Hacettepe University Graduate School of Social Sciences

Department of Economics

ECONOMIC COMPLEXITY AND ECONOMIC PERFORMANCE

Barbaros Güneri

Ph.D. Dissertation

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ACCEPTANCE AND APPROVAL

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ETİK BEYAN

Bu çalışmadaki bütün bilgi ve belgeleri akademik kurallar çerçevesinde elde ettiğimi, görsel, işitsel ve yazılı tüm bilgi ve sonuçları bilimsel ahlak kurallarına uygun olarak sunduğumu, kullandığım verilerde herhangi bir tahrifat yapmadığımı, yararlandığım kaynaklara bilimsel normlara uygun olarak atıfta bulunduğumu, tezimin kaynak gösterilen durumlar dışında özgün olduğunu, Doç. Dr. A. Yasemin YALTA danışmanlığında tarafımdan üretildiğini ve Hacettepe Üniversitesi Sosyal Bilimler Enstitüsü Tez Yazım Yönergesine göre yazıldığını beyan ederim.

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ABSTRACT

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Economic complexity is relatively a new concept developed in recent years to provide a holistic measure of the production characteristics of countries. Economic complexity not only explains the countries’ productive structures but also helps examine the income and growth differences across countries. This study aims to analyze the link between complexity and economic performance for a group of countries for the period between 1981 and 2015 by using the Economic Complexity Index developed by Hidalgo and Hausmann (2009). This thesis contributes to literature in various ways. First, the effect of economic complexity on economic growth and convergence is examined by applying a dynamic panel data methodology. Second, causal relationship between growth and complexity is investigated. Finally, the link between output volatility and economic complexity is also analyzed for a group of countries using a panel vector autoregressive model. The estimation results reveal that economic complexity is an important determinant of economic growth. Furthermore, the findings show that complexity also positively affects the speed of convergence. In addition, it is demonstrated that economic complexity also helps to stabilize an economy through reducing the negative effects of output volatility. These findings suggest that improving the economic complexity contributes greatly to the performance of an economy. Therefore, policies that aim to increase the economic complexity should be one of the major objectives of economies.

Key Words: Economic Complexity, Economic Growth, Output Volatility, Dynamic Panel Data, Panel Vector Autoregressive Model.

ÖZET

GUNERI, Barbaros. *Ekonomik Kompleksite ve Ekonomik Performans,* Doktora Tezi, Ankara, 2019

Ekonomik kompleksite, ülkelerin üretim özelliklerinin bütünsel bir ölçümünü sağlamak için son yıllarda geliştirilen yeni bir kavramdır. Ekonomik kompleksite yalnızca ülkelerin üretim yapılarını açıklamakla kalmaz, aynı zamanda ülkeler arasındaki gelir ve büyüme farklılıklarını da açıklamaya yardımcı olur. Bu çalışma, Hidalgo ve Hausmann (2009) tarafından geliştirilen Ekonomik Kompleksite Endeksi'ni kullanarak kompleksite ve ekonomik performans arasındaki bağlantıyı bir grup ülke için 1981 - 2015 yılları arasında analiz etmeyi amaçlamaktadır. Bu tez, literatüre çeşitli şekillerde katkıda bulunmaktadır. İlk olarak, ekonomik kompleksitenin ekonomik büyüme ve yakınsama üzerindeki etkisi dinamik panel veri metodolojisi uygulanarak incelenmiştir. İkinci olarak, büyüme ve kompleksite arasındaki nedensel ilişki araştırılmıştır. Son olarak, çıktı oynaklığı ile ekonomik kompleksite arasındaki ilişki, panel vektör otoregresif model kullanılarak çeşitli ülkeler için analiz edilmiştir. Tahmin sonuçları, ekonomik kompleksitenin, ekonomik büyümenin önemli bir belirleyicisi olduğunu ortaya koymuştur. Ayrıca, bulgular, kompleksitenin, yakınsama hızına pozitif bir etkisi olduğunu da göstermiştir. Ek olarak, ekonomik kompleksitenin, çıktı oynaklığının olumsuz etkilerini azaltarak ekonominin istikrara kavuşmasına yardımcı olduğu da gösterilmiştir. Bu bulgular, kompleksitenin geliştirilmesinin bir ekonominin performansına büyük katkı sağladığını göstermektedir. Bu nedenle, ekonomik kompleksiteyi arttırmayı amaçlayan politikalar, ekonomilerin temel amaçlarından biri olmalıdır.

Anahtar Kelimeler: Ekonomik Kompleksite, Ekonomik Büyüme, Çıktı Oynaklığı, Dinamik Panel Veri, Panel Vektör Otoregresif Model

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ABBREVIATIONS

ADF: Augmented Dickey Fuller

ARDL: Autoregressive Distributed Lag Model

ASEAN: Association of Southeast Asian Nations

CD: Coefficient of Determination

ECI: Economic Complexity Index

GCC: Gulf Countries Council

GDP: Gross Domestic Product

GMM: Generalized Method of Moments

HS: Harmonized System

IMF: International Monetary Fund

IRF: Impulse Response Functions

MAIC: Modified Akaike Information Criterion

MBIC: Modified Bayesian Information Criterion

MC: Marginal Cost

MMSC: Moment and Model Selection Criteria

MQIC: Modified Hannan-Quinn Information Criterion

OLS: Ordinary Least Squares

PCI: Product Complexity Index

PP: Phillips Perron

RCA: Revealed Comparative Advantage

REER: Real Effective Exchange Rate

R&D: Research and Development

SITC: Standard International Trade Classification

TOT: Terms of Trade

UK: United Kingdom

UNCOMTRADE: United Nations Commodity Trade

USA: United States of America

VAR: Vector Autoregression

INTRODUCTION

One of the most important issues in economics is the income and growth differences among countries. Explaining these differences among nations is a crucial objective of economics; hence many theories have tried to analyze the reasons behind the income gap among countries. They pointed out different factors, such as technology, human capital, international trade or quality of institutions as a source of income level differences. In recent years, a strand of the literature has emphasized that one of the main reasons behind the huge income distinctions is the productive structure of countries. In some countries, economies produce highly sophisticated goods, such as airplanes, computers and microcircuits. On the other hand, some countries produce relatively simple goods such as t-shirts or apricots. In this sense, every country has different productive characteristics that allow them to produce goods and services. Hence, understanding the drivers behind these productive characteristics has a crucial importance in terms of analyzing the income differences between countries.

Hidalgo and Hausmann (2009) and Hausmann et.al (2011) tried to analyze productive structures of countries. They argued that every country has different productive knowledge which includes many aspects, such as infrastructure, labor, capital, institutions and much more. Since it is almost impossible to measure and analyze these complicated characteristics of productive knowledge directly, Hidalgo and Hausmann (2009) proposed using export structures of countries as a proxy to measure the productive knowledge among countries and created the Economic Complexity Index (ECI) together with Simoes and Hidalgo (2011).

In this perspective, economic complexity examines every country individually through their productive structure and offers different paths for different countries in terms of economic growth and development. Thus, rather than one size fits all approach, economic complexity suggests specific ways for each country to reach higher growth rates. By analyzing the productive structure of a country elaborately, it reveals which products are feasible for a country to produce given their level of complexity. Within this context, economic complexity actually brings a new perspective to economic growth and development. In this sense, the main motivation of this thesis is to inspect the implications of economic complexity on economic growth, convergence and output volatility in a detailed way.

Although various studies have been conducted regarding the relationship between complexity and other macro variables, such as economic growth and income inequality, many aspects of economic complexity still remain unexplored**.** The purpose of this study is to inspect the relationship between economic complexity and economic performance in general. Specifically, there are four main contributions of this thesis. After analyzing and exploring the implications of Economic Complexity, the first contribution is to examine the link between complexity and economic growth. This study also contributes to literature by analyzing whether economic complexity helps poor economies to catch up with rich countries, namely convergence. Furthermore, a causal relationship will also be examined to check whether there is a bidirectional relationship exists between complexity and growth. Last but not least, investigating the link between complexity and output volatility is the fourth main contribution of this thesis.

The most common indicator used in the economics literature for the economic performance of countries is the real GDP growth rate. After analyzing the concept of economic complexity and its theoretical connections with growth, the empirical relationship between economic complexity and economic growth will be analyzed using a dynamic panel data methodology for a large set of countries by taking into account different income sizes and various control measures, covering the 1981-2015 periods. Until now, only a few studies have analyzed this relationship and the number of studies that have used dynamic panel methodology is fairly limited. Furthermore, together with the dynamic panel data methodology, using a broad time span and considering different control variables allows this study to distinguish from the previous ones.

There is a broad discussion in literature about the sources of income level differences and whether there is divergence or convergence among countries. After checking the link between complexity and growth, the implications of economic complexity on economic convergence will be examined. There are only a few studies that have analyzed this relationship before, thus analyzing the complexity and convergence relationship will contribute greatly to the literature. In this perspective, implications of economic complexity for developing countries will also be investigated.

One of the major purposes of this thesis is to determine whether a causal relationship exists between Economic Complexity and GDP per capita growth. Economic complexity suggests that countries should accumulate the productive knowledge to improve their living standards. Hausmann et.al (2011) argued that the distinctions in income levels are due to the differences of productive knowledge among nations, and the reason behind these differences lies behind the diversity of production structures. Authors like Acemoglu and Zilibotti (1997) suggested that economic development and an increase in GDP growth might increase diversification among an economy. Evaluating these findings together with the fact that economic complexity is the collective productive knowledge among an economy, there might be a bi-directional relationship between complexity and GDP per capita growth. To the best of my knowledge, this thesis is the first to analyze this kind of relationship, which will be one of the main contributions of this thesis to the literature.

Another major purpose of this study is to inspect the effects of complexity on output volatility. In addition to the importance of economic growth on a country's well-being, an additional critical factor is having stable growth rates. Huge and frequent fluctuations in an economy will create an instable atmosphere and under these circumstances, economic agents are more likely to move their resources into foreign economies. Moreover, sustainable economic development is the most important target of many economies, especially for developing ones, and sustainable development requires sustainable economic growth and macroeconomic stability. In addition to these aspects, it is proven by empirical literature that volatility cause growth to slow down. Since the empirical evidence suggests that volatility is a barrier for economic growth, economic policies that aim to lower the volatility should be a major concern of economies. The construction of economic complexity suggest countries to diversify and increase the sophistication of their production, thus complexity might arise as a useful instrument to help countries to lower the effects of output volatility by creating a more stable environment. Therefore, investigating the link between complexity and volatility has a significant importance. For this purpose, firstly, the implications of complexity on output volatility in a theoretical perspective will be discussed. Then, the link between economic complexity and output volatility at the macro level will be examined for a group of countries with additional control variables, and using a panel vector autoregressive methodology. To the best of my knowledge, this thesis will be the first to analyze this relationship at the macro level.

The thesis is structured as follows: First chapter analyzes the Economic Complexity Index, its measurement and the concept of product space. Second chapter examines the effects of economic complexity on growth and convergence, as well as the causal relation between growth and complexity. Third chapter discusses about the theoretical background between economic complexity and output volatility, and furthermore, investigates the effects of complexity on volatility in an empirical way. Last but not least, the findings of the thesis will be summarized in conclusion.

1. ECONOMIC COMPLEXITY INDEX

The purpose of this chapter is to explain and analyze the economic complexity index. After analyzing the background on the creation of economic complexity, two additional sections is also added to better understand complexity. The first section will explain the economic complexity index by discussing about its mathematical measurement and the second section will analyze the idea of product space. The concept of product space is especially important because it examines how complexity evaluates the productive structure of countries and helps us better understand the possible diversification mechanisms of production.

Since the beginning of economics literature, economists have argued what lies behind the economic prosperity of nations. In the last two hundred years, economists have produced many theories that could explain the drivers of the economic growth and huge income differences among countries. Some of them argued that capital accumulation generates growth, while others have emphasized different concepts such as international trade, technology and investment etc. Hausmann et.al (2011) argues that the reason behind the economic growth and prosperity is productivity. Mainly, growth is a process of changing what and how you produce. As time passed by, technology and thus production around the world has evolved furiously and created a highly complex world. Thanks to many different types of capital and labor today, even producing a simple good such as “bread” requires a combination of different activities. One needs to plant wheat, collect it from fields, process the wheat into flour by adding salt and water, and then cook it in a proper way. However, it does not end like that. That bread has to reach the customers through an organized market, which requires at least some level of institutional quality and adequate human capital. Thus, even in order to organize a simple market, one country must have sufficient human capital and institutional organizations, and infrastructure such as bridges, roads etc.

The complexity of the economic system is constantly increasing and this brings us to the problem of modeling this complex world. Hidalgo and Hausmann (2009) and Simoes and Hidalgo (2011) have tried to analyze this complex structure through international trade data. They argued that global markets connect countries together, but there are still huge differences among their income levels. The reason behind this phenomenon should be that there are some things that cannot be imported, such as types of physical/human capital, labor, institutional quality, market regulation etc. That is, the productivity of a society must depend on its local or non-tradable sources or capabilities. Modern societies are characterized by the variety of knowledge among individuals and their capability to synthesize the knowledge through complicated social interactions. Thus, a society functions properly as long as its members specialize, share and spread their knowledge among other members (Hausmann et.al, 2011). All members of a society have some productive knowledge, which can be called as capability. Products are combinations of a large number of productive knowledge, and countries can make products if they have all the required productive knowledge. Hausmann et.al (2011) analyzed these capabilities[1] and productive knowledge among countries, and created an index that explains the complex structure of an economy, namely Economic Complexity Index.

Recall that it has been argued that even producing bread needs many functions. If a country or an organization can bring these functions together, then a successful production occurs. It does not make sense to expect only one person to harvest wheat, make flour, using a machine to cook bread and then transfer it to other people via roads or markets. In modern world, someone specialize in harvesting, another one specialize in building roads on so on. Thus, when every individual's productive knowledge come together, an operative and functioning market occurs. Hence, modern economies must organize capabilities/productive knowledge in order to have an organized system. Therefore, as Hausmann et.al (2011:18) states:

> "Economic complexity, therefore, is expressed in the composition of a country's productive output and reflects the structures that emerge to hold and combine knowledge"

Hidalgo, Klinger, Barabási, and Hausmann (2007) and Hidalgo and Hausmann (2009) showed that the development and growth scheme of a country depends on the ability of

[1] Capabilities can be thought as anything that contributes to production of any good and service.

accumulating productive knowledge to produce diverse and more sophisticated products. Therefore, the concepts of diversification and sophistication have a fundamental role in terms of economic complexity.

Diversity could be one of the strongest words that could describe the complexity of the world. The economies around the world are fairly diverse in terms of capital, labor, markets, institutional quality etc. According to the European Central Bank[2], diversity implies the relative importance of various economic activities that contributes to aggregate output. Although one of the famous economists, David Ricardo, argues that countries must specialize, not diversify, many scholars today such as Hesse (2008) and Agosin (2007) showed that diversification leads to higher growth.

A famous English saying "*Putting all of one's eggs in one basket*" emphasizes the importance of diversification. This saying suggests that one should divide their eggs into different baskets in order to lower the risk, since if something happens to the basket, one could lose all they have. Similar to this saying, diversification of output structure decreases the possible risks a country faces. Relying on one or few products may harm the country in a significant way if an unexpected shock comes to that product(s). Thus, the purpose behind diversification is to generate various income sources (Hvidt, 2013). By diversifying their export bundles, countries decrease the variability in export revenues and gain advantage in terms of trade, which improves their economic performance (Herzer and Nowak-Lehnmann, 2006). The prices of commodity products are usually volatile, and this could deter investment, increase uncertainty and finally hinders economic growth (Hesse, 2008), thus diversifying the export basket acts as a defense mechanism against uncertainty. Moreover, as Al-Marhubi (2000) argues; export diversification strategies might be useful for other firms and sectors by enhancing production techniques and creating knowledge spillovers. In addition to these effects, export diversification might also contribute to the economy by the demand side. Especially in small countries with low domestic demand, diversification of export basket might generate advantages by opening up new opportunities in foreign markets and contribute to higher growth. (Hesse, 2008)

[2] https://www.ecb.europa.eu/mopo/eaec/diversity/html/index.en.html

In addition to the importance of diversity, producing sophisticated goods is also crucial for countries. Export sophistication can be defined as: "*An export is more sophisticated the higher the average income of its exporter*" (Lall, Weiss and Zhang, 2006:223). Similarly, Hausmann, Hwang and Rodrik (2007) also argued that the products that will contribute higher to growth can be considered as a more sophisticated good. According to Singer Prebisch thesis, the countries which mostly produce primary goods will experience a slowdown in their economy eventually, since the price of primary goods decrease relative to manufactured goods in the long run and cause terms of trade to decline (Toye and Toye, 2003). Therefore, producing complex or sophisticated goods also help countries to improve their performance. Sophistication can also be defined as the changes in the composition of production. Export sophistication suggests that economic development requires a switch from simple products to complex ones (Romero, Freitas, Britto and Coelho, 2015). Complex, or high value added products have important advantages such as they usually have a higher productivity, generate increasing returns, and creates high possibility of technological change (Gala, Rocha and Magacho, 2018). Thus, the transformation that allow countries to switch from simple sectors such as mining to complex sectors such as electronics and manufacture, can be considered as a key driver behind economic growth.

By taking into account diversification and sophistication concepts, economic complexity tries to capture the capabilities and productive knowledge among a country/region. Using international trade data, diversity/ubiquity measures and cross country and product comparisons, Hidalgo and Hausmann (2009) and Hausmann et.al (2011) created the economic complexity index, which reveals the complexity of a country. They argue that complexity of a country is basically the average complexity of products it exports, and complexity of a product is basically the average complexity of countries that are exporting that product. In the next section, the measurement of complexity will be discussed and a clear explanation of its measurement will be provided.

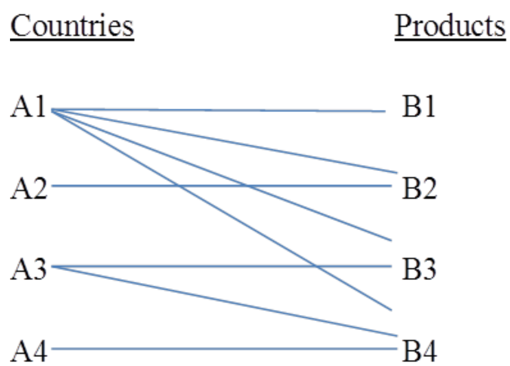
1.1. MEASUREMENT OF ECONOMIC COMPLEXITY

Economic Complexity aims to combine the two properties, namely diversity and ubiquity to create an index which measures how complex the productive structure of an economy is. Exporting a diverse set of goods implies that a country has many capabilities. Measuring diversification is fairly easy, it can be calculated through the number of products a country exports. On the other hand, measuring sophistication is somewhat controversial. To measure sophistication, many authors such as Lall et.al (2006), and Hausmann et.al (2007) created indexes that reflect sophistication of exports. However, both papers used income levels of countries which might create some bias. For example, Xu (2010) argued that using the average income level of China lead to an underestimation of sophisticated exports of China. To overcome this issue, Hausmann et.al (2011) stated that sophisticated goods tend to be less ubiquitous since producing them requires combining many capabilities and most of the countries cannot produce them due to the lack of capabilities. For example, producing bread is relatively easy, because it requires a few capabilities to combine, whereas producing airplanes or engines requires many capabilities to combine. Therefore, by analyzing the capabilities throughout a country, Hausmann et.al (2011) created a more robust sophistication measurement. Combining the ubiquity -which is a measure of sophistication- with diversification, provide valuable information about the capabilities of a country.

Hausmann et.al (2011) showed that to capture the complexity of a country, measures of diversity and ubiquity should be used to correct each other. Being a diverse country or producing only non-ubiquitous goods would not be enough for a complex productive structure. Consider the following example by Hausmann et.al (2011): Both Pakistan and Singapore export same number of products (133) with revealed comparative advantage greater than one. However, in terms of GDP per capita, Singapore is thirty eight times richer than Pakistan. Since both countries are exactly same in terms of diversity of the exported products, the huge difference must come from the types of products they export. When checking for the ubiquity of exports, the exports of Pakistan on average are also exported by twenty eight other countries, whereas the exports of Singapore on average are only exported by seventeen other countries. Although this might not seem as a huge difference, these rankings put Pakistan in the sixtieth percentile in terms of ubiquity, and put Singapore in the first percentile in terms of ubiquity. Furthermore, Singapore's exports are mostly exported by countries with higher diversification, whereas Pakistan's exports are mostly exported by lowly diversified countries. As this example suggests, diversity by itself does not give enough information about complexity.

Consider another example about raw diamonds by Hausmann et.al (2011). It is produced by only a few countries and makes it fairly non-ubiquitous. But if producing raw diamonds requires high productive knowledge/many capabilities, then it must be the case that the countries' export diamonds should also export many other products. However, the data shows that countries that export diamonds are not diversified and they mostly export simple products. Thus this is an indication that raw diamonds are not complex goods, they just require geographical luck. This example shows that ubiquity by itself also is not a perfect measure of complexity or high income.

The examples above showed that diversity and ubiquity must be used simultaneously to correct the information they carry. If a country is diversified, it is an indicator that country has many capabilities. However, if you are a diverse country that exports products that few countries export and if those countries are also diversified, the indicator of having many capabilities assumption gets stronger. Thus, diversity must be corrected with ubiquity and vice versa. This method is called method of reflections and a simple example of method of reflections from Hidalgo and Hausmann (2009) can be seen below:



In the example above, A's represent countries and B's represent products. The links between each country and product implies that a country is exporting that product. That is, country 1 exports all products, country 2 exports only second product, country 3 exports products 3 and 4, and country 4 exports product 4 only.

For the example above, diversity of countries and ubiquity of products can be written as:

Diversity:	*Ubiquity:*
$k_{a1,0}=4$	$k_{b1,0}=1$
$k_{a2,0}=1$	$k_{b2,0}=2$
$k_{a3,0}=2$	$k_{b3,0}=2$
$k_{a4,0}=1$	$k_{b4,0}=3$

In the above equations, a1 through a4 represents countries, b1 through b4 represents products and 0 represents the number of iterations. For example, since country 1 exports all 4 products, $k_{a1,0}$ is equal to four and since product 2 is exported by two countries, $k_{b2,0}$ is equal to two.

Let's calculate the first reflection. It includes average ubiquity of a product and average diversification of countries. Thus,

$k_{a1,1}=(1/4)(1+2+2+3)=2$ $k_{b1,1}=(1/1)4=4$

$k_{a2,1}$=(1/1)2=2 $k_{b2,1}$=(1/2)(4+1)=2.5

$k_{a3,1}$=(1/2)(2+3)=2.5 $k_{b3,1}$=(1/2)(4+2)=3

$k_{a4,1}$=(1/1)3=3 $k_{b4,1}$=(1/3)(4+2+1)=2.3333

The second reflection is calculated by considering the neighbors of first reflection values. Thus,

$k_{a1,2}$=(1/4)(4+2.5+3+2.3333)=2.9583 $k_{b1,2}$=(1/1)2=2

$k_{a2,2}$=(1/1)2.5=2.5 $k_{b2,2}$=(1/2)(2+2)=2

$k_{a3,2}$=(1/2)(3+2.3333)=2.66 $k_{b3,2}$=(1/2)(2+2.5)=2.25

$k_{a4,2}$=(1/1)2.3333=2.3333 $k_{b4,2}$=(1/3)(2+2.5+3)=2.5

This process can go on forever to calculate more reflections, but this example would be enough for the purpose of explaining the method of reflections. It is clear that every time diversity is corrected by ubiquity and vice versa, new information about products and countries are extracted. For example, the values of second iteration place country A1 in first place, followed by A3, A2 and A4. The reason A2 is ahead of A4 is that although both countries export one product, A2 exports a more non ubiquitous product, namely B2, which is only exported by A1 and A2. On the other hand, A4 exports B4, which is exported by A1, A3 and A4. Since B4 is a less ubiquitous good, A4 stays at the end of the rankings.

