Hacettepe University Graduate School of Social Sciences

Department of Economics

LINKING GREEN COMPLEXITY TO FINANCIAL DEVELOPMENT: CROSS COUNTRY, REGIONAL AND FIRM LEVEL ANALYSES

Pınar YAŞAR

Ph.D. Dissertation

Ankara, 2022

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The jury finds that Pınar YAŞAR has on the date of 13/09/2022 successfully passed the defence examination and approves her Ph.D. Dissertation titled "LINKING GREEN COMPLEXITY TO FINANCIAL DEVELOPMENT: CROSS COUNTRY, REGIONAL AND FIRM LEVEL ANALYSES"

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Professor Dr. Arzu AKKOYUNLU WIGLEY (Jury President)

Signature

Professor Dr. Başak DALGIÇ (Main Adviser)

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Professor Dr. Ayşe Yasemin YALTA

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Professor Dr. Aydın ÇELEN

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ABSTRACT

YAŞAR, Pınar. Linking Green Complexity to Financial Development: Cross Country, Regional and Firm Level Analyses, Ph.D. Dissertation, Ankara 2022.

Productive capabilities and its role on economic growth and development have attracted a lot of attention among researchers and policy makers since the introduction of the concept of “economic complexity index”. Another dimension of economic complexity which is “green complexity”, has recently gained increasing attention as climate change challenges intensify and countries around the world lay out ambitious agenda for moving towards a green economy. Building on economic complexity literature, Mealy and Teytelboym (2020) introduced a novel concept “green complexity” to measure the green capabilities of countries. Acknowledging that green economic complexity is the amount of knowledge materialized in a country’s green productive structure, financial development could be an important determinant of green complexity and play a key role at enhancing competitiveness of green products in export markets. In this regard, the main motivation of this study is to analyse how financial development affects green production capabilities and green complexity at cross-country level and province level for Turkey and how financial vulnerability affects green complexity of Turkish firms. Results point out a positive impact of financial development on green complexity for developing countries as well as for Turkish provinces. A rise in financial vulnerability adversely impacts green complexity of Turkish firms. Overall, the results of the study suggest that financial development should be one of the priorities of policy makers to enhance green production capabilities of economic units. In addition, financial soundness is critical for firms to channel their resources to innovation and R&D for enhancing product sophistication.

Keywords

Economic Complexity, Green Complexity, Financial Development

ÖZET

YAŞAR, Pınar. Yeşil Karmaşıklık ve Finansal Gelişme Arasındaki İlişki: Ülke, Bölge ve Firma Düzeyinde Analiz, Doktora Tezi, Ankara 2022.

Ekonomik birimlerin üretken yetenekleri ve bunların büyüme ve kalkınma üzerindeki rolü, "ekonomik karmaşıklık endeksi" kavramının ortaya çıkmasından bu yana araştırmacılar ve politika yapıcılar arasında büyük ilgi görmüştür. Ekonomik karmaşıklığın diğer bir boyutu olan "yeşil karmaşıklık" kavramına yönelik ilgi ise, iklim değişikliği konularının ön plana çıkması ve ülkelerin yeşil ekonomiye geçiş için kararlı hedefler oluşturması ile birlikte gitgide artmaktadır. Ekonomik karmaşıklık literatürünü temel alan Mealy ve Teytelboym (2020), ülkelerin yeşil üretim yeteneklerini ölçmek için yeni bir "yeşil karmaşıklık" kavramı ortaya koymuştur. Yeşil ekonomik karmaşıklığın bir ülkenin yeşil üretken yapısında var olan bilgi miktarı olduğu kabul edildiğinde, finansal gelişme yeşil karmaşıklığın önemli bir belirleyicisi olabilir ve yeşil ürünlerin ihracat pazarlarında rekabet gücünü artırmada kilit bir rol oynadığı düşünülebilir. Bu bağlamda, bu çalışmanın temel motivasyonu, finansal gelişmenin yeşil üretim yetenekleri ve yeşil karmaşıklık üzerindeki etkilerini ülke düzeyinde ve Türkiye için iller düzeyinde incelemek; bununla birlikte firmalara ilişkin finansal kırılganlığın bunların yeşil karmaşıklığı üzerindeki etkilerini analiz etmektir. Çalışmanın sonuçları, gelişmekte olan ülkeler ve Türkiye için il düzeyinde; finansal gelişmenin yeşil karmaşıklık üzerindeki olumlu etkisine işaret etmektedir. Ayrıca, finansal kırılganlığın artması firmaların yeşil karmaşıklığını olumsuz yönde etkilemektedir. Bu sonuçlar, finansal gelişmenin; iktisadi birimlerin yeşil üretim kapasitelerini artırmada politika yapıcılar tarafından önemli bir bileşen olarak ele alınması gerektiğini göstermektedir. Finansal sağlamlık, firmaların kaynaklarını ürün karmaşıklığını artırmak üzere inovasyona ve Ar-Ge'ye yönlendirmeleri için kritik öneme sahiptir.

Anahtar Kelimeler

Ekonomik Karmaşıklık, Yeşil Karmaşıklık, Finansal Gelişme

TABLE OF CONTENTS

ABBREVIATIONS

APEC: Asia-Pacific Economic Cooperation
CBAM: Carbon Border Adjustment Mechanism
CVI: Corporate Vulnerability Index
EBIT: Earnings before Interest and Taxes
ECI: Economic Complexity Index
EU: European Union
FDI: Foreign Direct Investment
GCI: Green Complexity Index
GDP: Gross Domestic Product
GFC: Global Financial Crisis
GMM: Generalized Method of Moments
HH: Herfindahl-Hirschman
HS: Harmonized System
ICR: Interest Coverage Ratio
IMF: International Monetary Fund
MENA: Middle East and North Africa
NUTS: Nomenclature of territorial units for statistics
OECD: Organization for Economic Co-operation and Development
OLS: Ordinary Least Squares
PCA: Principal Component Analysis
PCI: Product Complexity Index
PGI: Product Gini Index
RCA: Revealed Comparative Advantage
R&D: Research and Development
ROA: Return on Assets
SAR: Spatial Autoregressive Model
SAC: Spatial Autoregressive Combined Model
SDM: Spatial Durbin Model
SEM: Spatial Error Model
SITC: Standard International Trade Classification
TurkStat: Turkish Statistical Institute
UN: United Nations
WTO: World Trade Organization

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INTRODUCTION

The evolution of economic growth theories dates back to Adam Smith who contributed significantly to the economic growth theory. He put a great emphasis on the role of economies of scale and specialization. Since then, many theories have put significant efforts on analysing the drivers of income gap among countries. A well-established empirical literature, supporting production sophistication as an essential way to overcome underdevelopment, has started to evolve in 2000s. This literature highlights that the productive structure of countries is a relevant ingredient to economic growth and countries which specialize in more sophisticated goods subsequently grow faster (Rodrik 2006; Hausmann, Hwang and Rodrik, 2007; Hidalgo and Hausmann, 2009). Hausmann and Hidalgo (2009, 2011, 2014) have significantly contributed to this literature by developing an economic complexity index which measures the non-observable capabilities (know-how) required in the production process. Since the introduction of "economic complexity" concept in late 2000s, the literature on economic complexity and its links to socio-economic factors (i.e. economic growth, human capital, income inequality, technology, trade, quality of institutions, financial development) has developed rapidly.

Rising climate change challenges in the economic growth and development literature have led to development of a new innovative concept called "green complexity" introduced by Mealy and Teytelboym (2020). Economic complexity concept introduced by Hausmann and Hidalgo (2009) is combined with the rapidly evolving literature on green growth to measure complexity of green products or countries' green production capabilities and shed light on green growth strategies of countries. Green complexity brings a new perspective to economic growth and development.

There exist many studies analysing the role of socio-economic factors on economic complexity. Recent studies (Nguyen et al., 2020; Nguyen and Su, 2021; Chu, 2020; Njangang et al., 2021) draw the attention to the role of financial development to explain the differences in economic complexity between countries. These studies highlight the positive impact of financial development on complexity of the economies. On the other hand, the literature on green complexity is relatively new and number of empirical studies is very limited. Regarding the link between financial development and green growth, while some studies argue that financial development could hurt green growth (Shahzad et al. 2017; Pata, 2018), some other studies claim it could help support environmentally friendly production technology (Adams and Klobodu, 2018; Zhong and Li, 2020).

Acknowledging that green economic complexity is the amount of knowledge materialized in a country's green productive structure, financial development could be an important determinant of green complexity and play a key role at enhancing competitiveness of green products in export markets. In this regard, building on the aforementioned theories and existing empirical literature on the impact of financial development on economic growth and economic complexity, the main motivation of this thesis is to investigate how financial development affects green production capabilities or green complexity both at cross-country and subnational level and how financial vulnerability affects green complexity of Turkish firms.

This study aims to be unique for two reasons. First of all, it is the first attempt exploring the relationship between financial development and green complexity both at country level and province level for Turkey. Second, it calculates the green complexity for Turkish firms and links financial vulnerability to green complexity concept at firm level. To the best of our knowledge, there exist no other study exploring the relationship between financial development/financial vulnerability and green complexity at three dimensions, namely country level, province level and firm level.

The first contribution of this thesis is to examine the link between green complexity and financial development of countries, whether financial development helps countries to upgrade their green production capabilities for the period of 1999-2019 using GMM methodology. In addition, the impact of financial development is analysed for two sub-groups of countries, namely developed and developing countries. The second contribution of this thesis is to estimate green complexity index of provinces in Turkey, following the methodology of Mealy and Teytelboym (2020) and analyse the link between green complexity and financial development of Turkish provinces for 2004-2019 period, using spatial estimation methods. The third contribution is to estimate green complexity index at firm level for Turkey and investigate how corporate financial vulnerability of Turkish firms impacts green complexity by using standard Heckman two-stage (or control function) procedure to control for selection bias issue. The financial vulnerability index is estimated based on a novel methodology introduced by Feyen et al. (2017) and the green complexity at firm level in Turkey is estimated by using the Green Complexity Index methodology introduced by Mealy and Teytelboym (2020).

The thesis is structured as follows: First chapter presents a brief overview of growth theories in the last century, detailed explanation of Economic Complexity Index (ECI) and Product Complexity Index (PCI) and empirical literature on complexity. The chapter also discusses about the concept of green complexity and its methodology linked to ECI. Second chapter provides a brief overview of export competitiveness and green complexity in Turkey over the last two decades. Third chapter presents the data, methodology of cross-country analysis and empirical results of the impact of financial development on green complexity of countries. Fourth chapter estimates the Green Complexity Index (GCI) at province level and investigates the impact of financial development on green complexity of Turkish provinces. Fifth chapter estimates the GCI at firm level for Turkey and investigates the impact of corporate financial vulnerability of Turkish firms on their green production capabilities, namely green complexity. Last but not least, conclusion chapter summarizes the findings of the thesis.

CHAPTER 1

THEORETICAL FRAMEWORK AND LITERATURE REVIEW ON ECONOMIC COMPLEXITY

This chapter aims to provide information about the evolution of theory and literature in a historical framework that paved way to the creation of Economic Complexity Index (ECI) and Product Complexity Index (PCI). In this context, the chapter presents a brief overview of growth theories in the last century, detailed explanation of complexity indices and empirical literature on complexity. Lastly, the chapter presents the concept of green complexity and its methodology linked to economic complexity index.

1.1. A BRIEF OVERVIEW OF GROWTH THEORIES

1.1.1. Growth Theories in Pre-1950 Period

The evolution of economic growth theories dates back to Adam Smith's book, Wealth of Nation where he made significant contribution to the economic growth theory. Smith (1776) stressed that population growth, capital growth, division of labor and institutional framework of the economy are the main factors affecting the economic growth and put a great emphasis on the role of economies of scale and specialization. His theory was based on laissez faire approach, where invisible hand allocates the resources and he supported limited government intervention. Adam Smith's views were further flourished by classical economists Ricardo, Malthus and Mill who developed classical theory of economic growth.

Keynes in his famous book *The General Theory* (1936), heavily criticized the views of classical economists, particularly about Say's law, its implications and the role of the government, after the Great Depression in 1929. Keynes focused on changes in the economy over the short-run and did not extend his theory of demand determined equilibrium into a growth theory. This gap was filled by Harrod (1939, 1948) and Domar (1946) extended Keynesian analysis of full employment and income theory into the long-run period with a dynamic structure. Keynes highlighted the role of investment on aggregate demand whilst Harrod and Domar highlighted how investment spending also raised productive capacity of an economy.

The Harrod-Domar economic growth model focused on the importance of capital accumulation for the economic growth. The model suggests that economic growth relies on the national savings level and the productivity of capital investment (capital-output ratio) with assumptions of exogenous rate of labor force growth, given technology (constant capital-labor ratio) and a fixed capital-output ratio. In the model, more investment leads to capital accumulation, which generates economic growth. The growth rate of output is exactly proportional to the saving rate, indicating the critical importance of savings for economic growth. The model was criticized due to its strong assumptions. Solow (1956) criticized the central assumption of fixed proportions in Keynesian Harrod-Domar long term growth.

1.1.2. Exogenous and Endogenous Growth Theories

The evolution of growth theory has been remarkable in two distinct phases since late 1950s with emergence of exogenous growth models first and then endogenous growth models. Long-run growth was first introduced by Solow (1956, 1957) and Swan (1956) into the traditional neoclassical macroeconomic model. In these models, long-run growth rate is linked to demographic factors which are considered as exogenously determined. The policies that would increase population growth or productivity of labor force can lead to increase long-term growth.[1]

Starting with the seminal work of Romer (1986), revival of interest in economic growth theory led to a second generation of growth models. Both Robert Lucas (1988) and Romer (1986) referred to lack of cross-country growth convergence which is a sign of inadequacy of neoclassical growth theory (Romer, 1994).

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[1] https://pdfs.semanticscholar.org/eee5/c6e1ad5da265af4553d931401ee594ee7d5d.pdf

1.1.2.1. Solow Model: Neoclassical Approach

Solow (1956) proposed a long-run growth model, incorporating all the Harrod-Domar assumptions except that of fixed proportion in production and considering labor-capital substitution and flexibility of factor prices. Solow's growth model had a remarkable impact on growth analysis as Acemoğlu (2009) mentioned that this model shaped the approach to economic growth and macroeconomics.

The model assumes that output of a country is produced by a representative neoclassical production function (1.1):

$$Y = A\,F(K_t, L_t) \tag{1.1}$$

where Y, K, L show output, capital stock and labor, respectively and A denotes a measure of technological progress, known as Solow residual. Technological progress is set to be exogenous. The model also assumes there are diminishing marginal returns to capital accumulation, capital growth depends negatively on the capital-output ratio. In the model, technological progress and capital deepening are two sources of increases in output per worker.

A steady state growth path, on which output growth is constant, is ensured in the model when output, capital and labor all grow at the same rate. The model also provides useful insights about convergence process. Countries, having same savings rate, population rate and depreciation rate, have the same steady state and so they will converge (conditional convergence). The model predicts that poor countries should grow faster (per capita) than rich countries since capital per worker is relatively lower in poor countries and hence marginal products of capital is higher compared to rich countries.

1.1.2.2. Endogenous Growth Theories

The revival of endogenous growth models has been motivated by several issues on exogenous growth models in early 1980s. These cover: (a) an effort to elucidate characteristics of the data not addressed by the neoclassical model (b) a better elucidation of international differences in economic growth rates; (c) a more vital role for the knowledge accumulation; (d) a greater role for macroeconomic policy instruments in explaining the long-run growth process (Romer, 1994; Turnovsky, 2003). Arrow (1962) made an early attempt to incorporate technological progress endogenous in growth models, but Romer's (1986) influential paper changed the direction of growth literature by following Arrow's (1962) "Learning by Doing" mechanism. Romer (1986) created an increasing returns model. In the model, a stable positive equilibrium growth rate was achieved led by endogenous knowledge accumulation. This was an important turning point with the existing literature, in which technological progress had mostly been treated as completely exogenous. While economic growth is determined by the rates of savings and capital accumulation in neoclassical growth model, endogenous growth models have focused on how innovations, technology and human capital can lead to economic growth in the long-run. Notable contributions have been made to endogenous growth models by Romer (1986, 1989, 1990), Lucas (1988), King and Rebelo (1990), Rebelo (1991), Barro and Sala-i-Martin (1992, 1995), Levine and Renelt (1992), Summers and Heston (1988), and Mankiw, Romer, and Weil (1992), among others.

The models of the endogenous growth literature can be divided into two broad groups, namely accumulation-based models, and innovation-based models. The first group of models focus on the role of human capital and physical capital accumulation on economic growth (Lucas, 1988; Rebelo, 1991). Lucas' (1988) model, which goes back to Uzawa (1965), initiated the literature on the impact of human capital accumulation on growth and his model has been extended in various forms. In his model, the rate of human capital accumulation is considered as a factor of production and productivity of the human capital accumulation technology is an important determinant of the growth rate. Rebelo (1991) extended Lucas (1988) model by incorporating the contribution of physical capital in human capital accumulation.

The second group models focus on the creation of new knowledge as important sources of economic growth. Romer incorporated innovation and imperfect competition to the growth theories. According to this, imperfect competition creates incentive to innovators to develop new ideas. In Romer (1986, 1987, 1990) models, growth is driven by specialization and increasing division of labor. His focus is on horizontal innovation driving the growth where discovery of new goods leading to new branches of trade. Aghion and Howitt's (1992) theory concentrated on vertical innovation and its impact on growth.

There has been vast amount of extensions to the endogenous growth theory. Two of these extensions (Barro, 1990; Grossman and Helpman, 1991a; 1991b) in terms of policy implication are important as government expenditures and international trade were incorporated to the growth models.

Some of the economists have focused on the impact of institutions on economic growth and convergence. The studies on this (North, 1990; Acemoğlu et al., 2004; Acemoğlu and Robinson, 2010) point out the pivotal role of institutions on economic growth as institutions shape the incentives of key economic actors in society. They affect physical and human capital and technology investments and the production organization.

1.1.3. Structuralist Approach

The structuralist development economics was developed in early 1940s and became influential until 1960s. The starting point of structuralist approach was the fight against poverty and recognition of structural challenges faced by developing countries which are different from that of high-income countries. The Great Depression, the successful industrialization in Soviet Union and the birth of Keynesian economics were the main events that triggered the evolution of this approach.

The structuralist literature stresses the importance of industrialization as a process of structural change necessary to economic development. According to structuralists, it is not possible for a country to boost employment, productivity, and per capita income and to decrease poverty without industrialization. They argue that the development process comprises a production reallocation from low productivity to high productivity sectors where increasing returns to scale prevail (Gala et al., 2018).

Structuralists highlighted that productive sectors are different regarding their potential to generate growth and development. Manufacturing sectors have high potential and trigger economic development with their high increasing returns, high incidence of technological change and high spillovers and linkages. Thus, this sector with features such as technical progress, high R&D spending, economies of scale and scope has the potential for productivity increase and climb the technological ladder. However, the specialization in agriculture and mining does not have this potential for technological change. Considering high importance of the sector, it is suggested that big push to investment coordinated by the government is sine qua non condition for the establishment of a new institutional environment and the successful industrialization in underdeveloped countries (Gala et al., 2018). Structural economists Raul Prebisch (1950), Celso Furtado (1964, 1970) and Lance Taylor (1983, 1991, 2004) criticized neoclassical approach to economic analysis. They argue that it is not applicable to developing countries where there exists structural rigidity due to distribution of political power, or distorted price signals due to monopoly, obstinate response by labor to price signals, or the immobility of factors (Lin, 2010).

The structuralists have shaped their approach in a descriptive framework and failed to validate their approach with robust empirical content. In this regard, economic complexity concept and analysis developed by Hausmann and Hildalgo (2011) is considered as an empirical innovation to support to structuralist view that indicates production sophistication as a fundamental way to deal with underdevelopment successfully (Gala et al., 2018).

1.2. EVOLUTION OF EMPIRICAL LITERATURE ON ECONOMIC COMPLEXITY

A well-established empirical literature, supporting the structuralist view that places production sophistication as a fundamental means to deal with underdevelopment successfully, has started to evolve in 2000s. This literature highlights the productive structure of countries is a relevant ingredient to economic growth and countries which specialize in more sophisticated goods grow faster (Rodrik, 2006; Hausmann et al., 2007; Hidalgo and Hausmann, 2009). Hausmann and Hidalgo (2009, 2011, 2014) has significantly contributed this literature by developing an economic complexity index which measures the non-observable capabilities required in the production process. This index combines both diversity and sophistication characteristics of exports and thus production. It is worth analysing the short history of this literature that gives an important role to the complexity of a country's economy on economic growth by using disaggregated trade data.

Hausmann et al. (2007) introduced an advance measure of export sophistication called as EXPY. This measure assumes that higher income countries export higher sophisticated goods. The authors constructed a quantitative index. The index ranks traded goods based on their implied productivity. Quantitative index is constructed by taking a weighted average of the per capita GDPs of the countries exporting a product, where the weights reflect the revealed comparative advantage of each country in that product. Thus, they generated an associated income/productivity level for each good, called as PRODY. Then, they constructed the income/productivity level that corresponds to a country's export basket, called as EXPY by calculating the export weighted average of the PRODY of the country. EXPY is a measure of the productivity level associated with a country's specialization pattern.

To calculate EXPY, the authors first constructed an index PRODY by using disaggregated trade data. It is a weighted average of the GDP per capita of countries exporting a product and hence represents the income level associated with that product (Hausmann et al., 2007). j and l represent countries and goods, respectively. Y_j denotes the GDP per capita of country j. Productivity level associated with product k is denoted as $PRODY_k$.

Total exports of country j is $X_j = \sum_l X_{jl}$ (1.2)

Productivity level associated with product k is

$$\text{PRODY}_k = \sum_j (X_{jk}/X_J) / \sum_j (X_{jk}/X_j) \, . \, Y_j \tag{1.3}$$

This is summation of the share of product k in overall export basket of country j divided by the share of product k in all countries multiplied by country j's per capita income. Thus, the index is a weighted average of per capita GDPs. The weights are revealed comparative advantage of each country in good k. The RCA is chosen as a weight to control for country size.

After constructing PRODY, commodities are ranked based on the income levels of the countries that export them. In this setup, commodities that are exported by rich countries get ranked more highly than commodities that are exported by poorer countries. The sophistication level of a country's export basket EXPY is defined as follows:

$$\text{EXPY}_i = \sum_l (X_{il}/X_i) \, PRODY_l \tag{1.4}$$

This is a weighted average of PRODY_l for the country i, where the weights are simply the value shares of the products in the country i's total exports.

The authors find high correlation of EXPY with per capita GDP. They also explored the link between EXPY and economic growth in both cross-national and panel settings and using a wide variety of econometric estimation techniques. Human capital is used as a regressor as well as capital-labor ratio and a rule of law index are added to the regression. Regression results display that EXPY had a large and positive coefficient that is statistically significant in all of these specifications. The results indicate that a 10 percent increase in EXPY increases growth by half a percentage point. Based on the results, countries that export goods associated with higher productivity levels grow more rapidly, controlling for initial per capita income, human capital levels, and time-invariant country characteristics. Hausmann et al.'s (2007) measure of export sophistication was criticized due to use of income information in the creation of PRODY and EXPY as it causes a circularity issue that “rich countries export rich-country products”.

Hidalgo et al. (2007) analysed the network of relatedness between products or product space. They found that countries tend to move to goods close to those they are currently specialized in. This allows countries located in more connected parts of the product space to upgrade their exports basket more rapidly. Hausmann and Klinger (2006) drew the attention to the importance of proximity concept which is the probability that two goods are co-exported in other countries. They suggested that countries which are in a better position in the product space or having more nearby products, are likely to have better opportunities to diversify and tend to outgrow countries that produce products that are less connected.

Following Hausmann et al. (2007), study which used information on GDP per capita to calculate export sophistication, Hidalgo and Hausmann (2009) developed an economic complexity index by using the links between countries and products (structure of network of countries and products). They argued that productive capabilities including all the inputs, technologies, and ideas determine the frontiers of what an economy can produce. With this approach, they tried to explain cross-country differences in income by differences in economic complexity, as measured by the diversity of productive capabilities[2] present in a country and their interactions. In this framework, the capabilities are measured indirectly by analysing the mix of products that countries export.

