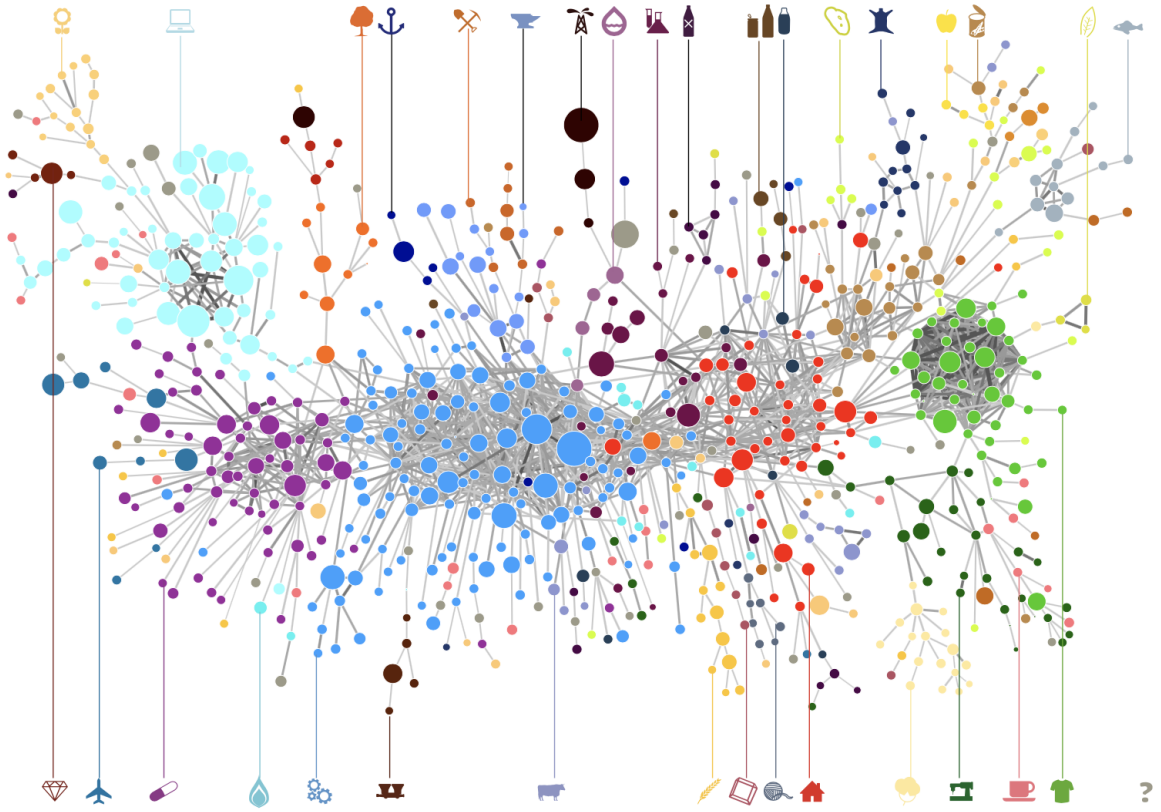

https://atlas.cid.harvard.edu/

Optimal Industry Development Strategy Using Economic and Product Complexity

Turkey

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Optimal Industry Development Strategy for Turkey

0. Executive Summary

In this report, we aim to uncover the economic path Turkey went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Turkey from the perspective of Gross Domestic Product (GDP) and Economic Complexity Index (ECI), which reflect countries' production capability and production structure, respectively. We find that during the period of our interest, Turkey demonstrated a promising level of economic growth with an annual GDP growth rate of -1.9%, concurrent with a stability in economic complexity as compared with other emerging economies in the world.

