Changes in the EU Product Space During European Integration

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3rd May, 2018
Globalization and European Economies
Section A

Abstract

Throughout the integration of European economies under the European Union, trade deals have shaped the macroeconomic landscape and export baskets of the region. Classical economic theory predicts both specialization and product complexification across such integrated economies. With C. A. Hidalgo's empirically-focused, production factor-agnostic idea of the product space, we calculate the EU's comparative advantages and location within that network. We use metrics including shares of export basket, number of Revealed Comparative Advantages (RCAs), degree within the product space, and Economic Complexity Indices to quantify changes. From this theoretical perspective, the Union has become less specialized and not altered its product complexity.

Executive Summary

This paper examines changes in the product space of the European Union over the course of European integration, focusing on trends in specialization and product complexity. Integration has resulted in harmonization of export regulations, greater liquidity in factor markets, and expanded market access. Classical theory, then, predicts an increase in specialization and product complexity, which could heighten the effect of asymmetric shocks. But publications from the European Parliament, for instance, caution against such straightforward analyses.

We draw on the theory of the product space, popularized by C. A. Hidalgo. This analytical lens calculates the relationship amongst products using export data, organizing all products into a sparse network. Analysis uses and develops metrics around the product space, including share of export basket, Revealed Comparative Advantage (RCA), and degree in the product space network. We supplement this data-centered analysis with the Economic Complexity Indices from the Hidalgo's own Observatory of Economic Complexity. Data is drawn from the Atlas of Economic Complexity's aggregation of 1962-2014 bilateral export data, which includes value exported by year, product, origin nation, and destination. Analysis itself has been conducted in the Python programming language, with the open source libraries of pandas, numpy, and matplotlib.

We find that, contrary to the predictions of classical trade theory, the EU's level of product specialization decreased, and product complexity held constant. Absolutely and relative to Europe and the world, the EU has seen a decline in RCAs and a consistent degree of product space complexity. Hidalgo's own Economic Complexity Indices agree with this conclusion, conveying that EU economies have seen their relative complexity decline (in aggregate).

This paper offers a preliminary investigation of changes in the product space under European Integration, in the aggregate. As the product space theory works on export data alone, it is politics and input-agnostic; therefore, a causal model has not been implemented in this paper. Further research may examine individual nations under European Integration, and analyze product space trends alongside policy changes.

I. Introduction

Following Theresa May's 2017 invocation of Article 50, the UK began negotiating trade deals in a post-European Union Britain. With America's election of Donald Trump, progress on the Transatlantic Trade and Investment Partnership halted, and the proposed EU-US agreement remains in limbo. Beyond the headlines, trade policy continues to have a profound impact on European economies, and evaluating trade patterns remains key to assessing the future of said economies. But especially in the case of the European Union, anticipating future trade requires a knowledge of how European integration has already shaped the economic landscape.

Of particular concern to the EU28, asymmetric shocks complicate monetary and fiscal policy. Rosati's "Asymmetric Shocks in the Euro Area: Convergence or Divergence?" introduces asymmetric shocks as an "opposite sign difference" between the EU's and a member's GDP growth rate due to a trend or event. Within integrated economies, product specialization increases the risk of such shocks, while diversification and convergence can align economic conditions. Classical trade theory, including the Ricardian model and H-O theory, predict specialization under integration, while the European Commission offers counterarguments.

To reconcile the question of how European economies have changed under integration, this paper focuses on the indicative power of export statistics. A greater number of comparative advantages suggests the existence of, or opportunity for, product diversification. To explore shifts in comparative advantage, among other changes, the idea of product spaces offers an ideal theoretical foundation. Cesar Hidalgo's concept maps 'proximity,' or similarity, between products by their tendency to be exported together, and creates a network of product nodes linked by proximity. He notes that countries producing in dense areas of the network can export new products more readily than countries producing in outlying areas.

I use raw import and export data from both Feenstra's Center for International Data and UN Comtrade, aggregated at Hidalgo's own Observatory of Economic Complexity. From over one hundred million lines of data I determine the Revealed Comparative Advantages (RCA) of each nation from 1962-2014. I propose measures of similarity in the product spaces of different nations. For the sake of comparison, I develop both pre-EU product spaces and provide product spaces from outside the EU.

With this theory in mind and data in hand, I will address the pertinent question: how have the product spaces of countries within the EU changed under integration, especially with regards to specialization and product complexity? Underlying this problem are a series of multifaceted, interconnected questions: what did the product spaces of EU members look like prior to the EEC — how many RCAs did they have, and did they export from similar sectors? How has the product space of individual nations, and the EU as whole, changed — have the number of RCAs decreased within the EU, and do they produce more similar export baskets? Do movements in the product space agree with, or provide evidence contrary to, the prediction of specialization within the EU?

To begin addressing these questions, I will provide a literature review that explores classical economic thought, draws on papers regarding the product space, and touches on predictions of European specialization. Following samples of the raw trade data and supplementary datasets, I will present visual and written analyses of changes in RCAs and product spaces. Finally, discussions and interpretations of the aforementioned analysis will lead into a concluding review of the research question.

I find that, despite predictions to the contrary from classical economics, product space metrics point to a decrease in specialization and constant product complexity under European Integration.

II. Literature Review

Generations of economics have contributed to today's lexicon of international trade theory, most notably beginning with Adam Smith's commentary on comparative advantage. Traditional economic texts including David Ricardo's 1817 *On the Principles of Political Economy and Taxation* explored how comparative advantage shaped countries' production patterns, noting that "England exported cloth in exchange for wine, because, by doing so her industry was rendered more productive to her"; Ricardo began modeling the specialization of individual countries and regions. Then with trade barriers relaxed under economic integration, due to the decrease of transport costs and standardization of regulations, we would anticipate a fall in the cost of exporting goods and services. In turn, trade and thus specialization would increase. Leamer's account of the Heckscher-Ohlin model in *The Heckscher-Ohlin Model in Theory and Practice* adds to this classical understanding of economic integration; the theory asserts that countries will export products that make use of their abundant resources, that they import products based on their scarce resources, and that trade "compensates for the uneven distribution of productive resources." Again, classical theory holds that regional differences will result in greater specialization. Yet the H-O theory does not account for differences in technology or institutions, and Ricardo's two-nation model may not hold in this newest wave of globalization.