In order to explain the intuition behind the productive capabilities of a country and construction of this new complexity measure, the authors used the example of Lego models. In this example, each capability in a country is a building block or Lego piece. A product is equivalent to a Lego model, and a country is equivalent to a bucket of Legos. The different Lego models that can be built based on the kind, diversity, and exclusiveness of the Lego pieces in a bucket. A Lego bucket which contains pieces that can only build a bicycle, most likely does not contain the pieces to create an airplane

[2] The productive capabilities are all the inputs, technologies and ideas that determine the frontiers of what an economy can produce.

model. Nevertheless, a Lego bucket that contains pieces that can build an airplane model may also have the essential pieces to build a bicycle model. Also, two Lego buckets can build the same number of models, but these models may be totally different from each other. Hence, the authors mentioned that the connections between countries and products signal the availability of capabilities in a country just like the creation of a Lego model indicates the availability of a specific set of Lego pieces.

Hidalgo and Hausmann (2009) and Hausmann et al. (2011, 2014) argued that a complex product is one that requires many or exclusive capabilities. This exclusive set of capabilities used by a product can then be inferred from its **ubiquity** and from the **diversity** of the export basket of the countries that export it. Thus, complex products are defined as the products which are exported by fewer countries with RCA and by countries with many and diverse capabilities.

Ortiz-Ospana and Beltekian (2018) used a metaphor to explain the intuition behind the complexity concept. In the metaphor, economies are considered as restaurants and the productive capabilities are all the stuff needed in the kitchen. Hence, the economic complexity index reflects that restaurants that have a more diverse and sophisticated menu are scored higher, and restaurants that have similar menus have similar scores.

The authors developed a method of reflections that consists in calculating jointly and iteratively the ubiquity and diversity indicators to introduce in the product complexity measure as much as information as possible from the network structure of countries and products. This method uses trade data[3] as a network connecting the set of countries and the set of products that they export with revealed comparative advantage.

As a first step, they correct the export data by excluding the non-competitive products in the international trade market. That revealed comparative advantage is transformed into a matrix of 0 and 1. RCA_{cp} takes value of 1 if it is equal to or greater than 1, it takes value

[3] They used international trade data as a proxy of production in their complexity measurement due to data unavailability. The production data is most of the time is scarce and incomplete but international trade data is available and more standard.

of 0 otherwise, where c and p represent country and product, respectively. With all this RCA_{cp} data, they construct the matrix Mcp which will be the key tool for the construction of the complexity index.

By using Mcp matrix, diversity and ubiquity are defined as follows:

$$\textbf{\textit{Diversity}} = k_{c,0} = \sum_p Mcp \tag{1.5}$$

$$\textbf{Ubiquity} = k_{p,0} = \sum_c Mcp \tag{1.6}$$

where $M_{cp}=1$ if country c exports product p with RCA, 0 otherwise.

These measures are generated in a more precise way by using each one of the measures to correct the other. The diversity of countries with the average ubiquity of that products is corrected. For products, the ubiquity of the different products is corrected by the average diversity of countries that produce these products. This can be expressed by the recursions.

$$K_{c,N} = (1/\ K_{c,0}) \sum_P Mcp * kp, N-1 \tag{1.7}$$

$$K_{p,N} = (1/\ K_{p,0}) \sum_c Mcp * kc, N-1 \tag{1.8}$$

where,

$K_{c,0}$ is a vector containing each countries' diversification score
$K_{p,0}$ is a vector containing each products' ubiquity score
$K_{c,N}$ is the nth iteration over the country dimension
$K_{p,N}$ is the nth iteration over the product dimension

Inserting (1.4) into (1.3):

$$K_{c,N} = (1/\ K_{c,0}) \sum_P Mcp * (1/\ \mathrm{Kp}, 0) \sum_{c\prime} Mc'p * \mathrm{Kc}', \mathrm{N}-2) \tag{1.9}$$

$$K_{c,N} = \sum_{c'} kc', N - 2 * \sum \frac{McpMc'p}{kc,0\ kc,p} \quad (1.10)$$

This derivation can be rewritten as follows:

$$Kc, N = \sum_{c'} \acute{M}cc'kc', N - 2 \quad \text{where} \quad \acute{M}cc' = \sum \frac{McpMc'p}{kc,0\ kc,p} \quad (1.11)$$

When $K_{c,N} = K_{c,N-2} = 1$, the equation (1.11) is satisfied. This is the eigenvector of $\acute{M}cc'$, associated with the largest eigenvalue. As this is a vector of ones and not informative the authors look for the eigenvector that captures the largest amount of variance in the system, which is the measure of Economic Complexity measure. This measure is defined as:

$$ECI = \frac{K\rightarrow - < K\rightarrow >}{\text{stdev}(K\rightarrow)} \quad (1.12)$$

where < > represents an average, stdev stands for the standard deviation and $K \rightarrow =$ Eginevector of $\acute{M}cc'$ associated with second largest eigenvalue

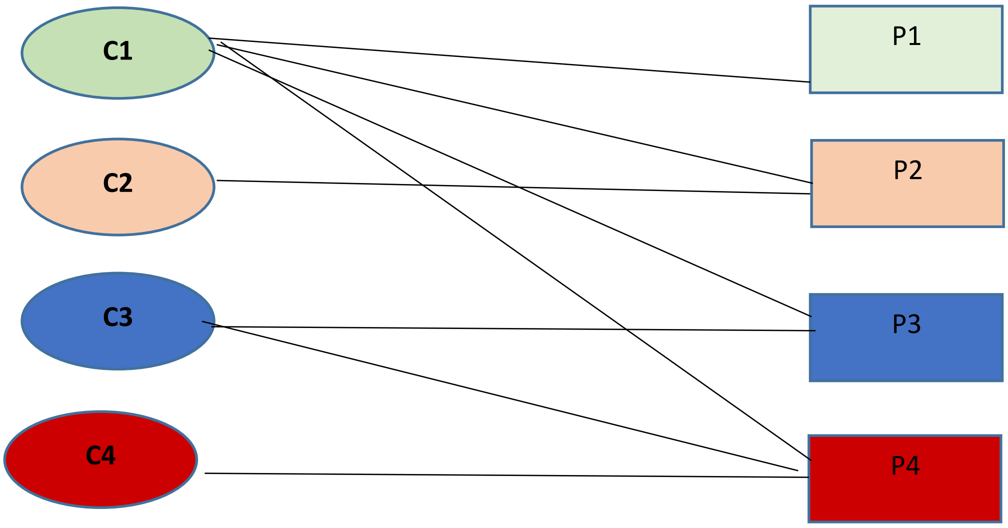
Product Complexity Index (PCI) can be defined in a similar context. The index of countries (c) is replaced by that for products (p) in equation (1.12) and PCI can be obtained:

$$PCI = \frac{Q\rightarrow - < Q\rightarrow >}{\text{stdev}(Q\rightarrow)} \quad (1.13)$$

where $Q \rightarrow =$ Eginevector of $\acute{M}pp'$ associated with thesecond largest eigenvalue.

To explore the mechanics behind this iterative methods of reflections in a simple framework, an example of four countries (C1, C2, C3 and C4) and four products (P1, P2, P3 and P4) is followed from Hidalgo and Hausmann (2009) as shown in Figure 1.

Figure 1: A Simple Network Used to Illustrate the Method of Reflections



Source: Hidalgo and Hausmann (2009), Supplementary Material.

In this example, first country exports all four products (P1, P2, P3, P4), second country exports only second product (P2), third country exports third and fourth products (P3, P4) and fourth country exports only fourth product (P4). Therefore, the **diversification** of countries and the **ubiquity** of products can be presented as follows:

How many products are exported by countries? (diversification of countries)

$K_{c1,0} = 4$

$K_{c2,0} = 1$

$K_{c3,0} = 2$

$K_{c4,0} = 1$

How many countries are exporting the specific product? (ubiquity of products)

$K_{p1,0} = 1$

$K_{p2,0} = 2$

$K_{p3,0} = 2$

$K_{p4,0} = 3$

Given this information, higher reflections of the method or iterations can be calculated. The first reflection comprises the **average ubiquity of country's products** and of the **average diversification** of a product's exporters.

$k_{c1,1}$=(1/4)(1+2+2+3)=2 $k_{p1,1}$= (1/1)(4)=4

$k_{c2,1}$=(1/1)(2)=2 $k_{p2,1}$= (1/2)(4+1)=2.5

$k_{c3,1}$=(1/2)(2+3)=2.5 $k_{p3,1}$ = (1/2) (4+2)= 3

$k_{c4,1}$=(1/1)(3)=3 $k_{p4,1}$ =(1/3) (4+2+1)= 2.33

The second reflection is given by the average first reflection values of a node's neighbours.

$k_{c1,2}$=(1/4)(4+2.5+2.25+2.5)=2.9583 $k_{p1,2}$= (1/1)(2)=2

$k_{c2,2}$=(1/1)(2.5)=2.5 $k_{p2,2}$= (1/2)(2+2)=2

$k_{c3,2}$=(1/2)(3+2.333)=2.66 $k_{p3,2}$= (1/2)(2+2.5)=2.25

$k_{c4,2}$=(1/1)(2.333)=2.33 $k_{p4,2}$= (1/3)(2+2.5+3)=2.5

This iteration can be repeated by several times, but these two iterations provide the enough information to show the intuition behind this mechanism. Before the iterations, by looking at the number of products that countries export, it is observed that the most diversified country is C1 with exporting all four products. C2 and C4 export only one single product. However, the only export of C2 is relatively non-ubiquitous product that is exported only by C1 which is the most diversified country. On the other hand, C4 exports a product that is exported by all countries except C2.

The iteration process takes into account relative position of countries and products relative to one another and changes the ranking of the countries and products accordingly. For instance, after second iteration, C1 is ranked as the first country followed by C3, C2 and C4. C2 has a higher ranking compared to C4 even though they export the same number of products. The methodology incorporates the information that C2 produces a non-ubiquitous product that is found only in diversified countries while C4 produces a product that is ubiquitous, requiring relatively simple productive structures. Thus, the ranking of countries C2 and C4 changes after second iteration.

In this process, diversity is used to correct the information provided by ubiquity and ubiquity is used to correct the information provided by diversity. This process can continue by an infinite number of times using mathematics. However, it can converge after a few iterations and no more additional information can be obtained by further iterations. As a result of this process, quantitative measure of complexity (ECI) which, shows how diversified a country's export basket is, can be obtained. The corresponding measure for products is the Product Complexity Index, which captures the amount and sophistication of know-how required to produce a product.

Similarly, Hausmann et al. (2014) provides an example of two countries, Pakistan and Malaysia. Both countries export the same number of products, but products of Malaysia are exported by fewer countries than ones exported by Pakistan. Hence, the analysis suggest that Malaysia's productive structure is more complex to that of Pakistan.

The literature on economic complexity has been growing continuously. The proposed economic complexity index by Hidalgo and Hausmann (2009) has been criticized by Tacchella et al. (2012) as the approach relies on a linear relationship to define the product complexity. Tacchella et al. (2012) proposed a new iterative approach able to capture efficiently the basic link between the export basket of different countries and their industrial competitiveness. Tacchella et al. (2012) methodology was also challenged by Albeaik et al. (2017). They introduced a new and simpler metric of economic complexity (ECI+) that measures the total exports of an economy corrected by how difficult it is to export each product and by the size of that country's export economy. The authors compared the new measure of complexity (ECI+) with the original economic complexity index (ECI) and Fitness complexity index proposed by Tacchella et al. (2012) over the period of 1973-2013. Based on the results of a wide variety of econometric specifications, ECI+ is found to outperform ECI and Fitness complexity index in its ability to predict economic growth.

1.3. THE CONCEPT OF GREEN COMPLEXITY

Mealy and Teytelboym (2020) introduced a new concept "green complexity", focusing on the measures proposed by Hausmann et al. (2014) and Tacchella et al. (2012). There are some previous studies that aimed to link the economic complexity and relatedness to the green economy.

Sbardella et al. (2018) classified countries that are likely to be "leaders" and "laggards" in the development of green technologies by implementing Tacchella et al.'s (2012) Fitness and Complexity measures to green patent data. They developed a "Green Technology Fitness" measure based on countries' patenting activities, and also ranked two-digit environmental technology patent classes in terms of their complexity. Fraccascia et al. (2018) estimated a country-level "Green Diversity" metric. The metric measures the number of green products countries can competitively export and implemented it to a dataset of 41 green products and 141 countries. Fankhauser et al. (2013) analysed "Green Competitiveness" of 8 countries by merging patent, export, and industry output data, by using 110 manufacturing sectors (Mealy and Teytelboym, 2020).

Hamwey et al. (2013), Huberty and Zachmann (2011) and Fraccascia et al. (2018) are three important studies that analyzed the potential for relatedness measures to elucidate green diversification opportunities. Hamwey et al. (2013) mapped out 11 green products in the Product Space for Brazil. They argued that green product space maps could be useful informing green diversification opportunities. Huberty and Zachmann (2011) analysed the position of 6 green products in the Product Space. They showed that EU countries' future competitiveness in solar cells and wind turbines could be predicted by their historical competitiveness in related products, based on a regression analysis. Fraccascia et al. (2018) introduced an alternative measure of relatedness which is called "Max Proximity". This measure shows the relatedness between a country and a new green product based on the single most related product in that country's export basket. Fraccascia et al. (2018) applied this measure and found that green products with the highest potential for growth tend to be products that are the most related to countries' existing exports (Mealy and Teytelboym, 2020).

Mealy and Teytelboym (2020) is the first study that examined the complexity of green products or countries' green production capabilities from export data and brought both complexity and relatedness measures together to study countries' green future diversification opportunities. The authors used 293 green products and renewable energy products. They developed the Green Complexity Index (GCI) that estimates the production capabilities of a country and predicts future increases in the GCI and the number of green products which a country is competitive. Mealy and Teytelboyn (2020) ranked countries according to their ability to export complex green products. They examined the potential for countries to transition to green product production in the future and found the path to dependence on the accumulation of green capabilities. They found that richer countries are more likely to have more advanced green production capabilities.

Mealy and Teytelboym's (2020) Green Complexity Index draws on the PCI measure based on the approach set out in Hausmann et al. (2014). It aims to capture the extent to which countries can competitively export a diverse range of technologically sophisticated green products and is given by Equation 1.14:

$$GCI_c = \sum_g \rho_g^c \widetilde{PCI_g} \quad (1.14)$$

Here, ρ_g^c is a binary variable which takes value 1 if country *c* has Revealed Comparative Advantage *(RCA)* > 1 in green product *g* and 0 otherwise, and PCI_g is the Product Complexity Index of *g* normalized to take a value between 0 and 1. Similarly to the ECI, the GCI measure is standardized by subtracting the mean and dividing the result by the standard deviation. While the ECI represents the average PCI of all products a country is competitive in, the GCI sums up the PCI of green products a country is competitive in.

Mealy and Teytelboym (2020) constructed a new dataset of traded products with environmental benefits and developed a measure of green capabilities across countries (green complexity index) and a measure that predicts future green export growth across countries (green complexity potential), based on the methodology developed by Hidalgo and Hausman (2009) and Hausmann et al. (2011, 2014).

1.4. LITERATURE REVIEW ON ECONOMIC COMPLEXITY AND ECONOMIC GROWTH

The economic complexity index developed by Hidalgo and Hausman (2009) and Hausmann et al. (2011, 2014), reflecting production capabilities of countries, have been employed by a vast number of empirical studies to analyse the growth path of the countries in relation to their productive structures. Although most of the studies concentrated on complexity analyses at macro (aggregated) level, there is a growing number of studies focusing on regional and firm level complexity analyses.

Hidalgo and Hausmann (2009) is the pioneer study which showed how complexity measures are strongly correlated with income per capita and the deviations from this correlation are predictive of future economic growth and development. Based on the results, the authors suggest that development efforts should concentrate on creating the conditions that would stimulate complexity to generate sustained growth and prosperity.

Hausmann et al. (2011, 2014) analyse the impact of the Economic Complexity Index on future economic growth by regression analyses over 10-year periods for 128 countries. Per capita income growth is regressed on economic complexity controlling for the initial income and, an interaction term between initial income per capita and the complexity index is included. The size of complexity effect is found to be large. Regression results point out that an increase of one standard deviation in complexity is associated with a subsequent acceleration of a country's long-term growth rate of 1.6 percent per year.

Bastos and Wang (2015) analyse the role of export diversification and sophistication on long-run growth by using a sample of 103 countries for 1970-2010. They found that more complex and diversified economies tend to have higher GDP per capita growth on average over the following decade. The results also suggested that the complexity measure by Hausman et al. (2014) are more powerful predictors of long-term growth than simple export diversification, indicating the additional predictive content of controlling for the knowledge intensity of goods.

Demiral (2016) investigates the impact of complexity on economic growth for 86 countries over the period of 1995-2011 by grouping countries based on their development stages. The estimation results show that the long-run relationship between complexity and growth vary remarkably across the country groups. While complexity fosters growth most for the countries that are moving into innovation-driven stage, it has a negative impact on growth for innovation driven countries

Stojkoski and Kocarev (2017) examine the short-run and long-run impact of economic complexity for Southeastern and Central Europe countries over the period of 1995-2013. Their analysis result shows that economic complexity has a substantial impact on the long run income changes, but no evidence is found for the short-run impact.

Ertan Özgüzer and Oğus-Binatlı (2016) explore the impact of economic complexity on growth in the context of the EU and EU expansion over the 1995-2010 period. While a strong association between economic complexity and growth with higher economic complexity is found, there is a negative correlation between economic complexity and future economic growth for countries with lower economic complexity. The authors argue that convergence is faster across the countries of which economic complexity exceeds a threshold.

Poncet and Starosta (2012) construct the city complexity index by following Hidalgo and Hausmann (2009)'s methodology and analyse city upgrading-growth relationship in China over the 1997-2009 period. The results of alternative model specifications using city-level panel data, confirm that stylized fact in cross country regressions that regions specializing in more complex goods subsequently grow faster.

Gao and Zhou (2017) quantify the economic complexity of China's provinces through analysing 25 years' firm data. First, they estimate regional economic complexity index, and find that the ECI of provinces is relatively stable. Moreover, ECI is found to be positively and significantly correlated with the economic development level.

Pérez Balsalobre et al. (2019) compute subnational complexity indices for 50 provinces of Spain over the period of 1995-2016. They find that economic complexity is important as a leading indicator for future per capita GDP. They suggest the inclusion of intra-national trade flows for enriching the complexity indicators.

Maggioni et al. (2016) adopt a micro-level perspective in their study of the complexity-volatility nexus and investigate the consequences of firm export complexity on firm output volatility. They measure firms' export complexity according to Hidalgo and Hausmann (2009) methodology. They show that the complexity level of firms' foreign sales has a positive and significant stabilizing effect on their output, signalling firms that specialize in more complex goods are less exposed to external shocks.

Javorcik et al. (2017) examine the link between the complexity of products newly introduced by Turkish firms and regional presence of foreign affiliates. The complexity is captured using a measure developed by Hidalgo and Hausmann (2009). The analysis shows that Turkish firms in sectors and regions more likely to supply foreign affiliates tend to introduce more complex products. Their results point out the critical role of FDI for upgrading the domestic production structure in an emerging economy.

Hartmann et al. (2017) suggest that countries exporting complex products tend to be more inclusive. They find a strong and robust correlation between the economic complexity index and income inequality based on multivariate regression analysis. They also introduce a measure that associates a product to a level of income inequality equal to the average GINI of the countries exporting that product called as Product Gini Index (PGI). While commodities such as cocoa beans and animal hair are found to be associated with the highest level of income inequality, low PGI products, comprise more sophisticated forms of machinery and manufacturing products.

Güneri (2019) analyses the link between complexity and economic performance over the period of 1981-2015 by using the Economic Complexity Index developed by Hidalgo and Hausmann (2009). Economic complexity is found to be an important determinant of economic growth and it reduces the negative effects of output volatility.

CHAPTER 2

EXPORT COMPETITIVENESS, ECONOMIC COMPLEXITY AND GREEN COMPLEXITY IN TURKEY

2.1. OVERVIEW OF TURKISH EXPORTS, EXPORT COMPETITIVENESS AND ECONOMIC COMPLEXITY

Turkey underwent significant transformation in terms of export performance over the last decades. Trade liberalization and export-oriented growth strategy in early 1980s and Customs Union Agreement in 1996 were the main milestones for the evolution of Turkish export patterns. Strong economic reform period following financial crisis in 2001 and buoyant global demand conditions helped Turkey to upgrade its production structure and increase its integration into the world economy further in 2000s. The global market share of Turkey increased from 0.6 percent in 2002 to around 1 percent in 2019-2020.

Exports displayed a strong performance after 2001 with double digit growth rate every year until the global financial crisis (GFC) in 2009 (Figure 2). Exports increased by 22.8 percent on average in 2002-2008 period and reached $132 billion in 2008. This rapid export expansion was more than 8 percentage points above the global annual average growth of exports and almost twice that Euro area and OECD countries. Export volume also grew at double digit levels (12.8 percent on average) in the same period despite real appreciation of Lira and contributed to the growth positively.

Global financial crisis and slowdown in demand brought about a new challenge for exporters in Turkey like in many other countries. Unlike the other crises in Turkish economy in 1994 and 2001 which ended up sharp depreciation of Lira and surge in exports, exports contracted by 22.6 percent in 2009. This can be attributed to the limited currency depreciation in 2009 compared to previous crises and sharp declines in external demand and global liquidity as it stemmed from global developments rather than domestic ones. Demirhan Atabek and Ercan (2018) find that significant international trade collapse with 2008 GFC caused further declines in both export propensity and export volume of the Turkish manufacturing firms.

Figure 2: Total Exports (Billion $)

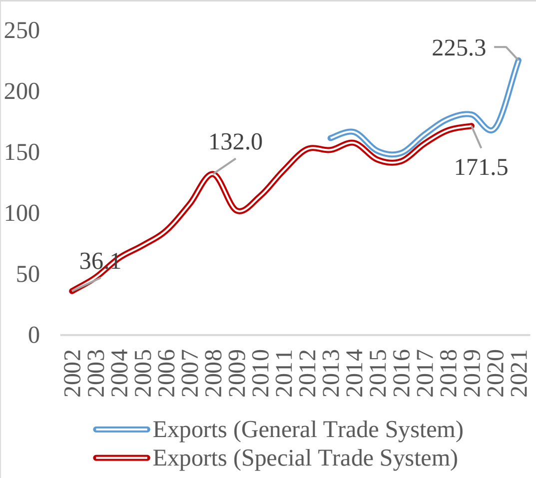
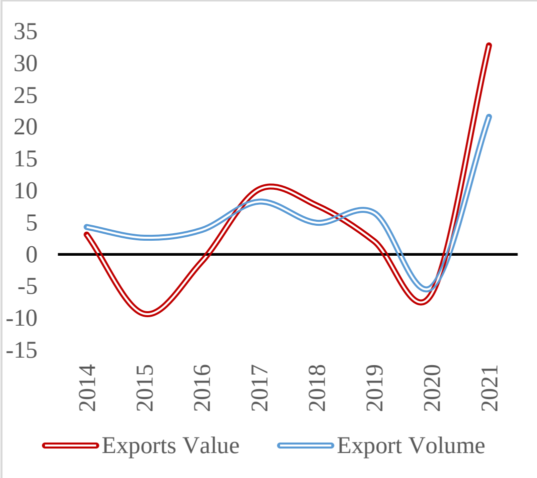


Figure 3: Annual Growth Rate of Exports (Value and Volume, %)



Source: TurkStat

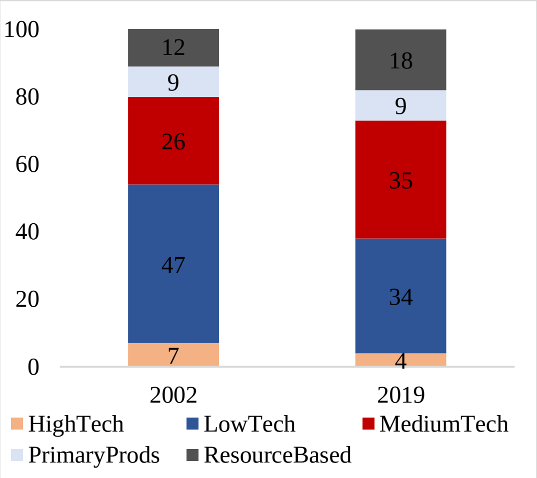
Note: Exports based on special trade system excludes the exports from free trade zones.

