary union. If one country in a monetary union is undergoing an expansion while another one is in a recession, a restrictive monetary policy will benefit the booming economy but exacerbate the problems of the depressed one. The area of focus in this respect has usually been the euro area, with the optimality of the U.S. as a single currency area a foregone conclusion. This paper will however take a closer look at the U.S. and see just how the individual states' business cycles are similar to the aggregate U.S. business cycle. If there are states that are out of sync with the national business cycle, then that might indicate that those states are subjected to monetary policy that doesn't suit them. Thus on at least one dimension, business cycle similarity, the asynchronous states will deviate from the optimum currency area ideal.

To study this issue, we rely on wavelet based measure of business cycle synchronization. Wavelet analysis is particularly well-suited to study business cycle synchronization. This is so, because with wavelets one can estimate the spectral characteristics of a time-series as a function of time, revealing how the different periodic components of a particular time-series evolve over time. Rua (2010) was probably the first author to rely on wavelet analysis to measure comovements between different regions in the time-frequency space. We will follow the procedure proposed by Aguiar-Conraria and Soares (2011) — also applied by Aguiar-Conraria, Martins and Soares (2013) and Aguiar-Conraria, Magalhães and Soares (2013) — to compare the wavelet spectra of two regions. By doing so, we test if the contribution of cycles at each frequency is similar, if this contribution happens at the same time or not, and, finally, if the ups and downs of each cycle occur simultaneously.

We also look at how much the distance between states can explain business cycle synchronization. Tinbergen (1962) originally proposed that bilateral trade between countries had a strong gravity-type mechanism, i.e. that trade flows between countries A and B were “proportional to the gross national products of those countries and inversely proportional to the distance between them.” High trade flows between states due to close proximity to each other causes their economies to integrate, and, therefore, may cause their business cycles to synchronize.[2] If this is correct then states far away from the economic core will be less synchronized with the national business cycle than those close to it.

Our results show that U.S. states' business cycles are remarkably well synchronized with the national business cycles, with only a few exceptions. A comparison with the euro area indicates that the U.S. is a considerably more suitable currency area, with U.S. states having on average a lower business cycle dissimilarity with the aggregate business cycle than countries in the Eurozone, urging EU policy makers to implement policies that can mitigate asymmetric shocks. The results also show that there is a significant positive correlation between business cycle dissimilitude and distance between each pair of states. In other words, the closer the states are geographically the more synchronized their business cycles are. Also, we find a strong and significant association between a state's degree of industry specialization and its dissimilitude with the aggregate cycle, another factor that exacerbates the costs associated with the monetary union.

It should be noted that this exercise only concerns the macroeconomic costs of a single currency on one dimension, i.e. dissimilitudes across business cycles. The other costs might be minimal, and the microeconomic benefits of belonging to a single currency area (i.e. lower transaction costs, removal of exchange rate risks) might more than offset the costs. Therefore, the fact that a state might have a business cycle asynchronous with the aggregate business cycle does not imply that it should break away from the Federal Reserve system and adopt its own currency.

2. Literature Review

The classical optimum currency area (OCA) literature e effectively begins with Mundell (1961). Other important contributions to the literature are made by McKinnon (1963),

[2] Assuming that intra-industry trade dominates trade in final goods. Otherwise, the two regions will specialize according to their respective comparative advantages, and their business cycles may diverge from each other.

who looks closer at factor mobility and makes a distinction between geographic factor mobility and factor mobility across industries. McKinnon also emphasizes the degree of openness, defined as the ratio of tradables to non-tradables, as a criterion in forming an OCA. Small open economies would find it advantageous to join a larger currency area since changes in the exchange rate influence a large part of their economy compared to large closed economies. A high degree of trade openness in these economies reduces the effectiveness of an independent monetary policy and limits the usefulness of exchange rate changes as a means of restoring competitiveness, since devaluation is rapidly transmitted to the domestic cost of living. Kenen (1969) argues that product diversification is an important OCA criterion. A country with a well-diversified economy can more easily absorb shocks affecting one industry and will not have to undergo changes in its terms of trade as often as a single-product economy. It can thus tolerate the small costs of abandonment of their national exchange rates and benefit from a single currency.