As international trade has increased and complexified, contemporary scholarship is needed to explain developments like the Eurozone. Rather than ignoring the role of institutions or the movement of factors of production, the product space takes a backwards approach. That is, it empirically analyzes the trade balance of a nation, calculates comparative advantages, and describes the complexity of the underlying economy. In "The Product Space Conditions the Development of Nations," Hidalgo et. al. ask readers to "[t]hink of a product as a tree and the set of all products as a forest" with relatively dense and sparse areas. While the authors acknowledge the factors that make products complementary in production, or in this case exportation, they follow the premise that "if two goods are related [...] they will tend to be produced in tandem" and gauge products' similarity using National Bureau of Economic Research export data. They introduce the metrics of Revealed Comparative Advantage (RCA) and proximity to produce a network representation of the product

space, and include measurements of countries' diffusion across said space. In this paper, RCA and proximity will be used to study the product space of nations in the EU, and the concept will be used as a general theoretical framework.

Further scholarship has broadened the analytical capability of the product space, as well as studied changes in trade under EU integration. Ferrarini and Scaramozzino, for example, weigh the benefits and pitfalls of complex production in "Production complexity, adaptability, and economic growth," noting the greater risk of failure when specializing in complex production. They find that "losses outweigh the gains from greater specialization" in terms of output levels, although specialization remains beneficial regarding economic growth. Felipe et.al. also argue for adaptability and diversification in "Product Complexity and economic development," emphasizing that specialization risks asymmetric shocks and leads to bimodal distributions of wealth. While Ferrarini and Felipe point out the risks of specialization, "Economic complexity: Conceptual grounding of a new metrics for global competitiveness" by Tacchella et. al. assert that empirical data contradicts the specialization predicted by the Ricardian model. Rather than the block diagonal country vs. product matrix of the Ricardian paradigm, they find a triangular shape in the matrix; few countries produce very complex goods, but many produce less complex goods. Whether from a theoretical or empirical background, examinations of the product space compel a reexamination of shifts in the EU's product space. Contrary to classical theory, European integration may not entirely promote specialization.

Regarding the EU in particular, Velickovski's "Is the European integration speeding up the economic convergence process of the Central and South-Eastern European countries? A shock perspective" contrasts viewpoints predicting specialization and diversification as a result of European integration. The European Parliament, in working paper "The Shortcomings of OCA Theory," argued that "convergent or divergent factors predominate would indeed appear to be a matter of fine balance." Economist Paul Krugman, on the other hand, focused on inter-industry trade to point out how "closer market integration could enhance greater specialization," and Nielsen and Kesting's "Small is Resilient—the Impact of Globalization on Denmark" credits Denmark's success to its adaptable specialization. All that to say, the outcomes of integration are by no means universally agreed upon.

While classical international trade theory serves as an important explanatory role and conveys the power of specialization, specialization does not depend entirely on resource endowment. The theory of the product space identifies countries' comparative advantages by examining their exports, utilizing measures of RCA and proximity. Recent scholarship on the product space and European integration both push against the idea that integration and trade necessarily lead to specialization, empirically and theoretically. With this literature in mind, studying the effects of integration on European product spaces becomes more achievable and more useful.

III. Data

Unique in its simplicity, Hidalgo's product space relies only on export data to analyze the economic development of countries. As such, I draw on export values by product and country from 1962 to 2014. I use data from the Center for International Data and UN Comtrade, collected by the Observatory of Economic Complexity. It includes over one hundred million lines of data ordered as year, origin (ISO Alpha-3), destination (ISO Alpha-3), import value (in 2014 nominal USD), export value (in 2014 nominal USD), and product number (SITC Revision 2). A sample is included below:

	year	origin	dest	sitc	export_val	import_val
0	1962	ago	civ	6785	0.0	3000.0
1	1962	ago	civ	2654	158000.0	0.0
2	1962	ago	civ	6651	1000.0	0.0
3	1962	ago	cod	2483	0.0	1000.0
4	1962	ago	cod	1123	0.0	2000.0

To interpret the data, I supplement the csv with keys to ISO Alpha-3 country codes and SITC Revision 2 product names. Although much of my analysis mirrors the work at Hidalgo's Observatory of Economic Complexity, all analyses presented here were conducted using the raw export data unless otherwise specified. A sample is included below:

	id	id_3char	name
0	afago	ago	Angola
1	afbdi	bdi	Burundi
2	afben	ben	Benin
3	afbfa	bfa	Burkina Faso
4	afbwa	bwa	Botswana