Following a sharp decline in 2009, exports recovered quickly in 2010-2012 period and reached $150 billion. However, there has been a slowdown in exports since 2013 with fading favourable external environment and political tensions with some trading partners. Exports in nominal terms grew by only 1.9 percent on average over 2014-2019 period whilst export volume growth was around 5 percent on average (Figure 3). Exports was hit by COVID-19 pandemic in 2020 and contracted by 6.2 percent. However, strong rebound in external demand, particularly in EU market coupled with rise in price competitiveness helped export to rebound sharply in 2021.

Turkish exports showed a dramatic change in terms of technological composition in the last two decades. The share of medium-tech exports increased by 13 percentage points since 2002 to the detriment of low-tech (Figure 4). However, Turkey stagnated in high-tech exports, where its share is around 4 percent in total exports. Turkey compares unfavourably in terms of high-tech exports with all of its competitors in Central and Eastern Europe, which might have benefited far more from technology transfer through

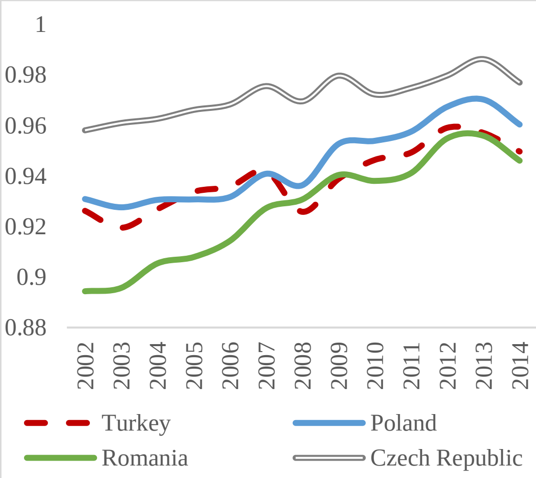
FDI and the integration into European production networks.[4] In terms of export quality, Turkey showed a gradual progress over time, and it lags behind of peer countries such as Poland and Czech Republic (Figure 5).

Figure 4: Share of Exports (%) by Technological Content, 2002 and 2019



Source: World Bank, WITS Database

Figure 5: Export Quality Index (2002-2014)



Source: IMF Export Quality Index Database

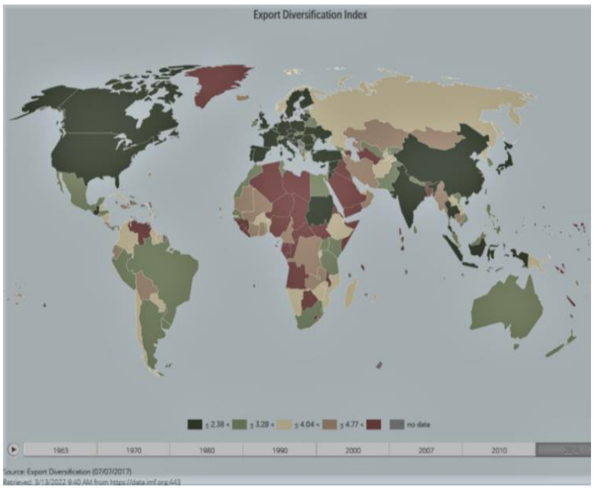
Note: Higher values of index correspond to higher quality levels

Turkey was successful to diversify its exports over the last two decades despite little progress on technology content of exports. According to IMF export diversification index, Turkey's export diversification displayed a progress in 2002-2014 period. The index declined for 2.1 in 2022 to 1.81 in 2014, indicating an increase in diversification. Turkey's diversification index value is close to values of many European economies (Figure 6). Looking at the top export items of Turkey, it is observed that export basket was dominated by mostly less sophisticated products such as textile and garments in early 2000s. However, automobile and machinery and equipment has increased its importance significantly over the last two decades and has become one of top export items (Table 1). While the share of textile and garments (chapters 61-62) in export basket was more than 20 percent in 2002, it dropped to around 9 percent in 2019. The share of motor vehicles

[4] For details see Country Economic Memorandum on Trade (2014) World Bank.

rose by around 6 percentage points and reached 15.3 percent in 2019. Iron and steel and plastics account for an important share in total Turkish exports.

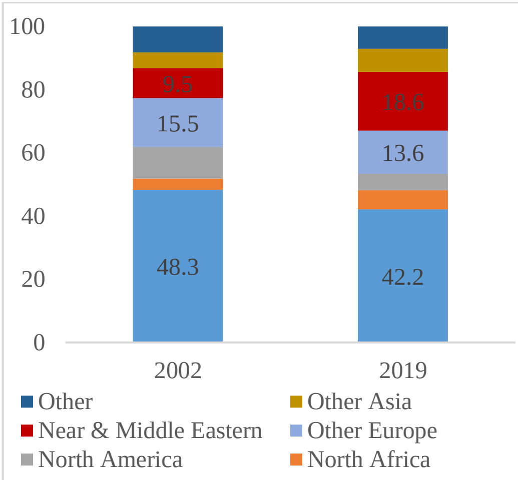
Figure 6: Export Diversification Map (2014)



Source: IMF Diversification Index Database

Note: Higher values of index correspond to lower export diversification

Figure 7: Share of Turkish Export by Destination (%, 2002, 2019)



Source: TurkStat

Turkey also diversified its markets and Turkish exports currently reach to almost all countries in the world. The EU has been always the main trading partner of Turkey, but Turkish exports are also concentrated on Middle East and North Africa (MENA). While the share of exports to EU declined from 48.3 percent in 2002 to 42.2 percent in 2019, the share of Turkish exports to Near and Middle Eastern and North Africa region rose by more than 11 percentage points and reached 24.6 percent in 2019 (Figure 7). During the global financial crisis (2008-2009) and European debt crisis, Turkey intensified its diversification efforts to compensate the loss in European markets and this led to an increase in the share of other markets, particularly MENA region. Following the crisis, the number of Turkish exporters entering the MENA market was larger than those entering the EU in 2010. Harmonization with the EU standards and increased competitiveness has facilitated Turkish exports to penetrate into the other markets such as those in MENA including in higher value-added sectors.[5] Currently, Germany, the United Kingdom, Iraq, Italy, and the US are the largest export destinations of Turkey.

Table 1: Top Ten Export Chapters of Turkey (2002, 2019)

	2002		2019	
	Level (Billion $)	**Share in Total Exports (%)**	**Level (Billion $)**	**Share in Total Exports (%)**
87- Vehicles other than railway or tramway rolling-stock, parts thereof	3.3	9.2	26.2	15.3
84- Boilers, machineries and mechanical appl., parts thereof	2.1	5.9	16.4	9.6
72- Iron and steel	2.3	6.3	9.9	5.8
61- Knitted and crocheted goods and articles thereof	4.4	12.3	9.1	5.3
85- Electrical machinery and equipment, parts thereof	2.9	8.0	8.7	5.1
71- Precious stones, precious metals, pearls and articles thereof	0.6	1.8	7.3	4.3
27- Mineral fuels, minerals oils and product of their distillation	0.7	1.9	7.3	4.3
73- Articles of iron and steel	1.2	3.4	6.5	3.8
62- Non-knitted and crocheted goods and articles thereof	3.3	9.0	6.4	3.8
39- Plastic and articles thereof	0.7	1.9	6.3	3.7

Source: TurkStat.

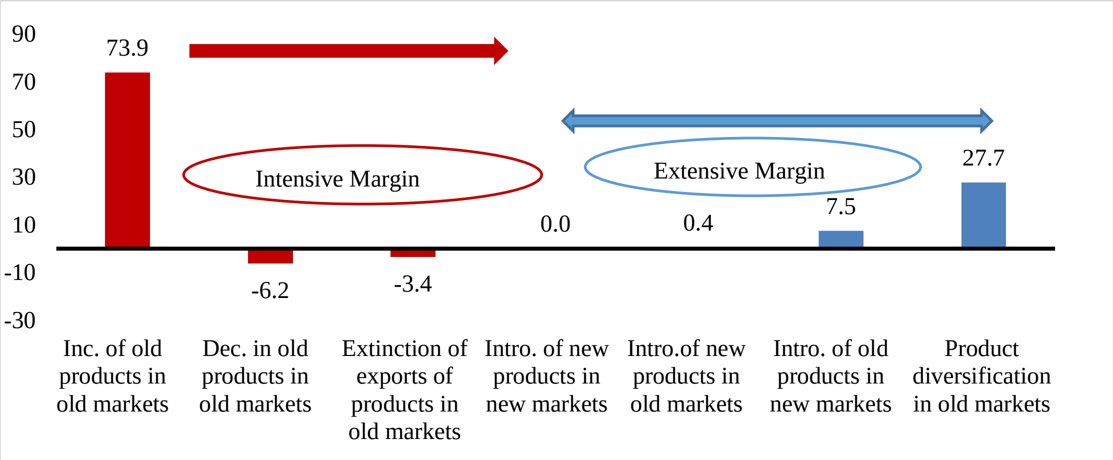
Note: Exports figures (HS classification) are special trade system export figures.

Export growth decomposition can provide insights on the trajectory of product and market diversification and export dynamics. Export growth can be divided into two components: (i) the expansion of existing trade flows (the intensive margin) and (ii) the addition of new products and markets (the extensive margin). Export growth of Turkey is decomposed for the period between 2002 and 2019 (Figure 8). The decomposition results show that the export growth was mostly driven by existing product increase to existing markets, namely intensive margin. When compared Turkey's share of export growth on the intensive margin countries across a range of development levels and geographies, a high reliance of export growth on the intensive margin is usual for a country at Turkey's stage of development.[2] Even though intensive margin played a significant role compared

[5] For details see Country Economic Memorandum on Trade (2014) World Bank.

to extensive margin, it is observed that market diversification contributed to some extent. Around 8 percent of export growth was explained by existing products to new markets. Turkish exporters were also successful in product diversification in established markets (27.7 percent). However, the contribution of introduction of new products in both new and established markets to export growth was negligible.

Figure 8: Export Growth Decomposition (%, 2002-2019)



Source: World Bank, WITS Database

Herfindahl-Hirschman (HH) market concentration index, which measures the dispersion of trade value across an exporter's partners also confirms the progress of Turkey on market diversification.[6] HH index is close to zero and displayed a downward trend particularly for the period of 2002-2010 (Figure 9). Turkey stands out in a good place in terms of number of export products and markets. The number of export destinations of Turkey increased particularly after the global financial crisis. This is comparable with the country reach of export-oriented economies such as South Korea, Poland and Malaysia and well above the number of destinations reached by Brazilian and Argentinean exporters (Figure 10). Index of export market penetration measures the extent to which a country's exports reach already proven markets.[7] A higher index shows that a country already exports to a greater percentage of existing markets for its products; a low value indicates potential for expansion. This index for Turkey has been on an increasing trend

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[6] A decline in the index is an indication of diversification in the exporter's trading partnerships.
[7] The index is calculated as the number of countries to which the reporter exports a particular product divided by the number of countries that report importing the product that year.

and higher than most of the peer countries Poland, Romania, Czech Republic, Russia, and Brazil.

Figure 9: Market Concentration and Penetration Indices (2002-2019)

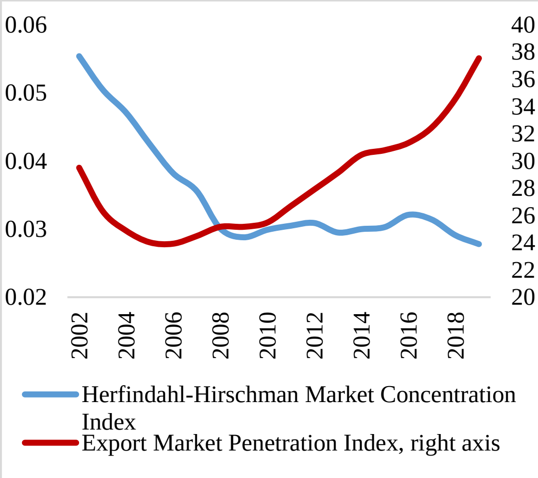
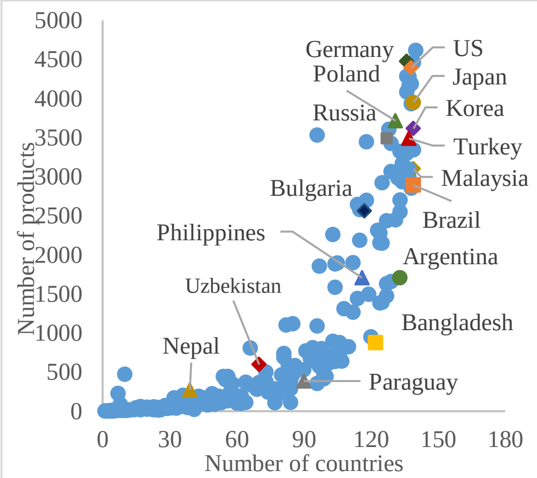


Figure 10: Number of Export Products and Markets, 2019



Source: World Bank, WITS Database.

Note: The figure shows the number of partner markets and number of products exported, counted at the 6-digit HS level for all countries. A market is counted if the exporter ships at least one product to that destination in the given year with a trade value of at least $10,000.

Hausman and Hidalgo proposed a proxy called "Economic Complexity Index"[8] for capturing the sophistication of a country's exports and measuring its productive capabilities. ECI provides a useful measure of economic development and a good predictor of future economic growth. It is calculated based on the **diversity** of exports a country produces and their **ubiquity**, or the number of the countries able to produce them. The least complex countries, at the bottom of the ECI rank, are the ones that export very few different types of products and those products that they do export are produced in many other countries. Based on Atlas of economic complexity indices, Turkey increased its complexity of exports significantly in 2002-2012 period. However, the progress slowed down in the last decade. Turkey's index increased from 0.1 in 2002 to 0.6 in 2019 and its ranking in the world improved as well (Figure 11). Figure 12 shows the trajectory of ECI for selected countries and Turkey. Turkey is ranked 40th out of 133 countries in

[8] Hausmann and Hidalgo (2009, 2011, 2014).

2019 and lags behind many of its comparator countries such as Romania, Hungary, Poland, and Malaysia.

Figure 11: Economic Complexity Index and Ranking of Turkey (2002-2019)

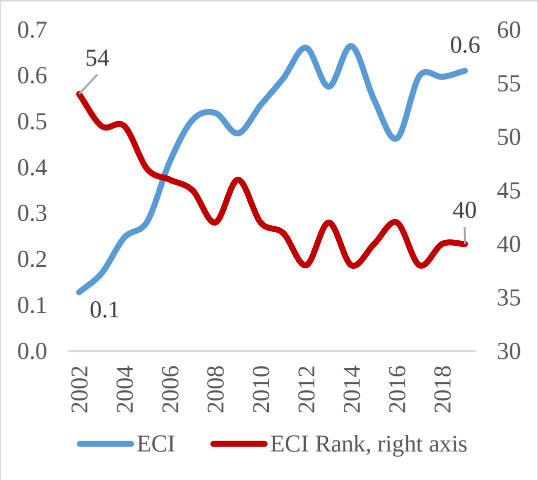
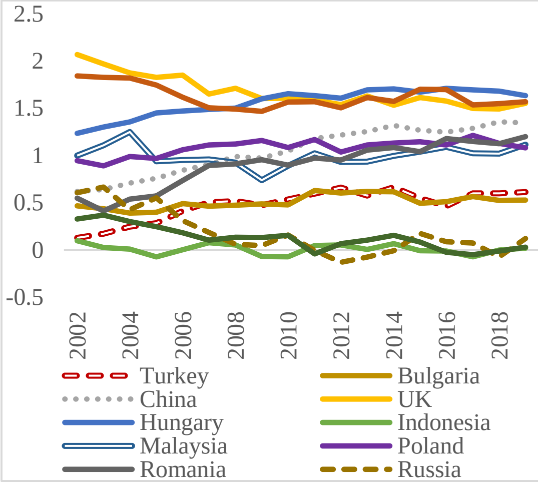


Figure 12: Economic Complexity Index for Selected Countries (2002-2019)



Source: The Growth Lab at Harvard University. The Atlas of Economic Complexity. http://www.atlas.cid.harvard.edu.

Countries with a high ECI tend to specialize in more technologically sophisticated products.

2.2. OVERVIEW OF GREEN COMPETITIVENESS AND GREEN COMPLEXITY

Mealy and Teytelboym (2020) introduced a new concept called "green complexity" which is a subset of economic complexity and measure the green capabilities of countries. Green complexity Index (GCI) is a measure of competitiveness indicating countries capabilities to export both green and sophisticated products in a competitive way. Similar to ECI, countries that rank highly in GCI tend to be richer countries. Turkey has shown a significant progress in its GCI over the last two decades (Figure 13) and is ranked 31st out of 225 countries in 2019. Comparator countries such as Romania, Bulgaria and Poland has high GCI compared to Turkey (Figure 14). China's progress in GCI over the last decade is striking. The gap in GCI between the Unites States and China narrowed substantially. The United States is ranked 4th and China is ranked 5th in 2019.

Figure 13: Green Complexity Index and Ranking of Turkey (1999-2019)

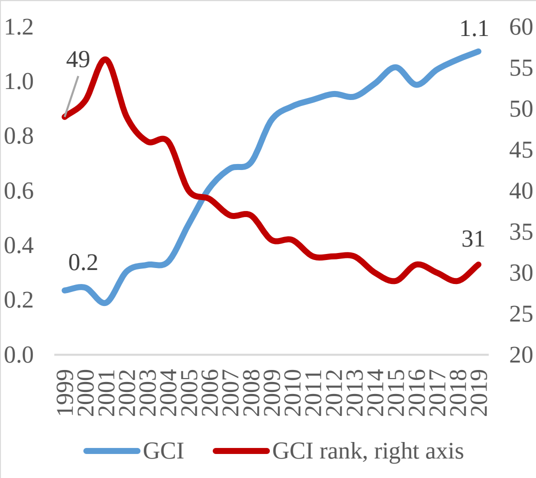
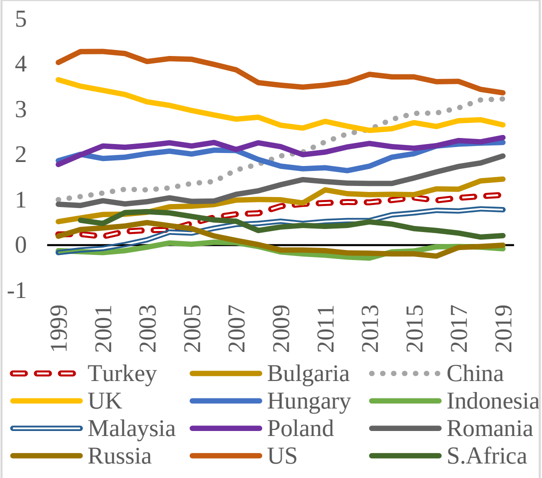


Figure 14: Green Complexity Index for Selected Countries (2002-2019)



Source: Andres, P. and Mealy, P. (2021) Green Transition Navigator. www.green-transition-navigator.org.

Note: Years refer to the end of each 5-year period (e.g. 2019 is based on average trade values over the period 2015-2019).

Figure 15: Top Exporters of Green Products

Source: Andres, P. and Mealy, P. (2021) Green Transition Navigator. www.green-transition-navigator.org.

China is the largest exporter of green products (21 percent of global green products), followed by Germany (14 percent), United States (11 percent) and Japan (7 percent).

These four countries export more than 50 percent of total green products in the world and are the top performers in terms of green complexity (Figure 15). Turkey exports around 1 percent of total green products exports in the world.

Turkey has competitiveness in many green products, whose revealed comparative advantage are greater than 1. Table 2 presents selected green products that Turkey exports competitively. For instance, Turkey has high competitiveness in green products in automotive sector, namely buses except diesel powered and other vehicles including gas turbine powered. These vehicles have lower gas consumption, CO2 emissions and pollutants. These product groups have also high product complexity. Turkey has competitive strength in product types such as nonwovens textiles except felt and hydraulic presses for working metal.

Table 2: Selected Green Products that Turkey has RCA> 1 and positive PCI

Green Product	Green Category	RCA	PCI
Liquid dielectric transformers > 10,000 KVA	Renewable Energy	6.61	0.13
Buses except diesel powered	Renewable Energy	5.35	0.36
Other Vehicles Including Gas Turbine Powered	Renewable Energy	4.32	1.47
Parts for diesel and semi-diesel engines	Noise and Vibration Abatement	3.84	0.86
Nonwovens textiles except felt	Waste Water Management and Potable Water Treatment	3.27	0.96
Multiple-walled insulating units of glass	Heat and Energy Management	3.09	0.62
Monoculars, telescopes, etc	Environmental Monitoring, Analysis and Assessment Equipment	3.07	0.51
Hydraulic presses for working metal	Management of Solid and Hazardous Waste and Recycling Systems	2.73	1.05
Trailers nes for the transport of goods	Cleaner or More Resource Efficient Technologies and Products	2.26	0.42
Liquid supply, production and calibrating meters	Heat and Energy Management	1.94	0.62

Source: Andres, P. and Mealy, P. (2021) Green Transition Navigator. www.green-transition-navigator.org.

CHAPTER 3

THE EFFECTS OF FINANCIAL DEVELOPMENT ON GREEN COMPLEXITY: CROSS-COUNTRY EVIDENCE

Countries around the world are moving toward a green economy in order to tackle climate change challenges. As this transition to green economy reshapes the landscape of competitiveness, countries which have the capabilities to produce green products and technologies are likely to gain economic benefits. Since the introduction of "economic complexity" concept by Hidalgo and Hausmann (2009), the literature on economic complexity and its links to socio economic factors has developed rapidly. Mealy and Teytelboym (2020) combined economic complexity concept with the rapidly evolving literature on green growth and introduced a new concept called "green complexity". They constructed a new, extensive dataset of traded products with environmental benefits to measure the green production capabilities of countries. Similar to the economic complexity, they found a positive association between Green Complexity Index (GCI) and GDP per capita. The literature on green complexity is relatively new. The link between the green complexity and socio-economic factors which could provide insights for the accumulation of countries' green capabilities is worth investigating.

The objective of this study to analyse the impact of financial development on a country's green economic complexity in a sample of 135 countries. Financial development can directly contribute to production of technological sophisticated products by encouraging entrepreneurial and innovation activities. The number of studies investigating the impact of financial development on economic complexity is very limited (Nguyen et al. 2020; Nguyen and Su, 2021; Chu, 2020). These studies highlight the positive impact of financial development on sophistication of the economies. Similarly, there exists limited number of studies that have investigated the impact of financial development on green growth and the empirical literature has not yet reached a consensus on the impact of financial development on environment. While some studies argue that financial development could hurt green growth (Shahzad et al. 2017; Pata, 2018), some other studies claim it could help support environmentally friendly production technology (Adams and Klobodu, 2018; Zhong and Li, 2020). Compared to conventional ones, green technologies are not always commercially viable and thus are more expensive and riskier ventures. Acknowledging that green economic complexity is the amount of knowledge materialized in a country’s green productive structure, we assume that financial development could be an important determinant of green complexity and play a key role at enhancing competitiveness of green products in export markets.

Given the limited number of empirical studies analysing the link between economic complexity and financial development, this study makes at least two important contributions to the literature. First, building on the aforementioned theories and existing empirical literature on the impact of financial development on economic growth and economic complexity, this study investigates for the first time how financial development of countries affects their green production capabilities or green complexity a new concept introduced by Mealy and Teytelboym (2020). Second, the impact of financial development on green complexity is also investigated for two group of countries, i.e. developing and developed economies to explore whether there is a heterogenous impact or not among country groups. Financial development of countries is measured by a broad index covering depth, access and efficiency of financial institutions and financial markets suggested by Svirydzenka (2016).