The more recent contributions to OCA literature were brought about by the birth of the European Monetary Union in the 1990s. Frankel and Rose (1997) point out that increased trade in a common currency area could theoretically lead to more asynchronous business cycles, since regions may specialize in industries in which they have a comparative advantage, see also Krugman (1993). Still they believe that increased trade leads to more synchronous business cycles since common demand shocks prevail and intra-industry trade accounts for most of the trade. They also emphasize that countries that may be unsuitable for a common currency area ex-ante may become suitable ex-post, when increased trade resulting from the common currency has integrated the economies to such a degree that the loss of monetary independence is no longer an issue.

Distance between trading partners and magnitude of trade was described as an inverse relationship by Tinbergen (1962). This leads us to infer that regions close to each other have a more synchronized business cycle, since trade intensity increases business cycle synchronization, as previously described by Imbs (2004), Baxter and Kouparitsas (2005) and Inklaar et al. (2008).

Previous work on business cycles on the U.S. state level include Owyang et al. (2005), who look at growth levels between states and finds that they differ greatly in the recession phase and in the expansion phase. The states also differ in the timing of switching between phases, indicating that states differ in the way that their business cycles are in sync with that of the aggregate economy. Guha and Banerji (1998/1999) find that the patterns of states' cyclical movement in employment differ significantly from the U.S. employment cycle. Those differences are explained by factors like industry diversification, difference in consumer sentiment and different fiscal policies. Kouparitsas (2001) identifies sources of common shocks and responses to those shocks for the eight Bureau of Economic Analysis regions of the U.S. He finds that five of them constitute a core region and three non-core. They differ significantly from each other in terms of sources of disturbances and responses to disturbances at business cycle frequencies.

3. Data

The monthly state coincident indexes published by the Federal Reserve Bank of Philadelphia will serve as data for our analysis. An alternative would be to use the gross state product published by the Bureau of Economic Analysis of the U.S. Department of Commerce, but those are annual numbers, which would imply significantly fewer observations

The coincident index uses four state-level variables to summarize current economic conditions in each U.S. state. The variables are non-farm payroll employment, average hours worked in manufacturing, the unemployment rate, and wage and salary disbursements deated by the consumer price index. Such an index was constructed by Stock and Watson (1989) using a Kalman filter to estimate a latent dynamic factor for the national economy, with the common factor designated as the coincident index. The methodology was then used by Crone and Clayton-Matthews (2005) to construct a coincident index for each of the 50 U.S. states.

We focus on business cycle frequencies. Data is filtered using the Baxter and King bandpass filter. The time span is from 1979:07 to 2013:12 for a total of 414 observations for each state — after filtering, we are left with 390 observations.

4. Methodology

Wavelet analysis performs the estimation of the spectral characteristics of a time-series as a function of time, revealing how the different periodic components of a particular time-series evolve over time. While in spectral analysis we break down a time-series into sines and cosines of different frequencies and infinite duration in time, the wavelet transform expands the time-series into shifted and scaled versions of a function that has limited spectral band and limited duration in time.

Apart from some technical details, for a function to qualify for being a wavelet it must have zero mean (implying that it has to wiggle up and down) and be well-localized in time (e.g. have compact support or, at least, fast decay), behaving like a small wave that loses its strength as it moves away from the centre, hence the term choice wavelet. It is this property that allows, contrary to the Fourier transform, for an effective localization in both time and frequency.

Complex analytic wavelets are ideal to study oscillations. We use the most popular wavelet with these characteristics, the Morlet wavelet.[3] Given a time series $x(t)$, its continuous wavelet transform (CWT) with respect to the wavelet is a function of two variables,$W_x(\tau, s)$:

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \bar{\varphi}\left(\frac{t-\tau}{s}\right) dt$$

where the bar denotes complex conjugation, s is a scaling or dilation factor that controls the width of the wavelet and τ is a translation parameter controlling the location of the wavelet. With our wavelet choice, there is an inverse relation between wavelet scales and frequencies, $f \approx 1/s$, greatly simplifying the interpretation of the empirical results.