We consider "European integration" for an individual nation as that nation joining the EU or its predecessors — the Coal and Steel Community, European Community, or the EU itself. The following dictionary, based on data from the European Parliament, are used as dates of integration, and are represented as "EU" in tables, graphs, and appendices.

```
eu_members = {'deu':1952,'ita':1952,'fra':1952,'lux':1952,
              'gbr':1973,'esp':1986,'grc':1981,'nld':1973,
              'mlt':2004,'pol':2004,'hrv':2013,'prt':1986,'cze':2004,'aut':1995,'swe':1995,
              'bel':1952,'dnk':1973,'cyp':2004,'fin':1995,'irl':1973,
              'rou':2007,'bgr':2007,'svk':2004,'svn':2004,'ltu':2004,'lva':2004,'est':2004,'hun':2004}
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The final section of analysis uses country rankings on the Economic Complexity Index from Hidalgo's online Atlas of Economic Complexity. On the whole, that data concerns years 2003 onwards, does not present detailed methodology, and is therefore included only to complement analysis from raw export data.

IV. Analysis

A brief examination of European and EU export baskets by product share reveals that, on a macroscopic level, the regions export a similar basket (see Appendix A). We can then use European exports as a baseline, or control, against which to better isolate changes in EU exports. In addition, we find that the composition of EU export baskets has grown more similar over 1962-2014, hinting at potential convergence. Again, this preliminary finding presents on a macroscopic, product category level; further analysis on the product space itself is required.

Analysis of changes in the European product space itself requires considerable data engineering, followed by qualitative interpretations and the development of quantitative metrics. On the quantitative side, I intend to explore European product spaces primarily by exploring changes in Revealed Comparative Advantages (RCAs) and advantage density. Popularized by Balassa and Noland, RCA represents the proportion of exports of x by a country over the proportion of exports of x by the world; a country has an revealed comparative advantage if this metric exceeds one.

$$x = \frac{value\ of\ product\ exported\ from\ country}{value\ of\ all\ country's\ exports} \div \frac{world's\ total\ exports\ of\ product}{world's\ total\ exports}$$

$$rca = \begin{cases} 0 & x < 1 \\ 1 & 1 \leq x \end{cases}$$

Here, I take RCAs as a proxy for successful product diversification versus specialization in the context of the product space. As the RCA measures exports relatively (both to the total export basket and the world's basket), it can be related to inter- and intra-nation specialization. Countries that focus on maintaining a single advantage, or export fewer products with comparative advantages, can be said to be specializing in that product relative to their exporting capabilities. On the other hand, countries that maintain many RCAs have capitalized on more of their comparative advantages, and thus have diversified production amongst their strengths. In the context of the European