The section 3.1 provides a survey of the literature. Section 3.2 describes the data and methodology. Section 3.4 presents the results and discusses the findings. Section 3.5 concludes.

3.1. BACKGROUND LITERATURE: FINANCIAL DEVELOPMENT, ECONOMIC GROWTH AND GREEN GROWTH

The literature on green growth has been rapidly evolving with the increasing importance of environmental protection to economic development. However, it still remains underdeveloped regarding its links with financial development. There exist limited number of studies exploring the link between financial development and green growth.

This section reviews the literature on the relationship of financial development with green economic growth and economic complexity to shed some light on our understanding the link between financial development and countries' green productive structure (green complexity).

3.1.1. Financial Development and Green Growth

The economic theory well establishes that a well-developed financial system is necessary for economic growth. Along with this theoretical background, there is a vast amount of empirical studies which extensively analysed the relationship between financial development and economic growth, suggesting positive impact of financial development on economic growth (Wachtel, 2001; Caporale et al., 2015; Asteriou and Spanos, 2019; Tripathy, 2019; Pan and Yang, 2019).

There has recently emerged a literature on the role of financial development on green growth along with the increasing importance of environmental protection to economic development. There exists limited number of studies that have investigated the impact of financial development on green growth and the empirical literature has not yet reached a consensus on the impact of financial development on environment. Some studies (Shahzad et al. 2017; Pata, 2018) show that firms increase production through financial support, and this leads to rise in emissions of pollutants. Moreover, financial resources can flow to polluting enterprises with high returns, which will cause financial development to have an adverse effect on the environment and reduce the overall efficiency of green economic growth (Li and Liao, 2020; Bautabba, 2014). On the other hand, financial development supports technological innovation which is conducive to increasing investment in advanced production technologies and technological progress (Hsu et al., 2014). This could help clean technology to replace high energy consumption and highly pollution-producing technology. Financial development also decreases energy consumption and pollution emissions by allowing funds to flow to companies (Zhang, 2011; Li and Liao, 2020). Financial development helps firms diminish financing costs, enlarge financing channels, and have more funds to invest on new projects and new equipment. Zhong and Li (2020) show that financial development supports eco-friendly innovation and the introduction of energy saving technology, leading to a decrease in energy consumption and pollutant emissions in China. Adams and Klobodu (2018) argue that financial development decreases environmental degradation through greater access to environmentally friendly production technology.

Ahmed et al. (2021) investigate the relationship between financial development and green growth for South Asian countries for the period of 2000-2018. Their results suggest that financial development is an important driving factor in promoting green economic growth in the long run. De Haas and Popov (2019) analyse how the financial structure of countries impact their transition to green growth. Using global industry-level data, they find that that carbon-intensive industries reduce emissions faster in economies with deeper stock markets. There are two main mechanisms. First, investment is reallocated towards energy-efficient sectors by stock markets. Second, in countries which have deeper stock markets, carbon-intensive sectors engage in more green innovation. This leads to lower carbon emissions per unit of output.

Yang and Ni (2022) analyse the impact of financial development on the efficiency of green development of 51 Belt and Road Initiative (BRI) countries from three dimensions (i.e. financial size, financial efficiency, and financial deepening) for 2005-2017 period. They construct a green total factor productivity measure to assess the efficiency of green development. The results of the study show that the financial development of BRI countries exert an adverse impact on the efficiency of green development in the aspects of financial size, financial deepening, and financial efficiency. Moreover, they confirm the heterogeneity of the impact of financial development on the efficiency of green development by considering the several characteristics (i.e., resource endowment, financial development level, institutional quality and industrialization stage).

3.1.2. Financial Development and Economic Complexity

Recent studies emphasize the role of productive structure of the countries on future economic growth in addition to usual macro indicators. Hidalgo and Hausmann (2009) introduced the concept of economic complexity by a method of reflections to explain the disparity in economic growth. Since their influential study, the literature has grown where economic complexity has been increasingly considered as a key driver of the economic development process. Some studies (Zaccaria et al., 2016; Gao and Zhou, 2018; Albarracin et al., 2019) apply Hidalgo and Hausmann's methodology to measure economic complexity at different levels such as country level, province level or sector level. Another group of studies focus on empirically investigating the relationship between economic complexity and some economic variables such as inequality, growth and productivity (Hartmann et al., 2017; Sweet and Eterovic, 2019). In addition, recent studies (Nguyen et al., 2020; Nguyen and Su, 2021; Chu, 2020; Njangang et al., 2021) draw the attention to the role of financial development to explain the differences in economic complexity between countries. Theoretically, a well-developed and functioning financial market, by reducing financing cost, allocating scarce resources, evaluating innovative projects and managing risks (Hsu et al., 2014) paves the way to attract financial flows to develop new and innovative projects, all of which will contribute to the complexity of the production structure (Njangang et al., 2021). Schumpeter's "financial promotion theory" and Goldsmith's "financial structure theory" had theoretically and systematically showed that financial institutions can promote economic growth via "capabilities of credit creation" and "resource-allocation capabilities" (Yang and Ni, 2022).

There exist limited number of studies on the direct link between economic complexity and financial development. These studies show that financial development increases economic complexity. For instance, Nguyen et al. (2020) analyse the impact of patents and financial development on economic complexity in a sample of 52 economies 32 of which are high-income economies and 20 middle-income economies. The rationale behind combining the financial development and patents together is that the financial development is important since the diversity of services offered by financial intermediaries can encourage entrepreneurial and innovation activities (Meierrieks, 2014). Combination of financial development and innovation can contribute to the sophistication of the economic system via the development of new/alternative products. In addition to usual macroeconomic indicators (income level, population density, human capital etc.) they incorporate the patents and the financial development indicators. Their results point out that the patents have a positive effect on a country's economic complexity. However, the results are more diversified for the financial development. Patents directly contribute to the complexity of a country; a too large financial sector does not contribute to the diversification and sophistication of an economy. However, financial markets' efficiency has a positive impact on such processes probably because financial markets provides alternative ways of funding patents and knowledge. Xiao and Zhao (2012), Hsu, Tian and Xu (2014), Law et al. (2018) and Ho et al. (2018) empirically support the existence of significant relationship between financial development and innovation.

Nguyen and Su (2021) extend the work of Nguyen et al. (2020) by using a broader sample (86 countries) for the period of 2012-2017 and adding additional control variables (e.g. institutional quality, internet usage). They examine the link between financial development and economic complexity where financial development is proxied by IMF financial development indicators (Svirydzenka, 2016). Their results suggest that financial institutions, financial markets and their sub-indices namely financial access, financial efficiency, and financial depth impact economic complexity positively. The impact of financial institutions is more pronounced compared to the impact of financial markets.
Fang et al. (2015) investigate the impact of financial development on the upgrading of export technical sophistication in 31 provinces and municipalizes of China by employing an endogenous technological progress model. To measure the level of financial development of provinces in China from different perspectives, the study used three indicators (i) regional financial scale; deposit and credit as a percentage of GDP (ii) regional financial efficiency; combination of three indicators which are gross capital formation as a share of savings, credit to private sector and elasticity of capital change to GDP and, (iii) regional credit term structure; long-term and short-term credit classification. The results show that financial development is a very important factor for

the upgrading of the technical sophistication of exports. Chu (2020) examines the effect of financial development (both banking sector and stock market) on economic sophistication by using a panel of 94 countries. They show that both financial intermediaries and stock market development have significantly positive effect on productivity knowledge.

Njangang et al. (2021) investigate the impact of financial development on economic complexity using a panel dataset of 24 African countries. Using financial institutions, financial markets, and a composite index of financial development, they show that financial development increases economic complexity in Africa. Qi and Wang (2011) show that the financial development promotes specialized production of hi-tech and sophisticated products via overcoming the adverse selection problem. Özsoy et al. (2021) argue that financial development of countries can have an impact on the gains from FDI in terms of exporting more sophisticated products. Whilst FDI can enhance export sophistication in financially developed economies, it is not sufficient to increase the sophistication level in less financially developed economies.

In the light of existing literature on economic complexity, Mealy and Teytelboym (2020) develop a novel methodology for measuring productive capabilities to the green economy and a new comprehensive dataset of traded green products. They generate a list of 293 green products, benefitting from WTO core lists, OECD lists, and the APEC list. They estimate green complexity index by using this list of these green products drawing on previous economic complexity methods introduced by Hausmann and Hidalgo (2009). With this dataset, they aim to capture the extent to which countries are able to competitively export green, technologically sophisticated products. GCI is calculated as follows in Equation 3.1:

$$GCI_c = \sum_g \rho_g^c \widetilde{PCI_g} \qquad (3.1)$$

ρ^c_g is a binary variable which takes value 1 if country c has revealed comparative advantage bigger than 1 in green product g and 0 otherwise, and PCI_g is the Product Complexity generated based on Hausmann and Hidalgo (2009) methodology. Whilst the economic complexity index denotes the average product complexity index of all products a country is competitive in, the green complexity index adds up the product complexity index of green products a country is competitive. Therefore, same methodology is applied on a subset of products for generating GCI of countries. Mealy and Teytelboym (2020) rank countries in terms of their ability to export complex green products competitively. They show that GCI is strongly positively correlated with the number of environmental patents across countries and countries with higher GCI tend to have lower CO_2 emissions.

Acknowledging that green economic complexity is the amount of knowledge materialized in a country's green productive structure, we assume that financial development could be an important determinant of green complexity. Building on the aforementioned theories and existing empirical literature on the impact of financial development on economic growth and economic complexity, it is of great importance investigating how financial development of countries affects their green production capabilities or green complexity.

3.2. DATA AND METHODOLOGY

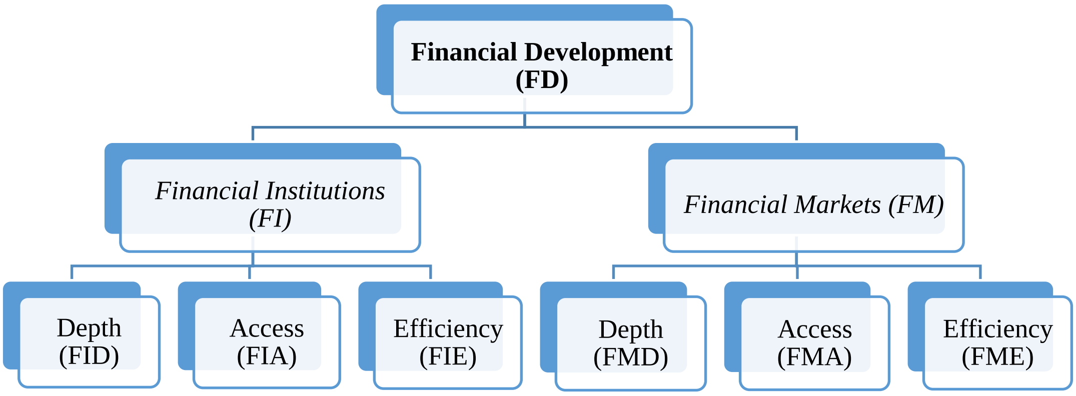
The primary objective of this paper is to assess the effect of financial development on green complexity of the countries. Following the Nguyen et al.'s (2020) model, the baseline specification employed is described by the following equation (3.2):

$$GCI_{it} = GCI_{it-1} + \beta FD_{it} + \delta X_{it} + \varphi_i + \alpha_t + \varepsilon_{it} \qquad (3.2)$$

Where i and t denote the country i at year t; φ and α represents the country and year fixed effects respectively and, ε is the residual term. X_{it} represents the vector of control variables including income (GDP) per capita at constant 2010 US$ prices, population density, human capital index (HCI), general government final consumption expenditure as a share of GDP and gross capital formation as a share of GDP to consider the possible dynamics affecting green complexity. Aggregate financial development index (FD) and its sub-indices suggested by Svirydzenka (2016) are added to the model to measure the impact of financial development on green complexity (Figure 16). Considering the importance of trade openness and FDI inflows in technology progress and sophistication of economies (Ghebrihiwet, 2018; Teixeira and Fortuna, 2010), trade openness as a share of GDP and net FDI inflows as a share of GDP (FDI) are also included in the model. Human capital index values, based on years of schooling and returns to education, are obtained from Penn World Tables version 9.1. where the literature highlights the positive association of human capital with economic complexity (Zhu and Li, 2017; Yalta and Yalta, 2021). Population density (people per sq. km of land area), gross capital formation as a share of GDP, trade as a share of GDP, general government final consumption expenditure as a share of GDP, net FDI inflows as a share of GDP are collected from the World Development Indicators of the World Bank.[9]

Following Nguyen and Su (2021) and Svirydzenka (2016), Financial Development (FD) Index of IMF is employed as a proxy for financial development in the model (Figure 16). The financial development index covers nine sub-indices that show how developed financial institutions and financial markets perform in terms of depth, access, and efficiency. The index takes values between 0 and 1 and higher values indicate greater financial development.

Figure 16: Financial Development Index



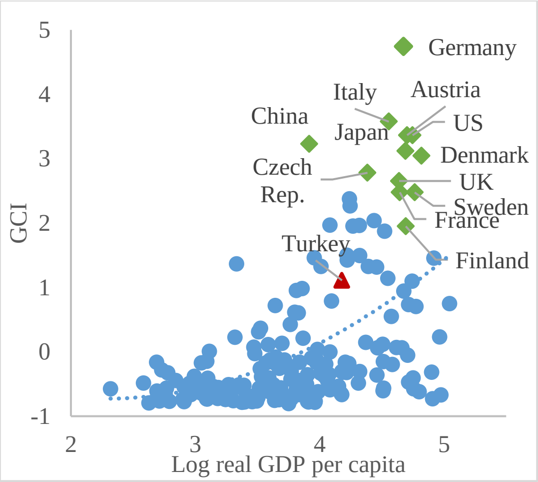
Source: Svirydzenka (2016)

[9] Following Nguyen et al. (2020), patent applications of countries are added to the model to analyze the impact of patents on green complexity. However, patent applications data is dropped since no significant impact on GCI is found.

Green complexity index measures the ability of countries to export complex products in a competitive way. Green complexity indices for countries are obtained from Andres and Mealy's (2021) Green Transition Navigator (www.green-transition-navigator.org). In order to ensure that results are robust to yearly trade fluctuations, countries' GCI at a specific year are generated based on 5-year average trade values. For instance, GCI value in 2010 represents the average value of the period 2006-2010.

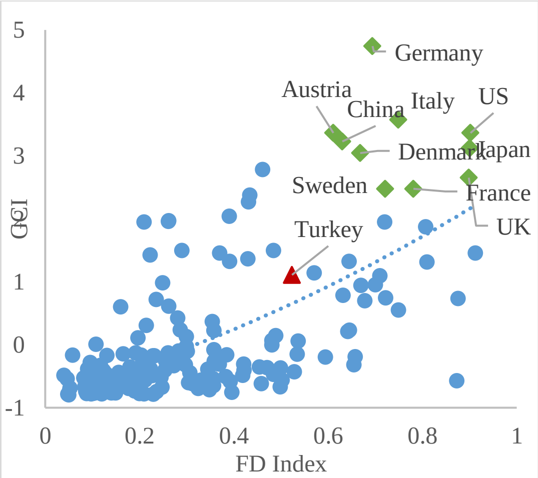
Figure 17 shows the relationship between GCI and logarithm of GDP per capita in real terms. Richer countries tend to have higher green production capabilities. As Mealy and Teytelboym (2020) has also shown, Germany, Italy, Japan, China, Austria have higher GCI scores compared to their GDP per capita level and are the top performers in terms of green production capabilities. Figure 18 shows the relationship between GCI and financial development index. Countries which have developed financial markets are likely to have higher green production capabilities.

Figure 17: Green Complexity Index and Real GDP per Capita by Country (2019)



Source: WDI and www.green-transition-navigator.org

Figure 18: Green Complexity Index and Financial Development Index by Country (2019)



Source: Svirydzenka (2016) and www.green-transition-navigator.org

All variables are in level terms except population density which is included into the model in logarithmic terms. The panel covers 135 countries over the period of 1999-2019. To explore the relationship between financial development and green complexity, we use the system generalized method of moments (GMM) dynamic panel estimators developed by Arellano and Bover (1995) and Blundell and Bond (1998). The system GMM is employed since it provides unbiased and consistent parameters as well as handling the endogeneity problem where some explanatory variables might not be exogenous or predetermined.[10] Further, time series information is more efficiently used in system GMM methodology, and it is preferred to obtain more robust results. In order to ensure the robustness of the results, estimations are replicated with a fixed effects estimator. We also estimate the model for two country subgroups i.e. developing and developed countries to explore the possible heterogenous effects among two different income groups of countries.

3.3. RESULTS AND DISCUSSION

The specified model is first estimated for the full sample by using aggregated financial development indices namely, financial development index (FD) and its two main sub-indices financial institutions (FI) and financial markets (FM). According to Svirydzenka (2016), financial institutions cover banks, insurance companies, and funds whilst financial markets cover stock and bond markets.

The results are reported in Table 3. In terms of control variables, population density is found to be positively impacting on green complexity in all specifications in line with the findings of Lapatinas (2019) and Nguyen et al. (2020). Similarly, gross capital formation has a positive impact on sophistication of production. On the other hand, the results show an insignificant impact of government consumption, trade, human capital index and net FDI inflows on green complexity. Nguyen and Su (2021) argue that negative impact of FDI on economic complexity could be due to polluting FDI (Singhania and Saini, 2021) or low technological FDI (Arvanitis, 2006).

[10] In order to ensure the robustness of the results, estimations are replicated with a fixed effects estimator.

The estimated impacts of financial development on green complexity indicate that financial development has a significant positive impact on green complexity of countries, signalling that financial development is an important driving factor in promoting green production capabilities. These results suggest that developed financial markets relax firms' liquidity constraints, support firms to increase capacity and upgrade product quality of green products, diversify their export basket and improve the green complexity. This is consistent with the studies suggesting that financial development is important in financing innovation to upgrade product quality and financial development supports economic complexity (Fan et al., 2015; Chu, 2020; Nguyen et al., 2020; Nguyen and Su, 2021; Njangang et al., 2021). Njangang et al. (2021) highlights the importance of well-developed financial system and financial system's key role of information collection to facilitate ex-ante evaluation and ex-post monitoring of investment opportunities. This information collection mitigates information asymmetry problems and eases the allocation of resources to innovative projects and thereby to stimulate more complex production.

In terms of two main sub-indices of financial development (financial institutions and financial markets), different results are obtained. Financial institutions (banks, funds etc.) are found to have a significant positive impact on green complexity and its coefficient is greater than the coefficient of financial development whilst financial markets have no statistically significant impact on green complexity. Financial institution access and efficiency measures are more bank specific. This provides an evidence that banking sector plays a significant role in transferring resources for green product quality upgrading. However, there is no evidence on the complementary role of financial markets (bonds, stock markets) for upgrading green complexity unlike the findings of Nguyen and Su (2021) who emphasize that financial markets also have a significant positive impact on economic complexity. Nonetheless, both Nguyen and Su (2021) and Njangang et al. (2021) find that the positive impact of financial institutions on economic complexity is much higher than the impact of financial markets. Nguyen and Su (2021) argue that financial institutions might have a stronger impact than financial markets on the dynamics of economic complexity since financial markets support development through facilitating the trading of ownership of firms and allowing agents to diversify portfolios (Levine, 1991) and simply benefits investors.

Table 3: The Effects of Financial Development (aggregated indices) on Green Complexity

	(1)	(2)	(3)	(4)	(5)	(6)
	FE	**GMM**	**FE**	**GMM**	**FE**	**GMM**
Financial Development	0.1477**	0.9457**				
	(0.059)	(0.395)				
Financial Institutions			0.1669***	1.7262***		
			(0.047)	(0.467)		
Financial Markets					0.0207	0.3595
					(0.041)	(0.327)
Green Complexity Index	0.8940***	0.6270***	0.8936***	0.6118***	0.8970***	0.6366***
	(0.017)	(0.062)	(0.018)	(0.069)	(0.018)	(0.061)
GDP per capita	0.0000	-0.0000	0.0000	-0.0000	0.0000	0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population Density	-0.0295	0.1279***	-0.0212	0.1060***	-0.0408	0.1498***
	(0.027)	(0.044)	(0.026)	(0.041)	(0.029)	(0.051)
Human Capital Index	-0.0055	0.1526	-0.0125	-0.0040	-0.0006	0.1913
	(0.019)	(0.137)	(0.019)	(0.156)	(0.019)	(0.147)
FDI (share in GDP)	-0.0000	-0.0009	-0.0000	-0.0014	-0.0001	-0.0009
	(0.000)	(0.001)	(0.000)	(0.002)	(0.000)	(0.002)
Trade (share in GDP)	0.0000	-0.0007	0.0001	-0.0004	0.0000	-0.0009
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Gov. consumption (share in GDP)	-0.0002	0.0054	-0.0003	-0.0040	-0.0000	0.0127
	(0.001)	(0.013)	(0.001)	(0.012)	(0.001)	(0.012)
Capital Formation (share in GDP)	0.0007**	0.0100***	0.0006*	0.0089**	0.0008**	0.0120***
	(0.000)	(0.004)	(0.000)	(0.004)	(0.000)	(0.004)
Observations	2599	2599	2599	2599	2599	2599
R-squared	0.811		0.812		0.810	
Number of id	135	135	135	135	135	135

Notes: Dependent variable is GCI. All the explanatory variables are lagged one period except HCI and population density. Population density is in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4 provides the estimation results for the impact of sub-indices of financial institutions and financial markets. When the different dimensions of financial institutions, which are access, depth, and efficiency are considered, the financial institutions efficiency and financial institutions access produce significant and positive impact on green complexity. On the other hand, financial institutions depth does not have a significant impact on green production capabilities of countries. That is, a higher financial access and higher efficiency of financial institutions have a positive impact on green complexity whilst deeper financial institutions seem to have no impact on green complexity. This suggests that a too big financial sector does not necessarily contribute to the product sophistication of countries whereas financial institutions efficiency and access are likely to have a critically important role to play in green product sophistication. As discussed by Nguyen and Su (2021), financial efficiency determines the cost of funds and financial services which help stimulate investment in innovation activities and product sophistication. Svirydzenka (2016) further highlights that even if financial systems are large, their contribution to economic development would be limited if they are wasteful and inefficient. Accordingly, financial institutions efficiency and access could be more important for green product upgrading. Since financing of green investment and technologies is more challenging compared to non-green investment and technologies and there is a high level of uncertainty related to investment in green industries whose assets tend to be more intangible (Youssef et al., 2020). Noh (2018) highlights that under the current private financial mechanism, green fields are difficult to invest in since the risk and return profile of green fields are different compared to traditional industries. Thus, efficient financial system with less information asymmetry is likely to play a key role in green complexity.

The models are further estimated for developing and developed country subgroups[11]. Table 5 presents the estimation results for developing countries. The results point out that both financial institutions and financial markets have positive impacts on green complexity in developing countries. The financial institutions have a more pronounced effect compared to the impact of financial markets on green complexity. Among the sub-indices of financial institutions, financial efficiency is found to have the largest impact. No significant results are found for financial market access and financial market

[11] The classification is based on IMF classification where developed countries refer advanced countries and developing countries refer emerging market and developing countries.

efficiency for developing economies. This could be due to more money flowing into financial markets for high return financial investment purposes, rather than for innovation investment and product upgrading purposes, as argued by Nguyen and Su (2021).