The major advantage of using a complex-valued wavelet is that we can compute the phase of the wavelet transform of each series and thus obtain information about the possible delays of the oscillations of the two series as a function of time and frequency, by computing the phases and the phase difference. The phase is given by $\tan^{-1}\left(\Im(W_x(\tau,s))/\Re(W_x(\tau,s))\right)$ and the phase difference by $\tan^{-1}\left(\Im\left(W_{xy}(\tau,s)\right)/\Re\left(W_{xy}(\tau,s)\right)\right)$, where, for a given complex number z, $\Re(z)$ and $\Im(z)$ denote, respectively, its real part and imaginary part. A phase-difference of zero indicates that the time series move together at the specified frequency; a phase-difference between 0 and $\pi/2$ (0 and $-\pi/2$) indicates that the series move in-phase, with x (y) leading y (x), while if the phase-difference is between $\pi/2$ and π ($-\pi$ and $-\pi/2$), then variables are out-of-phase with y (x) that is leading.

[3] The reader is referred to Aguiar-Conraria and Soares (2014) for technicalities about the optimal properties of such wavelet.

In this paper, we will use the measure of the dissimilarities between the wavelet transform of two time-series proposed by Aguiar-Conraria and Soares (2011). We use the Singular Value Decomposition (SVD) of a matrix to focus on the common high power time-frequency regions.

For that purpose, given two wavelet spectral matrices $W_x(\tau, s)$ and $W_y(\tau, s)$, let $Q_{x,y} = W_x(\tau, s)W_y^H(\tau, s)$, be their covariance matrix, where W_y^H is the conjugate transpose of W_y. After applying SVD to $Q_{x,y}$, the first extracted components correspond to the most important common patterns between the wavelet spectra. With those, we construct leading patterns and leading vectors. Using just a few of these, say K, one can approximately reconstruct the original spectral matrices.

Then, to define a distance between the two wavelet transforms, we compute the following distance:

$$\mathrm{dist}(W_x, W_y) = \frac{\sum_{k=1}^{K} \sigma_k^2 \left[d\left(\mathbf{l}_x^k, \mathbf{l}_y^k\right) + d\left(\mathbf{u}_x^k, \mathbf{u}_y^k\right)\right]}{\sum_{k=1}^{K} \sigma_k^2}$$

In the above formula, $\mathbf{l}_x^k$ and $\mathbf{l}_y^k$ are the leading patterns, $\mathbf{u}_x^k$ and $\mathbf{u}_y^k$ the singular vectors and σ_k the singular values. We compute the distance between two vectors by measuring the angle between each pair of corresponding segments, defined by the consecutive points of the two vectors, and take the mean of these values.

The above distance is computed for each pair of regions and, with this information, we can then fill a matrix of distances. The closer to zero our measure of distance is, the more similar are the wavelet transforms of $x(t)$ and $y(t)$.

5. Results

In Figure 1, we see the results of the wavelet spectra dissimilarity calculation for each state vis-à-vis the national aggregate. The states with the lowest dissimilarity, i.e. those that are the most in sync with the national business cycle, are Maryland, Illinois, Missouri, New Jersey and Tennessee. The most dissimilar are Alaska, North Dakota, Wyoming, Louisiana and Kansas.

The darker a state is, the tighter it is synchronized. We can see a pattern, the states right in the middle of the country, stretching from Oklahoma all the way up to North Dakota, are not too tightly synchronized. Possible explanations might include relatively low population numbers and therefore low economic activity which doesn't weight heavily in the aggregate cycle or different economic structures with a relatively higher weight on agriculture and oil production. We see as well that Alaska is the least synchronized state, which may as well be explained by a heavy reliance on oil production as well as the distance between it and the contiguous 48 states. Hawaii is also relatively loosely synchronized, which matches our hypothesis that states far away from other states have high business cycle dissimilarity.