Hidalgo and Hausmann (2009) found out that as iterations continue, there is a possibility of finding new information about a country or product. Therefore, applying this process again and again retrieves more information about the capabilities a country has. Hence, whenever diversity is corrected by ubiquity and vice versa, new information about a country's complexity will be discovered. The process converges to a number after some iteration, which represent the Economic Complexity Index (ECI). It has been discovered that after the 18th iteration, this process completes its convergence (Hausmann et.al (2011). Thus, the 18th iteration has been used as the mathematical value of economic complexity index. The raw data to calculate complexity comes from UNCOMTRADE data. The authors use both

Harmonized System (HS) and Standard International Trade Classification (SITC) types. However, countries with small export volumes and countries those have unreliable data have eliminated from the database. Also, the numbers of countries are subject to change throughout years due to the unreliable data, but these changes are miniscule. Using the same methodology, the authors also calculate product complexity index (PCI). Product complexity measures how complex a product is. A product is said to be complex if it requires high amount of productive knowledge and created by complex organizations where a high amount of skillful individuals interact.

Hausmann et.al (2011) generalized the method of reflections to calculate ECI for all countries. To analyze the mathematical calculation, following Hausmann et.al (2011), define a matrix called M_{ab} and assume that the matrix equals to one if country a exports product b with a revealed comparative advantage[3], (RCA>1) and zero otherwise. Then diversity and ubiquity can be calculated by adding the rows and columns of the matrix together:

$$\text{Diversity} = k_{a,0} = \sum_b M_{ab} \qquad (1.1)$$

$$\text{Ubiquity} = k_{b,0} = \sum_a M_{ab} \qquad (1.2)$$

Then, to acquire a better measure, the authors correct the information from diversity and ubiquity by using both of them to correct each other. Calculating the diversity and ubiquity measures iteratively gives the equations (1.3) and (1.4) below, where n represents number of iterations.

$$k_{a,N} = (1/k_{a,0}) \sum_b M_{ab} . k_{b,N-1} \qquad (1.3)$$

$$k_{b,N} = (1/k_{b,0}) \sum_a M_{ab} . k_{a,N-1} \qquad (1.4)$$

Substituting latter into former,

[3] As Hausmann et.al (2011:25) states "A country has Revealed Comparative Advantage in a product if it exports more than its "fair" share, that is, a share that is equal to the share of total world trade that the product represents".

$k_{a,N}$= $(1/k_{a,0})\sum_b M_{a,b}\ (1/k_{b,0})\ \sum_{a'} M_{a'b}.k_{a',N-2}$ (1.5)

This can be written as:

$$k_{a,N}=\sum_{a'} k_{a',N-2}\sum\frac{MabMa'b}{Ka,0Kb,0} \quad (1.6)$$

The equation above can be rewritten as,

$$k_{a,N}=\sum_{a'} \acute{M}_{aa'}k_{a',N-2} \quad (1.7)$$

Where,

$$\acute{M}_{aa'}= \sum\frac{MabMa'b}{Ka,0Kb,0} \quad (1.8)$$

Equation (1.7) is satisfied when $k_{a,N}=k_{a,N-2}=1$, which is the eigenvector of $\acute{M}_{aa'}$. However, this is not informative because it is just vector of ones. Hence, the authors consider the eigenvector related with the second largest eigenvalue. This is the measure of economic complexity.

Thus,

$$ECI=\frac{\check{K}-<\check{K}>}{stdev(\check{K})} \quad (1.9)$$

Where $< >$ represents an average, stdev stands for standard deviation and $\check{K}$ is the eigenvector of $\acute{M}_{aa'}$ associated with the second largest eigenvalue.

The authors also compute product complexity index (PCI) using the same analogy. Due to the symmetry, changing a by b gives the product complexity index:

$$PCI=\frac{\check{O}-<\check{O}>}{stdev(\check{O})} \quad (1.10)$$

Where $\check{O}$ is the eigenvector of $\acute{M}_{bb'}$ associated with the second largest eigenvalue.

In a nutshell, the measurement of economic complexity uses diversity and ubiquity measurements to analyze the productive knowledge among countries, and creates a mathematical index that captures the productivity among an economy.

1.2. HOW ECONOMIC COMPLEXITY EVOLVES: A PRODUCT SPACE ANALYSIS

It has been argued that products are combination of capabilities, and a country must combine these capabilities to produce a good. Hausmann and Klinger (2006) argued that capabilities needed to produce one good can be considered as imperfect substitutes for producing another good. Yıldırım (2014) emphasized that the probability of jumping between products that use similar productive knowledge is higher. Hausmann, Cunningham, Matovu, Osire, and Wyett (2014) highlighted a similar situation and stated that diversification process occurs through moving products that requires similar productive knowledge. Consider the following example: If a country is producing sweatshirts, it means that this country has necessary capabilities to produce sweatshirts, and it is plausible to assume capabilities to produce sweatshirts are closer to capabilities that needed to produce jackets than capabilities needed to produce chemicals. Therefore, countries diversify by jumping into goods that requires similar capabilities.

Although the example above explains the concept of similarity, to examine the diversification path of a country, one must need to measure the similarity mathematically between products. However, this is not an easy job because identifying and analyzing what is needed to produce one good requires high amount of information and would be too much time consuming, since one must not only consider inputs needed for that products, but also examine other capabilities (institutional factors, human capital, infrastructure etc.) that enters into production process.

To solve these issues, Hausmann et.al (2011) used a simple trick by analyzing the export structure of countries. If for example, wine requires capabilities that are close to capabilities required to produce grapes, but far from capabilities to produce computers, then the probability that a country exports grapes will also exports wine will be higher than the probability that the same country exports engines. Hence, the probability of co-exporting products displays important information about the similarity of these products (Hausmann et.al, 2011). Using this idea, Hausmann et.al (2011) calculated the proximity between products and creates a collection of them, which is a network that associates products that are likely to be co-exported.

The network system discussed above is called "Product Space". To analyze the paths of diversification among a country, one must make use of product space, which shows the relatedness between products traded among the world. The idea of product space first appeared in a seminal paper named by Hausmann and Klinger (2006) and it is formulated using international trade data. Product space consists of nodes and every node represents a product and their size represents the amount of total trade among the world. That is, bigger nodes imply high volumes of trade. Links that connects products to each other implies a high probability of being co-exported.

To analyze how similar or close (high probability of being co-exported) products to each other, Hausmann et.al (2011) created an index called "proximity". This index is based on the conditional probability that a country exports product b will also export product b'. Then the proximity can be defined as:

$$\Theta_{bb'} = \frac{\sum aMabMab'}{max(Kb,0\ ,Kb',0)} \tag{1.11}$$

Although it looks complicated, proximity measure is really straightforward and can be explained by a simple example. For example, assume that in 2010, with RCA>1, t-shirts are exported by 30 countries, sweaters are exported by 40 countries and both of them is exported by 20 countries. In this case, proximity between t-shirts and sweaters is equal to 20/40=0.5

It has been argued that in addition to the ECI, the authors also calculate the product complexity index (PCI) with the same analogy. As analyzed before, exporting sophisticated products is an indicator of wealth in a country since rich countries usually exports sophisticated products. Moreover, since structural transformation, which can be defined as expanding the production through more complex and productive sectors (Felipe, Kumar, and Abdon, 2010) requires exporting sophisticated products; PCI has important implications in terms of countries productive structure as a measurement of sophistication. Hausmann et.al (2011) emphasized this point and rearranged the product space based on the complexity of products. The only difference between two types of product space is that in the former one, the size of nodes depend on the volume of world trade, and in the latter one, the size of nodes depend on the product complexity index. The authors grouped 800 different goods in SITC4 classification into 34 communities and each community is shown by a different color. Of course, these colors or communities have not been decided randomly, the authors analyzed the capabilities required to produce the goods, and same color groups require similar set of capabilities. Hence, there exists a higher possibility for countries to co-export the products in the same community. It is found that similar products (in terms of proximity) tend to have similar levels of complexity. Moreover, both types of product space showed that the connections in the middle parts of product space are relatively dense than the connections in outer parts of the products space. This proves that relatively complex products and products with high trade volumes have more connections; therefore, countries exporting these products have clear advantages over countries exporting the products in outer parts of product space.

The product space represents the productivity issue of developing countries. The data shows that these countries usually export simple products, such as textile or agricultural goods, whereas developed countries usually export complex products, such as machinery or chemicals. The products space demonstrates that goods such as machinery or chemicals have high complexity and furthermore, they have intense connections with other products. On the other hand, textile and miscellaneous agriculture goods have low product complexity and appear in the periphery of the product space and thus have mild connections. This representation actually shows the challenge developing countries face; they need to jump denser areas or core of the product space from the periphery. In other words, they should expand and change their productive structure through more complex and productive goods. To analyze further the challenges these countries face, Hausmann et.al (2011) created an index named connectedness. It is measured by the average proximity of a community's product and shows the location of a community in the product space. There exist a positive link between connectedness and complexity. Hence, it proves that communities that have poor connections, such as cotton and rice have low complexity, whereas communities that have many connections such as electronics and machinery are very complex. The measure of connectedness also shows the difficulties developing countries face. Their main exports usually have fewer connections to other products and also they have a low complexity.

The shape of a country's product space produces vital information about the productive knowledge of that country and also analyzes its capacity to broaden the productive structure by looking for the possibility of moving into new products. To analyze further these implications of product space, Hausmann et.al (2011) found an index that calculates how far a country is to alternative products and how complex those products are. They called this as the opportunity value and it represents the possible opportunities for a country to jump into more complex products.

To show the mathematical representation of opportunity value, first the distance between products should be defined. By definition, distance is the weighted amount of goods that are connected to any other good such as b that country a is not exporting, where the weights are evaluated by proximities. If for example, a country is already exporting most of the products that are connected to product b, then the distance measure will be very close to 0 (Hausmann et.al,2011). But, if a country is exporting a small ratio of products that are close to b, then this measure will be close to 1. Mathematically,

$$d_{ab}=\frac{\sum b'(1-Mab')\,\Theta bb'}{\sum b'\Theta bb'} \tag{1.12}$$

Although distance shows the remoteness between products given a country's export, evaluating opportunity value only by distance would not be right since some countries might be close to simple and less complex products, whereas some countries might be close to complex and highly connected products, through their initial place in product space.

Hence, level of complexity should also be considered to analyze the opportunity value. Formally,

$$\text{Opportunity value}=\sum_{b'}(1- d_{ab'})(1-M_{ab'})\, PCI_{b'} \qquad (1.13)$$

Opportunity value analyzes the possibility of countries to jump into more complex products. According to findings of Hausman et.al (2011), countries with lower complexity have less opportunities and vice versa. By calculating distance and opportunity gain, Hausmann et.al (2011), analyzed similar products for a specific country's exports and discuss that countries should diversify into these goods because they have almost enough capabilities to product them. To implement this idea, authors have created "feasibility charts" which shows potential products to export for a country. Feasibility charts are basically combinations of distance and complexity and visualize the possible opportunities for countries given their productive structure. The part of charts which includes both complex and reachable goods in terms of distance should be considered as future target of production for countries.

Briefly, product space together with the economic complexity, examines the export formations of countries and act as an advisor for countries to diversify and expand their production. More specifically, it provides a unique path for each country, depending on its capabilities and productive knowledge taking into account proximity and distance measurements. Of course economic complexity index have some limitations. For example, while calculating the index, export-import data is considered but there might be cases such as a country produces that product but not export it. Although production data could yield a more detailed analysis in terms of economic complexity, it will not allow making comparisons about cross country trade. A huge advantage of export-import data is it also gives information about export and import destination about countries and thus allows checking for trading partners of a country. A second limitation of economic complexity is that it will not allow checking for service data, since trade data is collected through custom offices. And lastly, due to the making use of trade data, non-tradable goods cannot be included into the analysis.

2. ECONOMIC COMPLEXITY AND ECONOMIC GROWTH

The purpose of this chapter is to explain and analyze the relationship between economic complexity and economic growth. To do so, this chapter includes five sections. The first section will briefly cover the mainstream literature on economic growth research. The second section will analyze the theoretical connections between complexity and growth. Furthermore, differences and similarities between complexity approach to growth will be compared with mainstream growth theories and advantages of economic complexity will be discussed in section two. Third section will review the literature on complexity and growth relationship. Fourth section will examine the empirical relationship by explaining the dataset and discussing about the econometric methodology. Last but not least, fifth section will investigate whether a causal relationship exists between economic growth and complexity.

2.1. A BRIEF DISCUSSION OF THE ECONOMIC GROWTH RESEARCH

Since the beginning of the economics literature, many scholars have tried to analyze and explain the reasons behind the income differences among countries. The purpose of this section is to examine the vast literature on economic growth. For this purpose, this section is divided into eight parts and each part will cover a different economic growth analyses from Adam Smith and Classical view to contemporary growth research.

2.1.1. Adam Smith and Classical Views of Economic Growth

It can be said that the modern economics literature has started with Adam Smith. Since his influential book of "Wealth of Nations", economists tried to analyze the ways of gaining wealth and explain income differences. From Adam Smith to 20th century, almost all economists believed that growth and development requires laissez faire approach. That is, there exists an invisible hand that allocates resources among individuals and firms. Invisible hand idea suggests that both individuals and firms pursue their best interest and the economy reaches its equilibrium level without an intervention from the government. Smith and Classical economists also argued that the wealth was directly related with division of labor, and also capital accumulation is crucial for labor productivity. Although Marxist economists have challenged laissez faire approach, it continued to be the dominant view in the area of economics since the beginning of 20^{th} century. Despite the fact that ideas of Adam Smith and classical economics provide a basic perspective of growth, classical theory has been criticized because it ignored a very important driver of growth, namely technology.

2.1.2. Keynesian Views of Economic Growth

After the Great Depression in 1929, Keynes challenged the ideas of classical economists. Following Keynes's influential book of General Theory, Harrod (1939, 1948) and Domar (1946), independent from each other, developed theories about the source of long run growth and claimed that the growth rate depends on the capital stock of an economy. Known as the Harrod-Domer model, this theory assumes that the rate of labor force growth is exogenous, a given technology which has the properties of constant capital-labor ratio and a fixed capital output ratio. Based on these assumptions, this model argues that the growth rate is determined by savings and capital-output ratio among an economy. As savings rate increases and capital labor ratio decreases, economic growth occurs. The implication of this model is simple: Economic growth is mainly a process of increasing resources (savings) that are devoted to investment. Due to this important implication of this model, economists during 1950s and 1960s focused on increasing saving rates. However, it was not easy, especially for developing countries, since individuals in these countries have already earning lower incomes. The solution would be foreign aid. Thus, when domestic savings were not enough, countries could increase their savings through international markets. However, shortly after this idea, it became apparent that foreign aids would not cure the lower savings rate problem. It has been realized that in many cases, foreign aid yield a decline in domestic savings and also a decrease in the productivity of investment (Snowdon and Vane, 2005). This model is criticized due to the studying the long run issues of growth with short run assumptions (Solow, 1956).

2.1.3. Neo Classical Approach to Growth: Solow Model

After classical views of growth and theories of Harrod and Domar, with the contributions of Solow (1956, 1957) and Swan (1956), the neoclassical view of growth has appeared. By adding labor as a factor of production and abandoning the fixed capital output ratio assumption, this model greatly contributed to the growth literature. In this simple model, the effects of savings, population growth and technological progress on economic growth have been examined in a closed economy setting. Mankiw, Phelps and Romer (1995) stated that most economics students start with this model while studying economic growth, thus a detailed analysis of this model is crucial for following parts.

The Solow model assumes a neoclassical production function in the following form:

$$Y = A\,F(K,L) \qquad (2.1)$$

Where A is a measure of technology, K represents capital and L represents labor. An important assumption in Solow model is the exogeneity of technology. This assumption implies that technology can be considered as a public good and this idea suggests that technology is freely available to everyone and countries are assumed to share the same technology (Snowdon and Vane, 2005). Another important assumption made in Solow model is about the production function. According to Solow Model, the production function satisfies Inada conditions. In this model, as capital-labor ratio increases, output per worker will also increase, however, due to the diminishing marginal returns assumption, the growth of output per worker continuously decreases and become zero eventually (Snowdon and Vane, 2005). This suggests that in countries with scarce capital, the effect of increase in capital on output per worker would be huge, whereas, in countries with relatively abundant capital, the effect will be smaller (Romer, 2012). Thus, capital accumulation would have stronger effects in terms of productivity in developing countries. This implication of Solow model yields a major implication of convergence: Poor economies will grow faster and eventually catch up richer countries.

Together with the production function, the capital accumulation process in this model yields a steady state balanced growth path where output and capital per worker are constant. According to assumptions and analysis of this model, in the long run, economies will eventually converge to their steady state equilibrium (Romer, 2012). Interestingly, although technology is assumed to be exogenous, economic growth is only possible through technological progress in Solow model. Changes in savings rate or population growth would not cause long run growth effects; they would only cause level effects in the short run (Snowdon and Vane, 2005).

2.1.4. Endogenous Growth Theories

Although Solow model argues that the main driver of growth is technology, paradoxically, it does not explain how technological progress occurs and treat it as an exogenous variable. Due to this property of the model, it has been called exogenous growth model. Moreover, according to some economists, real life data showed that the convergence idea of Solow model does not hold. Due to these weaknesses of the model, in 1980s, a new approach to growth has been appeared and tried to endogeneize technology and source of growth. The starting point of these theories is that technological progress occurs via innovations, where innovations are mainly results of activities of economic agents. These theories argued that innovation and human capital are the key drivers of growth and concentrate on the ways of increasing human capital and/or innovation. These theories are called endogenous growth theories and developed by Romer (1986, 1990), Lucas (1988), Aghion and Howitt (1992) and Grossman and Helpman (1991).

One of the simplest versions of endogenous growth theories is AK model, developed by Rebelo (1991), and it defines a broader version of capital. Following Snowdon and Vane (2005) this model can be summarized as:

$$Y= K^{\alpha}H^{1-\alpha} = AK \qquad (2.2)$$

Where A is a constant that represents the level of technology and K represents capital. AK model assumes that the marginal product of capital is always equal to A, due to the constant returns (Jones, 1998). In some versions of the model, capital includes both human and physical capital, and human capital is the reason behind the constant returns. This theory suggests that long run growth depends on the investment rate of the economy because there are no diminishing returns (Jones, 1998)

Another approach to endogenous growth is formalized by Romer (1986). He constructed an analysis by using a different production structure. Following Snowdon and Vane (2005), Romer's analysis can be shown by modifying the production function by making use of technology such that:

$$Y= F (K, L, A) \tag{2.3}$$

In the above function, technology depends on capital and an increase in capital stock will raise the technology and productivity because an increase in capital promotes technological spillovers that in turn increase the productivity of capital (Snowdon and Vane, 2005). Thus, technology and productivity of firms in an economy can be improved through increasing the capital stock. In Romer's model, externalities play an important role since the expansion of technology occurs through learning externalities or learning by doing[4]. In this model, although one firm may exhibit decreasing or constant returns to scale, thanks to externalities, the economy as a whole will experience increasing returns to scale (Snowdon and Vane, 2005).

These theories of endogenous growth are followed by other theories such as Romer (1990), Aghion and Howitt (1992) and Grossman and Helpman (1991). These versions of endogenous growth can be summarized as innovation based theories (Howitt, 2008). The innovations or technological progress occurs due to the economic activities of individuals and furthermore, the growth in productivity is mainly due to innovations by creating new varieties of product (Howitt, 2008). Therefore, investment in R&D and implementation of successful policies that promotes R&D and innovation has a pivotal role in these theories. Last but not least, these models do not imply convergence as in Solow model among

[4] Learning by doing suggests that practice and minor innovations cause productivity to increase.

countries by endogeneizing the technology and abandoning the diminishing returns assumptions.

2.1.5. Augmented Solow Model

Recall that one of the main criticisms about the Solow model was that it cannot explain the huge income differences among countries, because it assumed that convergence exists. However, some economists argue that the real life data showed no evidence of convergence. This criticism is also contributed to the born and rise of endogenous growth theories. To answer this criticism, Mankiw, Romer and Weil (1992) augmented the Solow model by introducing the human capital into the system. Human capital causes an increase in the share of capital in total production and improves the shape of production function, which in turn changes the effects of diminishing returns and makes it slower (Snowdon and Vane, 2005). It should be noted that the production function still has diminishing returns, thus this is not an example of endogenous growth. Similar to Solow model, real GDP growth still depends on exogenous technological change, but convergence in augmented Solow model is much slower than the original one.

2.1.6. Institutions and Growth

The theories discussed above put emphasis on different sources in terms of growth, such as savings, investment, technological progress, human capital, and innovation and R&D. Moreover, while some of them imply convergence among countries, others argued against convergence. Another approach to economic growth analyzed the reasons behind the growth and convergence, and argued that institutions play a crucial role on economic growth and also conclude that convergence or divergence among countries can be explained by institutional factors. According to North (1991:1)

> "Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)."

This definition suggests that institutions play a crucial role in economic activities. Although economists were aware of the importance of institutional factors on economic growth such as property rights, the research on this area has gained significant importance on last decades with the influential work of brilliant economists[5].

Among these works, North (1990) suggested that better institutional quality reduce the uncertainty and increase the efficiency, which generates economic growth. However, poor quality in institutions might hamper growth since it creates an incentive for economic agents to engage in redistributive policies that have lower economic returns (Murphy, Shleifer, and Vishny, 1993). North (1990) also argued that efficient institutions help labor force to be used in productive activities, rather than rent seeking activities. Similar to North (1990), Iqbal and Daly (2014) stated that inefficient institutions cause resources to switch unproductive activities and thus creates rent seeking. Moreover, Acemoglu and Robinson (2010) argued that institutions have an essential value in economic growth because they have a big influence on both physical and human capital. Furthermore, they also help improving the technology.

In addition to these theoretical connections between growth and institutions, there are also some case studies and examples that emphasizes the importance of institutions. For example, as Snowdon and Vane (2005) states, the main reason behind the fast growth of East Asian Countries since 1960s and the continuous slow growth in African countries can be explained by institutional factors. Similarly, Acemoglu, Johnson and Robinson (2005) analyzed the Korean case. They argued that South Korea adopted a policy that promotes private ownership, and proper legal protection for investors. On the other hand, North Korea followed a centralized system with a little role for private property under a dictatorship. Years later, South Korea has developed rapidly, whereas there was not significant growth in North Korea. This example is especially important for the effect of institutions, since two countries are almost the same in terms of culture, natural resources, geography and other main characteristics at the beginning. As these examples suggest, quality of institutions has an important impact on economic growth.

[5] North (1990), North (1991), Acemoglu, Johnson and Robinson(2001)

2.1.7. International Trade and Growth

Another important layer of growth literature emphasizes the role of international integration on economic growth. Engaging in international trade creates knowledge spillovers and makes innovation easier through increasing the connections with the sources of innovator and foreign direct investment (Grossman and Helpman, 1990). Moreover, trade openness increases the size of the market and it helps countries to exploit the advantages of increasing returns (Kim, 2011). Furthermore, trade openness not only help policy makers to engage in less distortionary policies and also pushes them to follow relatively strict macroeconomic policies due to the effects of international competition (Kim, 2011). On the other hand, there are some opinions that suggest international trade may hamper growth. For example, international trade might lead countries to specialize in activities with a comparative disadvantage and thus harm countries. Moreover, if countries do not have the necessary human capital, resources or adequate institutional quality, then engaging in international trade does not generate growth.