The level of economic progress made during the period, we believe, can be largely explained through analysis of the economic and product complexity structure of Turkey on the industry group level. The product classification system we adopt allows us to measure the realized industry development for various industry groups and to observe that Turkey strategically invested in developing Services and Utilities, Textile and Clothing and Accessories industries during the period, while its regional peers and emerging economies around the globe have adopted much more progressive growth paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Turkey can further its gains by focusing on Machinery and Construction, and Transportation. We further note that Turkey has a slightly mismatched development strategy that indicates a moderate but not perfect level of fitness with the strategy calculated on a complexity level, having an adjusted R-square of around 21.8%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Turkey indeed adopted a more complex development plan as compared with other emerging economies both on a regional scale and on a global scale, and has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

1. Report Overview

In this report, we aim to uncover the economic path Turkey went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Turkey from the perspective of Gross Domestic Product (GDP) and Economic Complexity Index (ECI), which reflect countries' production capability and production structure, respectively. We then analyze the industrial framework and changes of Turkey during the period based on quantitative measures such as Product Complexity Index (PCI) and Product Family Complexity Index (PfCI), followed by a detailed analysis of how such changes have matched with development strategies as quantitatively measured by opportunity gains on an industry-level. We conclude our report with macro-level results and predictions of Turkey, as deduced from regression models we have established on a global scale, which take into account countries' stances in their product space.

2. Macroeconomic Results

2.1 GDP Ranking and Changes

As the 19th largest economy in the world by GDP, Turkey has a GDP of 950 billion USD in 2013 and 771 billion USD in 2018, exhibiting an extraordinary level of economic output. Figure 1 illustrates the time-series GDP results for European's major economies from 1999-2018, and Turkey ranks among its counterparts as a stable player. Turkey exhibits a consistent level of GDP during the twenty years from 1999 to 2018, however, it only has an average annual growth rate of -1.9% during the period from 2013 to 2018. This rate is clearly below the annual growth rate of the group of leading economies in Europe, which have a geometric average growth rates of 1% and an arithmetic average growth rate of 0.6%. The annual growth rate of -1.9% is particularly in sharp contrast to an annual growth rate of 1.4% for Spain, one of the European's economies with a comparable size and Turkey's competitor in many industries. The stagnant economic growth in Turkey, we believe, can be reflected through consistent ECI and PCI, and can be further explained by a the set of production strategies Turkey adopted during the period, which we will expand at the later stage of the report.

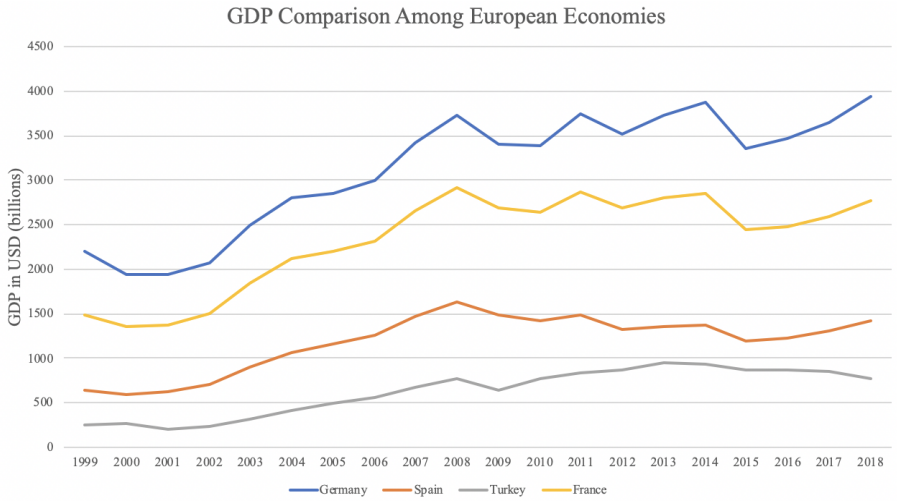


Figure 1: GDP Comparison Among European Economies

2.2 ECI Ranking and Changes

The Economic Complexity Index (ECI), as defined by Ricardo Hausmann and Cesar Hidalgo in 2009 to explain the knowledge accumulated in a country's population, exhibits a similar pattern for Turkey. As illustrated in Figure 2 below, Turkey exhibits a low level of production capability from 2013 to 2018, which is not true for most of the developed economies. This is in direct contrast to countries such as Germany, which demonstrate a advantage in terms of both ECI growth rate and GDP growth during the period.