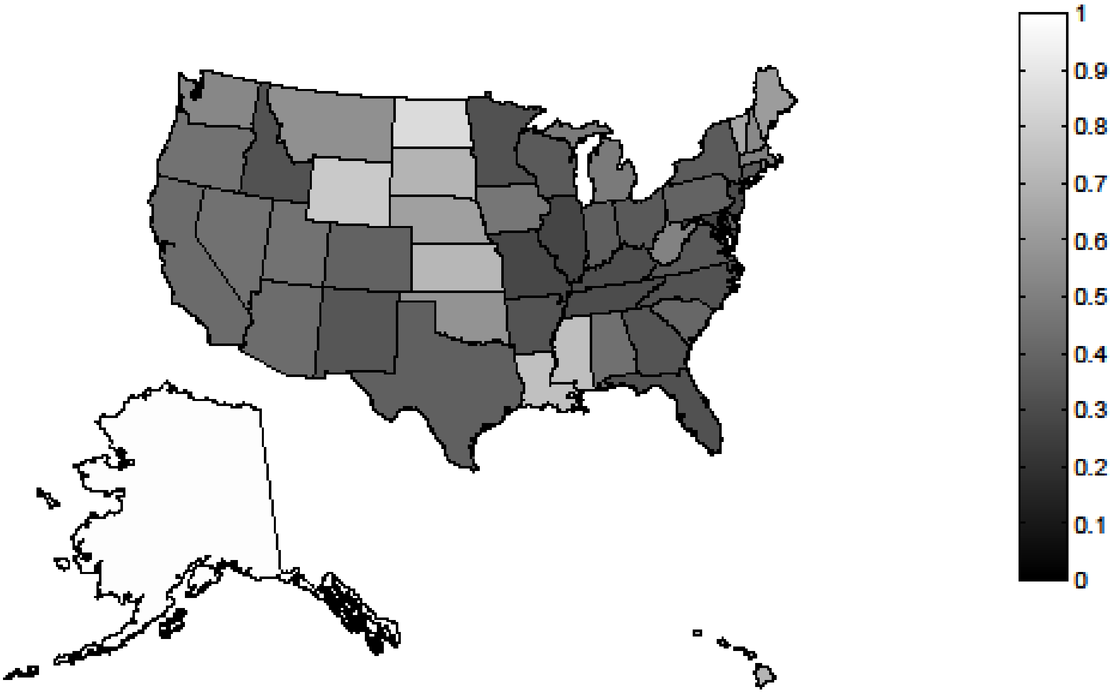

Figure 1: U.S. states' business cycle dissimilitudes

In Figure 2, we see a side-by-side comparison of business cycle dissimilitudes in the U.S. and the euro area.[4] We see how each state or country is synchronized with the aggregate business cycle where a low value, i.e. darker colour, indicates tight synchronization with the aggregate. Although the difference between the two areas may not be very stark, we do see that the U.S. is slightly darker, indicating tighter synchronization, and that the colours are more homogeneous. The average dissimilitude of U.S. states is 0.21, which is lower than the European average of 0.33.[5] Since lower

[4] Data was insufficient to get estimates for Estonia, Slovenia and Malta. Estimates are normalized to the state/country with the highest value. Dissimilitudes for the euro area were taken from Aguiar-Conraria and Soares (2011).

[5] A t-test reveals that the difference between the two averages is significant at the 1% level.

dissimilitude estimates indicate greater synchronization, we see that on the whole, U.S. states are more synchronized.