There are many empirical studies that have analyzed the trade and growth relationship. After a detailed literature survey, Lewer and Van den Berg (2003) claimed that trade has an important impact on economic growth. Furthermore, many empirical studies such as Krueger (1997), Dollar and Kraay (2001), and Winters (2004) found a positive link between trade liberalization and economic growth. Although many economists confirmed that globalization have a level effect on output, there is some controversy on the effects of liberalization on the rate of growth. For example, in an open economy version of the Solow model, liberalization would have a temporary effect on economic growth (Snowdon and Vane, 2005). Moreover, Rodriguez and Rodrik (2000) found little evidence that open trade promotes growth. Rodrik (1995) analyzed the drivers behind the rapid growth in Korea and Taiwan and argues that the reason behind the growth of these countries was not export orientation; it was the investment boom with well-educated labor force on those countries that yield a high return on capital. On the other hand, Srinivasan and Bhagwati (2001) claimed that export promoting strategies help countries to sustain higher growth rates. They argue that export promoting strategy creates incentives for domestic resources and help producing efficient outcomes.

2.1.8. The Structuralist Literature

The structuralist literature dominated the area of economics in the years between 1940 and 1960. Structuralist view basically argues that economic development is a process of a strong transformation in the production process to overcome the obstacles and rigidities of underdevelopment, and also emphasizes the importance of industrialization on economic growth (Gala, Rocha and Magacho, 2018). The industrialization refers to the idea that the transformation of labor and/or sources must progress from simple and less productive sectors to higher value added areas, such as sophisticated and more productive sectors (Bresser-Pereira, 2012). According to Sanchez-Ancochea (2000), an increase in production in one sector is beneficial as long as it is followed with an increase in the production of other sectors.

Structuralist theory argued that manufacture sectors usually have a higher productivity, increasing returns, and a high possibility of technological change. With these properties, manufacturing sectors enjoys the advantages of imperfect competition features, such as, economies of scale and scope, entry barriers, high R&D spending and product differentiation; on the other hand, simple sectors such as agriculture suffer from perfect competition features such as low R&D spending and low innovation (Gala, Rocha and Magacho, 2018). Therefore, jumping to sophisticated/complex sectors allow countries to move forward through growth and development. In this perspective, structuralist theory criticized the idea that developing countries should specialize on mostly primary products and enjoy permanent comparative advantage.

The structuralist literature differs from other approaches of growth in a few ways. First of all, structuralist approach adopts a different methodology. Rather than mathematically formulizing growth models and defining production functions or budget constraints, it follows a descriptive methodology. Secondly, neo classical growth models argue that market is the main mechanism for allocation of resources and government intervention is not necessary. However, as Sanchez-Ancochea (2000) states, the free market cannot be a solution to all problems according to structuralist approach because the price mechanism has some weaknesses. That is, government intervention might be necessary to regulate the economy. Moreover, the first firm/company to invest in any kind of activity cannot benefit from the externalities from knowledge diffusion or innovation since it is the only one in the market, thus rate of investment might stay at low levels. This is another reason for government to step in and encourage investments.

2.2 THE IMPLICATIONS OF ECONOMIC COMPLEXITY ON ECONOMIC GROWTH

In the previous section, the mainstream research on economic growth has been explained briefly. The purpose of this section is to analyze the theoretical relationship between economic complexity and growth by taking into account the measurement of complexity and product space. Additionally, by comparing the complexity with other growth theories, how complexity analysis distinguishes itself from previous approaches will also be examined.

The main idea behind the economic complexity (producing diverse and sophisticated products) implies that economic development cannot be sustained by producing more from a fixed set of goods; it must involve creating new products. Similarly, Rodrik (2014) also argued that the two pivotal things behind long run growth is accumulating capabilities and creating structural transformation, which means creating higher productivity industries and transferring labor from low productivity sectors to higher ones. Although Rodrik (2014) used the word capabilities in a narrower term such as human capital and institutional quality, accumulating capabilities is the key source of growth. Economic complexity, however, defines a wider term for capabilities and argues that accumulating capabilities in order to have a diverse productive structure and producing sophisticated/highly productive goods is necessary for higher growth in the long run. This phenomenon brings us to an important topic: What is the importance of diversification and higher productivity goods on economic growth?

Yildirim (2014) suggested that jumping to new and more productive activities is the key driver behind economic growth. Moreover, he also argues that process of diversification eventually leads to sophistication of production. According to Akhtar and Freire (2014) as countries diversify, GDP increases. They suggest that higher growth is directly related with diverse set of products exported. Empirically many papers such as Al-Marhubi (2000) and Agosin (2007) have found that export diversification is an important and significant determinant of economic growth and affects growth positively.

High productivity goods can be defined as sophisticated goods. Thus, producing them requires more capabilities. Hausmann et.al (2007) argued that specializing in some goods creates higher growth relative to others. They suggest that countries that specialize in products that are exported by rich countries would experience higher growth rates because rich countries, in general, export sophisticated products. To prove their point, they created two indexes: PRODY and EXPY. Among these, PRODY represent the income level affiliated with that product and EXPY shows the weighted average of the PRODY for a specific country. They analyzed the importance of these indexes on economic growth and concluded that exporting higher productivity goods will yield a rapid growth. More broadly, producing/exporting goods that rich countries export has important benefits in terms of economic growth.

According to Hidalgo and Hausmann (2009), growth requires countries to improve the capabilities they have in order to reach higher productivity sectors. Felipe, Kumar and Abdon (2010) argued that the type of exported goods determines the wealth of a country. If a country exports high productivity goods, that country become richer.

It has been argued above that diversification and producing complex/highly productive goods are necessary for economic growth. Combining these, Felipe, Kumar and Abdon, (2010, 2012) and Hausmann and Klinger (2006) defines structural transformation as the process of changing what and how they produce. Structural transformation implies diversifying the productive structure through more sophisticated and complex goods. Felipe et.al (2010) argued that the reason behind the recent high growth rates among Asian countries such as Korea and Singapore was due to the successful implementation of structural transformation. Moreover, they suggested that China is currently undergoing this transformation and this explains the high growth rates of China.

Many papers have tried to analyze the relationship between diversification and growth and sophistication and growth. General findings of these papers suggest that both concepts have a positive impact on economic growth. Economic complexity index considers these two concepts as an important determinant of economic growth and tries to create a measurement that combines these two properties. Empirical papers that analyzed the relationship between diversity and growth have used various diversity measurements, such as number of products exported, number of export sectors or Herfindahl Hirschman Index. Similarly, papers that have analyzed sophistication growth relationship also used various indexes such as EXPY, PRODY or normalized sophistication index. Economic Complexity Index tries to achieve one single measurement that considers both the effects of diversification and sophistication.

Recall that the theoretical background of economic complexity relies on the concepts of diversification and sophistication, which are proven to be important determinants of economic growth. Thus, there should be a strong relationship between economic complexity and growth. Hausmann et.al (2011) analyzed the relationship between complexity and economic growth and showed that for 75 countries with limited exports of natural resources, complexity can explain 75% of the variation in income per capita. Furthermore, after controlling for the income generated from natural resources, complexity explains 73% of variation in income for the whole sample, which includes 128 countries. To analyze this relationship deeply, check the table below that shows the top and bottom 10 countries in terms of economic complexity index and GDP per capita, according to year 2016.

Table 1: Complexity and GDP per capita Rankings for 2016

Country	ECI	ECI rank	GDP PC	GDP PC rank	GDP PC rank 2
Japan	2.229	1	47660.89	18	13
Switzerland	2.054	2	76682.64	3	2
Germany	1.955	3	45923.01	20	15
South Korea	1.798	4	25484.04	38	26
Sweden	1.754	5	56473.02	7	6
Singapore	1.716	6	53353.84	9	8
Austria	1.612	7	48077.88	17	12
UK	1.592	8	42039.74	23	17
USA	1.581	9	52319.16	11	9
Czech	1.577	10	21894.11	43	30
Sudan	-1.437	117	1923.995	145	98
Yemen	-1.469	118	432.3861	186	121
Cote d'Ivoire	-1.517	119	1552.861	152	103
Nigeria	-1.544	120	2455.919	139	92
Mauritania	-1.594	121	1296.007	157	105
Mozambique	-1.611	122	514.9615	182	118
Malawi	-1.649	123	481.4519	184	120
Cameroon	-1.659	124	1495.443	154	104
Papua New Guinea	-1.743	125	2398.171	140	93
Guinea	-1.985	126	779.9111	170	115

Source: World Bank Database and Atlas of Economic Complexity (2011)

Among one hundred and ninety two countries that have the data for GDP per capita and one hundred and twenty six countries that have the data for complexity, the table above shows that countries that with high complexity also have relatively higher GDP per capita and vice versa. It should also be noted that GDP per capita rankings are coming from World Bank Databank, and this data set includes countries that are not considered in ECI ranking due to low population, very low significance in international trade or unreliable data. For example, Luxembourg is at the top of GDP per capita rankings, but economic complexity of Luxembourg is not calculated due to the reasons mentioned before. Therefore, rank two column also added to the table to visualize the changes in ranking if one only considers the countries that are in both data sets, which adds up to one hundred and twenty six countries.

Rank two column also shows that there is a strong correlation between GDP per capita and economic complexity index.

In addition to the strong relationship between complexity and growth, economic complexity also provides a path for countries to grow further through the product space. Recall that the product space is a visualization of export structure of countries. Calculating distance, proximity and opportunity value measures; the product space shows what products are feasible according to the productive knowledge among a country. This property of product space actually implies that by allocating their productive knowledge, countries could diversify their productive structure through products that are close to their production.

Considering the importance of diversity and sophistication on economic growth, the correlation of complexity and GDP per capita and the measurement of economic complexity together with the product space analysis imply that economic complexity is strongly linked to economic growth. However, the importance of economic complexity in terms of economic growth does not end here. Hausmann et.al (2011) continued to analyze the importance of economic complexity to a great extent and showed that, countries that have a higher complexity in contrast to their income level are inclined to experience higher growth rates than those are too rich compared to their economic complexity. Therefore, economic complexity is not only a determinant of growth; it is also a crucial indicator for future growth. In this context, economic complexity provides a new perspective of examining economic growth through analyzing the productive structures of countries.

Many theoretical models discussed in previous sections such as Solow or endogenous growth have analyzed the economic structure around the world by compressing capital and labor into one variable that represents them all. Recall that, in terms of economic complexity, types of capital or labor have different implications for economic growth. In this perspective, economic complexity look similar to what structuralist literature argues: Development is a path dependent process and countries grow further by simply switching from simple sectors to complex ones. Like structuralist literature, economic complexity also argues that countries should transform their productive structure among sophisticated sectors. Both of them do not rely on mathematical formulations. Gala, Rocha and Magacho (2018) stated that until the economic complexity index, structuralist literature suffered from the lack of empirical evidence, and economic complexity index can be used as an indicator to reinforce the main ideas of structuralists. Economic complexity extends the structuralist approach to growth and development, and argues about the specific sectors to specialize for countries.

However, it also differs from structuralist literature in many ways. For example, economic complexity does not argue whether free market or government intervention is better. Moreover, structuralist literature descriptively and historically argues that manufacturing sectors is more productive; on the other hand, economic complexity shows what sectors are more productive by using a mathematical formulation through international trade data. Furthermore, economic complexity analyzes this transformation process in a great detail and actually offers different ways and different sectors for each country. While structuralist literature only emphasizes the importance of manufacturing sectors, it does not give much detail about which manufacturing sectors to specialize. Economic complexity, on the other hand, analyzes each country individually and actually shows them to specialize in sectors that would be advantageous. Additionally, structuralist literature emphasizes the importance of diversification among manufacturing sectors, whereas economic complexity highlights the importance on diversification not only in complex sectors, but also in simple ones.

In sum, economic complexity differs from mainstream growth theories by trying to examine the complex economic system around the world by analyzing the big international trade data, and not by formulizing production functions or simplifying the economic structure. Moreover, mainstream theories suggest one way for all countries in terms of economic growth. For example, Solow model argues that technology is behind the economic growth, endogenous growth theories argue that innovation, human capital and R&D are the main drivers of economic growth. Although economic complexity emphasizes the importance of increasing the technology and/or know-how in terms of economic growth, it does not argue or specify any variable as a source of growth, it analyzes the productive structure of countries and act as a guide for countries to diversify and sophisticate their productive structure. While complexity has similar properties with structuralist literature, it actually expands structuralist literature in many ways, and also has some major differences such as the case of government intervention.

2.3. LITERATURE REVIEW OF COMPLEXITY AND GROWTH RELATIONSHIP

As argued previously, economic complexity aims to reveal capabilities among a country or the productive knowledge a country has. For this purpose, it states that economies should transform their productive structure and accumulate capabilities in order to change and expand their production. Due to a being relatively new concept, there are only a few papers that empirically analyze the relationship between complexity and growth. The purpose of this section is to examine and discuss about the literature on complexity growth relationship. Among these papers, some of them use variables that are related to economic complexity such as distance or proximity measures, and some of them directly use economic complexity index (ECI) as an explanatory variable. Moreover, there are also some papers that make a descriptive analysis of countries or country groups by making use of product space concept. To gain better understanding of complexity and growth relationship, all papers that use ECI, product space or other indexes will be examined.

Abdon and Felipe (2011) analyzed the economic development of Sub Saharan African countries via product space. They found that most of these countries are stuck in the less sophisticated and poorly connected parts of the product space. Moreover, structures of the product space of these countries reveal that capabilities of these countries would not be enough to move into more sophisticated products. Therefore, to boost growth, government must promote policies that create incentives for investing in more sophisticated products.

Jankowska, Nagengast and Perea (2012) compared Asian and Latin American Countries by using product space, and examines why Latin American Countries were not as successful as Asian Countries in terms of escaping the middle income trap. They argued that, almost without exception, the countries that were successful of escaping the middle income trap were the ones that engage in a transformation of their productive structure from simple activities to manufacturing. Due to the lack of capabilities in Latin America, these countries could not be successful in this transformation. They also argued that this transformation is not successful because these countries did not have proper education, infrastructure and innovation policies, and their access to finance was limited.

Ferrarini and Scaramozzino (2013) also analyzed the effects of complexity on growth by using the density variable. Density is defined as *"A products' distance in the product space, and the average density of a country is linked to the adaptability of that country's production structure across its entire sector"* (Ferrarini and Scaramozzino, 2013:7) By using this measurement of diversity and controlling for years of schooling, labor force participation rate and total active population, they analyzed the effects of density on growth and concluded that on average, countries which have a more dense occupation on product space enjoyed relatively faster growth for the period 1990-2009.

Felipe, Kumar and Abdon (2014) classified 779 exported products around the world into three categories (good, middle, bad) based on their sophistication and connectivity to other products. The purpose behind this classification is that the main argument separates rich countries from poor ones is the productive structure of countries, and rich countries export sophisticated goods with a diverse structure and poor countries export simple goods and less diverse. They showed that countries like Belgium, France, Germany, USA etc. (high income countries) are belong to the high share of good products, that is they mostly export highly sophisticated products and these products are connected to many other ones. On the other hand, countries like Algeria, Benin, and Chad etc. belong to high share of bad products, which implies that they export simple products that have poor connections to other ones.

Bayudan-Dacuycuy and Lim (2014) examined the export portfolios of ASEAN Economies and evaluates the situation of these economies in terms of export sophistication and structural transformation. They found that the export portfolio of less developed Asian countries is in the sparse part of the product space but diversification opportunities exist.

However, in order to diversify, they argue that government must step in and promote proper policies for those countries.

Over the past 25 years, Uganda has experienced a substantial economic growth. Hausmann et.al (2014) analyzed the economic structure of Uganda and reached the conclusion that Uganda has understood the importance of diversification and sophistication. Although this understanding allowed Uganda to grow fast in recent years, the authors argue that they face capacity challenges and must increase educational, financial and managerial capabilities. A similar analysis has been done by O'Clery (2016) for Ireland and he argued that Ireland has been exporting less number of products over time, especially in the number of high complex products. The data proves his point: Ireland ranked 9th in terms of economic complexity in the year 2003 and ranked 17th in the year 2007. This fast decrease in complexity could explain a part of the crisis they underwent after the global financial crisis.

Fortunato, Razo and Vrolijk (2015) stated that economic development is not only a process that includes diversifying the export basket, but also it requires identification of high productivity sectors and moving towards them. To show the development opportunities, they make use of product space and assist countries to reach economic development. Using different measurements, such as EXPY, PRODY, distance and proximity, they argued that for 97 countries in the sample for the period 2008-2012, increase in sophistication contributes on average 0.5 per cent per year.

Until now, the papers that use economic complexity related concepts such as proximity, distance or product space is analyzed. From now on, the papers that directly use economic complexity index will be evaluated.

Hidalgo and Hausmann (2009) checked whether method of reflections has any effect on economic growth by using OLS methodology for different iterations such as $k_{c,1}$, $k_{c,2}$, ….$k_{c,n}$. They used different time intervals for short and long run effects. The results showed that all iterations have positive and significant effects on growth. Moreover, higher iterations of method of reflections are found to have more predictive power than lower iterations. They found that $k_{c,18}$ and $k_{c,19}$ have the most explanatory power. Recall that this number, $k_{c,18}$, is actually the measurement of economic complexity.

To analyze more deeply of implications of economic complexity, Hausmann et.al (2011) compared the effects of complexity on growth with other three important determinants of growth: Institutional quality, Human capital, and competitiveness. As a determinant of institutional quality, they use World Governance Indicators and conclude that Economic Complexity Index (ECI) is a better indicator for explaining growth than the six World Governance Indicators, both individually or combined. As an indicator of Human Capital, the authors used years of schooling from Barro and Lee (2001) and cognitive ability data from Hanushek and Woessmann (2008). Since the data on educational quality (cognitive ability) exists only for year 2000, they compared the impacts of education and complexity on growth for the year 2000 and conclude that ECI captures more growth information than human capital. Last but not least, using Global Competitiveness Index[6], they compared the effects of competitiveness vs. complexity on economic growth and argue that complexity, again, is a better contributor of economic growth.

Ourens (2012), using the same methodology but using a different dataset, created his own version of method of reflections to test the explanatory power of method of reflections on economic growth. To calculate different iterations, he used International Trade Database at the product level, or BACI. His final sample includes 178 countries and 4948 products. By using cross section and fixed effect techniques, and considering different time intervals, he found that although method of reflections is a good explanatory variable of growth in the long run, he did not found any relationship in the short run. To check for further robustness, he also added additional control variables and different country filters, but the results do not change. In the short run, method of reflections cannot explain economic growth. Ourens (2012) also argued that when $k_{c,18}$ value (refers to the ECI) changes a lot from one year to another, there must be some issue about the data since it is not expected to change a lot between two consecutive years. Thus, he uses a filter and eliminates the countries that have

[6] The Global Competitiveness Index (GCI) considers over 113 variables, which are considered as key determinants of competitiveness. Global Competitiveness Index aims to measure of institutions and policies that contribute to economic development/growth.

substantial changes in $k_{c,\ 18}$ values. Adding this filter lowers the explanatory power of method of reflections a little bit, but adding controls such as human capital and income level dummies increases the explanatory power of method of reflections.

Bastos and Wang (2015) examined the importance of diversification and complexity for 103 countries for the period 1970-2010 and argued that diversification and complexity have positive and significant effects on economic growth. Then, adding a coefficient for Latin America and Caribbean countries, they analyzed the importance of complexity for the countries belong to this region. They argued that diversification and complexity of Latin American Countries is significantly lower than advanced economies, which is one of the reasons behind the growth differences. Using the estimation results, they tried to forecast the future growth rates. Lastly, they offer some policy recommendations to increase the diversity and complexity of these countries.

Demiral (2016) followed a different strategy in terms of grouping countries and he bundles them according to their development stages to prove that economic complexity is not based on innovation and it is mainly based on the productive structure of the economy. Then, he analyzed whether complexity affects growth, using different groups of countries for the years 1995 and 2011, using a panel ARDL strategy. Although complexity affects growth positively for many groups, he found an interesting result: Complexity has a negative effect on growth for innovation driven countries. This group mainly includes developed countries, and the results suggest that complexity has negative effects for growth in these countries.

Stojkoski and Kocarev (2017) studied the effects of complexity on growth for southeastern and central European Countries for the years 1995 and 2013 using panel dynamic OLS for long run effects and system generalized method of moments (system GMM) for short run effects. Similar to Ourens (2012), they found a significant and positive long run relationship, but found no evidence for short run.

Camargo and Gala (2017) examined the implications of economic complexity and export concentration to analyze whether Dutch disease can be explained through complexity. Besides, they also investigated two country cases: Indonesia and Nigeria because Indonesia is a good example of avoiding from the unfavorable impacts of Dutch disease, on the other hand, Nigeria could be considered as a bad example. The empirical results and the case of two countries showed that Dutch disease can be identified as having a low economic complexity.

Zhu and Li (2017) argued that human capital is a major component of complexity because production requires accumulation of different capabilities and human capital is one of the most important factors that affect capabilities. Thus, with a specific emphasize on human capital, they looked for the relationship between complexity and growth for 126 countries for the years 1995 and 2010, using OLS and Fixed Effects. They found out that both complexity and human capital have significant and positive impact on growth. Moreover, the interaction term of human capital and complexity also affect growth positively.

Hartmann, Guevara, Jara-Figueroa, Aristarán and Hidalgo (2017) investigated whether complexity affects income inequality for the period between 1963 and 2008 using pooled OLS and fixed effect methodologies. They found that complexity has significant and negative effects on income inequality. Therefore, countries that export complex products relative to others enjoy lower inequality. To analyze this relationship clearly, they create a Product Gini Index. Hartmann et.al (2017:16) defines this index as:

> "We decompose the relationship between economic complexity and income inequality into individual economic sectors by creating a product level estimator of the income inequality that is expected for the countries exporting a given product"

This index shows that products that are highly associated with income inequality are the products such as Cocoa Beans or Animal Hair, which usually shows lower complexity. On the other hand, low Product Gini Index goods mostly have high complexity, such as Textile Machinery and Road Rollers. This phenomenon confirms the finding that exporting complex products yield lower inequality.

According to the literature discussed above, in addition to the economic complexity, variables that are related to economic complexity, such as proximity or distance measures are also important determinants of economic growth. Among the papers that used ECI directly as an explanatory variable, some of them found a significant effect of complexity on growth for both short and long run, such as Hausmann et.al (2011), Bastos and Wang (2015) and Zhu and Li (2017), whereas some of them only found a significant long run relationship, such as Stojkoski and Kocarev (2017) and Ourens (2012). Moreover, Bastos and Wang (2015) found out that economic complexity is an important determinant of growth for a specific group of countries based on geographical classification; however, Demiral (2016) found that economic complexity has a negative effect on growth for innovation based countries. These findings suggest that although there is a consensus on the effects of complexity on growth for the long run, the short run effects and country classifications might produce different results. Following these literature, the next section will analyze the relationship between economic complexity and growth using an empirical methodology by taking into account development levels of countries and also distinguishing between long and short run.

2.4. EMPIRICAL ANALYSIS OF GROWTH AND COMPLEXITY RELATIONSHIP

The previous section has analyzed the economic complexity index, explained its measurement, discussed the importance of economic complexity, examined the theoretical relationship between complexity and growth and summarized the literature on economic complexity. The purpose of this section is to analyze the effects of economic complexity on economic growth by using an empirical methodology. To this end, this section has three parts. The first part will discuss about the data and the sources and the second part will examine the empirical methodology. The third part will present the regression results for the effects of complexity on economic growth and examine the implications of economic complexity on economic convergence. There will be two main regressions throughout this part; the first one inspects the impact of complexity on growth by using an annual database, whereas the second regression tests the model for the pooled data for five year sub periods to rule out time related fluctuations, such as economic/financial crises.

2.4.1. Data

This section explains and discusses the data set that will be used to estimate the econometric regression. The data set consists of a total of eighty one countries[7] for the years between 1981 and 2015. The dependent variable is the log differences of GDP per capita growth. Moreover, a lagged variable for GDP per capita growth is also included into the regression to capture the convergence effects.