economic community, such diversification may lessen the effect of asymmetric shocks amongst exports where the community's advantage is strongest.

To study the effect of integration, it is important to conduct a time-series analysis and study how the number of RCAs has changed over time. In addition, metrics regarding Europe as a whole, EU non-members, and the world's economies are displayed for the strength of comparison. The below diagram, and all others, are produced in Jupyter notebooks with Python, alongside the pandas, numpy, matplotlib, and networkx packages.
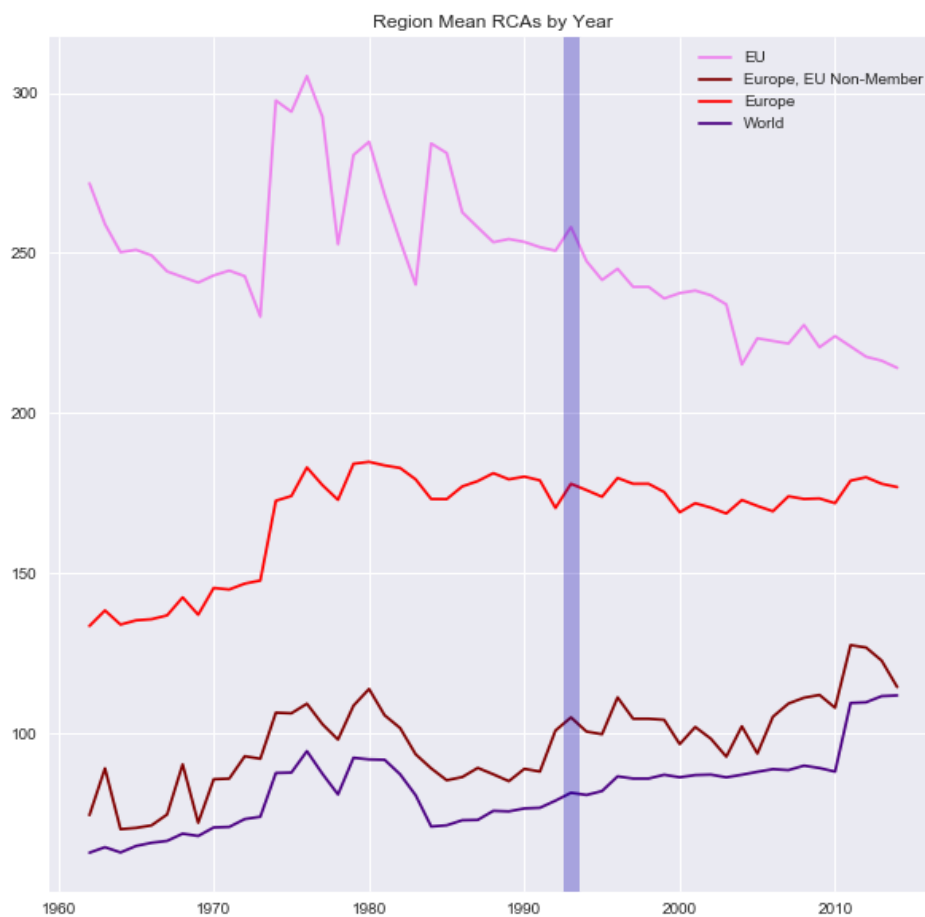
Despite an initial increase around 1973's first enlargement of the European Community, the mean number of RCAs amongst EU nations has continually declined since 1985. The figure shows a convergence in mean RCAs between EU member states and European non-members, although non-members still hold considerably fewer RCAs on average. In addition, the number of revealed

comparative advantages in the EU falls below the projected value based upon trends in members' prior performance. On the whole, European nations still have a higher number of revealed competitive advantages than the international average, and EU nations have a still higher rate of RCAs.

Understanding the number of RCAs as representative of a country's export diversification, the average EU member state has specialized production since 1973. Both Europe and the world as a whole, however, have remained consistently specialized in the same time frame; EU nations have declined in specialization both absolutely and relatively. Thus, on average, the EU's change in RCAs diverges from classical trade theory's prediction of increased specialization due to economic integration. Beyond the mean behavior of EU exports, however, we must study whether individual countries have altered their export diversity.
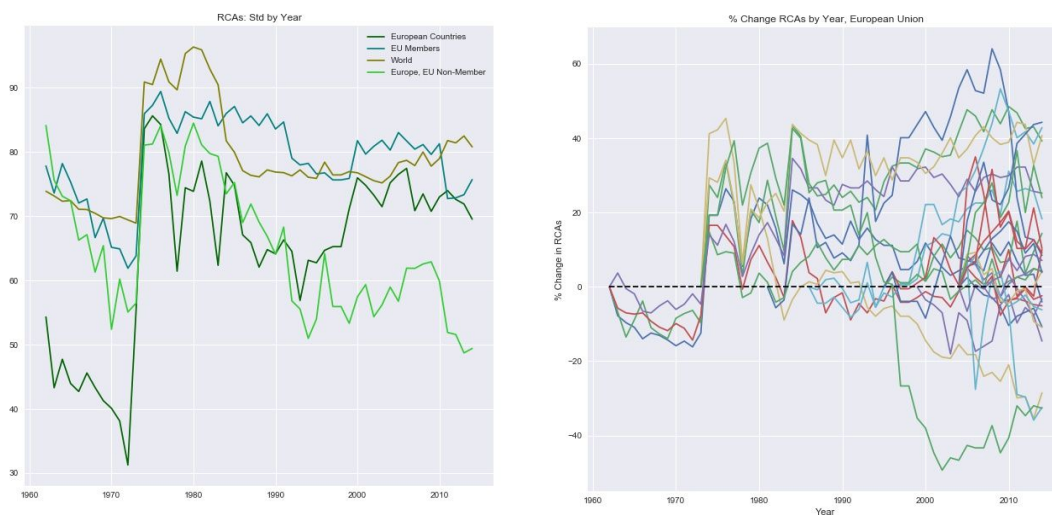

The first figure, above, reveals a higher standard deviation of RCAs amongst European Union members than in Europe as a whole, prompting examination of how individual countries have fared. When graphing percent change in RCAs, we see that the number of RCAs has increased in the majority of nations, but some have seen a more dramatic increase in RCAs. Germany, France, Luxembourg, Great Britain, the Czech Republic, Cyprus, Ireland, Romania, Bulgaria, Slovakia, Slovenia saw their total RCAs decline, as illustrated in the second figure (the black line represents a 0% change from the EU join date). Thus while the EU member countries' economies have

differentiated across their product spaces on the whole, individual economies do not necessarily follow the same trend.

Without a consistent trend, it becomes difficult to model a causal relationship between EU membership and specialization, at least on the basis of RCAs alone. For the purposes of this paper, then, we simply find that EU economies have specialized as a whole.