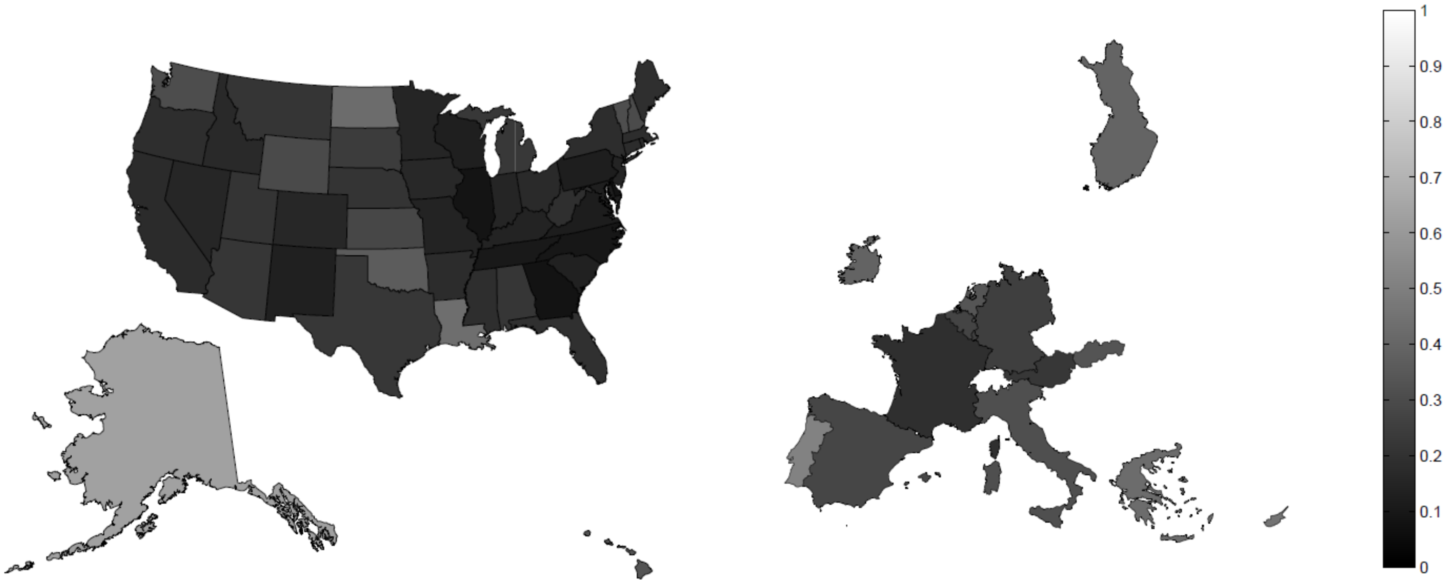

Figure 2: Dissimilitudes of each state/country with the aggregate business cycle for the U.S. and Eurozone

In Figure 3. we see the business cycle synchronization significance levels for each state and country for both the U.S. and the Eurozone. Black indicates significance at the 1% level (meaning that we reject the null of no synchronization), dark gray 5%, light gray 10% and white indicating insignificance. Here we see a much starker difference between the two areas, with the U.S. having considerably more significance than the Eurozone. There are only 5 states out of 50 which are out-of-sync with the national business cycle in the U.S., while in the Eurozone there are 6 out of 13 countries that are insignificant, a much higher proportion.

There are many possible explanations to why the U.S. has more similar business cycles than the euro area. The euro has only existed since 1999 while the dollar has existed for more than a hundred years, giving the U.S. states a longer time to converge. Fiscal policy may also explain the difference — the federal budget in the US is over 30% of GDP but in the EU is around 1%. Industry specialization may also play a role, with U.S.

states possibly less specialized, and therefore more diversified, than Eurozone countries, which results in more synchronized business cycles.[6]