Table 4: The Effects of Financial Development (disaggregated indices) on Green Complexity

	(1)	(2)	(3)	(4)
	GMM	GMM	GMM	GMM
Fin. Inst.-Efficiency	1.0495*** (0.394)			
Fin. Inst.-Access		1.2699*** (0.347)		
Fin. Inst.-Depth			-0.5222 (0.366)	
Fin. Markets-Depth				-0.3498 (0.332)
Green Complexity Index	0.6644*** (0.068)	0.5827*** (0.074)	0.6332*** (0.065)	0.6383*** (0.061)
GDP per capita	0.0000 (0.000)	-0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)
Population Density	0.1334*** (0.051)	0.1320*** (0.046)	0.1726*** (0.046)	0.1723*** (0.050)
Human Capital Index	0.1313 (0.152)	-0.0105 (0.178)	0.2336 (0.155)	0.1882 (0.147)
FDI (share in GDP)	-0.0009 (0.001)	-0.0013 (0.002)	-0.0009 (0.002)	-0.0016 (0.002)
Trade (share in GDP)	-0.0007 (0.001)	0.0001 (0.001)	-0.0008 (0.001)	-0.0006 (0.001)
Gov. consumption (share in GDP)	0.0062 (0.012)	-0.0032 (0.014)	0.0180 (0.013)	0.0134 (0.012)
Capital Formation (share in GDP)	0.0068* (0.004)	0.0104** (0.004)	0.0126*** (0.004)	0.0130*** (0.004)
Observations	2599	2599	2599	2599
Number of id	135	135	135	135

Dependent variable is GCI. All the explanatory variables are lagged one period except HCI and population density. Population density is in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: The Effects of Financial Development on Green Complexity for Developing Countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			GMM-Developing Countries				
Financial Development	1.7584*** (0.484)						
Financial Institutions		1.5095*** (0.497)					
Financial Markets			1.1583*** (0.339)				
Fin. Inst.-Efficiency				1.0417*** (0.366)			
Fin. Inst.-Access					0.5872** (0.284)		
Fin. Inst.-Depth						0.8999*** (0.331)	
Fin. Markets-Depth							0.5804** (0.252)
Green Complexity Index	0.7387*** (0.069)	0.7951*** (0.088)	0.7689*** (0.086)	0.8665*** (0.072)	0.8548*** (0.067)	0.8234*** (0.084)	0.8342*** (0.068)
GDP per capita	-0.0000** (0.000)	-0.0000 (0.000)	-0.0000** (0.000)	-0.0000 (0.000)	-0.0000 (0.000)	-0.0000 (0.000)	-0.0000* (0.000)
Population Density	0.0908** (0.044)	0.1060** (0.049)	0.1047*** (0.037)	0.0971** (0.048)	0.1417*** (0.043)	0.1062** (0.045)	0.1271*** (0.041)
Human Capital Index	0.0653 (0.115)	-0.0416 (0.128)	0.1130 (0.147)	-0.0348 (0.137)	-0.0431 (0.098)	0.0278 (0.149)	0.0656 (0.132)
FDI (share in GDP)	-0.0017 (0.002)	-0.0023 (0.002)	-0.0020 (0.002)	-0.0011 (0.002)	-0.0019 (0.002)	-0.0043** (0.002)	-0.0032* (0.002)
Trade (share in GDP)	-0.0001 (0.000)	-0.0001 (0.000)	-0.0002 (0.001)	-0.0001 (0.000)	-0.0000 (0.000)	-0.0003 (0.000)	-0.0004 (0.000)
Gov. consumption (share in GDP)	-0.0142 (0.011)	-0.0174** (0.008)	-0.0077 (0.012)	-0.0162 (0.010)	-0.0061 (0.008)	-0.0172 (0.012)	-0.0065 (0.010)
Capital Formation (share in GDP)	0.0112*** (0.004)	0.0145*** (0.004)	0.0111** (0.005)	0.0122*** (0.004)	0.0176*** (0.004)	0.0207*** (0.004)	0.0164*** (0.003)
Observations	1882	1882	1882	1882	1882	,882	1882
Number of id	99	99	99	99	99	99	99

Dependent variable is GCI. All the explanatory variables are lagged one period except HCI and population density. Population density is in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6 presents the estimation results for developed countries. Surprisingly, none of the financial development indicators is found to be statistically significant. Developed economies have higher green complexity and have reached a certain level of threshold in terms of financial development in contrast to developing countries. The average financial development index for advanced economies is five times higher than that for the low income and developing economies (Svirydzenka, 2016). As indicated by Mealy and Teytelboym (2020), richer countries tend to have more advanced green production capabilities. These results suggest that the level of financial development is not a binding constraint to higher green complexity in developed countries.

Table 6: The Effects of Financial Development on Green Complexity for Developed Countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				GMM-Developed Countries			
Financial Development	1.0422 (4.460)						
Financial Institutions		0.2344 (2.115)					
Financial Markets			0.1574 (3.917)				
Fin. Inst.-Efficiency				0.1839 (1.052)			
Fin. Inst.-Access					-0.2185 (2.431)		
Fin. Inst.-Depth						-0.9619 (2.418)	
Fin. Markets-Depth							-0.9654 (1.434)
Green Complexity Index	1.0384*** (0.345)	1.1036*** (0.323)	1.0729 (1.776)	0.8932** (0.392)	0.8916** (0.384)	1.2343*** (0.288)	0.6050 (0.651)
GDP per capita	-0.0000 (0.000)	-0.0000 (0.000)	-0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)
Population Density	0.0802 (0.353)	0.0153 (0.129)	0.0720 (0.874)	0.2945 (0.415)	0.2750 (0.437)	-0.0529 (0.372)	-0.0756 (0.370)
Human Capital Index	0.1940 (0.733)	0.0680 (0.441)	0.2161 (2.799)	0.1915 (0.454)	0.1552 (0.661)	0.0457 (0.464)	0.2958 (0.989)

FDI (share in GDP)	-0.0002 (0.004)	-0.0011 (0.002)	-0.0005 (0.012)	0.0001 (0.002)	-0.0002 (0.002)	-0.0003 (0.002)	-0.0016 (0.002)
Trade (share in GDP)	0.0003 (0.002)	0.0003 (0.002)	0.0007 (0.004)	-0.0014 (0.002)	-0.0013 (0.003)	0.0005 (0.001)	-0.0001 (0.001)
Gov. consumption (share in GDP)	-0.0168 (0.137)	0.0036 (0.113)		-0.0238 (0.076)	-0.0241 (0.088)	0.0636 (0.126)	-0.0069 (0.063)
Gov. consumption (share in GDP), level			0.0227 (0.221)				
Capital Formation (share in GDP)	-0.0037 (0.022)	0.0008 (0.013)	0.0044 (0.100)	-0.0038 (0.020)	-0.0041 (0.020)	0.0007 (0.010)	0.0048 (0.009)
Observations	717	717	682	647	647	717	717
Number of id	36	36	36	36	36	36	36
Dependent variable is GCI. All the explanatory variables are lagged one period except HCI and population density. Population density is in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.							

3.4. CONCLUSION

This study contributes to the existing literature on economic complexity and newly introduced concept “green complexity” by analysing the impact of financial development on green complexity. Developed financial systems are expected to enhance financial resources, upgrade product quality of products including green products, diversify their export basket and improve the complexity of products. Building on the previous studies (Nguyen et al., 2020; Nguyen and Su, 2021; Njangang et al., 2021) which explore the link between economic complexity and financial development, this study employs a panel dataset of 135 countries for the period of 1999-2019 and GMM methodology. Financial development is proxied by financial development index and its sub-indices suggested by Svirydzenka (2016). Green complexity is proxied by green complexity index from Andres and Mealy (2021) Green Transition Navigator (www.green-transition-navigator.org). The models are further estimated for developing and developed country subgroups.

First of all, estimation results indicate that financial development positively impacts green complexity of countries. This implies financial development is an important driving factor in promoting green production capabilities. Second, in terms of two main sub-indices of financial development (financial institutions and financial markets), the impacts differ. While financial institutions have a significant positive impact on green complexity whilst financial markets have no statistically significant impact on green complexity. This underlines the significant role of banking sector in transferring resources for green product quality upgrading. Third, a higher financial access and higher efficiency of financial institutions have a positive impact on green complexity whilst deeper financial institutions seem to have no impact on green complexity. Higher impact of financial institutions efficiency compared to financial access highlights the important role of the cost of financial resources on product quality upgrading through innovation.

Lastly, estimation results indicate that both financial institutions and financial markets have positive impacts on green complexity in developing countries. The financial institutions have a more pronounced effect compared to the impact of financial markets on green complexity. Among the sub-indices of financial institutions, financial efficiency is found to have the largest impact. None of the financial development indicators is found to be statistically significant for developed countries. This results suggest that the level of financial development is not a binding constraint to higher green complexity in developed countries. It is worth highlighting that higher ranked developed countries in terms of green complexity have relatively lower rankings in terms of green complexity potential.

Compared to conventional ones, green technologies are not always commercially viable and thus are more expensive and riskier ventures. The empirical results highlight the crucial role of financial development particularly financial institutions efficiency to support environmentally friendly production technology, green products upgrading for developing countries and contribute to their green transformation.

CHAPTER 4

THE EFFECTS OF FINANCIAL DEVELOPMENT ON GREEN COMPLEXITY: AN ANALYSIS ON NUTS 3 REGIONS IN TURKEY

Growing number of countries, particularly the EU-Turkey's largest trading partner, is committing to reduce carbon emissions and the focus has been shifting to more environmentally friendly production. Recently launched European Green Deal aims to transform the EU into a resource efficient economy, decouple economic growth from resource use and achieve zero carbon emissions by 2050. Many of the products and technologies required for the green transition are technologically sophisticated and associated with greater knowledge spillovers (Mealy and Teytelboym, 2020). Under these constraints, to achieve successful green transition and economic growth, enhancing the quality of products, complexity of economies without use of natural resources[12] and developing competitiveness in green technologies will be critical for the countries.

Turkey is one of the countries that will be impacted from globalization decarbonization trends, particularly the EU Green deal since the EU is the largest trading partner of Turkey. The European Green Deal is committed to transforming the carbon emissions of other countries. The EU proposes a Carbon Border Adjustment Mechanism (CBAM) which will impose a levy to reflect the price of carbon on EU imports for a set of products. Moreover, the global demand is expected to shift to more environmentally friendly products. To address the challenges of measures taken by the EU, rapidly changing competitiveness landscape and to achieve a successful transition to a green economy, Turkey needs to develop its green capabilities and enhance its green export competitiveness.

[12] https://theconversation.com/for-the-eus-green-deal-to-succeed-economic-theory-must-take-into-account-qualitative-growth-158821.

Considering the importance of green production capabilities of Turkey, the objective of this chapter is to examine the green complexity of Turkey's provinces and its links to financial development. First of all, this chapter estimates the green complexity at province level (NUTS 3 regions) in Turkey by using the Green Complexity Index methodology introduced by Mealy and Teytelboym (2020) and shows the leading provinces in terms of green complexity in Turkey. Second, the impact of financial development of provinces on their green complexity is analysed. There exist a big research gap in green productive capabilities, particularly in terms of subnational level. In this regard, this analysis tries to fill the gap on spatial dimension of complexity.

The chapter is structured as follows. The next section provides a brief survey of the literature. Section 3 describes the data and methodology. Section 4 presents the results and discusses the findings. Section 5 concludes.

4.1. BACKGROUND LITERATURE: ECONOMIC COMPLEXITY AND GREEN COMPLEXITY AT REGIONAL LEVEL

The literature of economic complexity has three main streams. One stream includes studies applying economic complexity method with a particular context in country-level, province-level, or sector-level (Nguyen et al., 2020). The other stream focuses on improving the methodology in measuring economic complexity (Tacchella et al., 2013) or introducing new complexity measures (Ivanova et al. 2017; Mealy and Teytelboym, 2020). The last streams covers empirical studies on the relationship between economic complexity and socio-economic factors such as income inequality, human capital, productivity, financial development (Hartmann et al., 2017, Yalta and Yalta, 2021; Sweet and Eterovic, 2019; Nguyen and Su, 2021).

There exist many studies in the literature on measurement of economic complexity and its relationship with other socio-economic factors at country levels. However, regional level analyses are relatively limited. Gao and Zhou (2018) estimate regional economic complexity index for 31 Chinese provinces through analysing 25 years' firm data. They find economic complexity index is positively associated with economic development level but negatively correlated with income inequality. Pérez-Balsalobre et al. (2019) estimate economic complexity indices for 50 Spanish provinces and their results support the importance of economic complexity as a leading indicator of future GDP per capita. Basil and Cicerone (2022) investigate the link between economic complexity and regional labor productivity growth in Italy and find that economic complexity has a key role on polarization of regional labor productivity. There are two regional analysis on economic complexity for Turkey. The first study, Tuncer et al. (2017) estimate economic complexity for NUTS-2 regions of Turkey and the other study (Çınar, Korkmaz and Baycan, 2021) estimate economic complexity for NUTS-3 regions of Turkey.

There are a few studies on green complexity at both country and subnational level. The green complexity concept is first introduced by the seminal work of Mealy and Teytelboym (2020) who estimate green complexity index for countries. To the best of our knowledge, there are only two studies that estimate green complexity index at regional level. The first study is Perez-Hernandez et al. (2021). They estimate green complexity indices for 32 Mexic.n regions for the period of 2004-2018 using the seminal work of Mealy and Teytelboym in order to measure the green production capabilities across Mexican entities. The second study on green complexity (Çınar, Korkmaz and Şişman, 2021) generates green complexity index for Turkish provinces (NUTS-3 level). They use more aggregated trade figures (SITC 4 digit) to calculate green complexity index. They investigate the relationship between green complexity index and two air pollution indicators such as SO2 and PM10 where no significant relationship is found.

4.2. DATA AND METHODOLOGY

Green complexity index for Turkey's 81 provinces are estimated by following Mealy and Teytelboym (2020). First, PCI for all products in the COMTRADE data are calculated based on the approach set out in Hausmann et al. (2014).[13] Second, by using PCI values for a list of 293 green products defined based on World Trade Organization (WTO) core list, OECD lists, and the Asia-Pacific Economic Cooperation (APEC) list and the formula

[13] This methodology is explained in detail in Chapter 2.

developed by Mealy and Teytelboym, green complexity of provinces is calculated. This index is an increasing function of both the number and complexity of green products that a province exports competitively.

$$GCI_c = \sum_g \rho_g^c \widetilde{PCI_g} \quad (4.1)$$

In 4.1, ρ_g^c is a binary variable which takes value 1 if province *c* has Revealed Comparative Advantage *(RCA)* > 1 in green product *g* and 0 otherwise. PCI_g is the Product Complexity Index of *g* normalized to take a value between 0 and 1. PCI values of green products for the period of 2004-2019 are obtained by Andres and Mealy (2021) Green Transition Navigator.[14]

The revealed comparative advantage is an important indicator for complexity calculations. It is calculated at the province level for all green products for the period of 2004-2019. The RCA of province c in the product p is denoted below (4.2):

$$RCA_{cp} = \frac{X_{cp} / \sum_p X_{cp}}{\sum_c X_{cp} / \sum_c \sum_p X_{cp}} \quad (4.2)$$

where X_{cp} is the total exports of province c in product p and $\sum_p X_{cp}$ is the total exports of province c. $\sum_c X_{cp}$ is the total exports in product p in Turkey. $\sum_c \sum_p X_{cp}$ is the total exports of Turkey. If this ratio is greater than one, that province has a revealed comparative advantage in product p. RCA is used to create binary variable ρ_g^c which takes value 1 if RCA is greater than 1, 0 otherwise.

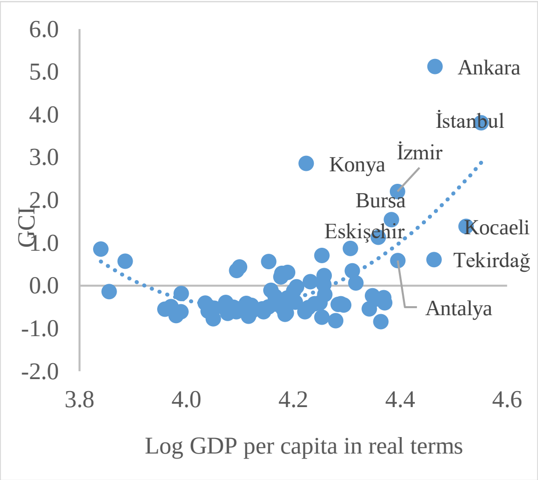
Before calculating RCA values for provinces, exports data for individual products at the level of 6-digit HS codes obtained from Turkish Statistical Institute (TurkStat) are adjusted. All product level export data is converted to HS2002 by using conversion tables of the UN[15] and full compliance of export data at 6-digit level with the product complexity

[14] www.green-transition-navigator.org.
[15] https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp.

index is ensured. The province level exports are aggregated from firm level exports data based on special trade system covering 2004-2019 period.

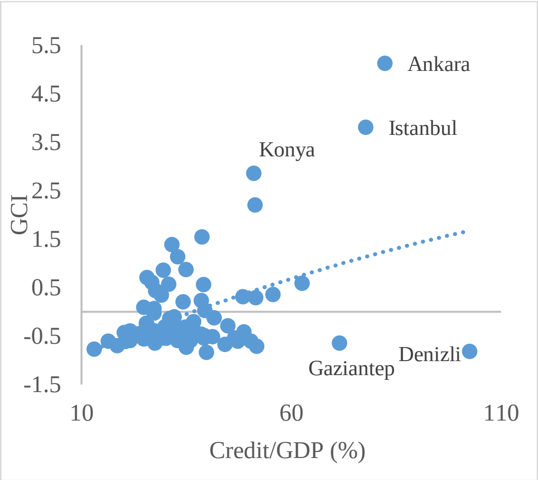
Figure 19 shows the relationship between estimated GCI and logarithm of GDP per capita in real terms. High income provinces tend to have higher green production capabilities. Ankara, İstanbul, İzmir, Bursa, Konya have higher GCI scores compared to their GDP per capita level and top performers in terms of green production capabilities. Figure 20 shows the relationship between GCI and financial development index. Provinces which have high credit to GDP ratio are likely to have higher green production capabilities. However, the relationship seems relatively weak compared to the one with per capita GDP.

Figure 19: Green Complexity Index and Real GDP per Capita by Province (2019)



Source: TurkStat and own calculations

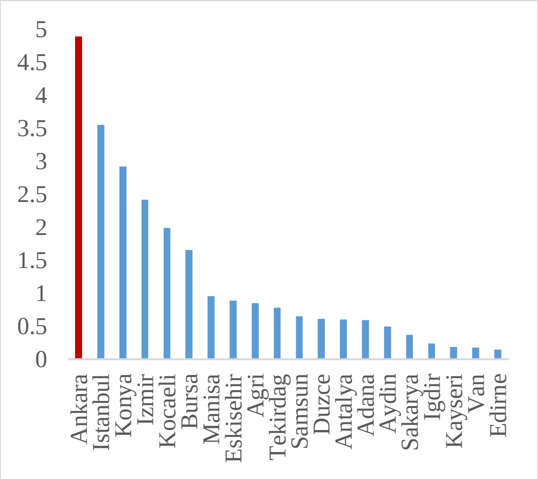
Figure 20: Green Complexity Index and Financial Development by Province (2019)



Source: TurkStat, the Banks Association of Turkey and own calculations

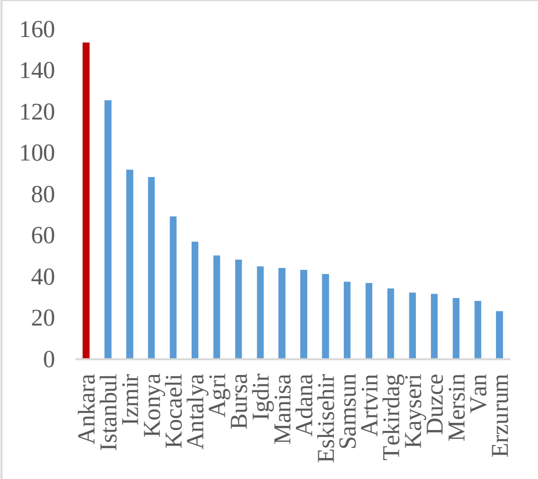
Top performers in terms of green production capabilities are Ankara, Istanbul, Izmir, Konya, Kocaeli and Bursa (Figure 21). This is reflected to the number of green products exported competitively (revealed comparative advantage higher than 1). Ankara exports more than 150 green products competitively (Figure 22). Competitive provinces in terms of green products concentrate in industrialized parts of Turkey. However, provinces Ağrı and Iğdır have also high competitiveness in green products. These results are in line with the findings of Çınar, Korkmaz and Şişman (2021).

Figure 21: Top Performing Provinces in terms of Green Complexity (2017-2019)



Source: TurkStat and own calculations

Figure 22: Number of Green Products Exported Competitively by Provinces (2017-2019)



Source: TurkStat and own calculations

Following the estimation of green complexity index, the effect of financial development on green complexity of the provinces in Turkey is investigated by using the following (4.3):

$$GCI_{it} = \beta FD_{it} + \delta X_{it} + \varphi_i + \alpha_t + \varepsilon_{it} \quad (4.3)$$

Where i and t denote the province i at year t; φ and α represents the province and year fixed effects respectively and, ε is the residual term. X_{it} represents the vector of control variables including income (GDP) per capita (deflated by GDP deflator), trade openness (exports+imports) as a share of GDP, number of patents granted per million people and population to consider the possible dynamics affecting green complexity. These data are collected from Turkish Statistical Institute regional accounts database. Fang et al. (2015) employ deposit and credit as a percentage of GDP as a proxy for regional financial scale. Svirydzenka (2016) uses bank branches and ATMs per adults as a proxy for financial access. Following those studies, in this study, the financial indicators banks credits as a share of GDP, bank deposits as a share of GDP and number of bank branches per million people are used as a proxy for financial development. These financial indicators are collected from the Banks Association of Turkey. There are other indicators such as number of ATMs, number of POS and number of deposit accounts at province level. Since the time horizon is short for these indicators, they are excluded from our estimations. All variables are in level terms which are included into the model in logarithmic terms. The panel covers 81 provinces over the period of 2004-2019.

In terms of estimation methodology, considering the possible spatial spillover impacts of financial development and other control variables, spatial models are utilized to analyse the impact of financial development of provinces on green complexity where spatial interaction effects are accounted for. This choice of the spatial model is verified below by Moran I statistics.[16]

As an initial step of spatial analysis, a weight matrix (W) is constructed. This matrix shows the degree of spatial dependence among cross section units in the sample. In this study, a distance-based weight matrix is constructed by using the longitude (x-coordinates) and latitude (y-coordinates) data. The matrix is standardized in a way that the sum of weights equal to one in each of the row of weight matrix that will give the average value of neighbour provinces. The size of the matrix is equal to the number of provinces.

Following the creation of matrix, the next step is to check the spatial dependency and proceed to the spatial estimation methods. To serve this purpose, Moran Index, a widely accepted method of spatial autocorrelation analysis by Moran (1950), is conducted. The Global Moran’s I statistics shows the overall spatial relationship for all provinces in the analysis.

[16] Moran index measures spatial autocorrelation and is widely used for checking spatial dependency and appropriateness of using spatial estimation methods.

$$I = \frac{N \sum_{i,j}^{N} W_{i,j} Z_i Z_J}{\sum_i \sum_j W_{i,j} \sum_{i=1}^{n} Z_i^2} \; i \neq j \quad (4.4)$$

In equation 4.4, N is the number of observations. W_{ij} is the spatial weight matrix. $\sum \sum W_{ij}$ is the sum of all weights. Z_i and Z_j represents the deviation from the mean of a variable of interest. For instance, for the observation i, Z_i is (Y_i-Y_{mean}). Moran Index takes values between +1 and -1. Large positive values indicate strong positive spatial autocorrelation. Large negative values implies strong negative spatial autocorrelation and 0 indicates no spatial autocorrelation.

Table 7: Spatial Econometric Models with Different Combinations of Spatial Interaction Effects

Type of Model	Spatial Interaction Effects	Equations	Coefficients
SAR, Spatial autoregressive model	WY	Y=pWY + Xβ + ε	λ=0, φ=0
SEM, Spatial error model	Wu	Y= Xβ + u u= λWu + ε	p = 0, φ=0
SAC, Spatial autoregressive combined model	WY, Wu	Y=pWY + Xβ + u u= λWu + ε	φ=0
SDM, Spatial Durbin model	WY, WX	Y=pWY + Xβ +WXφ + ε	λ=0
SLX, Spatial lag of X model	WX	Y= Xβ +WXφ + ε	p = 0, λ=0
SDEM, Spatial Durbin error model	WX, Wu	Y= Xβ +WXφ + u u= λWu + ε	p = 0
GNS, General nesting spatial model	WY, WX, Wu	Y=pWY + Xβ +WXφ + u u= λWu + ε	-

In the literature, there are several spatial econometric models with different combination of spatial interaction terms. Table 7 provides a simple description of spatial econometric models and their spatial interaction effects. There are common 4 models for estimation (Anselin, 1988; LeSage and Pace, 2009; Elhorst, 2014; Majeed and Mazhar, 2021): spatial autoregressive model (SAR), spatial autoregressive combined model (SAC), spatial error model (SEM), spatial Durbin model (SDM) and. Following the Moran I test, for the spatial analysis, Equation 1 is modified to include spatial lags.