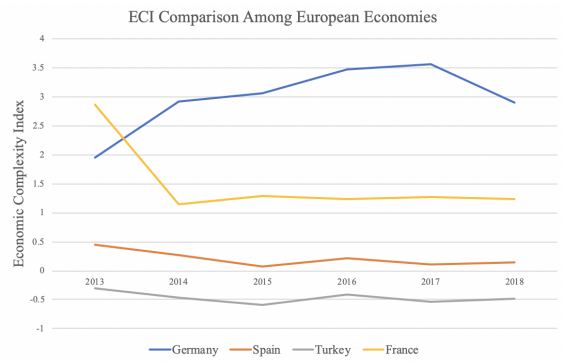


Figure 2: ECI Comparison

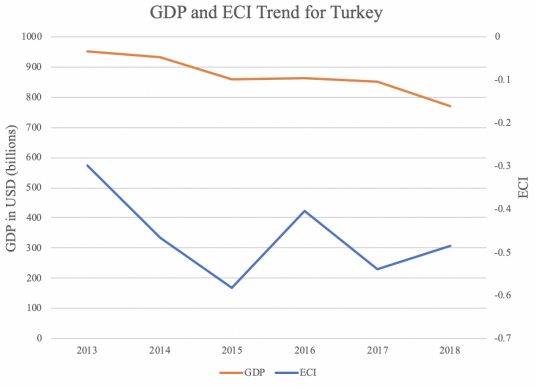


Figure 3: GDP and ECI (Turkey)

Figure 3 offers a further comparison of GDP and ECI over the time span from 2013 to 2018 for Turkey. Based on statistical analysis, ECI is a significant covariate for GDP with an adjusted R-square of 80.5%. In particular, the decrease in GDP during the period from 2013 to 2018 is accompanied by a unstable ECI, indicting the potential that the stagnant economic growth experienced by Turkey during the period from 2013 to 2018 might be attributed to its inconsistent ECI, or the ineffectiveness of the country in developing a competitive product space that helps to accumulate complicated knowledge and technology. In order to provide a more concrete answer to why this has happened, we will dive into an analysis of Turkey's production structure and its product space designs in the next few chapters.

3. Production Analysis

3.1 Product Categorization

Our main data source in this research is the UN Comtrade Website (https://comtrade.un.org), which provides us with valuable information on countries' export values on an annual basis, including highly specific export data for more than 5000 categories of products. In order to have a holistic vision of the product space of a country, however, a level of categorization is required. Products in our data source are labelled from 010000-999999, with the first two-digits representing a general category to which the product belongs. Based on the 99 categories as extracted from the label, we further group the products into 18 most widely-accepted industries, as summarized in Table 1.

Note that the High-complexity Products industry group is not a distinct industry but rather an aggregated industry that encompasses the most complicated products from the most technologically-advanced industries (as measured by PCI). This industry serves as an

indicator for us to quantitatively evaluate how well a country has performed in developing cutting-edge technologies and closing its technical gap with advanced economies, which has become a topic of wide concern today. Indeed, when we rank the 18 categories based on PfCI (an equivalent concept of PCI as calculated based on the 18 categorized product groups), the High-complexity Products industry has the highest PfCI among all industry groups.

Category	Description
Animals and By-products	All kinds of meat, livestock and related by-products
Vegetables, Fruits and Plants	All kinds of plants, edible vegetables and fruits
Food and Preparations	Edible preparations, raw cooking materials and appliances
Clothing and Accessories	All kinds of fabrics, filament, clothing and accessories
Textiles	All kinds of textile articles and related products
Wood Products	Book, paper and other elementary products related to wood
Metals	Mining of all sorts of raw Metals
Refined and Processed Stones	Refined or processed stone products such as pearl and ceramics
Energy Drilling and Mining	Mining industry for energy, minerals, stone materials, etc.
Daily Instruments	Basic daily instruments such as sport requisites, timing and measuring tools
Raw Manufacturing	Basic products made from plastic, rubber, leather, etc.
Chemical Manufacturing	Advanced chemical products and pharmaceutical products
Chemicals	Raw chemical materials and by-products
Machinery and Construction	Machinery and mechanical appliances, including electrical equipment
Transportation	Vehicles and locomotives including aircraft, ship, railway, etc.
Weapons	Explosives, arms and ammunition
Services and Utilities	Financial, business, legal, communication, travel Services and Utilities, etc.
High-complexity Products	Agglomeration of advanced products with highest PCIs

Table 1: Categorization of Products

We further observe a positive correlation between the GDP and the export of High-complexity Products. A higher adjusted R-square exists between GDP and High-complexity Products exports, indicating that more successful economics, as measured by GDP, tend to be those that are capable of producing and exporting High-complexity Products as we define them. The Figure 3 and 4 show the OLS results in a universe of 107 and 21 typical countries respectively.