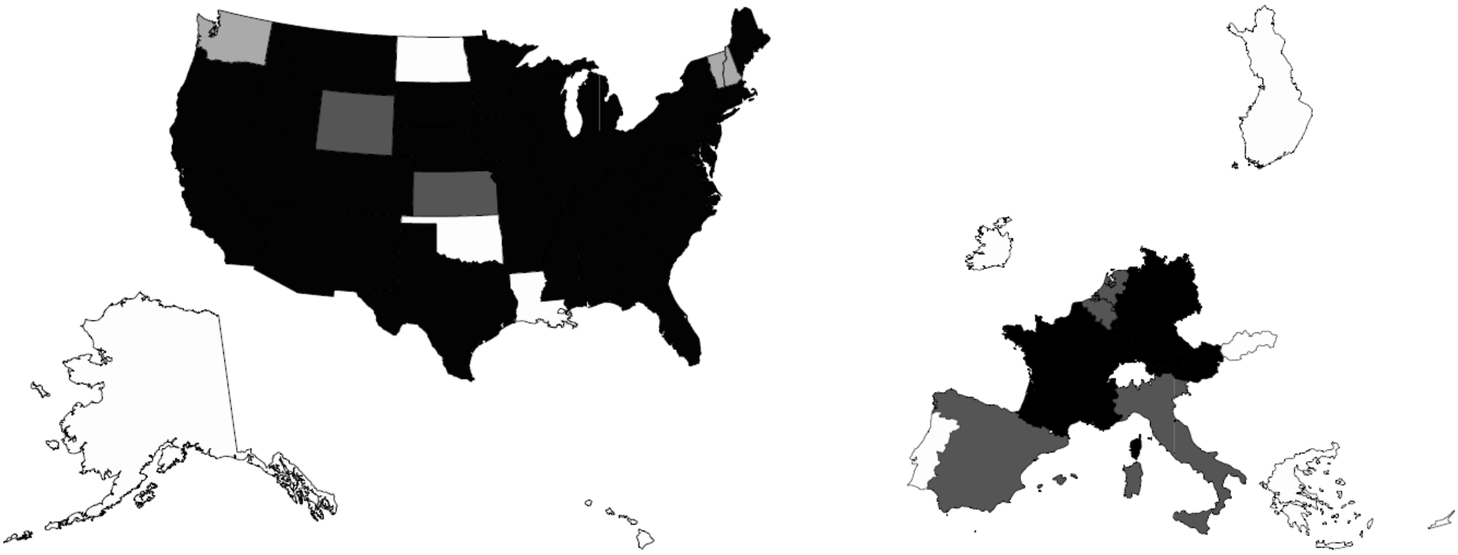

Figure 3: Significance of Bussiness Cycle Synchronization of the U.S. and the Eurozone

5.1. Spatial correlation

In Table 1, we see the Spearman rank correlation coefficient between states' dissimilarity and physical distance between state capitals,[7] along with their significance. In every case, with one exception which was statistically insignificant, we find a positive correlation between distance and dissimilarity with the national business cycle. Most of the positive cases were also highly significant, with 37 having significance of at least the 5% level. This indicates that the further states are away from each other, the more dissimilar they will be from each other.

The gravity equation explains, among other things, how distance between regions affects trade. It is one of the more robust findings in trade economics (Anderson and van Wincoop, 2003), so it is safe to assume that all else being equal, regions close to one another trade more than regions that are far away from each other. Theoretically though, more trade doesn't necessarily lead to more synchronized business cycles. Krugman (1993) argues that increased trade leads to more specialization between the

[6] Clark and van Wincoop (2001) look at all these factors, as well as bilateral trade, and find that the relatively lower level of trade between European countries explains to a large extent why U.S. Census regions are more synchronized than European countries.

[7] Estimates of surface distance between state capitals were taken from http://www.geobytes.com/CityDistanceTool.htm.

trading partners, as they specialize in the sectors of the economy they have a comparative advantage in. A specialized region is more vulnerable to shifts in tastes, especially those driven by technology, and, when such a shift happens, the region faces large and erratic changes in exports. If a shift in taste results in an export boom for a specialized region, then that boom is also reinforced by investment inflows. These accompanying capital movements serve to increase the difference in growth rates between booming regions and non-booming. All-in-all, greater trade integration will lead to divergence in economic structure and growth rates of regions.