While the RCA acts as a proxy for differentiation across a nation's product space, it says nothing regarding the complexity of those products. The crux of the product space theory describes how countries develop new comparative advantages, and uses the idea of proximity to quantify the similarity between different products. Under Haussmann's definition, proximity Φ between product x and y is equal to the conditional probability of a country exporting both goods if it exports one.

Given my product proximities calculated the world's 1962-2014 exports, the product space is calculated as a network. Nodes represent individual products, while edges connect products that have a proximity greater than 0.4. For a selected country and year, that nation's RCAs are highlighted in a red hue. Below, the Danish product space in 1967:

Product Space of dnk in 1967
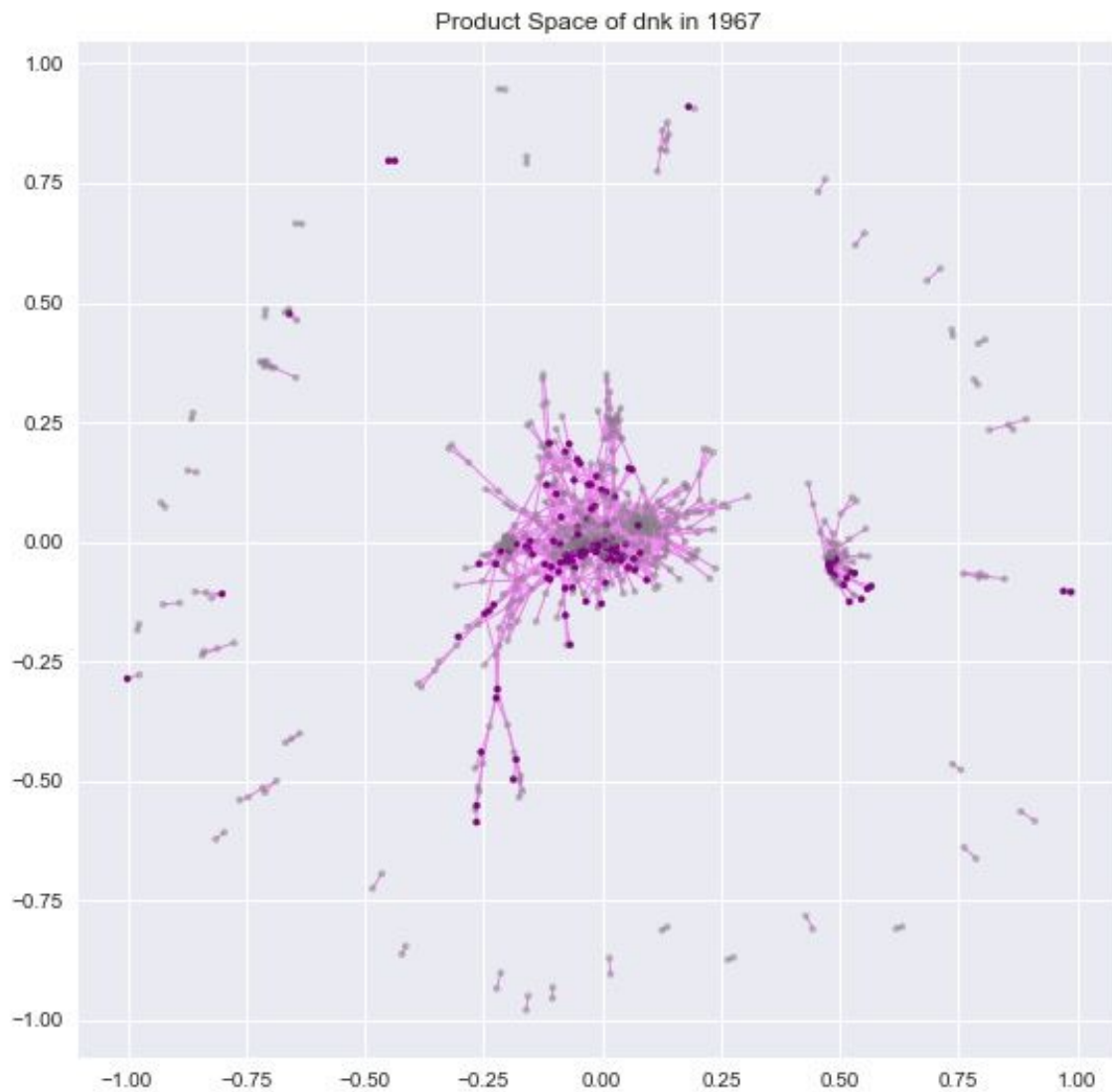
Viewing Denmark's product space in 1967, we realize that the nation mostly held revealed comparative advantages in dense areas of the product space. In turn, theory predicts that Denmark could more easily manifest revealed comparative advantages, with greater access to the 'core' of the network.

While measuring the proximity between products conveys whether RCAs are clustered in certain areas of the product space, it says little regarding possibilities for diffusion across the space. "The Product Space Conditions the Development Of Nations" uses the network structure to convey exactly that point — countries with RCAs in dense areas of the space have a higher

opportunity and probability of expanding across the space with new RCAs. I calculate density around a product by means of degree — the number of edges connected to a given node — and the country's diffusion potential as the sum of its RCAs' degree. The mean diffusion potential, then, constitutes its RCAs' average degree.
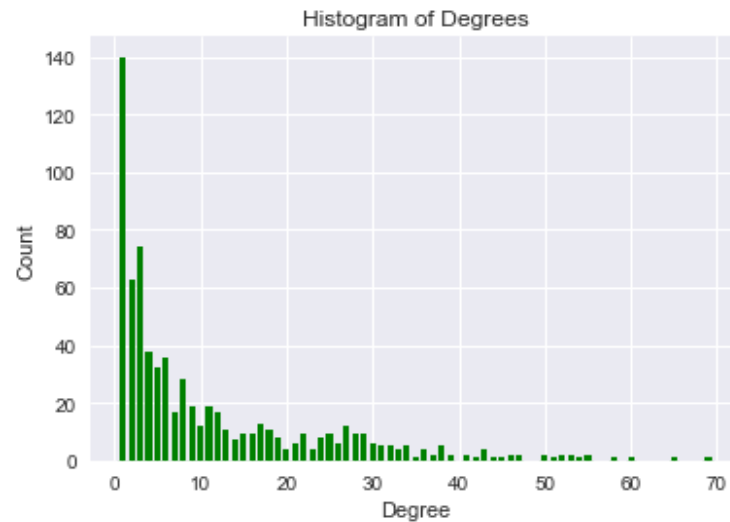

To contextualize any findings in our specific product space, a histogram of degrees per node illustrates the space's connectivity. While many nodes lie on the periphery with under five connections, the majority of products have a degree of at least five, and many are connected to dozens of other products. As the Hidalgo's theory predicts, we have a dense 'core' that allows for more product development and production. On the whole, our product space consists of 705 nodes (products), 3863 edges (proximity > 0.4 between product x, y), and an average degree of 10.9589.
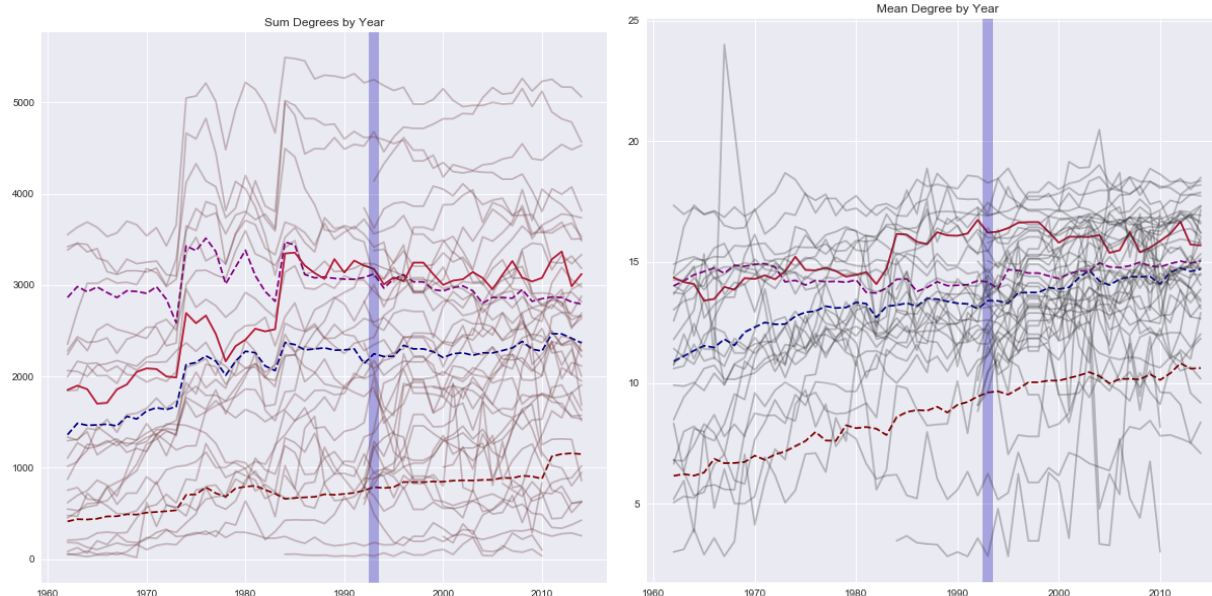
Visualizing regions' diffusion potential as a function of year, it becomes clear that the EU (pictured in purple) has seen a slight but steady decrease in diffusion potential since 1990; this trend runs against that of the world at large (pictured in blue). The world's degree is pictured with a dashed red line, and Denmark's with a solid red line. Perhaps more tellingly, we see the mean diffusion potential of EU nations (in purple) holding relatively stable around a degree of 14, while the world's mean diffusion potential (in blue) has steadily risen from 1962 to 2014. Therefore, while nations on the whole have been developing RCAs in denser, more connected areas of the product space, those of the EU have seen their RCAs' connectivity remain constant.