	High-complexity Products	Food and Preparations	Animals and By-products
Adj.R-squared	0.075	0.006	0.002
F-statistic	9.556	1.638	1.175
No. Observations	107	107	107

Figure 3: OLS Regression Results of GDP against Percentage Volume of Exports

	High-complexity Products	Food and Preparations	Animals and By-products
Adj.R-squared	0.149	0.003	-0.012
F-statistic	4.510	1.059	0.7542
No. Observations	21	21	21

Figure 4: OLS Regression Results of GDP against Volume of Percentage Exports

3.2 Realized Industry Development

Based on the product categorization aforementioned, we aim to capture Turkey's realized industry production strategy between 2013 and 2018 on a complexity level. In Hausmann and Hidalgo (2009), distance is defined to be a measure of how far a country is from a certain product not in its product space. We extend this concept to all product groups and quantify how technically equipped a country is to develop the corresponding product groups. In other words, the shorter the distance between a country and a product group, the more capable a country is in developing products within that group. Defining this net distance change as the Realized Industry Development (RID), our export data allow us to calculate and compare RID of Turkey and the 18 product groups in 2013 and 2018 through subtraction, where a positive RID indicates a shortening of the distance (i.e., advancement of the industry), and a negative RID indicates the reverse. As ranked in Table 2, during the period from 2013 to 2018, Turkey has focused on products with a moderate level of complexity and those requiring intermediate skills.

Rank	Category	RID	Rank	Category	RID
1	Services and Utilities	-0.048	10	Animals and By-products	-0.003
2	Textile	-0.040	11	Machinery and Construction	-0.001
3	Clothing and Accessories	-0.025	12	Chemical Manufacturing	0.007
4	Vegetables, Fruits and Plants	-0.017	13	Wood Products	0.009
5	Food and Preparations	-0.010	14	Chemicals	0.013
6	Raw Manufacturing	-0.009	15	Energy Drilling and Mining	0.015
7	Metals	-0.007	16	High-complexity Products	0.019
8	Precious Stones	-0.006	17	Transportation	0.043
9	Weapons	-0.003	18	Daily Instruments	0.065

Table 2: Realized Industry Development (RID) of Turkey

3.3 Regional and Global Comparison

Table 3 and 4 below summarize how the production strategy adopted by Turkey compares with leading economies and a selected group of emerging economies in the world, as measured in RID. It can be directly observed that Turkey focused on products with a lower complexity level, when compared against leading economies such as the United States and Germany, which gave a considerable level of attention to more advanced product groups such as clothing, services and utilities, and chemical manufacturing.

Ranking	France	The United States	Germany
1	High-complexity Products	Services and Utilities	High-complexity Products
2	Chemical Manufacturing	Weapons	Transportation

3	Daily Instruments	Raw Manufacturing	Wood Products
4	Animals and By-products	Precious Stones	Metals
5	Food and Preparations	Animals and By-products	Food and Preparations

Table 3: RID Comparison across Leading Economies

Ranking	China	South Korea	Singapore
1	High-complexity Products	Transportation	Transportation
2	Transportation	Textile	High-complexity Products
3	Machinery and Construction	High-complexity Products	Precious Stones
4	Energy Drilling and Mining	Chemical Manufacturing	Daily Instruments
5	Daily Instruments	Machinery and Construction	Services and Utilities

Table 4: RID Comparison across Emerging Economies

Table 4 further examines Turkey's development strategy against those of emerging economies on a global scale. Reasonably, emerging economies such as China, South Korea, Singapore and India have devoted the majority of their efforts into intermediate industry groups while developed economies such as Turkey should have relied more on advanced industry groups. This trend holds true in general, regardless of the continent or the time period, and serves as an indicator for which phase of development a country is currently in as evaluated from its production strategy. Based on this standard, Turkey is indeed adopting a moderate but slightly out-of-phase strategy that seeks development in industry groups with a lower level of complexity than it should.