4.2.1. Spatial Autoregressive Model (SAR)

The SAR estimates the spatial effects by incorporating the spatial lag of the dependent variable (GCI). It indicates that province's GCI is partially determined by the GCI of the neighbour province. The model which is the modified version of 4.3 is as follows:

$$GCI_{it} = GCI_{it-1} + \beta FD_{it} + \delta X_{it} + \rho WGCI_{it} + \varphi_i + \alpha_t + \varepsilon_{it} \quad (4.5)$$

Where ρ represents the spatial autoregressive parameter, which measure the intensity of spatial interdependency of GCI among provinces. W is the spatial matrix, showing the spatial configuration of provinces.

4.2.2. Spatial Autoregressive Combined Model (SAC)

The SAC estimates the spatial effects by incorporating the spatial lag of the dependent variable (GCI) and spatial dependence in the error term. The model is presented as follows

$$GCI_{it} = GCI_{it-1} + \beta FD_{it} + \delta X_{it} + \rho WGCI_{it} + \varphi_i + \alpha_t + \varepsilon_{it} \quad (4.6)$$

$$\varepsilon_{it} = \lambda W\varepsilon_{it} + \mu_{it} \quad (4.7)$$

where ρ represents the spatial autoregressive parameter and λ is the autoregressive parameter for the error lag. W_{ε} represents the spatial interaction effects among the disturbances. Spatial autocorrelation term captures the spatial dependence.

4.2.3. Spatial Error Model (SEM)

The SEM estimates the spatial effects through spatial dependence in the error term. Thus, spatial dependence enters into the model from the error term. The model is given as follows:

$$GCI_{it} = \beta FD_{it} + \delta X_{it} + \varphi_i + \alpha_t + \varepsilon_{it} \quad (4.8)$$

$$\varepsilon_{it} = \lambda W \varepsilon_{it} + \mu_{it} \quad (4.9)$$

where λ is the autoregressive parameter for the error lag.

4.2.4. Spatial Durbin Model (SDM)

The SDM estimates the spatial effects by incorporating spillover impacts coming from both dependent and independent variables. It includes spatially lagged dependent and independent variables. The model is given as follows:

$$GCI_{it} = \beta FD_{it} + \delta X_{it} + \rho WGCI_{it} + \psi_1 WFD_{it} + \psi_2 WX_{it} + \varphi_i + \alpha_t + \varepsilon_{it} \quad (4.10)$$

Where β and δ show the direct impact of FD and X on GCI of a province and, ψ measures the indirect or spillover impact of FD and X on province's GCI. ρ represents the spatial autoregressive parameter showing the impact of dependency of GCI among provinces.

All these models (4.5, 4.6, 4.8, 4.10) are estimated by using fixed effects models SDM, SAC, SAR and SEM. In spatial analysis, spatial effects are treated as fixed in FE model.

4.3. RESULTS AND DISCUSSION

Before estimating the models, to verify the spatial dependence in the variables, Moran's Index test, is conducted for the variables. The results indicate that all of these variables have spatial positive autocorrelation for most of the period (Table 8). Thus, a spatial model is suitable for this study.

Table 8: Moran's Index of the Spatial Correlation

	GCI	GDP per capita	Deposits to GDP ratio	Credit to GDP ratio	# of Bank Branches, per million people	Patent	Openness
2004	0.1081*	0.5662***	0.2094***	0.0146	0.3953***	-0.0050	0.0915
2005	0.0869	0.5829***	0.1789***	0.0150	0.3678***	0.0205	0.0726
2006	0.0592	0.5769***	0.1680***	0.1243*	0.3896***	0.1035	0.1045*
2007	0.0835	0.5742***	0.1869***	0.2388***	0.4212***	0.0035	0.1005*
2008	0.1100*	0.5767***	0.1855***	0.2277***	0.4410***	0.1418***	0.1155*
2009	0.0898	0.5816***	0.1762***	0.1978***	0.4366***	0.2393***	0.0695
2010	0.0557	0.5739***	0.1456**	0.2000***	0.4308***	0.2961***	0.1992***
2011	0.0456	0.5739***	0.1487**	0.1834***	0.4403***	0.1951***	0.2290***
2012	0.0860	0.5750***	0.1577**	0.1643**	0.4601***	0.2395***	0.2278***
2013	0.0986*	0.5620***	0.1619***	0.1379**	0.4877***	0.3490***	0.2264***
2014	0.1092*	0.5997***	0.1668***	0.0925	0.4985***	0.3634***	0.2405***
2015	0.1197*	0.6166***	0.1808***	0.0814	0.5171***	0.3272***	0.2565***
2016	0.1362**	0.6187***	0.1740***	0.0784	0.5141***	0.3287***	0.2626***
2017	0.1582**	0.6082***	0.1805***	0.0616	0.5008***	0.2761***	0.2709***
2018	0.1256**	0.6066***	0.1794***	0.0210	0.4922***	0.3058***	0.2712***
2019	0.1344**	0.5752***	0.1991***	0.0357	0.4786***	0.2809***	0.1946***
*** p<0.01, ** p<0.05, * p<0.1							

All the models (4.5, 4.6, 4.8, 4.10) presented in the previous section, namely SAR, SAC, SEM and SDM are estimated by using fixed effects models. These models are run by using alternative financial development indicators which are deposits to GDP ratio, credit to GDP ratio and number of bank branches.

The results are reported in Table 9, Table 10, and Table 11. Table 9 presents the outcomes of spatial fixed effects models including the first financial development indicator, deposit to GDP ratio. Regarding their selection, the choice is made though AIC and BIC values where minimum value of AIC indicates SAC as a preferred model. In SDM, except patents granted all variables and spatially lagged dependent and independent variables are found to be statistically insignificant.

Table 9: The Effects of Financial Development (Deposits to GDP ratio) on Green Complexity

	SDM	SAC	SAR	SEM
Deposits (as a share of GDP)	0.0243 (0.019)	0.0239*** (0.008)	0.0301*** (0.011)	0.0303*** (0.011)
GDP per capita	0.2693 (0.441)	-0.0103 (0.241)	-0.0033 (0.019)	0.0391 (0.353)
GDP per capita squared	-0.0157 (0.024)	-0.0002 (0.013)	0.0432 (0.354)	-0.0031 (0.019)
Openness	-0.0018 (0.003)	-0.0014 (0.003)	-0.001 (0.003)	-0.0015 (0.003)
Patents granted	0.0047*** (0.0016)	0.004*** (0.002)	0.005*** (0.002)	0.0052*** (0.002)
Population	-0.0454 (0.046)	-0.0606* (0.034)	-0.0572 (0.044)	-0.0575 (0.044)
ρ	-0.0143 (0.038)	0.4974 (0.082)	-0.0018 (0.038)	
Lambda		-0.6132*** (0.114)		
W*Deposits (as a share of GDP)	0.0279 (0.025)			
W*GDP per capita	-0.5926 (0.496)			
W*GDP per capita squared	0.0319 (0.027)			
W*Openness	0.0008 (0.007)			
W*Patents granted	0.0004 (0.003)			
W*Population	-0.0935 (0.064)			
AIC	-5008.99	-5024.534	-5011.246	-5011.334
BIC	-4936.651	-4978.031	-4969.91	-4969.998
N	1296	1296	1296	1296

Notes: Dependent variable is GCI. All the variables are in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

In SAC, SAR and SEM, the coefficient of deposit to GDP ratio have a positive and significant impact on green complexity. In all models, the coefficient of number of patents granted per million people is positive and significant. However, in SAR and SEM, spatial coefficients are not statistically significant. Since all the spatial coefficients are statistically significant and AIC and BIC are the lowest in SAC, the results of SAC are assessed.

The SAC results imply that deposits to GDP ratio, a proxy for financial development, has a positive and significant impact on green complexity. That is, a 1 percent increase in the credit to GDP ratio leads to 0.023 percent increase in green complexity. Similarly, patents have a positive and significant impact on green sophistication of provinces. Patents granted are used as a proxy for innovation. Sophistication of production regardless of green and non-green being an indicator of the amount of productivity knowledge that a country or region accumulates, the number of patents is considered as a measure of the explicit knowledge that can potentially contribute to the total amount of productivity knowledge (Nguyen et al., 2020). The patents, which are related to the innovation and new knowledge bases in an economy might also have a significant impact on the economic complexity of a country as suggested by Sweet and Eterovic (2019).

The spatial rho ρ, which is the intensity of spatial interdependency shows that 1 percent increase in adjacent province's GCI is associated with 0.497 percent increase in the relevant province's GCI.

Similar findings are obtained from the model results, using credit to GDP ratio as a financial development indicator (Table 10). Based on AIC and BIC criteria and significance of spatial coefficients, SAC is the preferred model. The SAC results show that credits to GDP ratio, a proxy for financial development, has a positive and significant impact on green complexity. Namely, a 1 percent increase in the credit to GDP ratio leads to 0.0067 percent increase in green complexity. The impact of financial development is less pronounced when credits are used. Patents are found to have positive and significant impact on green complexity in all models similar to the results in Table 9. The spatial rho ρ shows that 1 percent increase in adjacent provinces' GCI is associated with 0.490 percent increase in the relevant province's GCI.

Table 10: The Effects of Financial Development (Credits to GDP ratio) on Green Complexity

	SDM	SAC	SAR	SEM
Credits (as a share of GDP)	-0.0074 (0.008)	0.0067** (0.003)	0.0098** (0.005)	0.0099** (0.005)
GDP per capita	0.4352 (0.447)	0.0666 (0.244)	0.1071 (0.356)	0.1027 (0.355)
GDP per capita squared	-0.0257 (0.025)	-0.0044 (0.013)	-0.0069 (0.019)	-0.0067 (0.019)
Openness	-0.0018 (0.003)	-0.0013 (0.003)	-0.0015 (0.003)	-0.0014 (0.003)
Patents granted	0.0046** (0.002)	0.0045*** (0.002)	0.0052*** (0.002)	0.0052*** (0.002)
Population	-0.0313 (0.044)	-0.0389 (0.031)	-0.0396 (0.040)	-0.0398 (0.040)
ρ	-.019092 .0379831	0.4902*** (0.081)	-0.0047 (0.039)	-0.0134 (0.040)
Lambda		-0.6022*** (0.113)		
W*Credits (as a share of GDP)	0.0274*** (0.010)			
W*GDP per capita	-0.6966 (0.493)			
W*GDP per capita squared	0.0378 (0.027)			
W*Openness	0.0019 (0.007)			
W*Patents granted	-0.0005 (0.003)			
W*Population	-0.0572 (0.057)			
AIC	-5005.679	-5013.736	-5002.192	-5002.29
BIC	-4933.34	-4967.233	-4960.856	-4960.953
N	1296	1296	1296	1296

Notes: Dependent variable is GCI. All the variables are in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 11 presents the outcomes of spatial fixed effects models including the third financial development indicator, number of bank branches per million people. The results are similar to the results of models which use other financial development indicators (see Table 9 and Table 10). Based on AIC and BIC criteria, SAC is preferred model. The results imply that a 1 percent increase in the number of bank branches leads to 0.038 percent increase in green complexity. However, in this model, the spatial rho is found to be negative, implying negative impact of spatial spillover impacts.

Table 11: The Effects of Financial Development (Bank Branches) on Green Complexity

	SDM	SAC	SAR	SEM
Bank Branches per million people	0.0379* (0.020)	0.0377** (0.017)	0.0317** (0.013)	0.0319** (0.013)
GDP per capita	0.3338 (0.424)	0.2114 (0.398)	0.0725 (0.332)	0.0733 (0.334)
GDP per capita squared	-0.0197 (0.023)	-0.0127 (0.021)	-0.0052 (0.018)	-0.0052 (0.0182)
Openness	-0.0013 (0.003)	-0.0010 (0.003)	-0.0010 (0.003)	-0.0010 (0.003)
Patents granted	0.0040*** (0.002)	0.0043** (0.002)	0.0047*** (0.002)	0.0047*** (0.002)
Population	-0.0180 (0.048)	-.0172909 .0441783	-0.0276 (0.042)	-0.0276 (0.042)
ρ	0.0056 (0.039)	-0.5861*** (0.134)	0.0036 (0.038)	0.0054 (0.039)
Lambda		0.4933*** (0.096)		
W* Bank Branches per million people	-0.0108 (0.020)			
W*GDP per capita	-0.4101 (0.5057)			
W*GDP per capita squared	0.0228 (0.028)			
W*Openness	0.0028 (0.007)			
W*Patents granted	0.0011 (0.003)			
W*Population	-0.0459 (0.058)			
AIC	-5000.671	-5016.684	-5008.212	-5008.222
BIC	-4928.332	-4970.181	-4966.875	-4966.886
N	1296	1296	1296	1296

Notes: Dependent variable is GCI. All the variables are in logarithms. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

For further assessment, the impacts are divided into direct and indirect effects (or spatial spillover effects). The results of direct and indirect effects for spatial fixed effects SAC models based on alternative financial development indicators are shown in Table 12. The spatial spillover effect results from the impact of independent variables in one province on the dependent variables in the neighbour provinces. According to the estimates, relevant province's GCI is amplified by 0.02 percent, 0.006 with 1 percent increase in neighbour provinces' deposit to GDP ratio and credit to GDP ratio, respectively. The indirect impacts are positive and statistically significant. It is also worth mentioning that indirect impacts are as strong as the direct impacts, highlighting that improving the financial development level in a province generates a positive spatial spillover impact on the green complexity or green production capabilities of the surrounding areas. The results show consistent positive impacts of patents on green complexity in terms of both direct and indirect impacts. On the other hand, the results of the model based on a financial indicator of bank branches gives different results in terms of indirect impacts. The spillover impacts of bank branches and patents are negative and significant.

Table 12: The Decomposition of Direct and Indirect Impacts

	SAC (Deposits - financial development indicator)		SAC (Credits- financial development indicator)		SAC (Bank branches - financial development indicator)	
	Direct	**Indirect**	**Direct**	**Indirect**	**Direct**	**Indirect**
Deposits (as a share of GDP)	0.0255*** (0.008)	0.0221** (0.009)				
Credits (as a share of GDP)			0.0071** (0.003)	0.0062* (0.003)		
Bank Branches per million people					0.0407** (0.018)	-0.0170* (0.009)
GDP per capita	-0.0005 (0.266)	0.0100 (0.258)	0.0812 (0.268)	0.0758 (0.255)	0.2451 (0.439)	-0.1067 (0.187)
GDP per capita squared	-0.0008 (0.014)	-0.0013 (0.014)	-0.0053 (0.015)	-0.0049 (0.014)	-0.0147 (0.024)	0.0064 (0.010)
Openness	-0.0012 (0.003)	-0.0012 (0.003)	-0.0010 (0.0028)	-0.0010 (0.003)	-0.0009 (0.003)	0.0004 (0.001)
Patents granted	0.0048*** (0.002)	0.0042** (0.002)	0.0050*** (0.002)	0.0042** (0.002)	0.0046*** (0.002)	-0.0018*** (0.001)
Population	-0.0642* (0.037)	-0.0564 (0.038)	-0.0401 (0.033)	-0.0360 (0.033)	-0.0163 (0.047)	0.0060 (0.019)

4.4. CONCLUSION

This study contributes to the literature on economic complexity by analysing the influence of financial development and patents on green complexity at regional level as well as considering the spatial aspects of financial development and green complexity relationship. First of all, by using product complexity indices for green products, product complexity of Turkish provinces is estimated over the period 2004-2019. Alternative financial indicators, namely credit to GDP ratio, deposit to GDP ratio and number of bank branches per million people, are used to investigate their impact on green production capabilities. In addition, other control variables like openness, GDP per capita, population and, number of patents granted are also taken into account.

In terms of methodology, to account for spatial spillover impact, widely accepted spatial models, SAR, SAC, SEM, SDM are employed, and direct and indirect impacts are estimated. The results provide noteworthy findings. First of all, financial development (all indicators) has significant and positive impact on green complexity of Turkish provinces, highlighting the importance of financial development in provinces for upgrading green production technology. The spatial spillover impacts are also significant. Same results are found for the impact of patents on green complexity, implying strong knowledge spillover impacts. The provinces seem to be highly interlinked due to economic connections, therefore, economic development in one province can affect many other provinces. The empirical analysis underlines the need to incentivize financial development and innovation in order to diffuse green technologies and upgrade the quality of green products in lagging regions.

CHAPTER 5

THE EFFECTS OF CORPORATE FINANCIAL VULNERABILITY ON GREEN COMPLEXITY IN TURKEY: A FIRM LEVEL ANALYSIS

Economic complexity, sophistication of production or exports, is influenced by many factors such as human capital, financial development, R&D and innovation activities, trade openness of countries and firms. From a firm's perspective, financial soundness is also key factor for investment, technology upgrading and the production of high quality goods. The health of a firm's balance sheet could potentially impact its decision to invest and grow. Financially more vulnerable firms are likely to invest and hire less than firms with a robust financial position (Myers, 1977; Kalemli-Özcan et al., 2019; Philippon, 2010). In extreme cases, high vulnerabilities of the corporate sector can cause firm closures and adversely impact production process. Financial vulnerability of firms affects export activities, R&D investments and innovation as well (Bellone et al., 2010; Forlani, 2010; Engel et al., 2013; Hsu et al., 2014; Duval et al., 2020).

Turkish firms borrowed heavily over the last two decades. This enabled them to grow, contributing to Turkey's strong economic performance post Global Financial Crisis (GFC). However, saddled with high debt burdens, corporates were hit by several shocks and financial vulnerabilities have grown over time. These vulnerabilities are likely to impact firms' innovation activities and product quality upgrading. Building on the literature in financial vulnerability, the hypothesis of this study is: financially vulnerable firms are likely to invest less on R&D and innovation activities, high technology and produce and export less sophisticated/low quality products. This hypothesis focuses only on green production capabilities given the Turkey's need to adapt rapidly changing competitiveness landscape and to achieve a successful transition to a green economy. Two perspectives namely, green complexity and financial vulnerability are put together at firm level.

In this regard, the objective of this chapter is to examine the green complexity of Turkish firms and its links to their financial vulnerability. First, this chapter estimates the green complexity at firm level in Turkey by using the Green Complexity Index methodology introduced by Mealy and Teytelboym (2020). Second, corporate financial vulnerability of firms is calculated by following a novel methodology of Feyen et al. (2017). Third, the impact of financial vulnerability of firms on their green production capabilities is analysed by using standard Heckman two-stage (or control function) procedure to control for selection bias issue. There exist a big research gap in green productive capabilities, particularly at firm level. To the best of our knowledge, this is the first study estimating green complexity at firm level and also linking green complexity to financial vulnerability of firms. In this regard, this analysis tries to fill the gap on green complexity analysis at micro level and also contributing to financial vulnerability literature.

The chapter is structured as follows. The next section provides a brief survey of the literature. Section 5.2 describes the data and methodology. Section 5.3 presents the results and discusses the findings. Section 5.4 concludes.

5.1. BACKGROUND LITERATURE: FINANCIAL VULNERABILITY AND ITS LINKS TO FIRM ACTIVITY

In this section, the literature on the impact of financial vulnerability on firms' economic activity is presented to provide insights on the impact of financial vulnerability on green complexity of firms since there are no studies linking financial vulnerability to economic complexity or green complexity of firms.

Financial vulnerability of firms could impact their decisions to invest, export and grow and thus overall economic activity in an economy. Financially vulnerable firms (e.g. having high short-term debt and low earnings relative to interest expenses) are more likely to exit the market when financial conditions are tight or economic activity is weak (Banerjee and Kharroubi, 2020). Engel et al. (2013) show that financial constraints could impact firms' decision to cease exporting by using data on French firms over the period 2000-2002. They report that having a high leverage ratio or a low cash-flow ratio rises the probability that a firm will cease exporting. Jaud et al. (2015) highlight that financially vulnerable exporters are not able to fully realize economies of scale in production and access better-sophisticated technologies.

Besides, a long stream of literature examines how financial constraints and access to resources impact investment including R&D investments (Weitzman, 1979; Kaplan and Zingales, 1997; and Scharfstein and Stein, 2000; Hsu et al., 2014; Duval et al., 2020). It is a widely accepted view that the R&D activity is difficult to finance and highly susceptible to financing constraints and stress (Gezici et al., 2020). Hall and Lerner (2010) emphasize that financing constraints might be even more binding for R&D investment due to three reasons. First, asymmetric information problem is more severe for R&D investment (more complex and risky investment) than for ordinary investment. Second, intangible assets are not easy to be used as collateral for borrowing (Jarboe and Ellis, 2010). Third, since there are high sunk costs and adjustments costs in R&D investments, firms might decide to make new R&D investment only if it has adequate resources.

Juan Manez et al. (2014) show that financing constraints are important for the joint decision of export participation and investment in R&D for Spanish firms. Duval et al. (2020) analyse the role of financial frictions on productivity of firms by using a rich cross-country firm level data. They find that firms with more vulnerable balance sheets cut their investment in intangible assets and reduce the share of intangible in total assets substantially more than their less vulnerable counterparts. They argue that this result in lower innovation and a sharper productivity slowdown. Kalemli-Özcan et al. (2019) find that European firms with higher leverage, with higher share of short-term debt (financially vulnerable firms) reduce their investment more after the crisis.

There is only one study in the literature on Turkey, exploring the link between financial constraints and firms' R&D activity in Turkish manufacturing sector by using a rich firm-level dataset (Gezici et al., 2020). They find that financing constraints are negatively correlated with firms' R&D activity, i.e. both decisions to undertake R&D and the intensity of R&D.

Whereas development of green technologies requires intense investment in R&D and innovation activities, financial vulnerability or constraints of firms could have detrimental impacts on R&D and innovation activities as evidenced by abovementioned studies. Thus, green complexity of firms is likely to be affected by financial vulnerability of firms through R&D and innovation activities. To the best of our knowledge, no study has been conducted to explore this relationship.

5.2. DATA AND METHODOLOGY

5.2.1. Measurement of Green Complexity at Firm Level

To analyse the relationship between financial corporate vulnerability and green production capabilities of firms, two important indices, namely green complexity index and corporate financial vulnerability at firm level are calculated.

Green complexity index is based on exports data of Turkish firms for individual products at the level of 6-digit HS codes obtained from Turkstat. Exports data for individual products at the level of 6-digit HS codes are converted to HS2002 by using conversion tables of the UN[17] and full compliance of export data at 6 digit level with the product complexity index is ensured. Green complexity index for Turkey’s manufacturing companies are estimated by following Mealy and Teytelboym (2020). First, PCI for all products in the COMTRADE data are calculated based on the approach set out in Hausmann et al. (2014).[18] Second, by using PCI values for a list of 293 green products defined based on WTO core list, OECD lists, and the APEC list and the formula developed by Mealy and Teytelboym, 2020, green complexity of firms is calculated.

$$GCI_c = \sum_g p_g^c \, \widetilde{PCI_g} \tag{5.1}$$

[17] https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp
[18] This methodology is explained in detail in Chapter 2.

In 5.1, ρ_g^c is a binary variable which takes value 1 if province *c* has Revealed Comparative Advantage *(RCA)* > 1 in green product *g* and 0 otherwise, and PCI_g is the Product Complexity Index of *g* normalized to take a value between 0 and 1. PCI values of green products for the period of 2004-2019 are obtained by Andres and Mealy (2021) Green Transition Navigator.[19]

The revealed comparative is calculated at the firm level for all green products for the period of 2009-2019. The RCA of firm c in the product p is denoted below (5.2):

$$RCA_{cp} = \frac{X_{cp}/\sum_p X_{cp}}{\sum_c X_{cp}/\sum_c \sum_p X_{cp}} \quad (5.2)$$

where X_{cp} is the total exports of firm c in product p and $\sum_p X_{cp}$ is the total exports of firm c. $\sum_c X_{cp}$ is the total exports in product p in Turkey. $\sum_c \sum_p X_{cp}$ is the total exports of Turkey. If this ratio is greater than one, that firm has a revealed comparative advantage in product p. RCA is used to create binary variable ρ_g^c which takes value 1 if RCA is greater than 1, 0 otherwise.