Table 1: Distance vs states' business cycle dissimilarities

State	ρ_S	State	ρ_S	State	ρ_S	State	ρ_S
AL	0.2	AK	-0.21	AZ	0.35**	AR	0.25*
CA	0.29**	CO	0.14	CT	0.76***	DE	0.41***
FL	0.19	GA	0.32**	HI	0.51***	ID	0.28**
IL	0.34**	IN	0.62***	IA	0.29**	KS	0.28**
KY	0.60***	LA	0.32**	ME	0.88***	MD	0.59***
MA	0.71***	MI	0.52***	MN	0.15	MS	0.33**
MO	0.26*	MT	0.18	NE	0.44***	NV	0.11
NH	0.78***	NJ	0.68***	NM	0.16	NY	0.62***
NC	0.61***	ND	0.48***	OH	0.64***	OK	0.24*
OR	0.28*	PA	0.53***	RI	0.79***	SC	0.47***
SD	0.48***	TN	0.56***	TX	0.28**	UT	0.32**
VT	0.81***	VA	0.52***	WA	0.26*	WV	0.41***
WI	0.50***	WY	0.41***				

*** < 0.01; ** < 0.05; * < 0.10

Frankel and Rose (1997), using thirty years of data for twenty industrialized countries, find that countries with closer trade links actually have a more tightly correlated business cycle, which is the opposite of what is expected based on Krugman's (1993) analysis. They argue that most trade is actually intra-industry, i.e. trade is *within* rather than between industries. Greater trade intensity may also increase the covariance of country-specific aggregate shocks. Aggregate demand shocks affecting one country can spill over easily to its trading partners, since e.g. a positive demand shock can increase demand for both domestic and foreign output. Another channel where trade can increase business cycle synchronization is when it induces a more rapid spread of productivity shocks. Coe and Helpman (1995) argue this point, where a country's total factor productivity does not only depend on domestic but also on foreign R&D capital, and that this foreign productivity effect is stronger the more the domestic economy is open to foreign trade. In other words, trade acts as a transmission mechanism for shocks to spread more strongly across borders, whether it be demand or productivity shocks. These results are confirmed in Imbs (2004), Frankel and Rose (1998) and Inklaar et al. (2008) who find significant effects of trade in accounting for business cycle correlation.

5.2. Regression Analysis

Having looked at trade as a potential factor in explaining business cycle synchronization, we can also look at other factors. The single biggest factor that comes into mind is the level of industry specialization. Specialized states should have a more idiosyncratic business cycle, and so we should see a positive relationship between specialization and business cycle dissimilarity. To test this hypothesis, we regress business cycle dissimilarity on a measure of specialization, along with other controls.

Specialization Index

Krugman specialization index, as originally seen in Krugman (1991), measures how the industrial structure in a given state is different from the aggregate industrial structure. It takes a value from 0 to 2 where 0 is identical industrial structure to the aggregate, and 2 is complete dissimilarity. The index for state i, is defined as $K_i(t) = \sum_k abs\left(v_i^k(t) - \bar{v}_i^k\right)$; where v_i^k is industry *k*'s share in total industrial output of state *i*, and $\bar{v}_i^k$ is the national benchmark.

Using data from the Bureau of Economic Analysis, we get a measure of how specialized a state is in terms of its industrial structure. From Table 2 we get a significant and positive relationship between dissimilitude with the national cycle and the specialization index. This comes as no surprise, since states with a low index have a more diversified industrial structure, and are therefore more resistant to idiosyncratic sectoral shocks, compared to more specialized states. Diversified states also resemble the aggregate industrial structure more so than the less diversified states, so they should have more similar business cycles.

Table 2: Explaining Business Cycle Dissimilarity

Variables	Coefficient (Std. Err.)
Intercept	0.132**
	(0.063)
Specialization Index	0.189***
	(0.066)
State weights	-0.457
	(0.586)
Fed district HQ dummy	-0.018
	(0.032)
Fed Expenditure	0.196
	(0.252)
Oil & Gas Extraction	1.040***
	(0.362)
N	50
Adjusted R^2	0.448

*** < 0.01; ** < 0.05; * < 0.10

Controls

In Table 2 we control for factors which might affect both the dissimilarity and the specialization index, and see whether the results are robust.[8] First we control for state's weight in the aggregate GDP for the U.S. We see from Figure 1 that some of the least populated states are also some of the most dissimilar in terms of the national business cycle. A possible explanation for that is that lowly populated states weigh too little in the aggregate cycle. State weights might also affect the specialization index, since big states are more likely to be more diversified and thus have a comparatively less specialized industrial structure. We find the coefficient to be insignificant.