4. Product Space Design

4.1 Suggested Development Vector

As aforementioned, distance gives us an idea of how far each new product is from a country's current mix of exports. As defined in Hausmann and Hidalgo (2009), distance is "the weighted proportion of products connected to goods p that country c is not exporting, i.e., MCP=0." Based on this definition, the distance between a country and any product that the country is currently exporting (i.e., the country is a significant exporter in the product as compared to global average) is zero. Similarly, opportunity gain quantifies the contribution of a new product in term of opening up the doors to more and more complex products. Intuitively, a product that a country is currently exporting (i.e., MCP=1) has an opportunity gain of zero. And unreasonable investment on certain product p would lead to a relative decrement in export of more profitable products, and therefore lead to a negative opportunity gain of product p. The opportunity gain is not the only estimator of a country's level of economic development. However, among countries with comparable economics strength, those having higher ECI, or in other words, more reasonable economics structures are often in better shape.

Ranking	Italy	Greece	Turkey
1	Energy Drilling and Mining	Precious Stones	Energy Drilling and Mining
2	Precious Stones	Weapons	Machinery and Construction
3	Vegetables, Fruits and Plants	Clothing and Accessories	High-complexity Products
4	Animals and By-products	Machinery and Construction	Animals and By-products
5	Food and Preparations	Services and Utilities	Services and Utilities
6	Chemical Manufacturing	High-complexity Products	Weapons
7	Raw Manufacturing	Daily Instruments	Daily Instruments
8	Wood Products	Transportation	Transportation
9	Clothing and Accessories	Chemicals	Chemical Manufacturing
10	Textile	Animals and By-products	Chemicals
11	Metals	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
12	Machinery and Construction	Food and Preparations	Food and Preparations
13	Daily Instruments	Energy Drilling and Mining	Raw Manufacturing
14	High-complexity Products	Chemical Manufacturing	Wood Products
15	Weapons	Raw Manufacturing	Clothing and Accessories
16	Chemicals	Wood Products	Textile
17	Services and Utilities	Textile	Metals
18	Transportation	Metals	Precious Stones
ECI	1.179705915	-0.232930358	-0.314199878

Ranking	Italy	Greece	Turkey
1	Energy Drilling and Mining	Precious Stones	High-complexity Products
2	Precious Stones	Clothing and Accessories	Energy Drilling and Mining
3	Animals and By-products	High-complexity Products	Transportation
4	Vegetables, Fruits and Plants	Transportation	Machinery and Construction
5	Weapons	Machinery and Construction	Animals and By-products
6	Food and Preparations	Weapons	Weapons
7	Chemical Manufacturing	Chemicals	Services and Utilities
8	Raw Manufacturing	Services and Utilities	Daily Instruments
9	Wood Products	Daily Instruments	Chemicals
10	Clothing and Accessories	Animals and By-products	Chemical Manufacturing
11	Textile	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
12	Metals	Food and Preparations	Food and Preparations
13	Machinery and Construction	Energy Drilling and Mining	Raw Manufacturing
14	Daily Instruments	Chemical Manufacturing	Wood Products
15	High-complexity Products	Raw Manufacturing	Clothing and Accessories
16	Chemicals	Wood Products	Textile
17	Services and Utilities	Textile	Metals
18	Transportation	Metals	Precious Stones
ECI	0.878356738	-0.425579783	-0.468281415

Table 5: Opportunity Gain Ranking on a Regional Scale for 2013(up) and 2018(down)

We define the ranking of opportunity gain for a country c, as the Suggested Development Vector (SDV) of c. Table 5 and 6 summarize how the SDV of Turkey compares with a selected group of regional and leading economies in the world, with the industry groups ranked in decreasing order of significance. Dark blue indicates positive opportunity gain, light blue indicates zero opportunity gains, and white indicates negative opportunity gains. The result shows that leading countries barely have any industries with positive opportunity gain. In other words, those countries are already in the most stable and efficient economic structure. Without the necessity of economic transition, those countries merely need to maintain a steady and balanced economic development. In contrast, developing countries have nearly half of industries with positive opportunity gain, and share common interests in industrial manufacturing and High-complexity Products industries. It can be concluded that

Turkey shares the characters of developing countries, with a premature economics structure that leans towards basic to intermediate level industries.