5.2.2. Measurement of Corporate Financial Vulnerability

There is a growing literature on measurement of corporate financial vulnerabilities in emerging and developing economies (IMF, 2015, 2016; IIF, 2015; World Bank, 2016; Beltran et al., 2016; Gonzalez-Miranda, 2012; Alfaro et al., 2017). These studies employ different dimensions of financial vulnerabilities such as debt overhang, maturity mismatches and debt rollover or an index of vulnerability indicators.

Feyen et al. (2017) introduce a novel corporate financial vulnerability Index (CVI) by using the balance sheet information of 14,207 listed non-financial firms in 69 emerging markets and developing economies. They benefit from multiple financial vulnerability indicators since firms can be financially vulnerable across multiple dimensions at the

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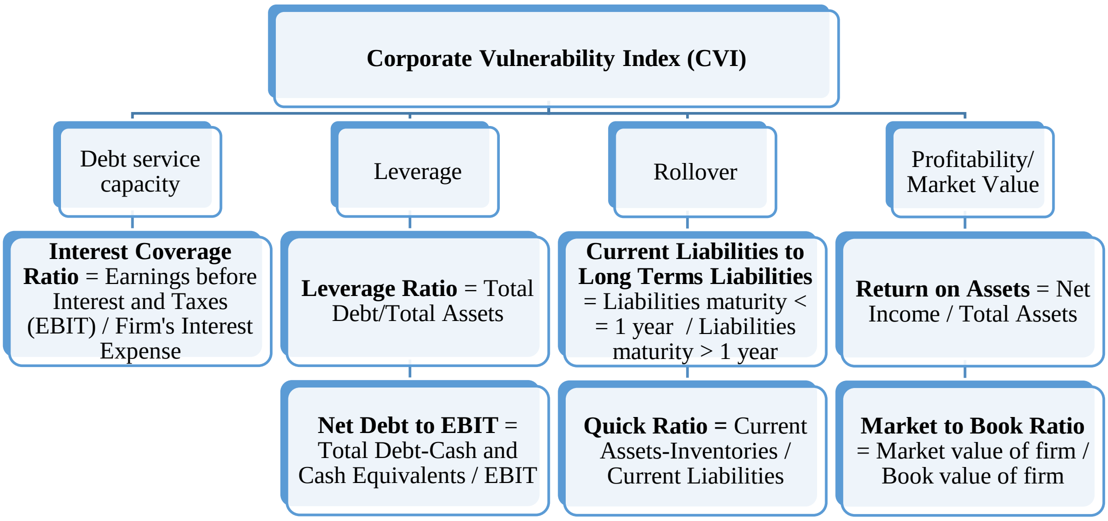
same time. The coverage of this study is far wider compared to the previous studies. Turkey is one of the countries covered in the study. One of the advantages of this balance sheet-based approach is that it can easily be extended to include non-listed firms. In this regard, this recent approach is used in our study to measure the corporate financial vulnerability of Turkish firms.

Figure 23: Structure of Corporate Vulnerability Index



Source: Feyen et al. (2017).

Feyen et al. (2017) estimates a composite indicator which assesses non-financial firms' financial vulnerability based on balance sheet information of firms, called as corporate vulnerability index (CVI). This index measures four key dimensions of financial vulnerability i.e. debt service capacity, leverage, rollover risk and profitability/market value. As presented in Figure 23, under these four dimensions of financial vulnerability, there are seven diverse mix indicators based on both stock and flow data. These indicators are Interest Coverage Ratio (ICR), Leverage Ratio, Net Debt to EBIT Ratio, Current Liabilities to Long-term Liabilities Ratio, Quick Ratio, Return on Assets and Market to Book Ratio.

Feyen et al. (2017) use thresholds to classify a firm as financially vulnerable (Table 13). For instance, firms that have interest coverage ratio below 1 are classified as vulnerable. Thresholds for other indicators are determined based on percentiles.

Table 13: Thresholds to Classify a Firm as Financially Vulnerable

Indicator	"At risk" Thresholds
❖ Interest Coverage Ratio	< 1 (profits less than interest expenses)
❖ Leverage Ratio ❖ Net Debt to EBIT ❖ Current liabilities to Long-term liabilities	> 90th percentile value of the indicator for **all firms** within the **same industry**, for the **whole sample**. One threshold per industry
❖ Quick Ratio ❖ Return on Assets ❖ Market to Book Ratio	< 10th percentile value of the indicator for **all firms** within the **same industry**, for the **whole sample**. One threshold per industry

Source: Feyen et al. (2017).

In this study, as a first stage, four indicators from balance sheet and income statements of firms covering four key dimensions (Figure 23) are chosen to measure corporate financial vulnerability. The selection is done based on the sample size as some indicators reduce the sample size significantly. For the first dimension, namely debt service capacity, interest coverage ratio is used. In this study, a firm with interest coverage ratio less than 1.5 (the lower limit accepted by the related literature)[20] are considered as financially vulnerable. An ICR dummy variable is created, and it takes value 1 if the firm's ICR value is below 1.5 and 0, otherwise. For the second dimension, namely leverage, net debt to EBIT ratio is used. The threshold specified in Table 1 is employed and a dummy variable for net debt to EBIT ratio is created. For the third dimension (leverage) and fourth dimension (profitability), dummy variables are created for quick ratio and return on assets ratio with specified thresholds in Table 13.

[20] By the time a firm's ICR falls below 1, it may have already been in distress. An ICR of 1.5 is widely used as a threshold as an early warning signal of potential corporate difficulties. Countries whose corporate sector with median ICR below 1.5 were more vulnerable during the Asian Financial Crisis (Chow, 2015).

As a second stage, the vulnerability index is constructed via principal component analysis (PCA)[21] using the following variables i.e. net debt to EBIT ratio, quick ratio and return on assets ratio. ICR is not included in the vulnerability index as it reduces the sample size. Higher values of vulnerability index indicate higher corporate financial vulnerability.

5.2.3. Description of the Dataset

The dataset covers the period of 2009-2019 and all exporting firms[22] both do and do not export green exports. The dataset is a combination of different datasets from TurkStat. The sources are Annual Trade Statistics (disaggregated export at HS6), Structural Business statistics (information on firm characteristics) and Company Account Statistics (financial indicators). Company account statistics cover the financial statements (balance sheet and income statements) of real sector firms based on compiling the financial tables of individual real sector firms from Revenue Administration and sector information from TurkStat.

Exporting firms constitute 9.6 percent of total firms on average in the sample. This corresponds to around 634,100 exporting firms.[23] In terms of firm size, the share of exporting firms tend to increase as the firm size rises. Exporting firms constitute 35.6 percent of large firms, 29.7 percent of medium firms, 15.2 percent of small firms and 3.9 percent of micro firms. In terms of sectors, the share of exporting firms is above 30 percent for tobacco, machinery and equipment and motor vehicles sectors.

The firms are classified into two categories: green product exporters and non-green product exporters. The share of green product exporters in total exporting firms in terms of number of firms is 38.7 percent on average for the whole sample. Table 14 shows the

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[21] The Principal Component Analysis (PCA) analysis is carried out by using STATA. PCA is a widely used methodology in the literature for creation of indices. It is a mathematical procedure which reduces the dimension of a dataset by synthesizing the information contained in a number of possibly correlated variables into a smaller or equal number of uncorrelated variables named principal components (Loko and Diouf, 2009). Each component is assessed using the contributions of variables to the component (Pearson, 1901; Jolliffe, 2002).

[22] Since green complexity index is calculated based on export data, this analysis covers only exporting firms.

[23] Detailed data tables are provided in the Appendix 1.

number of exporting firms by their green export status for the period of 2009-2019. The share of green product exporting firms vary between 36-40 percent throughout the period. The share of green product exporting firms is above 50 percent particularly in utilities sectors, manufacturing sectors such as basic metals, electronics, machinery and equipment and motor vehicles and construction sector.

Table 14: The Number of Exporters by Green Product Export Status

	Non-green exporters	Green Exporters	Total Exporters
2009	29,004	16,767	45,771
2010	29,622	17,680	47,302
2011	30,485	18,796	49,281
2012	31,888	20,273	52,161
2013	33,767	21,497	55,264
2014	35,185	22,778	57,963
2015	35,993	23,079	59,072
2016	37,047	23,590	60,637
2017	38,992	25,021	64,013
2018	41,664	26,649	68,313
2019	44,913	29,410	74,323

Table 15: The Number of Exporters by Green Product Export Status and Sectors

	Number of non-green product exporting firms	Number of green product exporting firms
Services	172,084 (58.21)	123,517 (41.79)
Manufacturing	141,887 (61.25)	89,753 (38.75)
Mining	3,998 (90.11)	439 (9.89)
Agriculture	2,478 (86.43)	389 (13.57)
Construction	8,114 (37.83)	13,337 (62.17)
*Numbers in parentheses show the percentage share of exporting firms in total firms for the corresponding year.		

In terms of main sectors, large share of green product exporting firms are operating in services and manufacturing sectors (Table 15). Similar to non-green product exporters, the share of green product exporting firms tend to increase as the firm size rises. A similar pattern is observed in terms of number of green products and green complexity of firms. Both green complexity and number of green products on average rise as firm size increases (Table 16).

Table 16: The Number of Green Products and Green Complexity by Firm Size

Firm Size	Number of green products (mean)	Green Complexity (mean)
Micro	1.0141539	1.4952626
Small	1.4540768	1.8485217
Medium	1.9428534	2.2306739
Large	2.58424	2.433317

5.2.4. Estimation Methodology

Following the creation of green complexity index and corporate financial vulnerability index at firm level, the next step is to test whether financial vulnerable firms tend to have less green production sophistication. Since we are interested in how firms' financial vulnerabilities impact their green production capabilities which is proxied by green complexity index, Heckman two-step procedure is employed to control for the selection bias stemming from firms' export decisions of green products.

When the observations are sorted non-randomly into distinct groups, this could possibly cause coefficient bias in estimation like in OLS (Maddala, 1991). Heckman (1979) developed a selection model to control for the bias. In our case, the non-random sample of green product exporters could lead to selection bias if the determinants of becoming an exporter of green products are correlated with the error term.

There are two stages in Heckman model. At the first stage, a probit specification is estimated where the probability of green product export decision is regressed on the variables that could impact green product export decision. The selection equation which covers all exporting firms takes the following form (5.3):

$$\text{Green Export}_{ijt} = \alpha \text{ Green Export}_{ijt-1} + X_{jt-1}\beta + \text{Controls}_{ijt-1} + u_{ijt} \quad (5.3)$$

The second stage equation (5.4) is as follows:

$$\text{Green Complexity}_{ijt} = X_{jt-1}\delta + \text{Controls}_{ijt-1} + u_{ijt} \quad (5.4)$$

where Green Export_{ijt} is a binary variable having a value of 1 if firm i industry j exports green products in year t and 0, otherwise. Green Export_{ijt-1} is firm's lagged green export status. It takes value 1 if the firm was exporting at time t-1 and, 0 otherwise. The lagged green export status is added to the selection equation to control for the export persistence. X_{jt-1} includes financial indicators which are dummy variables taking value 1 for financially vulnerable firms and composite corporate vulnerability index explained in data description section. Lagged values are used by considering the time effect of variable on green export behaviours. The vector of covariates Controls_{ijt-1} includes firms' characteristics as well as sector and year dummies. To avoid for possible endogeneity between firm controls and their green exporting behaviour, the firm-specific variables are included in the regressions in their one-year lagged values. Labor productivity index, number of employees for firm size (in logarithm), capital intensity of firm (logarithm of capital stock to employee ratio), tangible investment dummy (takes value 1 if the firm invested in tangible assets), intangible investment dummy (takes value 1 if the firm invested in intangible assets) are included in the model as control variables. All variables and their definitions are presented in Table 17.

In equation 5.4, the dependent variable Green Complexity_{ijt} is firm i's calculated green complexity index in industry j in and in year t. The impact of financial vulnerability on green complexity of firms is estimated by this equation. The error terms u_{ijt} are random variables which capture the impact of omitted variables that are presumed to be distributed bivariate normal with correlation ρ. If $\rho \neq 0$, estimating only the equation of green export performance causes selection bias for the estimates of β coefficients since u_{ijt} and X_{jt-1} would be correlated. To avoid this bias, two equations are estimated by using Heckman's (1979) maximum likelihood method which involves estimation of the inverse Mill's ratio.

Table 17: The Variables Covered in the Model

Variables	Definition
Green export dummy	Dummy variable taking value 1 if firm exports green products
Labor Productivity (LP)	Labor Productivity-Logarithm of value added per worker
Employee	Number of employees in logarithms
Capital intensity	Logarithm of the capital stock/employees ratio
Dummy Intangible assets	Dummy variable taking value 1 if firm invests in intangible assets
Dummy Tangible assets	Dummy variable taking value 1 if firm invests in tangible assets
CVI	Corporate vulnerability index
Dummy-Interest Coverage Ratio (ICR)	Dummy variable taking value 1 if a firm has an ICR above 1.5.
Dummy-Net Debt to EBIT (NDebt-EBIT)	Dummy variable taking value 1 if a firm has net debt to EBIT ratio greater than 90th percentile value of the indicator for all firms within the same industry.
Dummy-Quick Ratio (Quick)	Dummy variable taking value 1 if a firm has a quick ratio less than 10th percentile value of the indicator for all firms within the same industry.
Dummy-Return on Assets (ROA)	Dummy variable taking value 1 if a firm has a return on assets ratio less than 10th percentile value of the indicator for all firms within the same industry.

5.3. RESULTS AND DISCUSSION

As a first stage, factors spurring firms' likelihood of engaging in green product exporting activity by probit specifications are analysed. Next, the impact of firm specific factors and financial vulnerability on green complexity of firms is estimated. Table 18 documents the estimated coefficients with alternative financial vulnerability indicators for both first and second stage estimations. Financial vulnerability indicators include composite vulnerability index, dummy variables for vulnerability based on ICR, quick ratio, return on assets and net debt to EBIT, which are presented in Table 17. Two equations are jointly estimated and in reference to the Wald tests for the overall validity of the Heckman selection model. Lambda, which is the estimated coefficient on the inverse Mills ratio, is also provided in the table. The statistical significance of Lambda indicates the existence of sample selection bias validating further the Heckman selection model.

First stage estimation results show that lagged green export status is positive and statistically significant in all specifications (Table 18 and 19). This signals the existence of persistency for firms' green export behaviour. The firm size, proxied by number of employee, is found to increase the likelihood of firm's involvement in green product exporting activity. This is not surprising as increase in firm size increases the likelihood of being an exporter (Özler et al., 2009; Günaydin, 2013). The likelihood of being an exporter rises in the firm's size due to high capacity of larger firms for covering any sunk costs of entering into export market and taking advantage of economies of scale (Dalgıç et al. 2015). It is expected to be valid for green product exporting. The coefficient of the dummy indicating whether the firm has tangible asset investments is not significant in green product export decision equation. On the other hand, the dummy indicating whether the firm has intangible asset investments turns to be positive and significant in all specifications. This implies the importance of investing in intangible assets covering R&D expenses in increasing the likelihood of green product exporting activity. This is expected as development of green technologies requires intense investment in R&D and innovation activities. More productive and more capital-intensive firms are expected to have a greater propensity to becoming an exporter. However, labor productivity and capital intensity are found to be insignificant in green product export decision for all specifications. In terms of financial vulnerability of firms, the results imply that the likelihood of becoming a green product exporter declines as financial vulnerability of firms, measured by alternative indicators, rises. This in line with expectations as financial vulnerability of firms could adversely impact export activities and R&D investments as highlighted in Section 5.1.

Second stage estimation results show the impact of variables on green complexity of firms. Unsurprisingly, productivity impacts green complexity positively in all specifications. However, firm size does not appear to have an effect on green complexity of firms. Both tangible and intangible investments have a positive impact on green complexity and the impact of tangible investments is more pronounced. The results strongly suggest that green complexity of firms is affected negatively by their financial vulnerabilities. Coefficients of financial vulnerability indicators are negative and statistically significant. The difficulties in debt service capacity (dummy-ICR) and increased debt rollover risk (dummy-Quick) have higher impact on green complexity of firms compared to composite vulnerability index (CVI), leverage (net debt to EBIT) and profitability (return on assets) indicators. This result is not surprising as ICR and quick ratio are considered as important determinants of firm activity.

Table 18: Heckman Estimation Results-I

	Model 1		Model 2		Model 3	
Variables	**Green Export Decision**	**Green Complexity**	**Green Export Decision**	**Green Complexity**	**Green Export Decision**	**Green Complexity**
Green Export Dummy (t-1)	1.8504*** (0.000)		1.8728*** (0.000)		1.8521*** (0.000)	
Employee (t-1)	0.0143*** (0.000)	-0.0001 (0.986)	0.0158*** (0.000)	-0.0497*** (0.000)	0.0096*** (0.000)	-0.0162** (0.015)
LP (t-1)	0.0081 (0.924)	1.0460*** (0.000)	-0.0642 (0.548)	0.6612* (0.076)	-0.0318 (0.709)	0.8984*** (0.002)
Dummy-Tangible assets	0.0085 (0.438)	0.3631*** (0.000)	0.0073 (0.665)	0.4058*** (0.000)	0.0032 (0.771)	0.3439*** (0.000)
Dummy-Intangible assets	0.0334*** (0.000)	0.1531*** (0.000)	0.0316*** (0.000)	0.1357*** (0.000)	0.0295*** (0.000)	0.1413*** (0.000)
Capital Intensity	-0.0000 (0.204)	0.0000 (0.209)	-0.0000 (0.439)	0.0000 (0.354)	-0.0000 (0.118)	0.0000 (0.315)
CVI	-0.0241*** (0.000)	-0.0898*** (0.000)				
Dummy-ICR			-0.0954*** (0.000)	-0.1469*** (0.000)		
Dummy-Quick					- 0.0894*** (0.000)	-0.1629*** (0.005)
Mills Lambda	-1.1830*** (0.000)		-1.2272*** (0.000)		-1.1876*** (0.000)	
Number of observations	343009	194272	252704	141559	342569	193997

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Lambda is the coefficient estimate of the inverse Mills ratio. Significance of this Lambda implies the existence of sample selection bias.

Table 19: Heckman Estimation Results-II

	Model 4			Model 5		
Variables	**Green Decision**	**Export**	**Green Complexity**	**Green Decision**	**Export**	**Green Complexity**
Green Export Dummy (t-1)	1.8516*** (0.000)			1.8515*** (0.000)		
Employee (t-1)	0.0099*** (0.000)		-0.0153** (0.021)	0.0101*** (0.000)		-0.0150** (0.024)
LP (t-1)	-0.0415 (0.626)		0.8925*** (0.002)	-0.0188 (0.825)		0.9445*** (0.001)
Dummy-Tangible assets	0.0054 (0.618)		0.3439*** (0.000)	0.0050 (0.646)		0.3442*** (0.000)
Dummy-Intangible assets	0.0309*** (0.000)		0.1436*** (0.000)	0.0306*** (0.000)		0.1427*** (0.000)
Capital Intensity	-0.0000 (0.125)		0.0000 (0.309)	-0.0000 (0.135)		0.0000 (0.323)
Dummy-ROA	-0.1010*** (0.000)		-0.1298*** (0.005)			
Dummy- NDebt-EBIT				-0.0290*** (0.002)		-0.0302 (0.351)
Mills Lambda		-1.1875*** (0.000)			-1.1877*** (0.000)	
Number of observations	343169		194395	342775		194145

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Lambda is the coefficient estimate of the inverse Mills ratio. Significance of this Lambda implies the existence of sample selection bias.

Table 20 and Table 21 present the results of the model based on firm size classification. The results based on composite financial vulnerability and ICR are shown in Table 20 and Table 21, respectively. While the results show a variation among different size groups, financial vulnerability is found to have a negative impact on green complexity of firms for all firm size groups except micro firms. This impact is more pronounced for medium firms (Table 20). The positive impact of both tangible and intangible asset investments on green complexity is only evident for small and micro firms which have relatively more constraints on access to finance.

Table 20: Heckman Estimation Results by Firm Size-I

	Large firms		Medium firms		Small firms		Micro Firms	
Variables	**Green Export Decision**	**Green Comp.**	**Green Export Decision**	**Green Comp.**	**Green Export Decision**	**Green Comp.**	**Green Export Decision**	**Green Comp.**
Green Export Dummy (t-1)	1.8984*** (0.000)		1.9819*** (0.000)		1.8796*** (0.000)		1.7975*** (0.000)	
Employee (t-1)	0.1357 (0.187)	0.8354** (0.023)	0.0392** (0.038)	0.0716 (0.241)	-0.0025 (0.798)	-0.0007 (0.983)	-0.0074 (0.162)	0.0943*** (0.000)
LP (t-1)	42.3513 (0.364)	278.2711 (0.109)	16.4122*** (0.000)	98.672*** (0.000)	1.4095** (0.025)	44.1226*** (0.000)	-0.0634 (0.469)	0.2457 (0.387)
Dummy-Tangible assets	-0.7058 (0.280)	1.4134 (0.460)	0.1667 (0.296)	-0.1344 (0.808)	-0.0083 (0.828)	0.6166*** (0.000)	0.0242** (0.043)	0.2607*** (0.000)
Dummy-Intangible assets	-0.0578 (0.657)	0.7668 (0.121)	0.0544* (0.054)	-0.1090 (0.251)	0.0722*** (0.000)	0.1503*** (0.000)	0.0064 (0.424)	0.1184*** (0.000)
Capital Intensity	0.0000 (0.491)	-0.0000 (0.732)	-0.0000 (0.424)	0.0000 (0.745)	-0.0000 (0.710)	0.0000 (0.129)	-0.0000 (0.427)	0.0000 (0.666)
CVI	-0.0231 (0.416)	-0.1684* (0.092)	-0.0230*** (0.004)	-0.2033*** (0.000)	-0.0307*** (0.000)	-0.1271*** (0.000)	-0.0247*** (0.000)	-0.0141 (0.334)
Mills Lambda	-1.1011*** (0.000)		-1.1917*** (0.000)		-1.1978*** (0.000)		-1.1166*** (0.000)	
Number of observations	2728	1457	39898	20865	120578	67495	148186	86677

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Lambda is the coefficient estimate of the inverse Mills ratio. Significance of this Lambda implies the existence of sample selection bias. Micro firms: Less than 10 employee, Small Firms: 10 to 49 persons employed, Medium Firms: 50 to 249 persons employed, Large Firms: 250 or more persons employed.

Looking at the impact of financial vulnerability in terms of debt service capacity (Dummy-ICR), estimation results differ from the results obtained based on composite financial vulnerability (Table 21). Increase in financial vulnerability in terms of debt service capacity negatively impacts green complexity of all firms, except large firms. Debt service capacity does not seem a constraint for large firms on enhancing the sophistication of production. This could be due to their high resilience to both FX and interest rate shocks. The higher stock-pile of foreign exchange assets make large firms less vulnerable to market stress than medium-sized firms which have large negative FX positions (IMF, 2017).