With decreased trade barriers, standardized regulations, and increased mobility in labor and capital, theory suggests accelerated growth. According to the theory of the product space itself, such growth may manifest in diffusion across the space. Contrary to that analysis, however, we see that connectivity within the EU's product space has not kept pace with the world's.

I supplement ground-up data analysis with complexing rankings from Hidalgo's own Observatory of Economic Complexity. Based on the RCAs of each nation, the Atlas assigns nations a rank and growth potential. Below, the mean rank and growth potential in our regions, recorded over the period 2004-2015.

Economic Complexity Index, Mean by Region

Growth Projection, Mean by Region
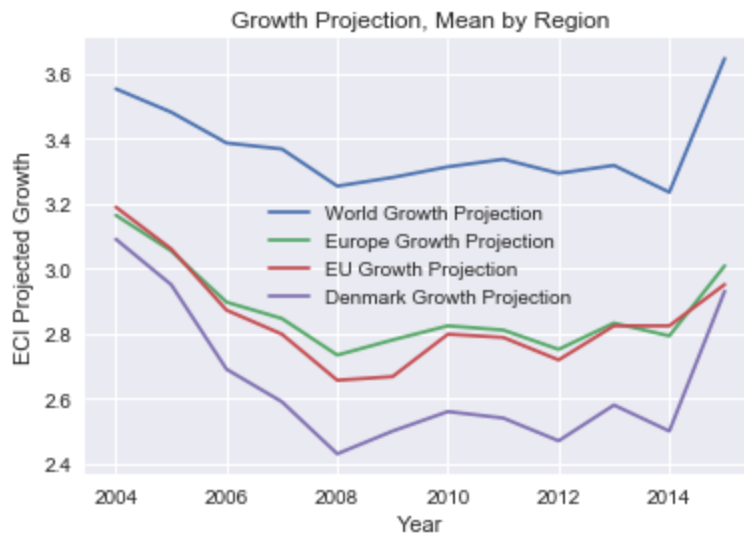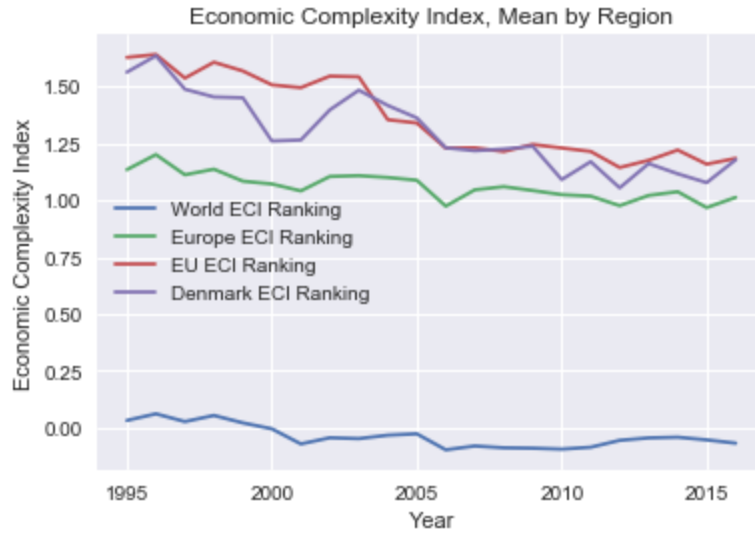
All regions, from the EU to the world as a whole, have seen a decline in complexity and a decrease in projected growth until 2015, according to the OEC. However, relative to the whole of Europe, EU nations have seen a greater fall in economic complexity, especially from 2003 to 2005.

Again turning to standard deviations to explain the distribution of economic complexity across EU versus European economies, we visualize their shift over time:

Standard Deviation in Growth Projection, EU

Standard Deviation in Economic Complexity Index, EU
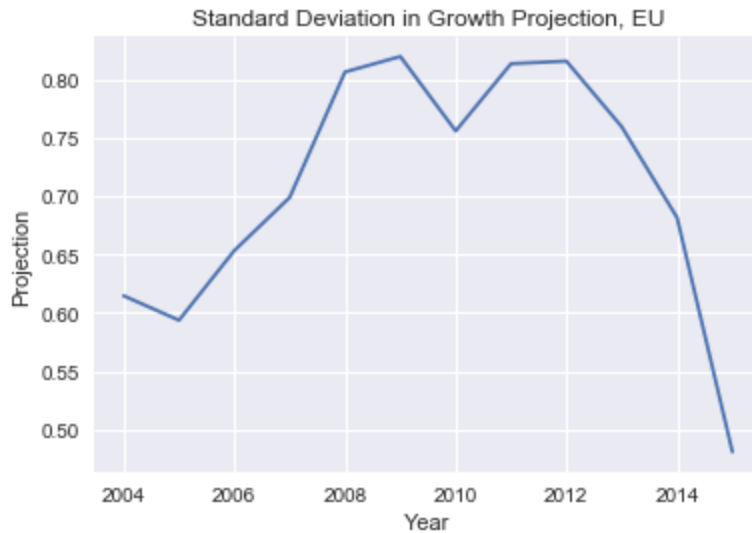
We see evidence of a convergence in the economic complexity of European Union member states; a decrease in stdev indicates mean ECI and growth projection reversion. Thus, according to the OEC's rankings, the EU's product space complexity has declined, but grown more similar, in recent years.

While based upon similar export data, the OEC takes a more holistic approach to ranking complexity, does not elaborate on their ranking methodology, and only releases such analysis for years following 1995. Thus we must weigh analysis of their rankings against our prior, ground-up analysis.

IV. Discussion & Conclusion

In review, we have used the theory of the product space to conduct an exploratory analysis of European economies' trade under European integration. Drawing on Hidalgo's metrics of revealed comparative advantage, proximity, and our own interpretation of degree, we quantitatively considered the changing EU economies.

According to classical trade theory, increased trade under European integration would increase product specialization. In addition, reduced barriers to trade would expand economies of scale, allowing economies to develop more comparative advantages and more complex products. Given this theoretical background, EU export baskets should become less similar over time. When exploring EU product spaces, one would expect an increase in RCAs and an increase in degrees.