The first explanatory variable is clearly the economic complexity index. There are two basic sources that calculate economic complexity index. The first one is the Atlas of Economic Complexity by Hausmann et.al (2011) and the second one is the Observatory of Economic Complexity by Simoes and Hidalgo (2011). Although both of these sources calculate similar measures, they slightly differ. In this thesis, the economic complexity index calculated by Simoes and Hidalgo (2011) will be used, since Hausmann et.al (2011) calculates the index for the period between 1994 and 2016, whereas the data set in Simoes and Hidalgo goes back to 1961. To calculate the economic complexity index, Simoes and Hidalgo (2011) have both used SITC (Standard International Trade Classification) and HS (Harmonized System). For the SITC classification for the years between 1962 and 2000, the authors use data from The Center for International Data by Robert Feenstra, and for the remaining years, they use UNCOMTRADE data. For HS data, the authors use the data from the BACI International Trade Database. Although economic complexity index is calculated for 126 countries, some countries are eliminated from the data set due to the lack of data.

Since growth is one of the major macroeconomic objectives of countries, many scholars have tried to examine the drivers behind economic growth and these efforts created a huge literature on economic growth. Thus, in addition to the economic complexity index, several other control variables are chosen to enter the regression based on the economic growth literature. These variables can be classified into two types. The first type is the macroeconomic variables, and these are investment to GDP ratio, population growth,

[7] The list of countries can be found in Appendix C.

human capital, inflation rate, trade openness, and regional trade agreements. The second type is the institutional variable that measures the quality of institutions among a country, namely polity2.

An important variable that have been used in the economic growth literature is investment rate. One of the most important ways for growth is to increase capital stock. Increasing capital stock, or increasing investment, will help to increase the aggregate demand and generate short run economic growth. Besides, investing in new capital goods can increase the productive capacity of a country and yield a long run growth. Furthermore, improved capital stock could also increase the productivity of labor and create a more efficient work force, which boosts economic growth. Recall that investment is recognized as the most important factor in economic growth by some growth theories, such as Harrod-Domer model or AK model. In addition to the theoretical connections between investment and growth, some seminal papers such as Barro (2003) and Levine and Renelt (1992) found a positive and significant relationship between these two. Therefore, investment to GDP ratio will be used as one of the control variable.

Another control variable for the regression is population growth. Since Thomas Malthus' famous theory that states population growth would reduce living standards, population is discussed to be a crucial component of growth. In general, it is assumed that bigger population needs more resources, which hinders economic growth (Zhang, 2015). For example, when families have more children, they reserve some of their resources for children care, which is expected to negatively affect growth. Thus, high fertility rates could also lower the growth rate. However, there are also different theories how population growth affects economic growth. Becker, Glaeser and Murphy (1999) argued that population growth has both favorable and unfavorable effects: In poorer and agricultural economies, larger population slows down growth, however, in economies with high rate of urbanization, population affects growth positively by promoting specialization, increasing investment in human capital and accumulation of knowledge. According to life cycle hypothesis introduced by Modigliani (1966), people save and invest when they are young and working and they use their savings when they are old. Thus, when the working-age population (population age between 15 and 65) increases, savings and investment could increase and this might cause an increase in growth. Many papers have tested the effects of population on economic growth and they found different results. For example, Kuznets (1967) could not find a significant relationship between population and income per capita. Barlow (1994), however, found an inverse relationship between economic growth and population growth. Yip and Zhang (1996) argued that there is a negative link between population growth and economic growth after controlling for exogenous factors. On the other hand, this link becomes ambiguous when exogenous factors, such as technology, are subject to change. Thus, the effect looks ambiguous.

A key variable used in the growth literature is the human capital. As discussed before, endogenous growth theory emphasized the importance of human capital on growth. Mincer (1984) stated that human capital can be considered as a factor of production that cooperates with physical capital. The relationship between human capital and economic growth can be measured by the investment in people's education. Pelinescu (2015) stated that investment in education cause not only an increase in productivity of an individual, but also increases the social rate of return. Thus, more education creates more earnings and boosts growth through positive externalities. Although education is the most important component of human capital, it is not the only one. Degree of human capital could increase by inherited or acquired abilities, or through mobility in labor force, or it can be developed through training. However, it is not easy to measure these factors, but years of education could easily get measured. Hence, using a human capital data based on years of education is chosen for the purposes of this thesis. Among the literature, as a measurement of human capital, economists use different sources such as Barro and Lee (2001) years of schooling, primary-secondary-tertiary school enrollments from World Bank World Development Indicators and/or human capital from Penn World Tables. Each one of these has its own features, but Penn World Tables database is preferred in this thesis as a measurement of human capital. Using the primary-secondary enrollment ratios from World Bank would be disadvantageous since it has many missing variables, and Barro-Lee (2001) measures years of schooling for only 5 year periods, whereas there will be empirical analyses for both the annual effects and 5 year averaged effects in this thesis. Penn World Tables database only have a few missing variables, and more importantly, it combines the information from Barro-Lee (2001) and Cohen and Leker (2014) to create a human capital data based on years of schooling. In this sense, it could be thought as an expansion of Barro-Lee (2001) database. Thus, the most proper data to use in this thesis was the data from Penn World Tables.

Another variable that could affect the growth is the inflation rate. Inflation rate is acknowledged by many empirical papers, such as Barro (1995) and Andrés and Hernando (1999) as an important barrier in economic growth. Inflation rate in a country not only gives information about the price stability, but also help understand the effectiveness of the central bank and its monetary policy. In recent decades, many central banks have concentrated on price stability and adjusted their policies accordingly. The reason behind these adjustments is the unfavorable effects of inflation on an economy, such as lowering the purchasing power, transferring money from savers to debtors and creating a highly unpredictable atmosphere. In addition to all these negative effects, inflation also lowers the economic growth by causing a decrease in total factor productivity (Andres and Hernando, 1999). Hence, economic agents are expected to perform poorly in the cases of high inflation (Barro, 1995). The high importance of inflation on the last decades is an encouraging reason to choose inflation as a control variable for economic growth. The literature about inflation and growth such as Barro (2003) and Barro (1995) suggested that there exist a negative link between these two.

Regional trade agreements and trade openness are also chosen to be used as control variables in the regression, since economic complexity is measured based on export-import data and capturing the effects of international trade is crucial for the purpose of this thesis. Regional trade agreement data is obtained from De Sousa and Lochard (2011) and is equal to one if a country has a regional trade agreement with another country in a given year, and zero otherwise. Having a regional trade agreement would ease the trade between countries and lowers the impacts of trade barriers. Other variable, namely trade openness, measures the weight of exports and imports on GDP. According to Young (1991) and Grossman and

Helpman (1991), international trade helps economic growth through innovation and technology and knowledge diffusion. Moreover, Hausmann et.al (2007) showed that countries with higher level of GDP per capita exports goods that have higher level of productivity, therefore there might be a direct relationship between exports and GDP per capita.

Institutional factors are also a fundamental part of economic growth. Seminal papers by Acemoglu, Johnson and Robinson (2005) and Acemoglu, Johnson, Robinson and Thaicharoen (2003) emphasized the importance of institutions on economic growth and argued that quality of institutions is the main factor behind economic growth. Furthermore, well-functioning economic and social institutions are demonstrated to have a positive effect on economic growth (Rodrik, Subramanian, and Trebbi, 2004). While discussing the effects of institutions on economic growth, different variables from different datasets have been used. One of the most common used data in growth literature is coming from the World Governance Indicators by Kaufmann, Kraay, and Mastruzzi (2011). Unfortunately, this data only goes back to 1996, which makes impossible to use in this thesis, since the regressions are estimated for the years between 1981 and 2015. Another common dataset used for quality of institutions is the Polity IV dataset by Marshall and Jaggers (2002). This is a wide range database that measures different branches of institutional quality in a country. This database has been used by many authors such as Acemoglu et.al (2003), Henisz (2000), and Bhattacharyya (2009). Although these papers use different variables from Polity IV database such as executive constraint, democracy index, polity index and political constraint index, the preferred variable in this thesis is the polity2 variable. Polity2 is a transformed variable of polity to be used in the time series. Originally, polity variable is calculated by subtracting the autocracy score from the democracy score (Marshall and Jaggers, 2002). Both the democracy and autocracy indicators are an eleven-point scale (0-10) and calculated by using various institutional and political factors. However, there are some special cases in the dataset for specific situations such as cases of foreign interruption, cases of interregnum and cases of transition. In these cases, polity score could get numbers such as “-66”, “-77” or “-88”. Polity2 variable transforms these extreme values to normal variables i.e -variables between -10 and 10- and thus helps analyzing the effects of institutional quality in a more efficient way (Marshall and Jaggers, 2002).

Additionally, two other variables will also be introduced to the regression. The first one is a dummy variable for developing countries, and equal to 1 if a country is classified as a developing country and zero otherwise. This variable will allow evaluating whether economic complexity helps developing countries to grow faster. The second one is an interaction term between economic complexity and developing dummy variable. This variable is included into the regression to test the hypothesis that the relationship between economic growth and complexity is different in developing countries than developed ones.

As explained above, in addition to the economic complexity index, several other variables have been chosen according to the theoretical and empirical background, to analyze the effects of complexity on economic growth. These variables, their brief definitions and data sources can be found in appendix A. In addition, summary statistics and correlation table for these variables can also be found in the Appendix.

2.4.2. Methodology

As explained in the previous section, the aim is to estimate the effects of economic complexity on economic growth. For this purpose, the econometric regression can be written as:

$$Y_{i,t}=\beta_0 + \beta_1 Y_{i,t-1} + \beta_2 ECI_{i,t} + \beta_3 Z_{i,t} + \mu_i + \varepsilon_{i,t} \qquad (2.4)$$

Where Y is the growth rate of GDP per capita, ECI is the economic complexity index, Z represents control variables, μ represents the individual fixed effects for country i and ε is the error term. i=1,2….N shows the countries, t=1,2….T shows the time period, β_0 is the constant and β_1, β_2, and β_3 are the coefficients to be estimated .

Clearly, easiest way to estimate the above regression is by using OLS, however, using OLS might cause some problems. For example, as Yalta and Yalta (2012) states, possible endogeneity of explanatory variables could yield biased and inconsistent estimates while using OLS. Moreover, there is a possibility of correlation between time invariant and explanatory variables (Yalta and Yalta, 2012). Furthermore, OLS estimates could get affected from omitted variables bias, due to the unobserved country specific effects (Voitchovsky, 2005). Last but not least, autocorrelation problem might arise because of the lagged dependent variable.

To overcome these problems, dynamic panel estimation technique, proposed by Arellano and Bover (1995) and Blundell and Bond (1998) will be used to estimate the above regression. As Roodman (2006) states, dynamic panel estimators works best for the following situations:

- Small time period and large observations (small T, large N)

- A linear relationship,

- A dynamic left hand variable, where the dependent variable is affected by its past realizations

- Endogeneity of some regressors

- Randomly distributed fixed effects.

Dynamic panel estimator consists of two types of estimation methods: Difference and System GMM. Bond, Hoeffler, and Temple (2001) argued that using difference GMM methodology when instrumental variables are weak might develop large finite sample biases. Moreover, they suggested that when the number of observations is small for time periods, lagged levels of variables are happen to be weak instruments for first differences and thus using first difference GMM might cause problems. Furthermore, Bond, Hoeffler, and Temple (2001) also stated that there might be serious downward finite sample bias in difference GMM estimator if the number of time periods is small. This might cause some problems while estimating the regression with the averaged data, since there are only 7 time periods. On the other hand, as Bond, Hoeffler, and Temple (2001;11) states:

> "System GMM estimator combines the standard set of equations in first-differences with suitably lagged levels as instruments, with an additional set of equations in levels with suitably lagged first-differences as instruments."

This suggests that there will be serious decrease in finite sample bias and serious gains in precision due to the additional moment conditions. In this sense, system GMM estimator can be thought as an expansion of difference GMM estimator that extracts more information in the equations (Voitchovsky, 2005). Moreover, system GMM estimators are more likely to have more satisfactory finite sample properties compared to difference GMM estimators because time series information is used more efficiently in system GMM methodology. Thus, system GMM estimation is chosen since it is expected to give more robust results. By taking the first differences of equation (2.4), we eliminate fixed effects:

$$\Delta Y_{i,t} = \beta_0 + \beta_1 \Delta Y_{i,t-1} + \beta_2 \Delta ECI_{i,t} + \beta_3 \Delta Z_{i,t} + \mu_i + \Delta\, \varepsilon_{i,t} \qquad (2.5)$$

The equation mentioned above will be used to estimate the effects of complexity on economic growth for both annual and pooled data. Using annual data allows checking for the short run effects, whereas pooled data helps better understand the long run effects. In addition, annual data might be disrupted from exogenous factors. For example, if a country experienced an economic/financial crisis in a given year or for a few years, using the data for those years in a regression might also cause a bias. Therefore, using pooled data allows decreasing the disruptive exogenous factors.

In order to get consistent estimates for the above regression, one needs to check for two specification tests proposed by Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998). These tests are Sargan test for over identifying restrictions, and a serial correlation test for error terms. In case of Sargan test, the null hypothesis is that there exist independence among instruments and error term, in the case of serial correlation test; the null hypothesis is that there is no serial correlation (Yalta and Yalta, 2012). Moreover, as Roodman (2007) argues, using too many instruments relative to observations might create some problems in system GMM setting, such as causing endogenous variables to over fit and yields biased estimates. Simultaneously, using too many instruments might also cause a weak Hansen test. To overcome this problem, the number of instruments is tried to keep low through estimations. Last but not least, to estimate the equation, xtabond2 code introduced by Roodman (2006) is used in this thesis. The estimations are done by using STATA.

2.4.3. Estimation Results

This section presents the empirical results and discusses about their implications. Difference in logs of GDP per capita is chosen as the dependent variable, because it helps to evaluate the effects of complexity on convergence in a clearer way. Although convergence and its properties have been briefly discussed in previous sections, some more information about convergence is necessary to make the results clearer in the empirical analysis.

Recall that one of the properties of Neo classical growth is the idea that less developed countries are expected to catch developed countries in terms of income per capita because of diminishing returns. According to Neo classical view, capital is scarce in developing countries and therefore the return on capital is higher than developed countries. The idea of developing nations will eventually catch up with developed nations corresponds to the idea of unconditional convergence in the literature.

Although there are two common concepts to test for convergence, namely sigma[8] and beta convergence, the most popular concept of measuring convergence is the beta convergence. The concept of beta convergence follows the diminishing returns assumption and existence of beta convergence happens when the rate of growth of poorer countries exceed the rate of growth in rich countries. If this definition holds, then there must be a negative link between the initial level of growth and growth rate (Islam, 2003).

On the growth regressions of Atlas of Economic Complexity, using ECI, increase in natural resources and an interaction term between ECI and income per capita, Hausmann et.al (2011) found that there is convergence among countries. Although checking for the

[8] Implies a decrease in the dispersion of income levels among economies

convergence is not their initial aim, according to the regression results, convergence exist. This finding is an encouragement to further analyze the implications of ECI on convergence. For this purpose, the regression is estimated twice, the first one includes ECI and the second one does not include ECI to check for the implications of complexity on convergence. To the best of my knowledge, there is only one single paper in the literature that comprehensively analyzes convergence in terms of ECI. Ertan Özgüzer and Oğuş-Binatlı (2016) analyzed the effects of ECI on economic convergence, using not only ECI, but also some other control variables and claimed that convergence exist for countries that are above a threshold level of complexity. Thus, they suggest that countries above a threshold level of complexity grow faster.

Following Barro (2003), and Ertan- Özgüzer and Oğuş-Binatlı (2016) the lagged GDP per capita growth is written in the form of logarithms to allow analyzing the convergence effects, since the coefficient of this variable represents the responsiveness of the per capita growth rate to a change in lagged growth. If the coefficient of this variable is negative and significant, then it can be said that there exists convergence among the countries in the data set.

Table 2 below presents the estimation results for annual data. Column 1 shows the effects of ECI and other control variables on economic growth, Column 2 eliminates the ECI to check for implications of ECI for convergence, and Column 3 includes two other variables, namely a developing dummy which is equal to one if a country is a developing country and zero otherwise. The other variable is an interaction term of developing dummy variable and ECI.

According to the Table 2**Hata! Başvuru kaynağı bulunamadı.**, in addition to the lagged ependent variable, only investment and inflation affect economic growth in all three specifications. Trade openness and population growth becomes significant when complexity is eliminated from the regression and also human capital becomes significant when developing dummy and the interaction term is added into the regression. The results showed that economic complexity does not have any significant effect in the annual data case. These results confirm the findings of Stojkoski and Kocarev (2017) and Ourens (2012) who also did not find any relationship between complexity and GDP growth in the short run. The positive coefficient on the investment variable supports the findings of Barro (2003) and Levine and Renelt (1992). In addition, the negative effect of inflation on economic growth is also consistent with the empirical literature.

Table 2: System GMM Results for Annual Data

	(1)	(2)	(3)
VARIABLES	dloglevgdp	dloglevgdp	dloglevgdp
L.loglevgdp	-0.037***	-0.028***	-0.035***
	(0.011)	(0.007)	(0.012)
ECI	0.014		0.019
	(0.011)		(0.043)
Investment	0.002***	0.002***	0.002***
	(0.000)	(0.001)	(0.001)
Pop.Growth	-0.010	-0.014*	-0.009
	(0.010)	(0.008)	(0.006)
Regional trade agree	0.008	0.003	0.003
	(0.009)	(0.009)	(0.008)
Polity2	0.000	0.001	0.000
	(0.001)	(0.001)	(0.001)
Inflation	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Human capital	0.039	0.032	0.040*
	(0.025)	(0.021)	(0.024)
Trade open	0.000	0.000*	0.000**
	(0.000)	(0.000)	(0.000)
Developing Dummy			-0.003
			(0.065)
Developing*ECI			-0.013
			(0.046)
Constant	0.193***	0.143*	0.169
	(0.067)	(0.074)	(0.130)
Hansen p value	0.061	0.057	0.152
AR(2) value	0.106	0.092	0.099
Number of inst.	31	27	33
Observations	2493	2502	2493
Number of country	81	81	81

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The reason for not getting satisfactory results might be related with the econometric specification and data structure. First of all, as mentioned above, annual data might be disrupted due to the exogenous factors such as an economic/financial crisis in a given year or for a few years. Second of all, the chosen econometric methodology for the regressions (system GMM) might not be the best technique to estimate this model. It has been argued that system GMM works best for the models where the time dimension is low, and number of observations is high (small T, large N). In the annual data case, there are 35 years of data for 81 countries, which might be problematic.

To overcome these problems, the second estimation includes 5 year pooled data. By taking averages of data for five years for each country, one can smooth the data and lessen the effects of exogenous factors such as economic and financial crisis. Last but not least, by taking averages for every 5 year, there will be 7 periods and 81 countries, which is a better fit for system GMM models. Furthermore, many seminal papers such as Barro (2003), and Beck, Levine and Loayza (2000) also used five or ten or more years of averaged data for growth regressions. Table 3 below shows the estimation results for averaged data for every 5 year period.

Like table 2, table 3 also shows the results for 3 different regressions. Column 1 shows the effect of ECI and other control variables on economic growth, Column 2 eliminates the ECI to check for implications of ECI for convergence, and Column 3 includes two other variables.

Table 3: System GMM Results for Averaged Data

	(1)	(2)	(3)
VARIABLES	dloglevgdp	dloglevgdp	dloglevgdp
L.loglevgdp	-0.070***	-0.037**	-0.061***
	(0.014)	(0.016)	(0.017)
ECI	0.059***		0.122**
	(0.019)		(0.054)
Investment	0.014***	0.014***	0.013***
	(0.002)	(0.002)	(0.002)
Pop.Growth	0.000	-0.013	-0.017
	(0.011)	(0.014)	(0.011)
Regional trade agree	0.050***	0.029	0.053***
	(0.018)	(0.019)	(0.018)
Polity2	0.001	0.002	0.001
	(0.002)	(0.003)	(0.002)
Inflation	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Human capital	0.085**	0.081*	0.088**
	(0.036)	(0.047)	(0.044)
Trade open	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Developing Dummy			0.154**
			(0.072)
Developing*ECI			-0.087
			(0.061)
Constant	0.154	-0.115	-0.038
	(0.102)	(0.111)	(0.147)
Hansen p value	0.188	0.068	0.212
AR(2) value	0.222	0.373	0.247
Number of inst.	79	68	81
Observations	468	468	468
Number of country	81	81	81

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results of the first column indicates that ECI has a positive and significant effect on economic growth as expected. This result confirms the findings of Hausmann et.al (2011), Ourens (2012) and Zhu and Li (2017). They all found that ECI has positive and significant effect on economic growth in the long run. Besides ECI, investment rate, regional trade agreements and human capital have positive and significant impact on economic growth, consistent with the theoretical and empirical literature. Inflation is found to have a negative impact on economic growth. Other variables are found to be insignificant.

Second column eliminates ECI to investigate whether ECI has an impact on economic convergence. It is observed that, when ECI is eliminated from the regression, the coefficient of the lagged growth rate decreases in absolute terms and thus implies a slower convergence. The coefficient of the dynamic variable (lagged growth) indicates that, ECI helps countries to grow faster. Therefore, countries with higher economic complexity tend to experience higher growth rates. The results of the second column also show that except regional trade agreements and human capital, all significant variables in the first column are also found to be significant.

The last column shows the results with ECI back into the regression and adds a developing dummy variable for developing countries, and an interaction term between economic complexity and developing dummy. Economic complexity index, investment rate, regional trade agreements and human capital have a positive and significant effect on economic growth, whereas the lagged log of GDP per capita and inflation has negative effects. Moreover, dummy variable is found to have positive impact on growth, however, the interaction term is found to be insignificant. A positive and significant coefficient of developing dummy variable demonstrates that there exists a positive effect on growth of being a developing country.

Comparing the results of 5 year averages with the annual data, it has been observed that the results are significantly improved by taking the averages and decreasing the time intervals. Firstly, in all three specifications, the values of Hansen test increases, which is an indicator for a more robust model. Secondly, the values of auto correlation tests also go up, which is another indicator for a more stable specification. Accordingly with these improvements, while many variables are insignificant in annual data, almost all variables are found to be significant for the pooled regression, and their signs are found to be consistent with the theoretical and empirical literature.

The only unexpected result observed in regression results is the institutional variable. Although the coefficient is positive, polity2 variable is found to be insignificant for all regressions. This might be related with different factors. For example, Sachs (2003) argued that although institutions may matter, the main problems of the developing world are not the institutions. For instance, fighting diseases, improving agriculture, building roads that connects markets to ports or airports, or shifting population from rural areas to city centers should get more importance. He mainly argues that when a threshold has been reached in terms of development, it would be good to try to improve institutions, but first there are more important problems that have to be addressed. In addition, Iqbal and Daly (2014) stated that although institutional quality increase growth in strong democracies, it does not help to boost growth in weak democracies. Moreover, Glaeser, La Porta, Lopez-de-Silanes, and Shleifer (2004) argue that poor countries usually become richer through better policies often established by dictators and then improve their institutional quality. The dataset used in this thesis includes many developing countries, and developing countries are mostly weak in terms of democracy, they are mostly poor and the polity2 score of developing countries are generally lower than the average. Hence, the insignificance of polity variable could be explained by the composition of the dataset.

It should also be noted that the estimations are also done with additional control variables, such as foreign direct investment or terms of trade for further robustness checks. The results of these estimations revealed that results do not change qualitatively when additional variables are considered.

2.5. CAUSAL ANALYSIS BETWEEN COMPLEXITY AND GROWTH

In previous sections, it has been shown that economic complexity is strongly linked to economic growth. However, what if the opposite of this is true? What if countries with higher GDP per capita are actually the countries with higher economic complexity? That is, maybe having a relatively higher GDP per capita increases the economic complexity of countries. Therefore, the purpose of this section is to investigate this relationship and analyze the causal effects between economic complexity and economic growth. Similar to the previous section, there will be two main regressions, for annual data and for pooled data, throughout this section.