Table 21: Heckman Estimation Results by Firm Size-II

	Large firms		Medium firms		Small firms		Micro Firms	
Variables	**Green Export Decision**	**Green Comp.**	**Green Export Decision**	**Green Comp.**	**Green Export Decision**	**Green Comp.**	**Green Export Decision**	**Green Comp.**
Green Export Dummy (t-1)	1.8889*** (0.000)		1.979*** (0.000)		1.8714*** (0.000)		1.8479*** (0.000)	
Employee (t-1)	0.1518 (0.153)	0.7038* (0.054)	0.039** (0.048)	0.0143 (0.819)	-0.0075 (0.477)	-0.0312 (0.386)	-0.0071 (0.323)	0.0725*** (0.003)
LP (t-1)	54.7360 (0.258)	278.927 (0.105)	16.204*** (0.000)	94.910*** (0.000)	0.0740 (0.914)	43.8577*** (0.000)	-0.1306 (0.242)	-0.3126 (0.404)
Dummy-Tangible assets	-0.7094 (0.278)	1.2299 (0.501)	0.1069 (0.559)	0.6477 (0.295)	-0.0365 (0.446)	0.5804*** (0.000)	0.0248 (0.194)	0.2688*** (0.000)
Dummy-Intangible assets	-0.0473 (0.735)	0.7067 (0.164)	0.0502 (0.106)	-0.0957 (0.352)	0.0730*** (0.000)	0.1228*** (0.006)	-0.0037 (0.727)	0.1226*** (0.001)
Capital Intensity	0.0000 (0.469)	-0.0000 (0.803)	-0.0000 (0.396)	-0.0000 (0.709)	-0.0000 (0.872)	0.0000 (0.679)	-0.0000 (0.742)	0.0000 (0.610)
Dummy-ICR	-0.0731 (0.224)	0.0023 (0.991)	-0.066*** (0.000)	-0.182*** (0.001)	-0.0781*** (0.000)	-0.1195*** (0.000)	-0.1260*** (0.000)	-0.1953*** (0.000)
Mills Lambda	-1.0386*** (0.000)		-1.1798*** (0.000)		-1.2342*** (0.000)		-1.1679*** (0.000)	
Number of obs.	2570	1375	37100	19333	101437	56211	86068	50452

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Lambda is the coefficient estimate of the inverse Mills ratio. Significance of this Lambda implies the existence of sample selection bias. Micro firms: Less than 10 employee, Small Firms: 10 to 49 persons employed, Medium Firms: 50 to 249 persons employed, Large Firms: 250 or more persons employed.

Table 22 and Table 23 present Heckman estimation results based on broad sector classification. The results point out to a negative impact of financial vulnerability (CVI) on green complexity for all manufacturing and services sectors (Table 22) but insignificant impact on construction sector. The vulnerability in terms of debt service capacity (ICR) appear to have more negative impact for all sectors including construction (Table 23). The impact is more pronounced for construction and services sectors. This result is not surprising since construction, some services sectors like accommodation and food are not properly hedged and/or low buffers and more financially vulnerable in comparison to manufacturing sector. This is also reflected in the deteriorating asset quality of the banking sector; where the highest non-performing loan (NPL) ratios currently belong to those sectors with highest corporate vulnerability. It is also worth noting that intangible assets significantly impacts green complexity for all sectors, indicating importance of R&D investments on green complexity of firms.

Table 22: Heckman Estimation Results by Sectors-I

	Manufacturing		Construction		Services	
Variables	**Green Export Decision**	**Green Complexity**	**Green Export Decision**	**Green Complexity**	**Green Export Decision**	**Green Complexity**
Green Export Dummy (t-1)	1.8809*** (0.000)		1.5146*** (0.000)		1.8001*** (0.000)	
Employee (t-1)	0.0239*** (0.000)	-0.0014 (0.864)	0.0656*** (0.000)	0.3719*** (0.000)	0.0357*** (0.000)	0.2413*** (0.000)
LP (t-1)	0.0283 (0.930)	4.1225*** (0.000)	0.5811 (0.449)	15.7397*** (0.000)	-0.0922 (0.304)	0.0451 (0.899)
Dummy-Tangible assets	-0.0079 (0.775)	0.1251* (0.082)	0.0889 (0.175)	0.2896 (0.312)	0.0243** (0.046)	0.3734*** (0.000)
Dummy-Intangible assets	0.0583*** (0.000)	0.1022*** (0.000)	0.0624* (0.052)	0.2893** (0.026)	0.0159** (0.040)	0.2018*** (0.000)
Capital Intensity	-0.0000 (0.124)	0.0000 (0.758)	-0.0000 (0.255)	0.0000 (0.984)	-0.0000 (0.417)	0.0000 (0.483)
CVI	-0.0186*** (0.000)	-0.0775*** (0.000)	-0.0575*** (0.000)	0.0120 (0.845)	-0.0317*** (0.000)	-0.0881*** (0.000)
Mills Lambda	-0.8064*** (0.000)		-2.1318*** (0.000)		-1.4636*** (0.000)	
Number of observations	157790	92199	10094	3147	176830	95857

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Lambda is the coefficient estimate of the inverse Mills ratio. Significance of this Lambda implies the existence of sample selection bias.

Table 23: Heckman Estimation Results by Sectors-II

	Manufacturing		Construction		Services	
Variables	**Green Export Decision**	**Green Complexity**	**Green Export Decision**	**Green Complexity**	**Green Export Decision**	**Green Complexity**
Green Export Dummy (t-1)	1.8901*** (0.000)		1.4806*** (0.000)		1.8283*** (0.000)	
Employee (t-1)	0.0251*** (0.000)	-0.0216** (0.021)	0.0504*** (0.000)	0.3983*** (0.000)	0.0400*** (0.000)	0.2280*** (0.000)
LP (t-1)	-0.6280* (0.099)	4.9224*** (0.000)	0.5988 (0.518)	19.2360*** (0.000)	-0.1396 (0.219)	-0.4190 (0.371)
Dummy-Tangible assets	-0.0255 (0.523)	0.0499 (0.630)	0.0990 (0.398)	0.5073 (0.341)	0.0278 (0.140)	0.4287*** (0.000)
Dummy-Intangible assets	0.0597*** (0.000)	0.1303*** (0.000)	0.0697* (0.082)	0.1644 (0.331)	0.0079 (0.425)	0.1653*** (0.000)
Capital Intensity	-0.0000 (0.522)	0.0000 (0.673)	-0.0000 (0.558)	-0.0000 -0.0000	-0.0000 (0.612)	0.0000 (0.603)
Dummy-ICR	-0.0834*** (0.000)	-0.2051*** (0.000)	-0.1132*** (0.002)	-0.3540** (0.018)	-0.1154*** (0.000)	-0.2145*** (0.000)
Mills Lambda	-0.8202*** (0.000)		-2.5167*** (0.000)		-1.5971*** (0.000)	
Number of observations	127392	73438	7073	2042	118916	63398

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Lambda is the coefficient estimate of the inverse Mills ratio. Significance of this Lambda implies the existence of sample selection bias.

5.4. CONCLUSION

This analysis contributes to the existing literature on economic complexity and newly introduced concept "green complexity" by analysing the impact of financial vulnerability of firms on green complexity. This is the first attempt of bringing two concepts together namely, green complexity and financial vulnerability at micro (firm) level. To the best of our knowledge, no prior studies have calculated green complexity indices at firm level and examined the impact of firms' financial vulnerability on their green production capabilities. Since there is no established literature, our hypothesis is built on the literature of financial vulnerability and its links to firm activity. There exists a growing literature analysing the linkages between financing constraints of firms and their R&D and innovative activities (Scharfstein and Stein, 2000; Juan Manez et al., 2014; Duval et al. 2020; Gezici et al., 2020). Among them, Gezici et al. (2020)[24] finds that financially constrained firms are likely to invest less on R&D and innovation activities in Turkey. Building on this limited literature, our hypothesis builds a bridge between financial vulnerability and green sophistication of products. In this regard, green complexity at firm level is estimated in Turkey by using the Green Complexity Index methodology introduced by Mealy and Teytelboym (2020), whereas corporate financial vulnerability of firms is calculated by following a novel methodology of Feyen et al. (2017). Following these calculations, the impact of financial vulnerability of firms on their green production capabilities is investigated by using Heckman's two-stage procedure. Accordingly, this study tries to fill the gap in green complexity analysis at micro level as well as contributing to the literature on financial vulnerability of firms.

Results of the study mainly point out that green complexity of firms is adversely affected by their financial vulnerabilities where the difficulties in debt service capacity and increased debt rollover risk have higher impact on green complexity of firms compared to composite vulnerability index, leverage, and profitability indicators.

The results among different size groups show a variation, whereas financial vulnerability is found to have a negative impact on green complexity of firms for all firm size groups except for micro sized firms. However, looking at the impact of debt service capacity, estimation results differ from the results obtained based on composite financial vulnerability. Debt service capacity does not seem a constraint for large firms on enhancing the sophistication of production. This could be due to their high resilience and strong buffers to both FX and interest rate shocks. In terms of different sector classifications, financial vulnerability is found to affect green production capabilities negatively for manufacturing and services sectors but no significant impact on construction sector. The impact for construction sector becomes negative and significant

[24] There are studies on the determinants of the R&D activity by Turkish firms, but Gezici et al. (2020) is the first study with specific focus on financing constraints.

considering the debt service capacity. The impact of vulnerability in terms of debt service capacity is more pronounced for construction and services sectors. This result is expected since the highest non-performing loan ratios currently belong to the construction and some services sectors like accommodation and food with highest corporate vulnerability in Turkey.

CONCLUSION

Productive capabilities and its role on economic growth and development have attracted a lot of attention among researchers and policy makers since the introduction of the concept of "economic complexity index". This index, which measures the non-observable capabilities (know-how) required in the production process, has brought a new perspective to economic growth and performance of countries. The literature on economic complexity and its links to socio-economic factors have grown enormously over the last two decades.

Another dimension of economic complexity which is green production capabilities, has recently gained increasing attention as climate change challenges intensify and countries around the world lay out ambitious agenda for moving towards a green economy. Building on economic complexity literature, Mealy and Teytelboym (2020) introduced a novel concept "green complexity" to measure the green capabilities of countries. Green complexity has brought a new perspective of evaluating the production capabilities of countries in a changing competitiveness landscape where countries having the capabilities to produce green products and technologies are likely to gain economic benefits. Finance and innovation policies are likely to play a key role at supporting green development and enhance competitiveness of green products in export markets. Developed financial systems are expected to enhance financial resources, upgrade product quality of products including green products, diversify their export basket and improve the complexity of products. This thesis examines the concept of newly introduced green complexity and its interaction with financial development contributing to the related literature in various ways. First of all, the impact of financial development on green complexity both at country level and province level of Turkey is analysed in this study for the first time. There are only a few studies examining the relationship between financial development and economic complexity. However, there is no study on the relationship between financial development and green complexity. Secondly, this study calculates green complexity of Turkish firms and investigates the impact of financial vulnerability of firms on their green production capabilities. There exists no study on firm level green complexity and also no study linking it to financial vulnerability. This thesis contributes to the literature not only by analysing this relationship at cross-country level but also at province level and firm level.

The cross-country analysis builds on the previous studies on economic complexity (Nguyen et al., 2020; Nguyen and Su, 2021; Njangang et al., 2021), investigating the impact of financial development on green complexity of countries. It employs a panel dataset of 135 countries over the period of 1999-2019 and GMM methodology. In addition, the impact of financial development is analysed for two sub-groups of countries, namely developed, and developing countries. Whilst financial development is proxied by financial development index and its sub-indices suggested by Svirydzenka (2016), green complexity index is obtained from Andres and Mealy (2021). Estimation results suggest that financial development positively impacts green complexity of countries. This implies that financial development is an important driver in promoting green production capabilities. Secondly, in terms of two main sub-indices of financial development (financial institutions and financial markets), the impacts vary. While financial institutions have a significant positive impact on green complexity, financial markets have no statistically significant impact on green complexity. This underlines the significant role of banking sector in transferring resources for green product quality upgrading. Third, a higher financial access and higher efficiency of financial institutions have a positive impact on green complexity whilst deeper financial institutions seem to have no impact on green complexity. This suggests that a too big financial sector does not necessarily contribute to the product sophistication of countries whereas financial institutions efficiency and access to finance are likely to have a critically important role to play in green product sophistication. Further, the impact of the efficiency is more pronounced than the impact of financial access. This highlights the important role of the cost of financial resources on product quality upgrading through investing in innovation. Lastly, estimation results show that both financial institutions and financial markets have positive impacts on green complexity in developing countries. On the other hand, no significant impact is found for developed countries. The empirical results highlight the crucial role of financial development particularly financial institutions efficiency to support green product complexity for developing countries and contribute to their green transformation.

The province level analysis explores the impact of financial development and patents on green complexity at regional level for Turkey. Using the product complexity indices for green products, product complexity of Turkish provinces is estimated over the period 2004-2019. Alternative financial indicators, namely credit to GDP ratio, deposit to GDP ratio and number of bank branches per million people, are employed as a proxy for financial development of provinces. In terms of methodology, to account for spatial spillovers, widely accepted spatial models, SAR, SAC, SEM, SDM are employed, and direct and indirect impacts are estimated. The results provide noteworthy findings. First, financial development (all indicators) has significant and positive impact on green complexity of Turkish provinces, highlighting the importance of financial development in provinces for upgrading green production technology. The spatial spillovers are also significant. It is worth highlighting that the impact of patents on green complexity, implying strong knowledge spillovers is positive and significant for all models. The provinces seem to be highly interlinked due to economic connections, therefore, economic development in one province can affect many other provinces. The empirical analysis underlines the need to incentivize financial development and innovation in order to diffuse green technologies and upgrade the quality of green products in lagging regions.

The firm-level analysis explores the impact of financial vulnerability on green complexity of Turkish firms by using Heckman's two-step procedure controlling for selection bias. Before estimating the model, the green complexity at firm level is estimated by using the methodology introduced by Mealy and Teytelboym (2020) and corporate financial vulnerability of firms is calculated by following a novel methodology of Feyen et al. (2017). The hypothesis of this study is that financially vulnerable firms are likely to invest less in R&D/innovation activities and better technologies where they produce and export less sophisticated/low quality products. This hypothesis focuses only on green production capabilities given the Turkey's need to adapt rapidly changing competitiveness landscape and to achieve a successful transition to a green economy. Results of the study point out a significant negative impact of financial vulnerability indicators. The difficulties in debt service capacity and increased debt rollover risk have a more pronounced impact on green complexity of firms compared to composite vulnerability index, leverage and profitability indicators. In terms of firm size, the results show a variation among different size groups.

Whilst financial vulnerability is found to have a negative impact on green complexity of firms for all firm size groups except micro firms; increase in financial vulnerability in terms of debt service capacity negatively impacts green complexity of all firms, except large firms. This could be due to their high resilience to both FX and interest rate shocks. The higher stock-pile of foreign exchange assets make large firms less vulnerable to market stress than medium-sized firms which have large negative FX positions (IMF, 2017). In terms of different sectors, the findings point out to a negative impact of financial vulnerability on green complexity in manufacturing and services sectors but an insignificant impact in construction sector. The vulnerability in terms of debt service capacity appear to have a more pronounced negative impact for construction and services sectors. This result is not surprising since construction, some services sectors like accommodation and food are not properly hedged and/or low buffers and more financially vulnerable in comparison to manufacturing sector. This is also reflected in the deteriorating asset quality of the banking sector; where the highest non-performing loan ratios currently belong to those sectors with highest corporate vulnerability. It is also worth noting that intangible assets significantly impacts green complexity for all sectors, indicating importance of R&D investments on green complexity of firms.

Overall, results of this thesis confirm the importance of financial development in enhancing green production capabilities across countries and provinces. This suggests that advancing financial system and improving financial efficiency should be one of the main concerns of countries, particularly for the developing ones to enhance their green production sophistication and avoid the adverse impacts of changing competitiveness landscape. Furthermore, the province level findings suggest that regional development policies can be revisited to benefit from the positive impact of patents and financial development on green product sophistication in Turkish provinces. From firm level perspective, financial soundness is critical for firms to channel their resources to innovation and R&D for enhancing product sophistication where good corporate governance practices, efficient institutional and policy framework to monitor corporate vulnerabilities, predictable and stable macro financial environment are one of the key factors for mitigating the financial vulnerability of firms.

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APPENDIX 1: DESCRIPTIVE FIRM LEVEL STATISTICS

Table A.1. Number of Exporting Firms (2009-2019)

Year	Number of exporting firms
2009	45,771 (8.79)
2010	47,302 (8.80)
2011	49,281 (8.92)
2012	52,161 (9.40)
2013	55,264 (9.83)
2014	57,963 (10.09)
2015	59,072 (9.86)
2016	60,637 (9.77)
2017	64,013 (9.82)
2018	68,313 (9.99)
2019	74,323 (10.36)
***Numbers in parentheses show the percentage share of exporting firms in total firms for the corresponding year.**	

Table A.2. Number of Exporting Firms by Firm Size

Firm Size	Number of exporting firms
Micro	176,206 (3.90)
Small	236,449 (15.23)
Medium	107,093 (29.67)
Large	14,797 (35.58)
Numbers in parentheses show the percentage share of exporting firms in total firms for the corresponding size group.	

Table A.3. Number of Exporting Firms by Sectors

Nace 2 Digit Code	Number of exporting firms	Nace 2 Digit Code	Number of exporting firms
1 Crop & animal prod., hunting & related service act.	2,437 (3.56)	**46 Wholesale trade, except of motor vehicles and motorcycles**	195,770 (15.81)
2 Forestry and logging	226 (2.95)	**47 Retail trade, except of motor vehicles and motorcycles**	27,115 (3.23)
3 Fishing and aquaculture	204 (3.98)	**49 Land transport and transport via pipelines**	8,323 (3.46)
5 Mining of coal and lignite	62 (1.71)	**50 Water transport**	958 (5.44)
6 Extraction of crude petroleum and natural gas	27 (10.23)	**51 Air transport**	164 (10.44)
7 Mining of metal ores	574 (9.06)	**52 Warehousing and support activities for transportation**	3,840 (3.35)
8 Other mining and quarrying	3,652 (10.49)	**53 Postal and courier activities**	229 (4.34)
9 Mining support service activities	122 (4.69)	**55 Accommodation**	559 (0.69)
10 Manufacture of food products	13,302 (11.42)	**56 Food and beverage service activities**	1,343 (0.58)
11 Manufacture of beverages	890 (17.35)	**58 Publishing activities**	435 (2.18)
12 Manufacture of tobacco products	49 (38.58)	**59 Motion picture, video and television programme production, sound recording and music publishing activities**	247 (1.25)
13 Manufacture of textiles	20,447 (24.97)	**60 Programming and broadcasting activities**	25 (0.17)
14 Manufacture of wearing apparel	25,776 (24.69)	**61 Telecommunications**	528 (2.60)
15 Manufacture of leather and related products	5,944 (24.03)	**62 Computer programming, consultancy and related activities**	1,977 (2.45)
16 Manufacture of wood and of products	3,319 (12.26)	**63 Information service activities**	125 (1.71)
17 Manufacture of paper and paper products	5,971 (29.71)	**68 Real estate activities**	773 (0.89)

18 Printing and reproduction of recorded media	3,323 (8.34)	**69 Legal and accounting activities**	187 (0.55)
19 Manufacture of coke and refined petroleum products	467 (17.45)	**70 Activities of head offices; management consultancy activities**	1,377 (2.10)
20 Manufacture of chemicals and chemical products	10,254 (26.47)	**71 Architectural and engineering activities; technical testing and analysis**	5,063 (2.31)
21 Manufacture of basic pharmaceutical products	964 (27.81)	**72 Scientific research and development**	295 (3.81)
22 Manufacture of rubber and plastic products	18,460 (25.17)	**73 Advertising and market research**	1,876 (2.68)
23 Manufacture of other non-metallic mineral products	10,093 (15.59)	**74 Other professional, scientific and technical activities**	1,100 (2.48)
24 Manufacture of basic metals	5,915 (23.51)	**75 Veterinary activities**	49 (0.71)
25 Manufacture of fabricated metal products	25,903 (20.43)	**77 Rental and leasing activities**	456 (1.57)
26 Manufacture of computer, electronic and optical products	2,266 (24.86)	**78 Employment activities**	83 (0.82)
27 Manufacture of electrical equipment	10,186 (26.54)	**79 Travel agency, tour operator and other**	1,260 (1.53)
28 Manufacture of machinery and equipment n.e.c	31,976 (33.25)	**80 Security and investigation activities**	382 (1.62)
29 Manufacture of motor vehicles, trailers and semi-trailers	8,216 (31.26)	**81 Services to buildings and landscape activities**	595 (1.07)
30 Manufacture of other transport equipment	1,597 (21.38)	**82 Office administrative, office support and other**	1,488 (3.45)
31 Manufacture of furniture	11,980 (18.51)	**85 Education**	289 (0.30)
32 Other manufacturing	8,688 (19.83)	**86 Human health activities**	641 (0.62)
33 Repair and installation of machinery and equipment	5,654 (10.41)	**87 Residential care activities**	15 (0.49)

35 Electricity, gas, steam and air conditioning supply	468 (0.92)	**88 Social work activities without accommodation**	35 (0.18)
36 Water collection, treatment and supply	67 (6.01)	**90 Creative, arts and entertainment activities**	169 (2.69)
37 Sewerage	111 (7.72)	**91 Libraries, archives, museums and other**	27 (4.34)
38 Waste collection, treatment and disposal activities	782 (6.84)	**92 Gambling and betting activities**	7 (0.21)
39 Remediation activities and other	28 (10.61)	**93 Sports activities and amusement and recreation activities**	271 (1.07)
41 Construction of buildings	9,877 (1.44)	**94 Activities of membership organizations**	11 (0.23)
42 Civil engineering	2,173 (3.39)	**95 Repair of computers and personal and household goods**	538 (2.78)
43 Specialised construction activities	9,401 (4.23)	**96 Other personal service activities**	379 (0.99)
45 Wholesale and retail trade and repair of motor vehicles and motorcycles	13,690 (7.43)		
Numbers in parentheses show the percentage share of exporting firms in total firms for the corresponding sector group.			

Table A.4. Number of Exporting Firms by Sectors and Green Product Classification

Nace Code	Number of non-green product exporting firms	Number of green product exporting firms	Nace Code	Number of non-green product exporting firms	Number of green product exporting firms
1	2,102	335	**46**	119,590	76,180
2	191	35	**47**	17,419	9,696
3	185	19	**49**	4,606	3,717
5	50	12	**50**	572	386
6	8	19	**51**	114	50
7	511	63	**52**	2,077	1,763
8	3,377	275	**53**	105	124
9	52	70	**55**	318	241
10	12,080	1,222	**56**	847	496
11	683	207	**58**	380	55
12	45	4	**59**	196	51
13	17,200	3,247	**60**	14	11
14	23,375	2,401	**61**	314	214
15	5,427	517	**62**	1,273	704
16	2,339	980	**63**	65	60
17	4,702	1,269	**68**	486	287
18	2,688	635	**69**	127	60
19	380	87	**70**	849	528
20	6,910	3,344	**71**	1,906	3,157
21	743	221	**72**	200	95
22	9,161	9,299	**73**	1,215	661
23	7,201	2,892	**74**	669	431
24	2,877	3,038	**75**	31	18
25	11,351	14,552	**77**	268	188
26	761	1,505	**78**	52	31
27	3,066	7,120	**79**	797	463
28	11,308	20,668	**80**	172	210
29	3,504	4,712	**81**	339	256
30	739	858	**82**	992	496
31	7,081	4,899	**85**	180	109
32	6,244	2,444	**86**	421	220
33	2,022	3,632	**87**	7	8
35	192	276	**88**	22	13
36	7	60	**90**	120	49
37	2	109	**91**	25	2
38	584	198	**92**	4	3
39	7	21	**93**	194	77

41	4,306	5,571	**94**	11	0
42	645	1,528	**95**	303	235
43	3,163	6,238	**96**	269	110
45	5,629	8,061			

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Anabilim Dalı:	İktisat
Programı:	İktisat
Statüsü:	☐ Yüksek Lisans ☒ Doktora ☐ Bütünleşik Doktora

DANIŞMAN GÖRÜŞÜ VE ONAYI

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Prof. Dr. Başak DALGIÇ

Detaylı Bilgi: http://www.sosyalbilimler.hacettepe.edu.tr
Telefon: 0-312-2976860 **Faks:** 0-3122992147 **E-posta**: sosyalbilimler@hacettepe.edu.tr

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Student No:	N11148372
Department:	Economics
Program:	Economics
Status:	☐ MA ☒ Ph.D. ☐ Combined MA/ Ph.D.

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Anabilim Dalı:	İktisat
Programı:	İktisat
Statüsü:	☒ Doktora ☐ Bütünleşik Dr.

DANIŞMAN ONAYI

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Department:	Economics
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