We tested these theoretical prediction using the empirical framework of product space theory. Building on raw bilateral 1962-2014 export data from the Center for International Data and UN Comtrade, we analyzed changes in European export baskets, calculated RCAs, developed the product space, and measured space density.

However, looking at product categories by share of total exports, we found that the standard deviation of shares has declined; the pattern has occurred more consistently amongst EU than amongst European economies. Contrary to the prediction of specialization, the EU export basket has grown more similar on a macroscopic, categorical level.

Revealed Comparative Advantages were used as a proxy for specialization, with a greater number of RCAs indicating that a country diversified amongst its potential advantages and a lesser number meaning it specialized. Although EU nations have a higher mean RCA count than European nations on the whole, that count has declined absolutely and relative to Europe. An increasing standard deviation in RCAs points to the need for further investigation and a lack of convergence in European economies. Again, despite theorized specialization, the metrics of the product space indicate that EU economies have diversified.

After calculating the proximity of various products and assembling the product space, we used the degree of each product node to signal whether it lay in a dense area of the space. The mean degree of RCAs within the EU's product space has remained constant, or declined relative to that of

the world's RCAs. Despite anticipation of a more complex EU product space given shared resources and economies of scale, the EU has not moved towards RCAs with greater connectivity.

Even according to Hidalgo's own Economic Complexity Index, the economic complexity of EU nations have declined relative to that of Europe. Likewise, projected growth has dropped up until 2015.

Altogether, despite the predicted impact of specialization, convergence, and complexification on the product space of integrated EU economies, changes in the product space indicate product diversification and declining complexity. Therefore, the risk of asymmetric shocks may be an oversimplification or overestimation, and the EU seems a more optimal currency area through the product space perspective.

This paper is meant as a preliminary, exploratory review of product space changes under the European Integration, reflecting several realities: (1) the impossibility of conducting an accurate, realistic analysis in holding all else equal (no European integration), (2) data analysis often required operations with processing time over twelve hours; the modeling process would require considerable more computing power than available, (3) comprehensive data is only available beginning in 1962, and (4) the product space is politics and input-agnostic, and it is thus difficult to establish causal links to it. Further research may focus on individual nations under European integration, or may align economic trends with changes in policy.

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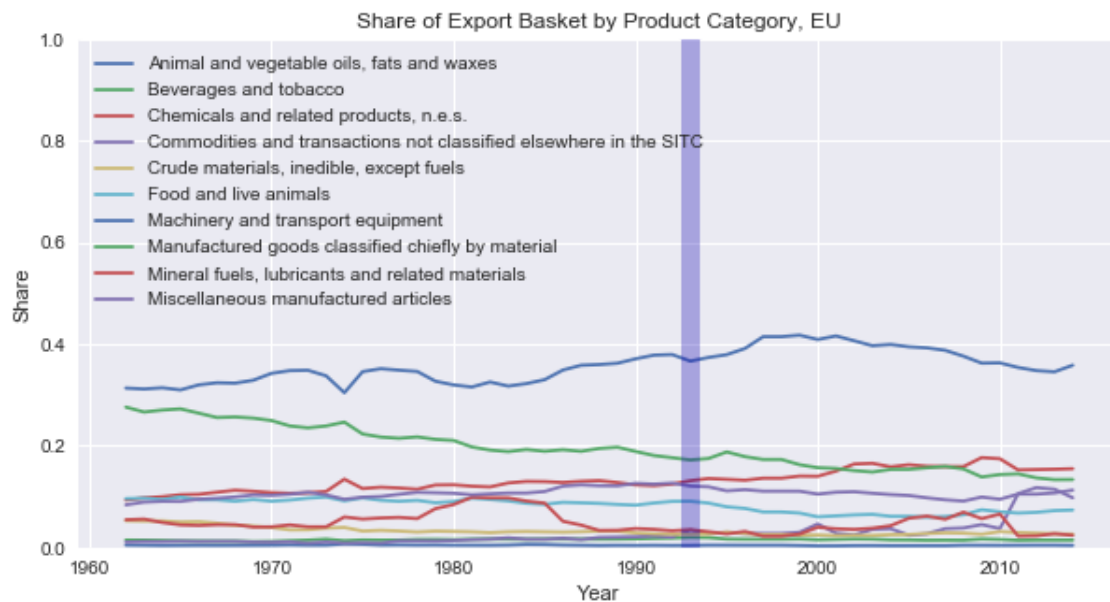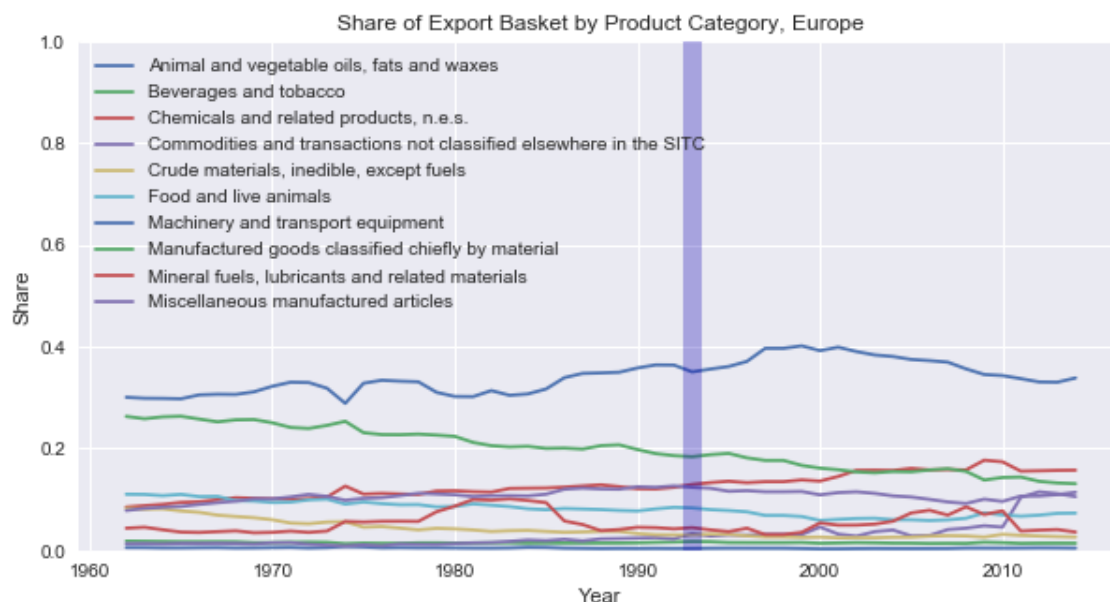   *(for export data)*