The most successful countries in terms of economic complexity are the countries that can combine two properties: Diversification and ubiquity. By diversifying their export basket and by producing ubiquitous goods, these countries reach a high complexity and experience higher GDP growth rates. Then, the question is how a country can diversify and produce ubiquitous goods? In order to achieve that goal, a country should definitely have enough human capital, have proper institutions and attract more investors. However, although these factors are important for diversity and ubiquity, before these factors, a country should be able to have enough resources/money to diversify in order to invest new goods/sectors. That is, if the gain in GDP through increasing economic complexity can act as a feedback for improving the productive knowledge, the economy will grow again.

Economic growth creates a better environment for investors and guarantees a more dynamic economic structure (Parteka and Tamberi, 2013). Acemoglu and Zilibotti (1997) presented a theoretical framework that shows opportunities of diversification is limited at lower levels of development. Moreover, Acemoglu and Zilibotti (1997) also suggested that economic development might increase diversification through encouragement of entrepreneurship and innovation. Thus, it can be argued that development and diversification occurs concurrently. Imbs and Wacziarg (2003) concluded that diversity-income relationship shows a reversed U pattern. That is, diversification increases at the initial development stages, but after some threshold level of income, diversification decreases and specialization increases. They also argue that individuals change their consumption pattern as long as they have non homothetic preferences. Changes in consumption patterns would creative incentives for investors to invest in new areas, and thus increase diversification among a country. On the other hand, Mau (2016) argues against this threshold level and claims that diversification is a major component of growth, independent of income level of a country. Similar to Imbs and Wacziarg (2003), also Elhiraika and Mbate (2014) argued that growth increases the possibility of diversification due to the rise in purchasing power of individuals and also affordability of a diverse consumption basket increases.

Furthermore, the role of GDP per capita has also been emphasized in the studies that analyze the determinants of diversification. For example, Ali (2017), Cabral and Veiga (2010), and Mau (2016) have used GDP or GDP per capita as an explanatory variable for determinants of diversification, and most of them have found a positive link between these two variables. Moreover, Mau (2016) checked whether a bi-directional link exist between diversification and GDP per capita and argues that inference of causality for GDP per capita affecting the diversification is weak but exists. He argues that the reason for this weak relationship is probably it takes some time to accumulate resources to invest in new areas. Thus, the effects of GDP per capita on diversification occur with a time delay. On the other hand, Mau (2016) also argues that there is a strong evidence that diversification affects GDP per capita.

In addition to the GDP-diversity relationship, there are some papers that argue whether an increase in GDP cause exports to increase. For example, Dodaro (1993) found a bi directional relationship between GDP growth and export expansion, although this relationship is pretty weak. Similarly, Sung-Shen, Biswas and Tribedy (1990) analyzed the directional link between export promotion and economic growth, and they conclude that there exists a bi directional relationship. Although both papers state the bi directional link, they do not examine whether increase in GDP growth cause countries to export more sophisticated goods, they just state that an increase in GDP growth cause countries to export more. To analyze whether GDP growth affects the sophistication of exports, Hausmann et.al (2007) used GDP per capita as an independent variable for the determinants of EXPY. Recall that EXPY is an index that shows the sophistication of products, and Hausmann et.al (2007) founds strong evidence that increase in GDP per capita affects the sophistication of exports positively. Following Hausmann et.al (2007) many authors such as Weldemicael (2012), Poghosyan and Kočenda (2016) and Spatafora, Anand and Mishra (2012) examined whether GDP per capita affects export sophistication and they all found that GDP per capita is an important determinant of export sophistication.

The findings of the papers mentioned above build the motivation to investigate whether a bi directional relationship exists between economic complexity and GDP per capita growth, considering economic complexity is a combination of diversity and sophistication. Although there were a few studies about the causality between diversification and GDP per capita, to the best of my knowledge, there is not a study examining the bi-directional relationship between ECI and GDP per capita growth. For this purpose, using the same dataset and a similar econometric methodology, the plan is to check if there exist a causal link between ECI and GDP per capita growth. To analyze this relationship, following Podrecca and Carmeci (2001) and Yalta and Yalta (2012), consider a time stationary VAR model modified to a panel data environment as in Holtz-Eakin, Newey and Rosen (1988) and Holtz-Eakin, Newey and Rosen (1989):

$$Y_{i,t}=\beta_0 + \beta_1 Y_{i,t-1} + \beta_2 ECI_{i,t-1} + \beta_3 Z_{i,t-1} + \mu_i + \varepsilon_{i,t} \quad (2.6)$$

$$ECI_{i,t} = \gamma_0 + \gamma_1 Y_{i,t-1} + \gamma_2 ECI_{i,t-1} + \gamma_3 Z_{i,t-1} + \tau_i + u_{i,t} \quad (2.7)$$

In the above equations, Y is the logarithm of growth of GDP per capita, ECI is the economic complexity index, Z represents control variables, μ and τ represent the individual fixed effects for country i and ε and u are the error terms. i=1, 2….N shows the countries and t=1, 2….T shows the time period.

Due to the possible econometric problems of using OLS that might arise as discussed in the previous chapter, the system GMM methodology will be used again. Thus, by taking the first differences of the above equation, causality equations can be written as,

$$\Delta Y_{i,t}=\beta_0 + \beta 1 \Delta Yi_{,t-1} + \beta_2 \Delta ECI_{i,t-1} + \beta_3 \Delta Zi_{,t-1} + \mu_i + \Delta \varepsilon_{i,t} \quad (2.8)$$

$$\Delta ECI_{i,t} = \gamma_0 + \gamma_1 \Delta Yi_{,t-1} + \gamma_2 \Delta ECI_{i,t-1} + \gamma_3 \Delta Z_{i,t-1} + \tau_i + \Delta u_{i,t} \quad (2.9)$$

Before testing the causality between two variables, one must need to determine the lag length since causality tests are sensitive to lag lengths. Lag length is chosen as 2 based on Schwartz Bayesian Information Criterion. Table 4 represents the panel causality results for annual data.

The causality results shows that both lags of difference of log of GDP per capita, first lag of complexity and the second lag of population growth have significant effects on growth. In terms of ECI, both lags of growth, both lags of ECI, first lag of investment, regional trade agreements, second lag of polity2, both lags of human capital and first lag of trade openness are found to be significant.

Assuming that there are two different time series such as X and Y, it can be said that if the prediction of Y improves when the lagged variables of X taken into consideration, then it can be argued that X is said to Granger cause Y (Yalta and Yalta, 2012). To test this hypothesis, the significance of both lags of X should be checked. If both lags of X are jointly statistically significant, then it can be said that X granger causes Y. In the context of this thesis, ECI_{it} is said to Granger cause GDP per capita growth if all the coefficients of lagged ECI_{it} are jointly statistically different from zero, and vice versa.

The joint significance of coefficients can be tested by using the Wald test. The Wald test coefficient in the first column is equal to 0.1, which is at the border of significance. Moreover, Wald test results on column 2 reveals that, GDP per capita growth Granger causes economic complexity. This relationship confirms the claims of Acemoglu and Zilibotti (1997), which suggest that economic development might increase diversification through encouragement of entrepreneurship and innovation.

Table 4: Panel Causality Results for Annual Data

VARIABLES	(1) D.loglevgdp	(2) ECI
L.loglevgdp	0.391***	1.208***
	(0.070)	(0.290)
L2.loglevgdp	-0.415***	-0.837***
	(0.067)	(0.269)
L.ECI	0.013**	0.742***
	(0.007)	(0.077)
L2.ECI	-0.002	-0.153**
	(0.007)	(0.057)
L.Investment	-0.001	-0.002*
	(0.001)	(0.001)
L2.Investment	0.000	0.003
	(0.000)	(0.002)
L.Pop.growth	-0.007	-0.029
	(0.004)	(0.030)
L2.Pop.growth	0.007*	0.003
	(0.004)	(0.041)
Regional trade agree.	0.010	-0.175**
	(0.009)	(0.083)
L.Polity2	0.001	0.002
	(0.001)	(0.004)
L2.Polity2	0.001	-0.007*
	(0.001)	(0.003)
L.Inflation	-0.000	0.000
	(0.000)	(0.000)
L2.Inflation	-0.000	-0.000
	(0.000)	(0.000)
L.Human capital	0.179	-2.961**
	(0.177)	(1.445)
L2.Human capital	-0.174	2.795*
	(0.173)	(1.475)
L.Trade open.	0.000	0.002*
	(0.000)	(0.001)
L2.Trade open.	-0.000	-0.000
	(0.000)	(0.001)
Constant	0.200***	-2.677***
	(0.070)	(0.408)
Hansen p value	0.065	0.53
AR(2) value	0.232	0.500
Number of inst.	59	75
Wald causality test p value	0.100	0.000
Observations	2474	2468
Number of country	81	81

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Table 5 below shows the panel causality results for averaged data, to further analyze the directional relationship between complexity and growth.

Table 5: Panel Causality Results for Averaged Data

VARIABLES	(1) D.loglevgdp	(2) ECI
L.loglevgdp	0.349**	-0.138
	(0.171)	(0.349)
L2.loglevgdp	-0.406**	0.183
	(0.164)	(0.328)
L.ECI	0.069**	1.139***
	(0.034)	(0.093)
L2.ECI	-0.037	-0.149**
	(0.038)	(0.061)
L.Investment	-0.001	0.003
	(0.003)	(0.007)
L2.Investment	0.001	-0.000
	(0.002)	(0.004)
L.Pop.growth	-0.016	-0.071**
	(0.021)	(0.035)
L2.Pop.growth	0.004	0.032
	(0.016)	(0.035)
Regional trade agree.	-0.024	-0.111**
	(0.025)	(0.048)
L.Polity2	0.007**	0.012*
	(0.003)	(0.007)
L2.Polity2	0.003	0.003
	(0.002)	(0.006)
L.Inflation	0.000	-0.000
	(0.000)	(0.000)
L2.Inflation	-0.000	-0.000
	(0.000)	(0.000)
L.Human capital	0.381**	0.703
	(0.155)	(0.435)
L2.Human capital	-0.393**	-0.848*
	(0.147)	(0.444)
L.Trade open.	0.000	-0.001
	(0.000)	(0.001)
L2.Trade open.	-0.000	0.002
	(0.001)	(0.001)
Constant	0.497***	-0.192
	(0.187)	(0.323)
Hansen p value	0.149	0.484
AR(2) value	0.062	0.361
Number of inst.	73	73
Wald causality test p value	0.0866	0.2521
Observations	376	376
Number of country	79	79

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The results from the table above shows that except the lagged levels of difference of log of GDP, first lag of complexity, first lag polity2 and both lags of human capital significantly affect economic growth. The results of the second column shows that both lags of ECI, first lag of population growth, regional trade agreements, first lag of polity and the second lag of human capital have significantly affect ECI. Causality result (Wald test) reveals that ECI Granger causes GDP per capita growth, whereas, on the contrary to annual data, causal relationship from GDP per capita growth to ECI could not be found in the case of averaged data. These results suggest that although GDP per capita growth granger causes economic complexity in the short run, it disappears in the long run. These results seem plausible according to the fact that the main driver behind the economic complexity is the collective productive knowledge of societies in the long run.

3. ECONOMIC COMPLEXITY AND OUTPUT VOLATILITY

Sustainability in economic growth is one of the major targets of countries since economic development requires sustainability in economic growth. Hence, economic development does not only require high growth rates, but stability of growth rates. The instability in growth rates takes place especially among developing nations. In a seminal paper, Lucas (1988) stated that growth rates are generally stable across developing nations, but they vary a lot in developing countries. Pritchett (2000) also argued that poorer countries tend to have more volatile growth rates. According to Mobarak (2005), the variation in economic growth is 6 times greater in developing nations than developed ones. Moreover, with the finding that volatility affects growth negatively in Ramey and Ramey (1994), it is considered that volatility is an important barrier in economic growth and development, and thus worthy of our attention.

According to the research of Fogli and Perri (2015), when an economy becomes more volatile, economic agents choose to hold their funds more in foreign assets. According to their calculations, a 0.5 percentage point increase in volatility over a period of 10 years cause an increase in net foreign assets by approximately 8 percent of GDP. They claim that volatility is strongly linked to uncertainty, and greater uncertainty not only results in higher savings and lower investment, but also creates an incentive for individuals to shift their resources to foreign assets.

As discussed above, volatility has crucial implications on economic growth. In this context, the aim of this chapter is to analyze whether there is a relationship between economic complexity and output volatility. For this purpose, firstly, the theoretical linkages between complexity and volatility will be examined, by utilizing diversity, ubiquity and product space concepts. Secondly, the measurement of output volatility and the possible determinants of volatility will be discussed, by making use of the empirical literature on the determinants of volatility. Afterwards, using a broad data set, the relationship between complexity and volatility will be analyzed empirically, using various control measures for a group of countries. Although there are studies that analyzed this relationship in micro level

(Krishna and Levchenko, 2013, Maggioni, Lo Turco and Gallegati, 2014) to the best of my knowledge, this thesis is the first to analyze this relationship at a macro level.

The structure of Chapter 3 is as follows: Section 3.1 examines the theoretical connections between complexity and volatility and also briefly covers the related literature. Section 3.2 analyzes and explains the dataset that will be used in the econometric regression by examining the theoretical and empirical connections of volatility with other variables and Section 3.3 reviews the econometric methodology. Section 3.4 represents the empirical results in two parts: The first part examines the results for the full sample, and the second part discusses the results for developing countries only, since volatility is especially an issue for these countries.

3.1. THEORETICAL FRAMEWORK AND THE REVIEW OF THE LITERATURE

In previous chapters, it is stated that diversity is an important determinant of economic growth. However, importance of diversity does not end here. Also in previous chapters, it has been argued that diversification has significant advantages for an economy such as creating a wide menu of exports and many different income sources. Moreover, diversification also acts like an insurance against risks and uncertainty. Furthermore, diversification improves production technologies and creates knowledge spillovers. Acemoglu and Zilibotti (1997) showed that as the number of sectors that are open to investment goes up, the savings individuals invest also increases. This process increases the capital accumulation and allows countries to take precautions about shocks and thus decreases volatility. Many papers such as Hvidt (2013), and Akhtar and Freire (2014) argued that economic diversification is also an important determinant of volatility and an increase in the diversity of an economy will cause volatility to decrease. This relationship is especially important for Arab-Gulf countries since their economies are mainly dependent on hydrocarbons. For example, Hvidt (2013) analyzed the diversification processes and benefits of diversification in GCC Countries and concludes that these countries should lower the impact of hydrocarbons on their export structure if they want to experience lower volatility and more stable growth rates.

Similarly, oil revenues are highly volatile and diversification in Arab countries will help these countries to protect them from the high volatility of oil incomes. A less diversified country's export revenues are dependent on only a few sectors or trading partners (IMF, 2016). During the 2015-2016 period, when oil prices decreased significantly, economies that mostly depends on oil, such as Saudi Arabia, has experienced serious economic problems and took precautions about the economy. The reason Saudi Arabia has suffered much from the decrease in oil prices is because Saudi Arabia does not have a diverse economic structure. According to the Economic Complexity Observatory (2014), oil products (crude petroleum, refined petroleum and petroleum) accounts for more than 65% of Saudi exports. On the other hand, Canada, for example, is also an important oil exporting economy, but since she has a diverse structure, she suffered less from the drop in oil prices. For the year 2015, oil products (crude petroleum, refined petroleum and petroleum) only accounts for approximately 14% of all exports (Economic Complexity Observatory, 2011). As this example suggests, diversification lowers the risks a country might face.

Akhtar and Freire (2014) made a similar analysis (volatility-diversification) for Asian landlocked countries. Due to being landlocked, these countries experience significantly higher transportation costs and many of them depends on one or few sectors like Arab countries for their economic structure. They argued that due to the high concentration on few sectors and/or industries, these economies are more likely to expose volatility and diversifying their economic structure could be a solution for volatility.

Felix (2012) analyzed the industrial diversity and its implications in the Tenth District in the USA, and concluded that industrially diverse counties have more stable employment and wage growth. He argued that, according to economic theory, specializing in fewer sectors causes that region/countries depend on that sector heavily and if a shock hits these sectors, it will negatively affect employment and wage growth. Thus, diversification of sectors/industries will help decreasing volatility. Felix (2012) examined this phenomenon in terms of distribution of employment, using a diversity index based on the distribution of employment around the district. He found out that industrial diversity has a positive effect on economic stability[9]

Vannoorenberghe, Wang and Yu (2016) analyzed whether a diversified export basket of firms make them more stable in terms of exports, based on Chinese exporters. They concluded that this argument is valid for firms with large volume of exports. Measuring export market diversification by using a Herfindahl Index, they concluded that as firms export market profiles become more diverse, volatility decreases, whereas the opposite of this is true for small exporters. For medium size exporters, the relationship does not exist.

All these papers examined the diversity volatility relationship at different levels (group of countries, territories among a country, firm level) and the common finding of these papers suggest that diversification creates a more stable environment and decreases volatility. Recall that ECI is an important indicator of diversity of countries, and thus it is expected that countries with higher complexity also face with lower macroeconomic volatility.

It has been argued that developing nations experience higher output volatility than developed ones. Koren and Tenreyno (2007) pointed out 3 possible reasons that could explain this difference: First, poor countries usually specialize in less and more volatile sectors, second, poor countries are more prone to shocks, and third, fluctuations in these countries are particularly connected with the sectors they choose to specialize. To study the sources of volatility, they divided its sources into three components. The first component includes sectoral shocks, which implies that economies specialize in sectors that experience higher volatility will also tend to experience higher aggregate volatility. The second one is country specific shocks and this suggests that some countries are inclined to get affected by policy shocks more than others. The last one brings the first two components together and it is related to the covariance between first two components, such as a macro policy shock that might affect some sectors more than others.

[9] Stability in terms of employment and wage growth

The reason behind the classification of volatility is to find how much variation is coming from sectoral shocks and how much of it is coming from other sources. As Koren and Tenreyno (2007:245) suggest:

> "Quantitatively, roughly 50 percent of the differences in volatility between poor and rich countries can be accounted for by differences in country-specific volatility, whereas the remaining 50 percent is accounted for by differences in the sectoral composition."

Moreover, the results of their empirical analysis showed that countries are inclined to specialize in less volatile sectors as the development process continues. At the early stages of development, diversification opportunities are restricted due to the lack of physical/human capital. According to findings of Koren and Tenreyno (2007), the sectors the poorer countries specialize carry a high sector specific risk. Furthermore, these countries tend to focus on few sectors and this creates an environment for high volatility. Thus, developing nations usually specialize in more volatile sectors. In addition, as nations develop, country specific volatility decreases. With the development of nations, production changes from high risk sectors to lower ones and this change caused a decrease in volatility. According to Koren and Tenreyno (2007), the reason for the decline in sectoral volatility is because as countries develop, they switch from strongly risky sectors such as agriculture and mining to lower risky sectors such as manufacture and service. Their calculations showed that standard deviations of shocks in agriculture and mining are approximately 5 and 7 percent, respectively. On the other hand, these shocks decreases to 2 percent in services, and fluctuate between 2 and 4 percent in manufacturing.

Similar to Koren and Tenreyno (2007), Kraay and Ventura (2007) analyzed why business cycles in developing nations is more volatile than developed ones. They measure business cycles as the standard deviation of GDP per capita growth, which is actually a measure of volatility. They examined the reasons behind this phenomenon and argued that excess volatility in developing nations is coming from more political instability, worse institutional factors and less developed nations usually use their resources in more volatile sectors such as agriculture. However, there are still differences between developed and developing nations in terms of volatility even after controlling for them. Thus, they developed an alternative method and argue that developed countries specialize in field of businesses that call for new technologies and in need of skilled labor; on the other hand, developing nations usually specialize in fields that use traditional technologies in need of unskilled workers. This explanation implies that developing nations are more responsive to country specific shocks and this idea explains the volatility differences between rich and poor countries. (Kraay and Ventura, 2007)

One of the reasons developing nations are more affected with shocks lies behind the idea that firms in developed nations that use new technologies experience more inelastic demand. Recall that market power in economics is described by Lerner index[10], which is equal to (P-MC)/P, where P is price and MC is marginal cost, or equivalently, $(-1/\varepsilon_d)$ where ε_d is the demand elasticity for a firm. Thus, as ε_d decreases, market power of a firm goes up. This suggests that firms that specialize in new technologies have more market power. Another reason behind this market power is that it is hard to imitate new technologies due to the technological and legal (patents, copyrights etc.) reasons, which enables these firms to act more like monopoly. On the other hand, imitating traditional technologies is relatively easier, and thus firms operate in traditional technologies do not have much market power.

Another reason for the volatility differences between countries is the type of labor. According to the economics theory, supply of skilled labor is more inelastic than supply of unskilled labor. Thus, a change in the demand of labor is expected to affect unskilled labor more than skilled labor. If a shock hits an industry, industries that use unskilled labor experience higher fluctuations in unskilled employment, whereas the strength of fluctuations in skilled labor is lower. Thus, industries/sectors that use unskilled labor are expected to affect more from a country or sector specific shock. Kraay and Ventura (2007), using a theoretical model and calibration techniques, showed that both factors (demand

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[10] Lerner Index is created in 1934 by Abba Lerner. The index ranges from one to zero. One implies full market power and zero implies no market power at all.

elasticities and labor supply elasticities) affect volatility, but demand elasticities have more explanatory power on volatility than labor supply factors.

All these implications of sources of volatility can be discussed through the product space. Recall that the shape of the product space of developed nations mostly located on center areas, whereas the shape of developing nations mostly located on the edges. The reason for this difference is coming from the construction of product space: Products that have high complexity and high connections with other products mostly placed on center areas and vice versa. Therefore, developed nations mostly export complex products; on the other hand, developing nations mostly export simple/less complex products. Recall that central areas of product space usually include powerful manufacturing sectors such as chemicals and electronics. However, areas close to borders of product space usually include simpler sectors, such as agriculture and mining. It has been argued that the effects of shocks in simple sectors are higher than the effect of shocks in complex sectors. Economic complexity tries to guide countries to diversify their productive structure through more complicated manufacturing sectors. In this perspective, countries that are able to increase their complexity should lower the unfavorable effects of output volatility. Moreover, the difference between the demand of complex and simple goods also contributes to the difference of volatility between developed and developing nations. As argued above, demand for complex goods is more stable and does not affected much by shocks, whereas demand for simple goods is elastic and can easily get affected by shocks. Therefore, the distinction in export structure provides developed nations with a powerful advantage in terms of volatility.

Koren and Tenreyno (2013) analyzed the process of technological diversification from a firms' point of view. They argued that firms using large number of inputs could weaken the effect of shocks through two ways. Firstly, as number of inputs increases, relative importance of an input in the production process becomes less, therefore, volatility in production decreases. Secondly, if a specific input gets hit by a shock, firms can minimize this shock by substituting other inputs. Thus, both aspects imply that firms using more inputs and developed technologies would be less volatile. Koren and Tenreyno (2013) also argued that aggregate and firm level volatility are synchronized and move together. Therefore, a decline in the volatility level of firms also causes a decline in aggregate volatility. Bringing this micro analysis from firms to the macro (countries) level, they conclude richer countries are less volatile since firms in rich economies mostly use a large number of inputs.

The model used in Koren and Tenreyno (2013) evaluates technological progress by an increase in the number of inputs. An increase in number of inputs, in aggregate, increases the productivity in general. One of the important features of their model is that it is stochastic so that it can be used to evaluate output volatility. They assumed that there is some possibility for each input to experience a shock and increasing the number of inputs creates an advantage in terms of diversification and reduces the effects of volatility in an economy. Therefore, when firms use a variety of inputs in production, volatility decreases.