The regression contains a dummy variable which takes on the value 1 if a state contains the headquarters of a Federal Reserve district. We include it to test if Federal Reserve district presidents use their influence on the FOMC to get preferential monetary policy for their state, which should make that specific state more synchronized with the

[8] Since we are dealing with variables that change over time, while the dissimilarity coefficient summarizes in a single value business cycle synchronization for 1979-2013, we will use an average of the variables over that period. Due to data restrictions and different industry classifications however, we must limit the average for the specialization index to the years 1979-2008, federal expenditures to 1981-2005, and oil production to 1997-2011. The estimates are however robust for different time frames for which data is available.

aggregate business cycle. The dummy might also affect the specialization index, since district headquarters are usually located in major metropolitan areas, and are as such less specialized due to industry diversification. We find the dummy not to be significant.

We also control for federal expenditures in each state. Expenditures like farm subsidies and military spending might affect both business cycle dissimilarity and the specialization index, but including it yields an insignificant estimate.

Finally, we control for oil and gas extraction, as a fraction of gross state product, to see if the relationship between business cycle dissimilarity and specialization isn't simply characterized by the oil producing sector. We see from Figure 1 that some of the biggest oil producing states like Alaska, North-Dakota and Oklahoma,[9] are also some of the least synchronized with the aggregate business cycle. Controlling for oil production does however not change the point estimate for the specialization index in any significant way, and we also find the oil extraction itself is significant at the 1% level and positive, meaning that a higher reliance on the oil producing sector increases dissimilarity with the aggregate business cycle.

6. Conclusion

Using the coincident index of economic activity for each of the 50 states and the U.S. aggregate, we calculate the continuous wavelet transform and use that to get an estimate of business cycle dissimilitudes. A low value for the dissimilitude between a pair of states, or between a state and the national aggregate, indicates that they have a similar contribution of their business cycles to total variance, the respective contribution to total variance happens at the same time, and the oscillations of each business cycle happens simultaneously. The results show that the states furthest away from the coasts are the least synchronized with the aggregate U.S. business cycle. Alaska and Hawaii show this trend clearly, but it also shows up in the central region of the U.S., stretching from Oklahoma to North-Dakota. When compared to the euro area, the U.S. shows a lot more similarity of business cycles, indicating that the euro area has a way to go until it reaches the optimum currency area ideal.

[9] Texas and California, being the biggest and 3rd biggest producers of oil respectively, are relatively synchronized. This is probably due to the fact that they are by themselves two of the largest economies in the U.S., and are therefore comparatively diversified and thus the oil producing sector doesn't dominate the states' economy, like it does in Alaska and North-Dakota.

We get a strong and significant correlation between distance and business cycle dissimilitudes between states, which is argued to be due to effects of increased trade intensity when regions are closer to each other, as predicted in the gravity model. Theoretically, increased trade might cause regions to specialize and therefore have a less synchronized business cycle, but as seen in Frankel and Rose (1998), Imbs (2004) and Inklaar et al. (2008), we find this not to be the case. Greater trade intensity can affect business cycle synchronization in various ways, but the literature mostly asserts that it acts as a transmission mechanism for shocks, whether they be demand or productivity shocks.

We estimate a simple regression to look at the relationship between business cycle dissimilitudes and industry specialization. We find a significant positive relationship between the two, meaning that states that have a high measure of specialization are more dissimilar to the national business cycle. States that rate low on the specialization index have a more diversified industrial structure and are less vulnerable to idiosyncratic sectoral shocks, which makes their business cycles more similar to the national business cycle. These results are robust even when controlling for states' weight in U.S. GDP, federal expenditures, whether a state contains a Federal Reserve district headquarters and whether the state is a major oil producer.

Together, these results show the economic geography of a monetary union to be a fundamental dimension to take into account in having a good assessment of the costs and benefits associated with having a single currency and monetary policy. It motivates for the need of alternative policy instruments, such as fiscal policy targeted at the state level, in order to minimize the associated costs.

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