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      (for Complexity ratings)

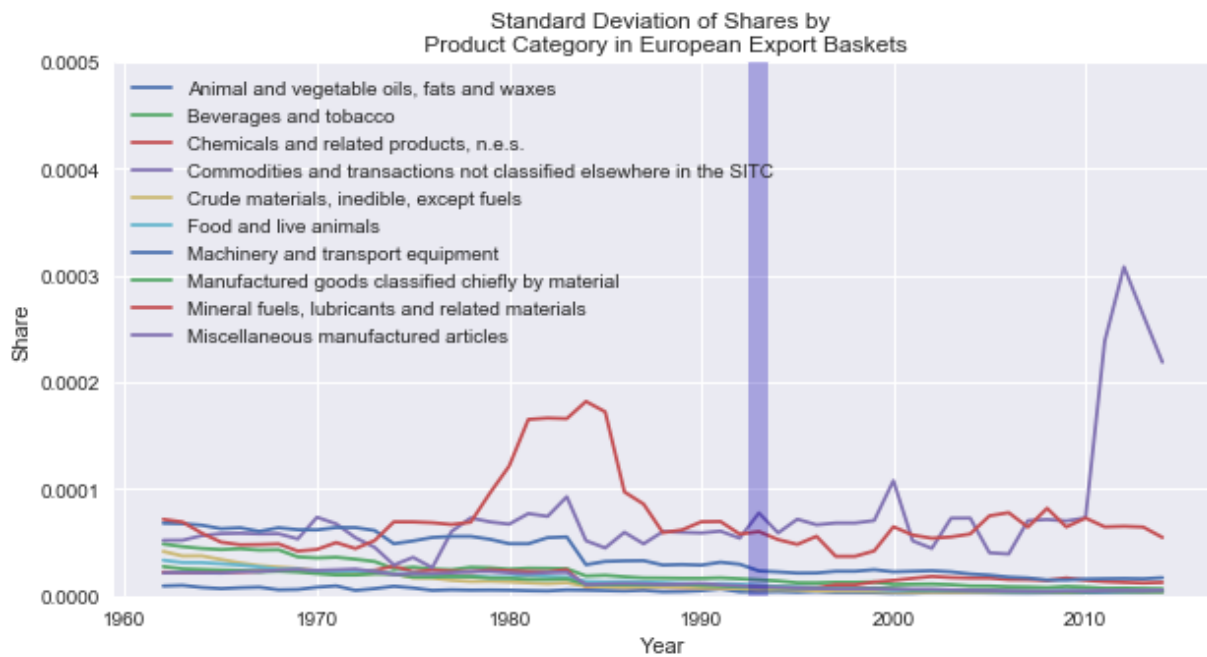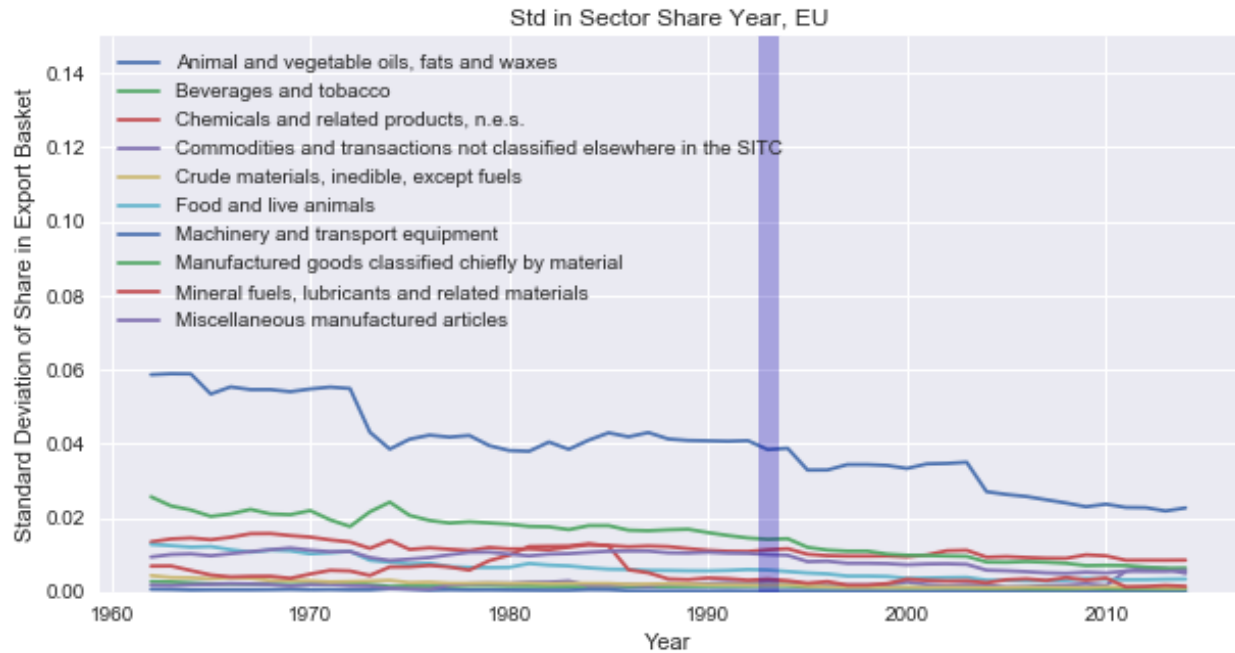**Appendix A: Examination of EU, European Export Baskets by Product Share**

Alongside examining the EU's product space, analyzing its underlying export basket will uncover specialization, or lack thereof. The HS1992 product classification divides products into ten categories — animal and vegetable oils, fats and waves, beverages and tobacco, chemicals and related products, crude materials (inedible) except fuel, food and like animals, machinery and transport equipment, manufactured goods, mineral fuels and lubricants, miscellaneous manufactures articles, and other commodities — both EU and European exports in each category are displayed below as a share of total exports.

Share of Export Basket by Product Category, Europe

Legend:
- Animal and vegetable oils, fats and waxes
- Beverages and tobacco
- Chemicals and related products, n.e.s.
- Commodities and transactions not classified elsewhere in the SITC
- Crude materials, inedible, except fuels
- Food and live animals
- Machinery and transport equipment
- Manufactured goods classified chiefly by material
- Mineral fuels, lubricants and related materials
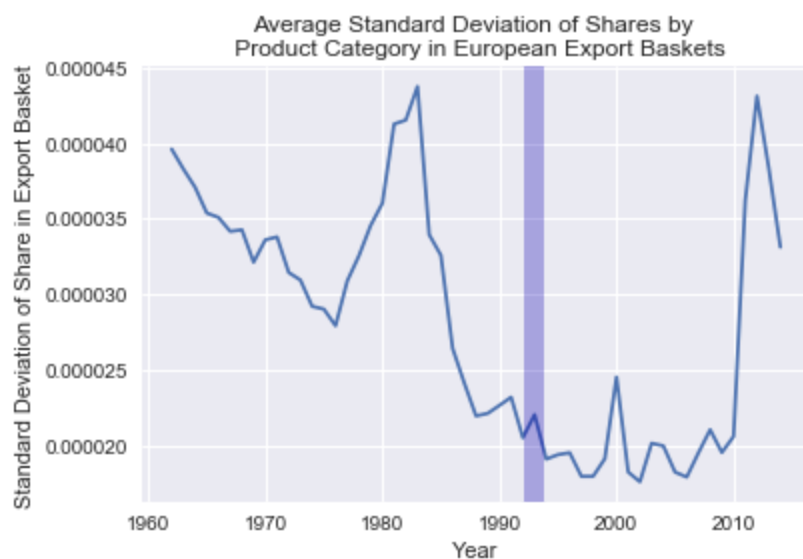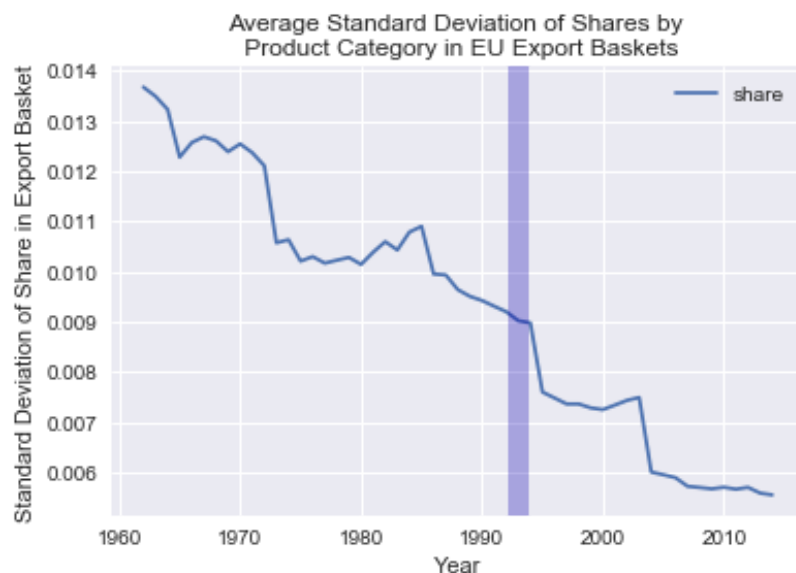- Miscellaneous manufactured articles

We find little difference between the regions, indicating that (1) EU exports constitute the bulk of European exports and that (2) the export basket by category is similar inside and outside the EU. This similarity provides for ease of comparison in other areas — without striking differences in exports, we can treat Europe as a whole as a base group against which to measure the effects of European integration.

Focusing again on export basket composition by HS1992 classification, we study the standard deviation from such shares of export basket within each region. These statistics reveal how much Europe and the EU, respectively, differ internally in their composition of exports. Although such a measure is an abstraction based on broad categories, it will provide a general perception of regional similarities. Both a breakdown by product category and averages are included.

Std in Sector Share Year, EU

Standard Deviation of Shares by
Product Category in European Export Baskets

Average Standard Deviation of Shares by
Product Category in EU Export Baskets

Average Standard Deviation of Shares by
Product Category in European Export Baskets

With a different number of region members underlying these regional statistics, we cannot compare standard deviations absolutely, but we can contrast trends. Both EU nations and Europe as a whole have seen the standard deviation in share of export basket decline — that says, on a macroscopic level, that the export baskets of EU economies have actually grown more similar. Again, this preliminary finding presents on a macroscopic, product category level; further analysis on the product space itself is required.