Another channel between volatility and technological diversification can be analyzed through capital and labor. Assume a poor or simple country that uses mainly labor for its productivity. If something happens to supply of labor; that country would be affected a lot from this shock. On the other hand, a country with an advanced capital structure would be less affected since it can replace labor with capital easily. An example would be the protests of American workers in McDonald's against their wages in previous years. The workers protested that the minimum wage is low and threaten to leave the job. After some time, McDonald's let them go and replace these workers by ordering machines.

Koren and Tenreyno (2013) assumed that diversification occurs within the firm, not across firms. In the first stages of development, countries usually specialize in low productivity industries, however, as development continues, they tend to specialize in higher productivity sectors. It is observed that developing countries experience higher volatility than developed ones. Last but not least, it should be noted that the diversification concept in their model does not include outputs; it only considers the number of inputs in a firm used in production.

Following the theoretical explanations in Koren and Tenreyno (2013), Krishna and Levchenko (2013) also analyzed the relationship between complexity, comparative advantage and volatility. They argued that trade openness cause developing countries to specialize in more volatile sectors. Within their perspective, complexity is the main driver that explains the relationship between trade openness, specialization and volatility. They measured complexity as the number of inputs needed to produce a good. They showed that volatility in a sector is highly dependent on the complexity of products that are being produced in that sector. Thus, complex goods are less volatile since they use a lot of inputs because a shock to that input will affect complex goods less due to the usage of a high number of inputs on the production of that good. Using these explanations, Krishna and Levchenko (2013) built two mechanisms that show why poorer countries specialize in less complex and thus more volatile goods. The first one is the quality of contract enforcement. As the production becomes more complex, agents that join the process gets higher and the number of contracts also increases. Thus, countries with worse institutional factors experience more losses in production due to the imperfect contracts. Second mechanism is based on human capital. Countries with higher level of human capital could produce more complex goods due to the capabilities and abilities of labor force.

The main theoretical concept Krishna and Levchenko (2013) argued is that less developed countries specialize in less complex goods which exhibits a higher volatility. To prove this point, after setting up a theoretical model, they also checked this relationship empirically. Using industry level data, and various control measures, they found out that variation in complexity has a significant effect on sectoral volatility. Both Koren and Tenreyno (2013) and Krishna and Levchenko (2013) evaluated the effects of complexity on volatility, using a different complexity definition from this thesis. Measuring the complexity of a product by counting the number of inputs, they found that complexity lowers volatility.

Maggioni, Lo Turco and Gallegati (2014) also checked for the link between complexity and volatility for Turkish firms. They argued that exports of a country mostly driven by a few big exporters and thus macroeconomic performance of exports are highly depended on these firms performance. Thus, analyzing firms' export choices has a crucial importance on an economy's export performance.

Expanding the work of Koren and Tenreyno (2013), Maggioni, Lo Turco and Gallegati (2014) analyzed the complexity-volatility nexus through two channels. First channel is the supply side. Maggioni, Lo Turco and Gallegati (2014) emphasized the importance of fixed and sunk costs and argue that production of complex goods usually specified by high fixed and sunk costs and thus they exhibit high barriers to entry. Due to these barriers, producers of these goods enjoy more market power, more stable sales and less competition. Second channel is the demand side. In general, substituting complex goods is harder than less complex goods due to technological factors behind the production process. Moreover, buyers of these (complex) goods usually include richer consumers from richer countries, and since these countries are less exposed to shocks, this assures a more stable demand for complex goods. Therefore, production of complex goods is expected to be less volatile.

For empirical research, Maggioni, Lo Turco and Gallegati (2014) analyzed data from Turkish manufacturing firms over the period 2003 and 2009. As a complexity index, they used the formulation of ECI for firms discussed in great detail in previous chapters. They also added control variables that points out firm characteristics that might affect volatility. Using OLS and instrumental variable techniques and various control variables for robustness, they concluded that complexity affects volatility negatively at the firm level.

The theoretical discussion and empirical literature reviewed in this section indicate that economic complexity might help countries to lower the output volatility through various channels. For example, by diversifying their export baskets, countries could lower the effects of shocks and decrease volatility. Moreover, as empirical evidence suggests complex products/sectors are expected to show lower volatility. These explanations suggest that there should be a negative link between complexity and output volatility. Following sections will investigate this relationship by analyzing the data, examining the methodology and presenting the empirical results.

3.2. DATA

This section explains and discusses the data set that will be used in the empirical regression for the volatility complexity relationship. Although, the same data set used for the growth regression in terms of time period (1981-2015) will be used, there will be 84 countries[11] and also there will be some changes in terms of control variables. There exist a broad literature on the determinants of output volatility, and control variables are selected according to this literature. However, before analyzing the control variables, measurement of output volatility should be briefly addressed.

Since the aim is to investigate the effects of complexity on volatility, clearly, output volatility will be used as the dependent variable. There are three widely used measurements of volatility in the literature. The first one is to calculate the volatility as the standard deviation of an economic variable. This is the most common measurement of volatility in the literature. Second, volatility can be calculated as the standard deviation of the residual of an econometric regression. Thirdly, volatility can be calculated as the standard deviation of a cycle isolated by a statistical filter. Although all measurement techniques have been used in the literature, the most common measurement is the first one. Seminal papers about volatility such as Ramey and Ramey (1994), Acemoglu et.al (2003), Karras and Song (1996), Easterly and Kraay (2000), Bejan (2006), Yang (2008) and many others have all used the standard deviation of an economic variable, such as GDP growth per capita or exports. Moreover, as Iseringhausen and Vierke (2018) states, the typical way to measure volatility is the rolling standard deviations. Following these papers, the output volatility is measured as the rolling standard deviations of real GDP per capita growth rate in this thesis.

As a complexity measure, obviously the Economic Complexity Index by Simoes and Hidalgo (2011) will be used. In addition to output volatility and economic complexity, several other variables will also be used in the regression. Among these, there will be macroeconomic variables, such as GDP per capita growth, government size, inflation rate,

[11] The list of countries can be found in appendix C.

terms of trade, financial openness and lastly real effective exchange rate. Moreover, there will also be an institutional variable, namely polity2.

The first control variable for the regression is the growth rate of GDP per capita. GDP growth is included into the model because it allows controlling for general macroeconomic conditions among an economy. Moreover, both theoretical and empirical literature suggests that there is a strong link between GDP growth and/or GDP per capita and volatility. For example, Easterly, Islam and Stiglitz (2000) and Bastourre and Carrera (2004) both found a negative link between growth and volatility. Koskela and Viren (2003) also found a negative but statistically insignificant relationship between growth rate and volatility.

A key variable for the determinants of output volatility is the government size. As a measurement of government size, this thesis benefits from the ratio of government consumption to GDP data. Theoretically, it has been argued that fiscal policy could act as a balancer for an economy such as it helps to stabilize business cycles (Koskela and Viren, 2003). In this sense, government size might reflect the effectiveness of automatic stabilizers. Moreover, Rodrik (1998) argued that governments in general lower the risk among an economy through social insurance. Gali (1994) introduced a real business cycle model and argued that there is a negative relationship between government size and volatility. Moreover, he also claimed that government purchases stabilize the economy. However, Pisani-Ferry, Debrun and Sapir (2008) argued that findings of Gali (1994) fail to match with the real life data. One of the possible explanations for this issue can be discussed through the arguments of Rodrik (1998). He revealed that the government size is usually bigger in countries with more open economies since one of the purposes of government is to stabilize the economy, however, this makes these economies more prone to international shocks. Moreover, Pisani-Ferry et.al (2008) claimed that increasing government spending has two opposite effects: It enlarges the non-volatile part of GDP, but also increases the consumption and investment volatility that might cause an increase in output volatility. Empirically, many papers after Gali (1994) have been analyzed this relationship such as Fatas and Mihov (2001) and Andres, Domenech and Fatas (2008) and they found a negative link between government size and volatility. Furthermore, studies like Koskela and Viren (2003) argued that there is not a robust relationship between these two variables. A different approach to this literature such as Fatas and Mihov (2003) and Hakura (2007) argued that discretionary fiscal policy might increase the volatility. In sum, the general opinion is that government consumption decreases volatility, however, there might not be a robust relationship, or maybe a positive relationship might exist.

Another important variable in the literature about the determinants of output volatility is the inflation rate. A high inflation generally creates uncertainty in an economy and thus lowers the confidence of businesses and consumers. The uncertainty created in an economy might cause individuals to canalize their resources to foreign assets and distorts the growth rate. Moreover, since price stability is one of the main purposes of a central bank, inflation is a crucial component of monetary policy. High inflation implies that monetary policy of central bank does not seem to be credible, which also increases the uncertainty. As Carboni and Ellison (2011) states, there exists an agreement among economists that credible and transparent monetary policy benefits hugely to the stability of an economy. These arguments makes inflation a crucial component of volatility, thus inflation is chosen as an explanatory variable of output volatility. General consensus among literature on the effects of inflation on volatility is that inflation positively affects volatility. Many papers such as Yang (2008), Mobarak (2005), Bejan (2006) and Anbarci, Hill and Kirmanoglu (2011) found that inflation increases output volatility.

Terms of trade also enters as another control variable to use in the regression. Kose, Prasad and Terrones (2003) argued that especially countries with limited diversification of exports and imports are more prone to the impacts of sudden changes in terms of trade. Kose (2002) showed that terms of trade shocks are especially an issue in small states with extremely volatile fluctuations. Buch, Döpke, and Pierdzioch, (2005) argued that terms of trade volatility helped analyze the business cycle volatilities in 1980s and 1990s and sudden changes in terms of trade could also lead to sudden changes in current account and affect the exports and imports of a country. Moreover, as Bejan (2006) argues, terms of trade volatility can be considered as a proxy of external risk, which is an important component of volatility. Among the literature, there are some studies that found a positive relationship between terms of trade and volatility such as Buch et.al (2005), however, there are also studies found a negative link between terms of trade volatility and output volatility, such as Bejan (2006). Moreover, there are also studies found no relationship such as Yang (2008). Thus, the relationship looks ambiguous.

Another key determinant for volatility in the literature is the financial openness. On recent decades, volatility has substantially decreased among the major economies. As Calderón and Schmidt-Hebbel (2008) states, volatility in 2005 is almost equal to 60% of the volatility in 1985. In the same time, both financial openness and trade openness among the world has increased in a considerable amount. Theoretically, the link between financial openness and volatility looks ambiguous. On the one hand, financial openness could lower the volatility by allowing countries to reach an extensive amount of financial instruments and thus reduce the effects of country specific risks (Calderón and Schmidt-Hebbel, 2008). Moreover, Kim, Lin and Suen (2012) argued that financial openness not only encourages capital accumulation and productivity growth, but also stimulates more disciplined macroeconomic policies and creates a better functioning domestic credit system under the competition of international competition. Furthermore, as Kose, Prasad, and Terrones (2006) stated, if openness leads to a diversification in countries with poor capital by providing them to new sources of capital, then it could lower the impacts of volatility. On the other hand, if openness lead specialization based on comparative advantage but not diversification, then it might harm countries by making them more vulnerable to shocks. In addition, Mishkin (2006) stated that financial openness might cause domestic institutions to take excessive risks through capital inflows, and thus increase the effects of shocks. In addition to the theoretical connections, the papers that have examined this relationship also found different results. For example, Loayza and Raddats (2007) found that financial openness lowers volatility, whereas Bekaert, Harvey and Lundblad (2006) could not find any significant relationship. As a measure of financial openness, this thesis benefits from the Chinn and Ito (2008) index, which is a measure of a county's capital account openness and measures the extensiveness of capital controls (Chinn and Ito, 2008).

The real effective exchange (REER) rate is also an important component of macroeconomic volatility since changes in exchange rates could easily affect a country's exports/imports and also affect the inflation. Furthermore, according to the empirical literature such as Anbarci et al. (2011), Bleaney and Fielding (2002) and Hnatkovska and Loayza (2004) volatility of growth could easily be influenced with exchange rate regime of a country. Exchange rate volatility can be considered as a source of instability and thus growth volatility. Therefore, REER is also considered as a control variable. Anbarci et.al (2011) and Karras and Song (1996) found a positive link between exchange rate flexibility and volatility. On the other hand, Haddad, Lim, Pancaro, and Saborowski (2013) found a negative or no link, dependent on the model specification, between output volatility and volatility of real effective exchange rates. To measure the real effective exchange rate, this thesis benefits from the Darvas (2012a, 2012b) dataset. Although World Bank database also have the exchange rate data, unfortunately, it has dozens of missing data. On the other hand, Darvas (2012a, 2012b) have only very few missing variables, thus it would serve better for the purposes of this thesis.

Institutional quality is also another important determinant of output volatility according to the theoretical and empirical literature. Acemoglu et.al (2003) stated many reasons about why instability in institutionally weak societies is relatively higher. For example, he argues that due to lack of sufficient constraints on rulers, when a change occurs in the balance of power, individuals/groups that gain power might redistribute income to themselves, which creates instability. Moreover, due to the benefits of gaining power, there will be greater conflicts between various political groups and thus volatility will be greater. Acemoglu et.al (2003) also asserted that individuals tend to invest in sectors from which they can extract their capital rapidly in case of a political crisis, in countries with weak institutions. Similarly, Rodrik (2000) also argued that democracies create more stability due to the separation of powers and rule of law. Many papers such as Acemoglu et.al (2003) and Yang (2008) have used different indicators of institutional quality. In general, a negative relationship is found between these two variables, (Acemoglu et.al, 2003, Malik and Temple, 2009), but there are also studies that found a conditional negative relationship depended on other factors such as ethnic diversity (Yang, 2008) and studies found no relationship such as Bugamelli and Paterno (2011). Thus, as theoretical and empirical evidence suggests, institutional quality is an important component of output volatility. As a measurement of institutional quality, polity2 variable, which is also used in the growth regression, from the Polity IV data set will be utilized.

In sum, apart from the Economic Complexity Index, many control variables that are expected to affect volatility is chosen to analyze the relationship according to the volatility literature. Brief definitions and sources of variables, summary statistics and correlation between variables can be found in Appendix B.

3.3. METHODOLOGY

This thesis benefits from the panel VAR approach as in Abrigo and Love (2016) in analyzing the effects of economic complexity on output volatility. There are only a few studies that have analyzed this relationship before (Maggioni, Turco and Gallegati, 2014, Krishna and Levchenko, 2013) and none of them have used panel VAR methodology. They both used cross section analysis; however, cross section analysis might suffer from endogeneity, and more importantly, panel VAR allows to capture dynamic effects, which cannot be captured through cross section analysis. Therefore, examining the complexity and volatility relationship through a panel VAR setting contributes significantly to the literature.

In addition to the benefits mentioned above, panel VAR methodology has several other advantages. Firstly, as Love and Zicchino (2006) states, panel VAR approach combines traditional VAR approach with panel data. The traditional approach allows treating all variables as endogenous, which solves the problem of endogeneity. The panel data framework of panel VAR includes fixed effects and thus allow for unobserved individual heterogeneity, which improves the consistency of estimation (Shen, Holmes and Lim, 2015). Secondly, as Grossman, Love and Orlov (2014) argue, applying a VAR is especially useful for the cases where there is not much theoretical background about the relationships among the variables. Thirdly, panel VAR methodology uses two important concepts: The first one is the variance decompositions, and the second one is the impulse response function analysis. Variance decompositions examine the contributions of shocks of variables to the variance of each endogenous variable, and the impulse response functions reports the response of a variable to a shock in another variable (Boubtane, Coulibaly and Rault, 2013). Moreover, impulse response functions allow analyzing the dynamic structure between two variables. As Grossman, Love and Orlov (2014) states dynamic effects cannot be captured by any other panel regressions, which is another important benefit of panel VAR model.

While estimating the econometric equation, the plan is to use the pvar code introduced by Abrigo and Love (2016). Panel VAR and thus pvar code actually estimates the regression in a GMM framework. Abrigo and Love (2016) states that pvar estimates the model by fitting a multivariate panel regression of dependent variables and on their lags and lags of other dependent variables.

The panel VAR equation in general form, following Abrigo and Love (2016) can be written as below

$$Y_{it} = Y_{it-1}A_1 + Y_{it-2}A_2 + \ldots\ldots + Y_{it-p}A_p + X_{it}B + \mu_i + \varepsilon_{it} \qquad (3.1)$$

Where i = 1,2….N represent countries and t=1,2,…..T represent time. Y_{it} is a vector of dependent variables, X_{it} is a vector of exogenous covariates, μ_i represents vectors of dependent variable-specific panel fixed-effects, ε_{it} is the error term, and A and B are coefficients to be estimated. Including μ_i into the regression allows capturing unobservable time- invariant factors at a country level. In addition to the output volatility, Y_{it} includes real GDP per capita growth, polity2, government consumption, inflation, terms of trade, financial openness, real effective exchange rate and economic complexity.

As Anderson and Hsiao (1982) suggests, the equation above can be estimated consistently by instrumenting lagged differences with levels and differences of Y from previous periods. However, this method might create some problems. As Abrigo and Love (2016) states, the transformation by taking first differences increases the gap in the unbalanced panel data setting. To solve this issue, Arellano and Bover (1995) suggested a different transformation. If the transformation is done by forward orthogonal deviation, then disposing of the fragility of first difference transformation is possible, by minimizing the data loss. Moreover, efficiency of the estimation can be improved by adding longer lags as instruments. However, this might cause some data loss by reducing observations, especially in the unbalanced panel data setting. As a solution to this issue, Holtz-Eakin, Newey and Rosen (1988) argued that creating instruments using observed realizations, in which missing data is replaced with zero, with the assumption that the instrument list is uncorrelated with the errors (Abrigo and Love, 2016). Therefore, estimating panel VAR through a GMM setting not only creates consistent estimates, but also with the suggestion of Holtz-Eakin, Newey and Rosen (1988), efficiency of the estimation can be improved substantially.

3.4. ESTIMATION RESULTS

The previous section has analyzed the methodology and discussed about the advantages of panel VAR. This section presents the regression results and also discuss about the implications of volatility and complexity relationship. Since output volatility is especially an important problem for developing countries, this section is divided into two sub parts. The first part analyzes the results for the full sample (developed and developing countries) and the second part examines the implications of complexity and other control variables on volatility for developing countries only.

3.4.1 Estimation Results for the Full Sample

Before starting the estimation procedure, the unit roots of the variables should be addressed since panel VAR requires variables to be stationary. To check whether variables are stationary, this thesis benefits from the fisher type unit root test. Although there are other tests available, such as Levin–Lin–Chu, Harris–Tzavalis or Im–Pesaran–Shin tests, Fisher type test have several advantages. First of all, the data set in this thesis have few missing variables and Fisher test does not require a balanced panel data, unlike Levin–Lin–Chu or Harris–Tzavalis tests. Secondly, as Choi (2001) states, Fisher type test combines the p values of individuals' statistics and according to his simulations; it is a more persuasive test than Im, Peseran and Shin. The results of unit root tests can be found in the table below.

Table 6: Unit Root Tests

	ADF-Fisher	ADF -Fisher including trend	PP-Fisher	PP -Fisher including trend
Variables				
GDP growth	908.1301(0.000)	869.4289(0.000)	1227.7421(0.000)	1181.9921(0.000)
Po12	284.9573(0.000)	262.7304(0.000)	293.6423(0.000)	252.7824(0.000)
Gov.Cons	272.5210(0.000)	228.9480(0.0012)	275.1789(0.0000)	309.6842(0.000)
Inflation	696.5094(0.000)	869.4288(0.000)	1227.7421(0.000)	1181.9921(0.000)
TOT	197.58521(0.000)	197.2573(0.0608)	261.1373(0.000)	269.6927(0.000)
Fin.Open	231.7717(0.000)	159.3088(0.6722)	379.9542(0.000)	364.0889(0.000)
REER	528.1829(0.000)	432.2597(0.0000)	345.2442(0.000)	220.4502(0.003)
ECI	252.8376(0.000)	235.4281(0.000)	217.2157(0.0063)	197.6914(0.0583)
Volatility	394.6009(0.000)	304.3686(0.000)	307.3949(0.000)	232.3477(0.0007)

The test statistics in the table above show the inverse chi squared test results and p values are represented in parenthesis. The first column shows the results with the Dickey Fuller option without the trend, and the second column introduces trend. The third and fourth columns show the results with Phillips-Perron test, since this statistics is more robust to serial correlation. The test has the null hypothesis of presence of a unit root. According to unit root test results, almost all variables are found to be stationary at least 10% level. The only exception is the financial openness rate, which is found to be non-stationary according to Dickey Fuller test with trend. However, Phillips-Perron test of financial openness with the trend option shows that this variable is also stationary, which implies that the panel VAR can be estimated by using these variables.

While estimating a panel VAR, first thing to do is to determine the lag selection. This could be done by using various moment and model selection criteria suggested in the literature. Andrews and Lu (2001) suggested a moment and model selection criteria (MMSC) for GMM models. Their suggestion is very similar to the several lag selection criteria used in maximum likelihood based models[12]. To choose the optimal lag, MMSC should be at its minimum value. The lag selection criteria of the model can be found in the table below. According to the results, the minimum value of MBIC and MQIC happens at the first lag, thus, it is chosen to employ a first order panel var.

Table 7: Selection Order Criteria

Selection order criteria
Sample: 5-34

Lag	CD	J	J p value	MBIC	MAIC	MQIC
1	.9981677	498.5325	9.13e-20	-1320.033	12.53247	-479.6599
2	.9999948	234.3067	.0001754	-978.07	-89.69328	-417.8216
3	.9999996	122.5382	.0019883	-483.6502	-39.46181	-203.5259

The estimation results of the first order panel VAR by using GMM-style instruments can be found in the table below.

According to the results below, it is observed that output volatility depend the past values of itself, GDP per capita growth, economic complexity, polity2, financial openness, and REER. Moreover, the coefficient of complexity is negative, which is an indicator that complexity negatively affects volatility.

[12] These selection criteria include Akaike information criteria (AIC), the Bayesian information criteria (BIC), and the Hannan-Quinn information criteria (HQIC).

Table 8: Panel VAR Results

VARIABLES	(1) Volatility
L.GDP Growth	0.050***
	(0.014)
L.Polity2	0.047**
	(0.021)
L.Gov. Cons.	-0.008
	(0.011)
L.Inflation	0.000
	(0.000)
L.Terms of Trade	0.005
	(0.003)
L.Fin. Open.	-3.049***
	(0.360)
L.REER	0.000**
	(0.000)
L.ECI	-3.392***
	(0.745)
L.Volatility	0.902***
	(0.043)
Observations	2,033

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In addition to the estimation results above, the model is also tested for Granger Causality results. The Granger Causality tests show that not only economic complexity, but also economic growth, polity2, terms of trade, financial openness and real effective exchange rate granger causes output volatility. The test results of granger causality can be found in the table below:

Table 9: Granger Causality Results

Equation/Excluded	Chi2	df	prob>chi2
Volatility			
GDP Growth per capita	13.384	1	0.000
Polity2	4.862	1	0.027
Gov. Cons	0.494	1	0.482
Inflation	0.324	1	0.569
Terms of trade	2.611	1	0.106
Fin. Open	71.637	1	0.000
REER	4.858	1	0.028
ECI	20.737	1	0.000
ALL	188.904	8	0.000

Before analyzing the variance decomposition and impulse response functions, first, the stability condition of panel VAR must be addressed since variance they cannot be interpreted if the panel VAR is unstable. Stability condition indicates that panel VAR is invertible and its representation has the property of infinite order vector moving average representation (Abrigo and Love, 2016). According to Lütkepohl (2005), a VAR model is stable as long as all moduli of companion matrix are less than one. The graph and the results for stability conditions can be found below:

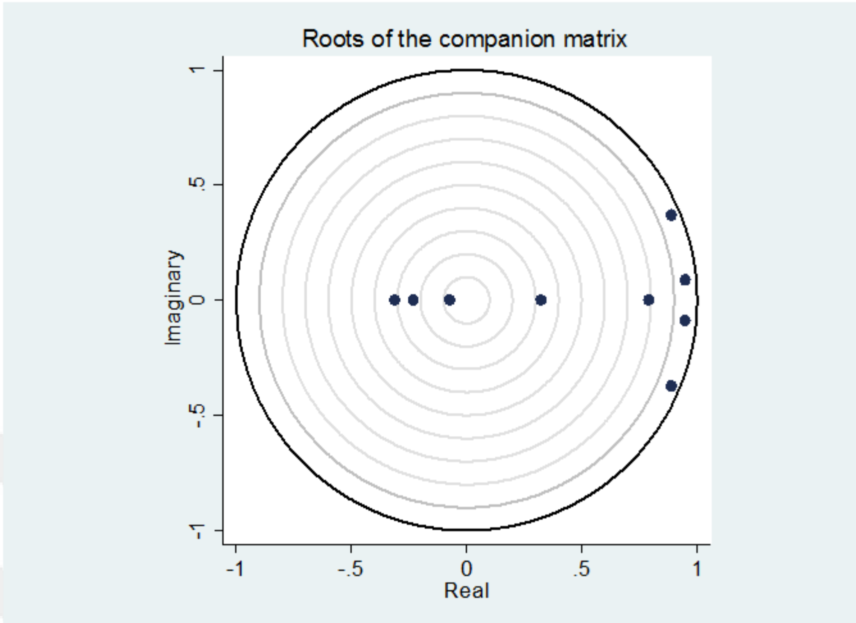

Figure 1: Panel VAR Stability Graph

As can be seen from the graph above, all roots lie in the unit circle and this ensures the stability of the panel VAR. In addition to the graphical representation, the stability of a panel VAR can also be shown through the eigenvalues and moduli. The table below represents the eigenvalues and moduli and further proves that panel VAR model used above is stable.

Table 10: Panel VAR Stability Conditions

Eigenvalue		
Real	Imaginary	Modulus
.8868811	-.3709318	.9613264
.8868811	-.3709318	.9613264
.9485099	.0884397	.9526241
.9485099	-.0884397	.9526241
.7904652	0	.7904652
.3224537	0	.3224537
-.312814	0	.312814
-.2302527	0	.2302527
-.0753487	0	.0753487

As can be seen from above, all the moduli are strictly less than one and thus panel VAR satisfies the stability condition.

Although the estimation results above give a hint about the effects of complexity and other variables on output volatility, one of the most important features of panel VAR is the variance decompositions. Variance decompositions show how much of the variation in a variable is caused by other variable(s) (Grossmann, Love and Orlov, 2014). While analyzing the variance decompositions, it should also be noted that ordering of the variables (Cholesky decomposition) is also important. The main assumption about such ordering is that the variables that come sooner affects all the other variables contemporaneously, while the variables come later has an impact on the previous variables only with a lag (Grossmann, Love and Orlov, 2014). As Shen, Holmes and Lim (2015) state, this assumption implies that the variables placed earlier in the ordering are more exogenous, whereas the variables placed later are more endogenous. While ordering the variables, it is chosen to place economic growth firstly; since it is the most common and strong variable that gives information about the general situation of an economy, which makes it the most exogenous. More importantly, it is expected to affect all other variables contemporaneously but other variables could affect growth with a lag. Furthermore, the empirical research suggests that volatility of output is directly related to GDP per capita growth. Following the real GDP per capita growth, it is chosen to place polity2 and government consumption as the second and third variables respectively, since these variables can respond quickly to a change in economic growth, but expected to affect growth with a lag. After these two variables, it is chosen to place monetary variables in the order of inflation, terms of trade, financial openness and REER. Following these variables, economic complexity and volatility of output are placed at the end of the ordering. Although economic complexity might give detailed information about the status of an economy, recall that international trade of countries has a significant importance on the measurement of economic complexity. Thus, it is chosen to place ECI after monetary/financial variables. In sum, the Cholesky ordering of the variables is in the following form: Real GDP per capita growth, Polity2, Government Consumption, Inflation, Terms of Trade, Financial Openness, Real

Effective Exchange Rate, Economic Complexity and Volatility. The results of variance decompositions through this ordering can be found in the table below, for a given of 10 period forecast horizon:

Table 11: Variance Decomposition

Response Variable	Impulse Variable								
	GDP Growth	Polity2	Gov.Cons	Inflation	Terms of trade	Fin.Open	REER	ECI	Volatility
Volatility									
0	0	0	0	0	0	0	0	0	0
1	0.1785393	0.0010164	0.038758	0.225506	0.001253	0.000021	0.00291	2.61E-06	0.551993
2	0.1339437	0.009277	0.0586611	0.202265	0.003272	0.016226	0.002896	0.045189	0.52827
3	0.0966715	0.0122062	0.053053	0.187692	0.010958	0.031223	0.003234	0.113833	0.491129
4	0.0748875	0.0189788	0.0456994	0.162198	0.019227	0.056455	0.003361	0.181989	0.437205
5	0.0710989	0.031064	0.0384131	0.139303	0.029166	0.081651	0.003362	0.223468	0.382475
6	0.0808241	0.0404156	0.0352088	0.123292	0.039166	0.103765	0.003152	0.235442	0.338735
7	0.094271	0.0446878	0.0380599	0.116422	0.048038	0.117489	0.002879	0.22489	0.313264
8	0.1030859	0.0435466	0.0462978	0.11691	0.054278	0.120702	0.002719	0.207011	0.305451
9	0.1033297	0.0401303	0.0568752	0.120118	0.057273	0.115423	0.002791	0.196285	0.307775
10	0.0973485	0.038519	0.0661573	0.121607	0.057554	0.106892	0.003078	0.198139	0.310705

The results show that the effects of economic complexity on volatility starts to rise significantly by period three and maximizes its effect around the sixth period. In period ten, approximately nineteen percent of the variation in volatility can be explained by the ECI. Moreover, approximately 12 percent, 10 percent and 9 percent of the variation in volatility is coming from inflation, financial openness and growth, respectively. Changes in government consumption and institutional quality contribute to approximately 4 and 6 percent variations in volatility, respectively, and terms of trade contributes almost five percent of variation in output volatility. Clearly, the highest effect on volatility is coming through itself by approximately 31 percent.

Although all these results deliver valuable information about the relationship between complexity and volatility, the strongest implication of panel VAR models can be extracted through impulse response functions (IRF). IRF's allow evaluating the impact of a shock of one variable on another variable, while holding all other variables are constant. The impulse response functions for the preferred model can be found below:

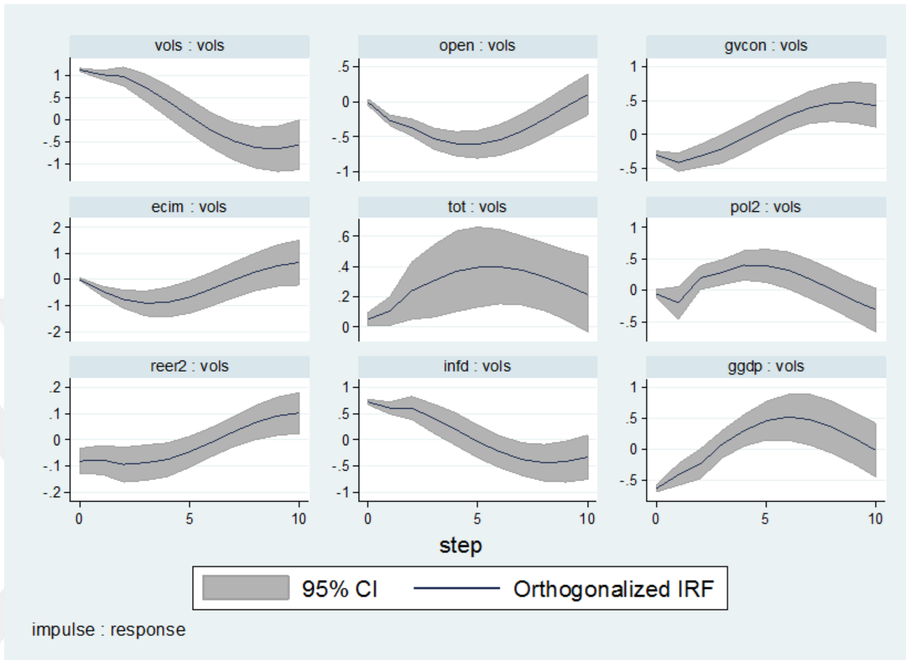

Figure 2: Impulse Response Functions

In the graphs above, vols stands for output volatility, open is the indicator of financial openness, gvcon represents government consumption, ecim stands for economic complexity index, tot is the terms of trade, pol2 shows Polity2 variable, reer2 represents the real effective exchange rate, infd represents inflation, and ggdp is the real GDP per capita growth rate.

The impulse response functions above shows response of output volatility to the impulse of economic complexity and other control variables for the first 10 periods. These graphs are constructed by using Monte Carlo simulations with 200 repetitions based on the estimated model. While estimating the significance on impulse response functions, one should check for whether the confidence interval contains zero or not. If the confidence interval contains zero for a given period, then the effect of one variable to another is statistically insignificant. For the purpose of this thesis, the most important one among these graphs is the one with the effect of ECI on volatility. This graph (2nd row, 1st column) reveals that a shock on economic complexity decreases volatility for at least 6 periods. Although the effect starts to increase after 6 periods, it is found to be insignificant. This finding confirms the negative relationship between economic complexity and output volatility and also consistent with the findings of Maggioni, Lo Turco and Gallegati (2014). In other words, complexity of a country could act as an important component to lower the effects of volatility.

Among other variables, a shock to the growth of real GDP per capita leads to a decrease in output volatility for the first three or four periods, which is consistent with the findings of Easterly et.al (2000) and Bastourre and Carrera (2004). According to the results, a shock on inflation causes volatility to increase. This result confirms the findings of many papers, such as Yang (2008), Mobarak (2005) and Bejan (2006). Similarly, a shock on terms of trade also increases the output volatility, similar to the findings of Buch et.al (2005) for the effects of terms of trade on volatility. On the other hand, financial openness is found to have a negative effect on volatility, which is consistent with the findings of Loayza and Raddats (2007). Similar to financial openness, a shock on government consumption also lowers the volatility for the first three to four periods and confirms the findings of Gali (1994), Fatas and Mihov (2001), and Andres, Domenech and Fatas (2008). However, after first few periods, it has been observed that the effect of government consumption becomes positive. Similarly, Pisani-Ferry et.al (2008) analyzed the effects of government size on volatility between the years 1961 and 2007 and argued that although the effect is negative before 1991, it changes direction after 1991 and becomes positive for the period 1991 and 2007. They also stated that the relationship is difficult to estimate precisely and beyond some level of government expenditure might be harmful in terms of stability for an economy. Another important implication of impulse response functions above is the effects of institutional quality on output volatility. According to the graphs above, a shock to polity2 variable increases the volatility for the first four or five periods, however this effect becomes negative in the following periods. Therefore, institutional quality is found to have a negative long run effects on output volatility. Similar to this thesis, many other papers such as Acemoglu et.al (2003) and Malik and Temple (2009) have also found a negative relationship between institutional quality and volatility. In a nutshell, the results of panel VAR are mostly consistent with the empirical literature and proved that economic complexity has a negative impact on output volatility, which also confirms the theoretical expectations. Hence, increasing the complexity of a country could lower the volatility and create a more stable economic environment.

As a robustness test, it has also been considered the case where polity2 is an exogenous variable in the model and thus it does not enter into variance decompositions and impulse response functions. After following similar steps for the panel VAR, such as determining the lag selection and checking for the stability condition, the impulse response functions below shows the estimation results when polity2 enters as an exogenous variable.

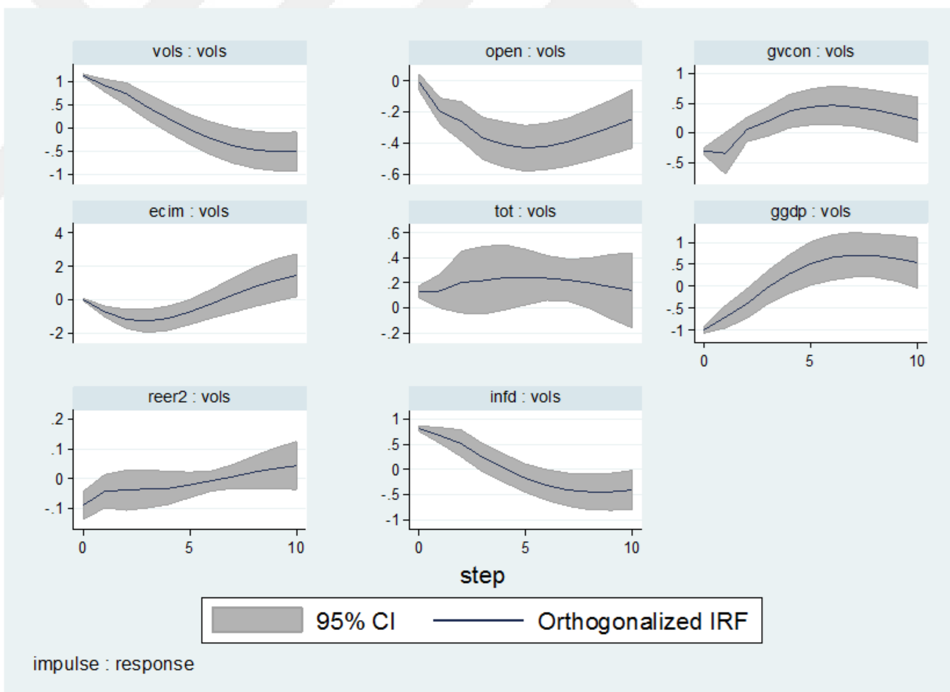

Figure 3: Impulse Response Functions 2

According to the results above, the effect of economic complexity on volatility does not change much at all. This specification showed that even when polity2 is considered as an exogenous variable, complexity still significantly lowers output volatility. The effects of other variables are mostly similar to the previous model, except the terms of trade, which becomes insignificant when polity2 is considered as an exogenous variable.

3.4.2 Estimation Results for Developing Countries

It has been argued in previously that output volatility is especially problematic for developing countries. For example, Koren and Tenreyno (2007) argued that developing nations mostly specialize in more volatile and less complex sectors and thus these countries are more vulnerable to shocks. Kraay and Ventura (2007) argued that developing countries usually produce goods that require traditional technologies and unskilled labor. Therefore, due to having a less diverse and relatively unsophisticated productive structure, developing nations mostly suffer from the consequences of macroeconomic volatility. Loayza, Rancie`re, Serve´n, and Ventura (2007) showed that independent of being small or large, or commodity exporters or rapidly industrializing economies, volatility is a common problem among developing nations. Thus, it is especially important for the purpose of this thesis to discuss the implications of ECI on output volatility for developing countries. Using the same methodology and same data set except the countries, this part estimates the same model and analyzes the implications of ECI on output volatility for developing countries.

Similar to the previous section, the unit roots of the variables should be checked before starting to the estimation procedure. Using Fisher type unit roots test again, the results can be found in the table below.

Table 12: Unit Root Tests for Developing Countries

Variables	ADF-Fisher	ADF -Fisher including trend	PP-Fisher	PP -Fisher including trend
GDP growth	690.7468(0.000)	657.2108(0.000)	978.7992(0.000)	966.6290(0.000)
Po12	269.9371(0.000)	257.3349(0.000)	282.1466(0.000)	248.7683(0.000)
Gov.Cons	190.5750(0.000)	156.4227(0.0259)	225.2687(0.000)	276.7403(0.000)
Inflation	493.5699(0.000)	468.5391(0.000)	852.0781(0.000)	788,0228(0.000)
TOT	164.1784(0.0091)	135.1206(0.2333)	226.5361(0.000)	223.4619(0.000)
Fin.Open	173.1176(0.0024)	131.7249(0.3005)	256.6766(0.000)	272.2744(0.000)
REER	443.2178(0.000)	365.2038(0.000)	285.6567(0.000)	181.0814(0.000)
ECI	223.3818(0.000)	207.4383(0.000)	197.4635(0.000)	180.4803(0.0007)
Volatility	282.9148(0.000)	216.9727(0.000)	225.4907(0.000)	175.4880(0.0016)

Almost all variables are found to be stationary, but, terms of trade and financial openness is non-stationary according to the Dickey Fuller procedure with a trend. However, these variables are found to be stationary according to the Phillips Perron procedure with trend. Therefore, all variables can be used directly in panel VAR estimations.

Before starting the estimation procedure, the proper lag should be selected. Thus, using the same methodology in the previous section for the lag selection, a first order panel VAR is selected since first lag has the minimum values for both MBIC and MQIC criteria, according to the table below.

Table 13: Selection Order Criteria for Developing Countries

Selection order criteria						
Lag	CD	J	J p value	MBIC	MAIC	MQIC
1	.9897298	448,2341	2,31e-14	-1331,777	-37,76592	-519,5443
2	.9999852	226,2978	.0006374	-960,3763	-97,7022	-418,8878
3	.9999984	90,74278	.2151533	-502,5943	-71,25722	-231,85

The panel VAR estimation results using GMM style instruments for developing countries can be found in the table below:

According to the results below, it is observed that output volatility depend the past values of itself, economic complexity, polity2, financial openness, government consumption and REER. Similar to the full sample, the response of volatility to economic complexity is negative in the estimated coefficients. Moreover, the coefficient increases in absolute terms relative to the full sample, which is an indicator that economic complexity might have stronger effects in terms of output volatility for developing countries.

Table 14: Panel VAR results for Developing Countries

VARIABLES	(1) Volatility
L.GDP Growth	0.014
	(0.014)
L.Polity2	0.101***
	(0.021)
L.Gov. Cons	0.026**
	(0.011)
L.Inflation	-0.000
	(0.000)
L.Terms of trade	-0.003
	(0.003)
L.Fin. Open.	-3.850***
	(0.347)
L.REER	0.000***
	(0.000)
L.ECI	-5.872***
	(0.957)
L.Volatility	0.778***
	(0.043)
Observations	1,706

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In addition to the estimation results above, the model is also tested for Granger Causality results. The Granger Causality tests show that not only economic complexity, but also polity2, government consumption, financial openness and real effective exchange rate also granger causes output volatility. The test results can be found in the table below.

Table 15: Granger Causality Results for Developing Countries

Equation/Excluded	Chi2	df	prob>chi2
Volatility			
GDP Growth per capita	1.062	1	0.303
Polity2	22.937	1	0.000
Gov. Cons	5.991	1	0.014
Inflation	2.079	1	0.149
Terms of trade	1.237	1	0.266
Fin. Open	123.350	1	0.000
REER	28.184	1	0.000
ECI	37,684	1	0.000
ALL	232,882	8	0.000

Before analyzing the variance decompositions and impulse response functions, the stability condition of the panel VAR should be discussed. The results for stability conditions can be found in the figure below:

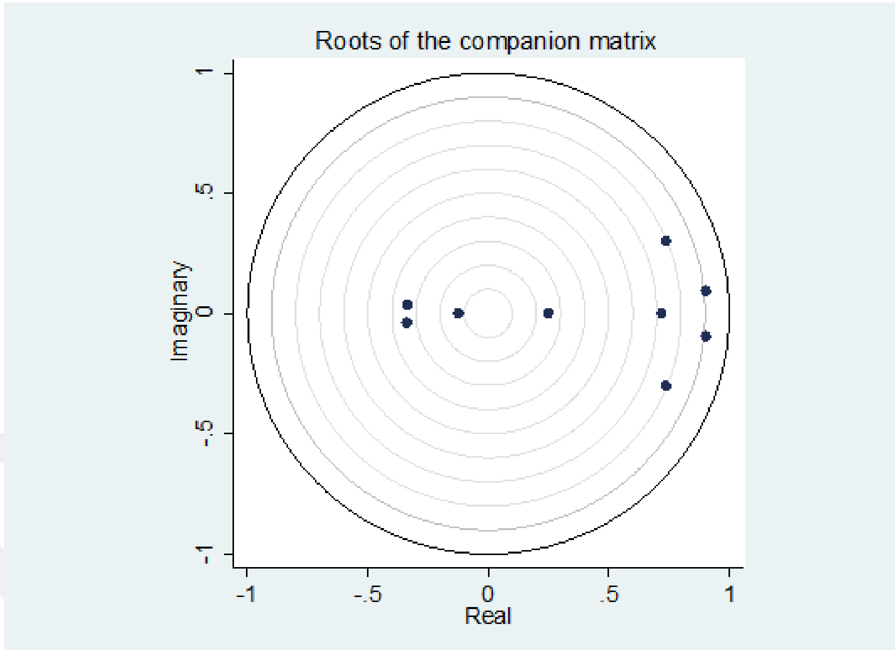

Figure 4: Panel VAR Stability Graph for Developing Countries

As can be seen from the graph above, all roots lie in the unit circle and this ensures the stability of the panel VAR. In addition to the graphical representation, the stability of a panel VAR can also be showed through the eigenvalues and moduli. The table below represents the eigenvalues and moduli and further proves that panel VAR model used above is stable.

Table 16: Panel VAR stability conditions for Developing Countries

Eigenvalue		
Real	Imaginary	Modulus
.9034196	.0945799	.9083569
.9034196	-.0945799	.9083569
.73729	-.3021059	.7967839
.73729	.3021059	.7967839
.7188095	0	.7188095
-.3376439	.0374905	.3397189
-.3376439	-.0374905	.3397189
.2492729	0	.2492729
-.1236795	0	.1236795

As discussed before, the strongest aspects of panel VAR methodology are the variance decompositions and impulse response functions. Thus to analyze the relationship deeply for developing countries, both of them should be analyzed. The results for variance decompositions can be found below.

Table 17: Variance Decomposition for Developing Countries

Response Variable		Impulse Variable								
		GDP Growth	Polity2	Gov.Cons	Inflation	Terms of trade	Fin.Open	REER	ECI	Volatility
Volatility										
	0	0	0	0	0	0	0	0	0	0
	1	0.233224	0.097455	0.062872	0.229503	0.002854	5.25E-05	0.000609	4.26E-08	0.373431
	2	0.174935	0.064309	0.063044	0.193968	0.001788	0.019575	0.000741	0.10604	0.375602
	3	0.133331	0.062489	0.052042	0.160442	0.001476	0.047453	0.000962	0.205967	0.33584
	4	0.132742	0.069366	0.044585	0.138087	0.002584	0.078867	0.00107	0.236432	0.296268
	5	0.144837	0.078106	0.041996	0.12627	0.006975	0.102588	0.001064	0.227786	0.270378
	6	0.153345	0.079562	0.043808	0.120488	0.014783	0.116365	0.000999	0.214042	0.256609
	7	0.152042	0.076389	0.048262	0.116584	0.02452	0.119976	0.000995	0.212223	0.249009
	8	0.145247	0.07251	0.053381	0.112862	0.033814	0.11738	0.001099	0.22048	0.243228
	9	0.139056	0.070927	0.057984	0.10928	0.041181	0.112916	0.001277	0.229655	0.237724
	10	0.136727	0.072229	0.061603	0.106273	0.046223	0.109234	0.001469	0.233644	0.232599

The Cholesky ordering of the variables are as same as the previous section. Variance decomposition results shows that ECI explains approximately twenty three percent of the variation in volatility in developing countries. Recall that this value was equal to approximately nineteen percent in the full sample. This suggests that ECI has stronger implications in terms of output volatility in developing countries. Other than ECI, GDP per capita growth and polity2 explains approximately thirteen and seven percent variation in volatility, respectively. Government consumption explains around six percent of variation in volatility, and a shock to inflation explains ten percent of the variation. Last but not least, terms of trade and financial openness explains four and ten percent of variation in volatility, respectively. Comparing these results with the previous section shows that in addition to the economic complexity, almost all variables, (except volatility itself and real effective exchange rate) are relatively more important for developing countries in explaining the variation in volatility.

The impulse response analysis for the developing countries sample can be found below:

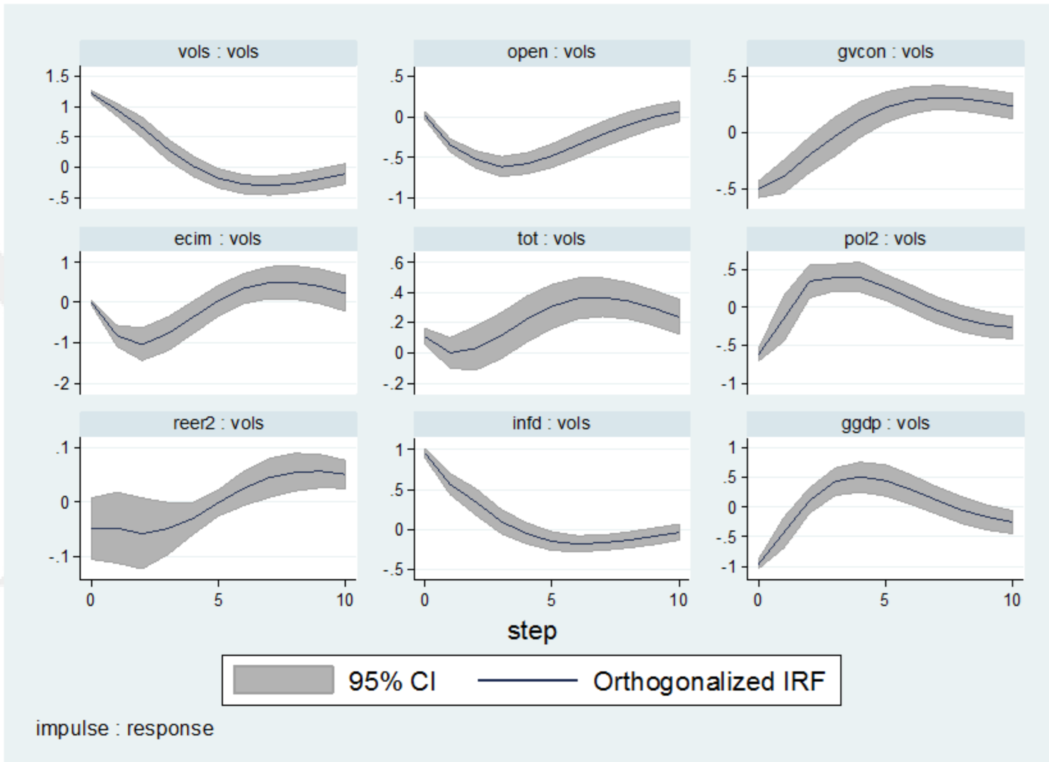

Figure 5: Impulse Response Functions for Developing Countries

In the graphs above, vols stands for output volatility, open is the indicator of financial openness, gvcon represents government consumption, ecim stands for economic complexity index, tot is the terms of trade, pol2 shows Polity2 variable, reer2 represents the real effective exchange rate, infd represents inflation, and ggdp is the real GDP per capita growth rate.

Similar to the impulse response functions of the full sample (developed plus developing), the graphs above also show that a shock on economic complexity leads to a decrease in volatility, although it becomes insignificant after the fifth or sixth period. Other results look fairly similar with the full sample. A shock to financial openness causes a decrease in output volatility and inflation cause volatility to increase. Government consumption lowers the volatility in first few periods, but then the effect becomes positive. Similar to the full sample, a shock to institutional quality increases volatility at first, but then the effect becomes negative in the long run.

The empirical analysis for developing countries showed that, economic complexity indeed negatively affects volatility. Relative to the full sample, the impulse response function dropped sharper for the first few periods. This idea suggests that economic complexity is especially important for developing countries to not only increase the growth rate, but also helps them to swiftly lower the effects of volatility. Therefore, policies that aim to increase the complexity of a country should be one of the very first purposes of policy makers in developing countries.

Similar to previous section, the case where polity2 is entered as an exogenous variable to the model is also considered for developing countries. The impulse response functions for this specification can be seen below.

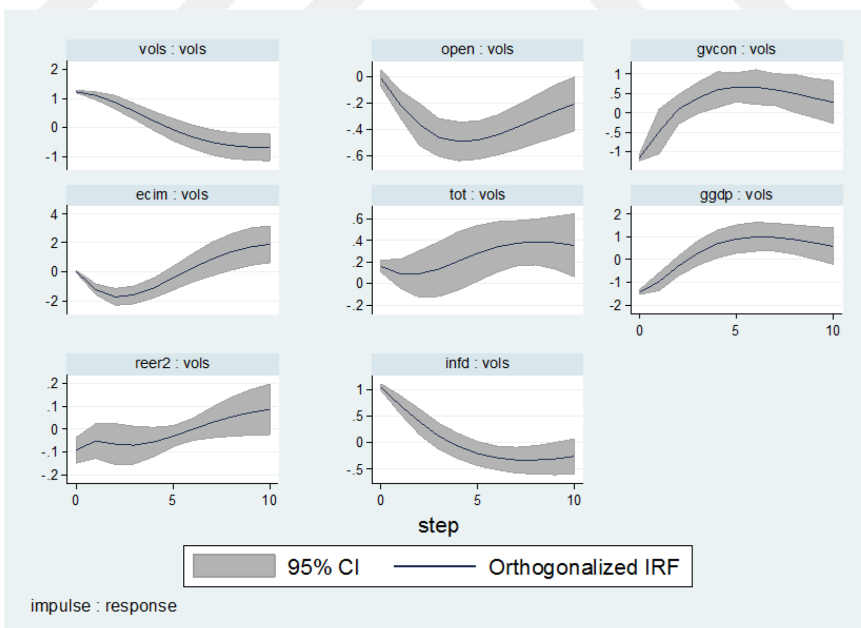

Figure 6: Impulse Response Functions 2 for Developing Countries

Similar to the previous section, the results do not change much when polity2 enters as an exogenous variable to the regression. A shock on complexity still decreases output volatility, and the effects of other variables on output volatility are almost identical with the previous case.

For further robustness, alternative Cholesky orderings are also analyzed both for the full sample and developing countries only, since the ordering of the variables is important. The results revealed that there are not any significant differences in terms of impulse response functions and variance decompositions. Almost all variables have similar effects for output volatility, and there are not any qualitative changes in estimation results.

CONCLUSION

Economic Complexity advocates that countries grow by improving their productive knowledge in order to expand their economic activities through more complex goods. Diversification and sophistication of production are separately considered as an important determinant of economic performance, and economic complexity brings them together to analyze the productive knowledge among a country. Therefore, economic complexity analysis provides a new perspective of evaluating the success of the performance of an economy. This thesis analyzes the concept of economic complexity and its implications on the performance of an economy and contributes to literature in various ways. First of all, this study inspects the relationship between economic complexity, economic growth and convergence. While there is a general consensus among the literature on the fundamental role of economic complexity in terms of economic growth, theoretical and empirical work supporting this idea is still very much in progress and there are only a few studies that have analyzed this relationship before. Among these few studies, the ones that have used a dynamic panel data methodology are fairly limited. To this end, using a dynamic panel data methodology, namely system GMM, this thesis examines this relationship for a large set of countries. Second of all, this study also examines the existence of the causal relationship between complexity and growth by using the same dataset and same methodology. Last but not least, this study also analyzes the link between output volatility and complexity, using a panel set of countries, extended time period and various control variables, through panel VAR methodology. There are only a few papers that have analyzed this relationship before, and none of them have considered this relationship at the macro level. Thus, this thesis contributes to the literature not only by analyzing this relationship at the macro level, but also using a panel VAR methodology.

The system GMM results of complexity and growth relationship revealed that economic complexity indeed is an important determinant of economic growth. In addition to the economic complexity index, investment rate, regional trade agreements and human capital also found to have a positive effect on economic growth. According to the estimation results, economic complexity and human capital play a bigger role in growth compared to investment and regional trade agreements. This suggests that countries should work on to improve their complexity by expanding their collective productive knowledge, which is possible by improving the level of human capital. Furthermore, the impact of economic complexity on convergence is also examined by using the same data set. The results showed that economic complexity also contributes to the speed of convergence. Thus, it can be inferred that increasing the complexity is a crucial factor for low income countries to boost their growth and catch up with rich countries.

The papers that have analyzed the complexity and growth relationship before assumed that causality runs from complexity to growth. Although this is a plausible assumption, economic complexity index is expressed in the composition of a country's productive output and thus it might be the case that countries with higher GDP per capita are actually the countries with higher economic complexity. Therefore, to analyze whether a bi-directional relationship exists between economic complexity and economic growth, the causal relationship is examined through a system GMM methodology. Using the same countries and time period, the results revealed that causality runs from GDP per capita growth to complexity in the case of annual data, however, the opposite is true for the pooled data. This result suggests that although growth causes an increase in the complexity in the short run, such relationship does not exist in the medium/long run.

In addition to the importance of economic growth on economic performance, another crucial factor for an economy's performance is the stability of growth rates. The instability in growth rates creates many problems for an economy such as it hurts the poor, harms the confidence on an economy and creates a negative atmosphere for economic agents. The most important component of a stable economy is the constant output growth, which can be measured by output volatility. Output volatility appears to be a major problem especially for developing countries and the literature on the sources of volatility reveals that diversification and sophistication of production structure is an important determinant of volatility.

Recall that economic complexity suggests countries to not only diversify their production structure, but also argues that countries should produce non ubiquitous goods. It also has been argued that non ubiquitous goods are mostly sophisticated ones that exhibit high levels of productivity. In this perspective, economic complexity could perform a critical role for decreasing the effects of output volatility. The empirical results of the complexity and volatility relationship revealed that economic complexity indeed lowers the output volatility. Therefore, countries can protect themselves from the unfavorable effects of output volatility by increasing their economic complexity. To investigate this relationship further, the connections between complexity and volatility is also examined for developing countries only, since volatility is a substantial problem especially in these countries. The findings suggest that economic complexity helps developing countries to lower their volatility, and the relationship looks stronger relative to the full sample. Thus, economic complexity is especially important for developing countries to strengthen their economic performance. Besides the economic complexity, GDP per capita growth and financial openness are also affects output volatility negatively, whereas inflation rate and has a positive impact on volatility, according to panel VAR results. Therefore, in addition to increasing the economic complexity, countries should engage in international financial markets to provide themselves with new sources of capital and diversifying the economy to lower the effects of volatility.

The results discussed above clearly suggests that economic complexity not only boosts growth, but also decreases the output volatility and thus help countries to have a more stable economic environment. Furthermore, its implications about convergence show that developing countries could grow faster and close the gap in terms of per capita income with developed countries by increasing their economic complexity. Therefore, improving their economic complexity should be one of the main concerns of countries. According to the economic complexity, the secret behind the economic growth lies behind the accumulation of productive knowledge at the community level. Analyzing the productive structure of every single country individually, economic complexity specifies a distinctive road map for each country. Product space, distance and proximity measures discussed in the first chapter provide great information for countries to increase their collective productivity by diversifying their productive structure and producing more complex goods. These concepts analyze the productive knowledge of countries meticulously and guide countries what to produce to increase the diversity and sophistication of production. The product space shows which type of new economic activities, especially complex ones, are within the reach of a country's initial productive knowledge. By producing and exporting in these activities, countries could increase their level of complexity and boost their economic growth. In this sense, economic complexity together with the product space can be considered as a road map to prosperity.

The data for the economic complexity is mainly collected from customs offices, and thus complexity analysis considers goods only, not services. Although this is an important drawback of the complexity analysis, with the recent improvements, some of product space maps are also available for services in tourism, transportation, finance and telecom. The introduction of the complexity of services together with the goods could produce a more robust analysis. Therefore, subsequent analysis can also consider the impact of services while analyzing the effects of complexity.

APPENDIX A

Table 18: Variables Definitions and Source

VARIABLES	DEFINITIONS	SOURCE
GDP per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population.	World Bank, World Development Indicators
Investment (Gross capital formation) (% of GDP)	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories.	World Bank, World Development Indicators
ECI(Economic Complexity Index)	Economic Complexity Index (ECI) ranks how diversified and complex a country's export basket is.	Simoes and Hidalgo (2011)
Population growth (annual %)	Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage.	World Bank, World Development Indicators
Regional Trade Agreement	A dummy variable equal to 1 if a country has a trade agreement with another country in a given year; 0 otherwise.	De Sousa and Lochard. (2011).
Polity2	The POLITY score is computed by subtracting the AUTOC score from the DEMOC score; the resulting unified polity scale ranges from +10 (strongly democratic) to -10 (strongly autocratic).	Marshall and Jaggers (2002).
Inflation, consumer prices (annual %)	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals.	World Bank, World Development Indicators
Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	World Bank national accounts data, and OECD National Accounts data files.
Human Capital Index	Human capital index, based on years of schooling and returns to education; see Human capital in PWT9.	Feenstra, Inklaar and Timmer (2015)
Developing Dummy	A dummy variable equal to 1 if a country is a developing country and 0 otherwise	UN Country Classification
Developing*ECI	An interaction variable of developing dummy and ECI	Author's calculations

Table 19: Summary Statistics for Annual Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Log of GDP PC	2.833	8.581625	1.498398	4.880119	11.42512
ECI	2.817	0.049702	1.039058	-2.76425	2.62482
Investment	2.765	23.18386	8.117717	0	70.22934
Pop. Growth	2.834	1.616041	1.089161	-2.170699	6.366168
RTA	2.835	0.69806	0.45918	0	1
Polity2	2.835	4.081481	6.674988	-10	10
Inflation	2.741	60.30417	768.807	-11.68611	24411.03
Human Capital	2.835	2.260681	0.770846	0	3.734285
Trade Open.	2.776	70.00215	45.88246	6.320343	441.6038
Developing Dummy	2.835	0.728395	0.444866	0	1
Developing*ECI	2.817	-0.29693	0.648817	-2.76425	1.97403

Table 20: Summary Statistics for Averaged Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Log of GDP PC	567	8.583641	1.497932	5.063327	11.4035
ECI	567	0.0422491	1.034944	-2.380818	2.53911
Investment	555	23.20298	7.536744	0	63.75677
Pop. Growth	567	1.61591	1.068123	-1.292244	6.061785
RTA	567	0.69806	0.4441768	0	1
Polity2	567	4.031393	6.320145	-10	10
Inflation	553	66.12369	526.5408	-0.442322	8503.581
Human Capital	567	2.335888	0.6761932	1.042946	3.722582
Trade Open.	557	70.01982	45.27928	13.3759	401.0236
Developing Dummy	567	0.7283951	0.44518	0	1
Developing*ECI	567	-0.302184	0.6421199	-2.380818	1.81233

Table 21: Correlation Table for Annual Data

	Log of GDP PC	ECI	Investment	Pop. Growth	RTA	Polity2	Inflation	Human Capital	Trade Open.	Developing Dummy	Developing*ECI
Log of GDP PC	1.000										
ECI	0.7794	1.000									
Investment	0.1277	0.1073	1.000								
Pop. Growth	-0.5777	-0.612	-0.0719	1.000							
RTA	0.3553	0.1987	-0.0334	-0.3201	1.000						
Polity2	0.5131	0.5121	-0.0394	-0.5722	0.2983	1.000					
Inflation	-0.0759	-0.0471	-0.0818	0.0467	-0.075	-0.0255	1.000				
Human Capital	0.6876	0.6303	0.088	-0.5383	0.2632	0.5047	-0.0377	1.000			
Trade Open.	0.1898	0.1519	0.2494	0.039	0.1585	-0.0153	-0.0284	0.1257	1.000		
Developing Dummy	-0.7614	-0.7121	-0.0003	0.6138	-0.3087	-0.5193	0.0447	-0.5833	0.0052	1.000	
Developing*ECI	0.5458	0.7751	0.1727	-0.4198	0.0691	0.3598	-0.035	0.4532	0.2448	-0.2703	1.000

Table 22: Correlation Table for Averaged Data

	Log of GDP PC	ECI	Investment	Pop. Growth	RTA	Polity2	Inflation	Human Capital	Trade Open.	Developing Dummy	Developing*ECI
Log of GDP PC	1.000										
ECI	0.78	1.000									
Investment	0.1271	0.1029	1.000								
Pop. Growth	-0.5851	-0.6248	-0.0698	1.000							
RTA	0.3738	0.2095	-0.0518	-0.3333	1.000						
Polity2	0.5212	0.528	-0.0624	-0.5856	0.3097	1.000					
Inflation	-0.1228	-0.0757	-0.149	0.0737	-0.1007	-0.0491	1.000				
Human Capital	0.8275	0.7288	0.1126	-0.6566	0.3778	0.6165	-0.0756	1.000			
Trade Open.	0.1899	0.1473	0.2564	0.0403	0.1631	-0.0239	-0.0443	0.1646	1.000		
Developing Dummy	-0.7591	-0.7183	0.004	0.6219	-0.3204	-0.5294	0.0716	-0.685	0.0073	1.000	
Developing*ECI	0.5513	0.7752	0.1711	-0.4345	0.0757	0.3742	-0.0566	0.5333	0.2418	-0.2789	1.000

APPENDİX B

Table 23: Variables, Definitions and Source

VARIABLES	DEFINITIONS	SOURCE
Output Volatility	Standard deviation of GDP per capita growth	Author's Calculations
GDP per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population.	World Bank, World Development Indicators
ECI(Economic Complexity Index)	Economic Complexity Index (ECI) ranks how diversified and complex a country's export basket is.	Simoes and Hidalgo (2011)
Government Consumption	General government final consumption expenditure (formerly general government consumption) includes all government current expenditures for purchases of goods and services	World Bank, World Development Indicators
Polity2	The POLITY score is computed by subtracting the AUTOC score from the DEMOC score; the resulting unified polity scale ranges from +10 (strongly democratic) to -10 (strongly autocratic).	Marshall and Jaggers (2002).
Inflation, GDP deflator (annual %)	Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole.	World Bank, World Development Indicators
Financial Openness	This is an index measuring a country's degree of capital account openness.	Chinn and Ito (2008)
Net barter terms of trade index (2000 = 100)	Net barter terms of trade index is calculated as the percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000.	World Bank, World Development Indicators
Real Effective Exchange Rate	Real effective exchange (REER) measures the development of the real value of a country's currency against the basket of trading partners of the country	Zarvas (2012a, 2012b)

Table 24: Summary Statistics for the Whole Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP growth	2.936	1.716767	4.414255	-45.32511	30.35658
Polity2	2.895	3.937478	6.758743	-10	10
Gov. Cons.	2.862	15.22955	5.599581	2.047122	43.47921
ToT	2.372	111.2464	35.35997	39.2	357.5757
Fin. Open	2.852	0.5313864	0.3732402	0	1
REER	2.879	140.914	1060.296	16.89	56242.74
ECI	2.911	0.0511	1.028289	-2.76425	2.62482
Inflation	2.936	56.7193	716.5709	-29.69104	26762.02
Volatility	2.932	2.931505	2.397812	0.1408355	24.54245

Table 25: Correlation Table for the Whole Sample

	GDP growth	Polity2	Gov. Cons.	ToT	Fin. Open	REER	ECI	Inflation	Volatility
GDP growth	1.000								
Polity2	0.0727	1.000							
Gov. Cons.	-0.1677	0.0856	1.000						
ToT	0.0243	-0.1592	0.0184	1.000					
Fin. Open	0.0555	0.4297	0.255	-0.0891	1.000				
REER	-0.0447	-0.0332	0.1076	0.0148	-0.046	1.000			
ECI	0.0735	0.4458	0.3264	-0.2683	0.5326	-0.016	1.000		
Inflation	-0.1421	-0.0069	0.0007	-0.0046	-0.0804	0.0461	-0.0453	1.000	
Volatility	-0.087	-0.1956	-0.0381	0.1124	-0.1997	0.0159	-0.1521	0.0586	1.000

Table 26: Summary Statistics for Developing Countries

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP growth	2.166	1.74043	4.900383	-45.32511	30.35658
Polity2	2.125	1.863059	6.692716	-10	10
Gov. Cons.	2.092	13.72735	5.463102	2.047122	43.47921
ToT	2.001	112.9226	37.63404	39.2	357.5757
Fin. Open	2.110	0.4148774	0.340347	0	1
REER	2.109	157.253	1238.473	16.89	56242.74
ECI	2.141	-0.386603	0.73343	-2.76425	1.97403
Inflation	2.166	74.89421	833.2915	-29.69104	26762.02
Volatility	2.164	3.333363	2.596939	0.140836	24.54245

Table 27: Correlation Table for Developing Countries

	GDP growth	Polity2	Gov. Cons.	ToT	Fin. Open	REER	ECI	Inflation	Volatility
GDP growth	1.000								
Polity2	0.1144	1.000							
Gov. Cons.	-0.1502	-0.1399	1.000						
ToT	0.0182	-0.1286	0.0914	1.000					
Fin. Open	0.1271	0.2521	-0.0088	-0.0276	1.000				
REER	-0.0476	-0.0281	0.1371	0.013	-0.0438	1.000			
ECI	0.1645	0.2695	0.0736	-0.2466	0.2684	-0.0063	1.000		
Inflation	-0.1506	0.0089	0.0195	-0.0086	-0.0745	0.0455	-0.0324	1.000	
Volatility	-0.104	-0.1201	0.0642	0.1084	-0.095	0.0126	-0.025	0.0539	1.000

APPENDIX C

Table 28: List of Countries for Chapter Two

Albania	Gabon	Nigeria
Algeria	Germany	Norway
Argentina	Ghana	Pakistan
Australia	Greece	Panama
Austria	Guatemala	Paraguay
Bangladesh	Honduras	Peru
Belgium	India	Philippines
Bolivia	Indonesia	Portugal
Brazil	Iran, Islamic Rep.	Saudi Arabia
Bulgaria	Ireland	Senegal
Cameroon	Israel	Singapore
Canada	Italy	South Africa
Chile	Jamaica	Spain
China	Japan	Sri Lanka
Colombia	Jordan	Sudan
Congo, Dem. Rep.	Kenya	Sweden
Congo, Rep.	Korea, Rep.	Switzerland
Costa Rica	Madagascar	Thailand
Cote d'Ivoire	Malaysia	Trinidad and Tobago
Denmark	Mauritania	Tunisia
Dominican Republic	Mexico	Turkey
Ecuador	Mongolia	United Kingdom
Egypt, Arab Rep.	Morocco	United States
El Salvador	Mozambique	Uruguay
Ethiopia	Netherlands	Venezuela, RB
Finland	New Zealand	Zambia
France	Nicaragua	Zimbabwe

Table 29: List of Countries for Chapter Three

Albania	Georgia	Nigeria
Algeria	Germany	Norway
Argentina	Ghana	Oman
Australia	Greece	Pakistan
Austria	Guatemala	Panama
Bangladesh	Honduras	Paraguay
Belgium	Hong Kong SAR, China	Peru
Bolivia	India	Philippines
Brazil	Indonesia	Portugal
Bulgaria	Iran, Islamic Rep.	Saudi Arabia
Cameroon	Ireland	Senegal
Canada	Israel	Singapore
Chile	Italy	South Africa
China	Jamaica	Spain
Colombia	Japan	Sri Lanka
Congo, Dem. Rep.	Jordan	Sudan
Congo, Rep.	Kenya	Sweden
Costa Rica	Korea, Rep.	Switzerland
Cote d'Ivoire	Madagascar	Thailand
Denmark	Malaysia	Trinidad and Tobago
Dominican Republic	Mauritania	Tunisia
Ecuador	Mexico	Turkey
Egypt, Arab Rep.	Mongolia	United Kingdom
El Salvador	Morocco	United States
Ethiopia	Mozambique	Uruguay
Finland	Netherlands	Venezuela, RB
France	New Zealand	Zambia
Gabon	Nicaragua	Zimbabwe

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APPENDIX 2

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