Ranking	USA	Germany	Singapore	Japan
1	Energy Drilling and Mining	Chemical Manufacturing	Chemicals	Chemicals
2	Precious Stones	Wood Products	Transportation	Metals
3	Animals and By-products	Metals	High-complexity Products	Machinery and Construction
4	Vegetables, Fruits and Plants	Machinery and Construction	Services and Utilities	Transportation
5	Food and Preparations	Transportation	Machinery and Construction	Weapons
6	Chemicals	Weapons	Daily Instruments	Daily Instruments
7	Chemical Manufacturing	High-complexity Products	Weapons	High-complexity Products
8	Raw Manufacturing	Services and Utilities	Textile	Services and Utilities
9	Wood Products	Energy Drilling and Mining	Chemical Manufacturing	Precious Stones
10	Machinery and Construction	Precious Stones	Raw Manufacturing	Energy Drilling and Mining
11	Weapons	Textile	Clothing and Accessories	Textile
12	Daily Instruments	Clothing and Accessories	Metals	Clothing and Accessories
13	High-complexity Products	Chemicals	Wood Products	Chemical Manufacturing
14	Services and Utilities	Animals and By-products	Precious Stones	Animals and By-products
15	Clothing and Accessories	Vegetables, Fruits and Plants	Animals and By-products	Wood Products
16	Metals	Food and Preparations	Food and Preparations	Vegetables, Fruits and Plants
17	Textile	Daily Instruments	Energy Drilling and Mining	Food and Preparations
18	Transportation	Raw Manufacturing	Vegetables, Fruits and Plants	Raw Manufacturing
ECI	1.220401303	1.937171566	2.751108815	2.154947

Table 6: Opportunity Gain Ranking on a Global Scale

4.2 Budgeted Industry Development Strategy and Interpretation

The optimal budgeted industry development strategy aims to solve the most efficient allocations under the budgeted constraint of different situations of heuristic total export growth. In order to obtain such an allocation portfolio, we formulate an optimization problem as the following:

$$\max_{x \in \mathbf{R}^{|P|}} \quad \left(\frac{k(x) - < k(x) >}{stdev(k(x))}\right)_C$$

Subject to

$$\sum_{p \in P} x_p \leq B$$

$$x \succcurlyeq 0$$

where k(x) is the second largest eigenvector of $M_{CC'}$ after adding x to the original export vector, C is the country that we are interested in, P is the product space, B is the heuristic budget.

If we can solve this problem, then we can know what the largest ECI that a country can improve to. Accordingly, the optimal solution x * that we obtain here is exactly our optimal allocation. However, the biggest problem is that the objective function is not convex. Therefore, we cannot apply the classical tools for convex optimization on this problem. In order to solve this problem, our idea is to use greedy algorithm. The way that we apply greedy algorithm is that firstly we separate the total budget into k equal parts, and then for the first equal part we try to search for the product that can optimize our objective function by iterating through each $p \in P$. After we find the optimal product p for this equal part, we add the amount back to the export value of this product p and update the ECI for this country. If we observe that ECI does not change after iterating all the products, then we can add up one

more equal part to invest. Until we find there is an ECI increment, we add the amount now to that product. The rest equal parts can be done in the same way.

However, as is known to all, greedy algorithm is a kind of local search algorithm, which is pretty possible to run into a local minimum. Therefore, for local search algorithms, one typical way is to keep it away from the local minimum is to enhance the vision of the algorithm by looking more steps forward. In our setting, whenever we obtain an increment of ECI, we mark down the required amount of export growth. Simultaneously, we continue searching for the next ECI increment point, compare the ratios of these two possibilities and pick the largest one. The ratio is defined as the following:

$$Ratio(p) = \frac{ECI_p - ECI_0}{||x_p - x_0||_1}$$

where ECI_p is just the ECI of the country after adding some amount of export increment to product p, which is exactly the amount that is able to make ECI change. Also, we can express it in the way of $||x_p - x_0||_1$.

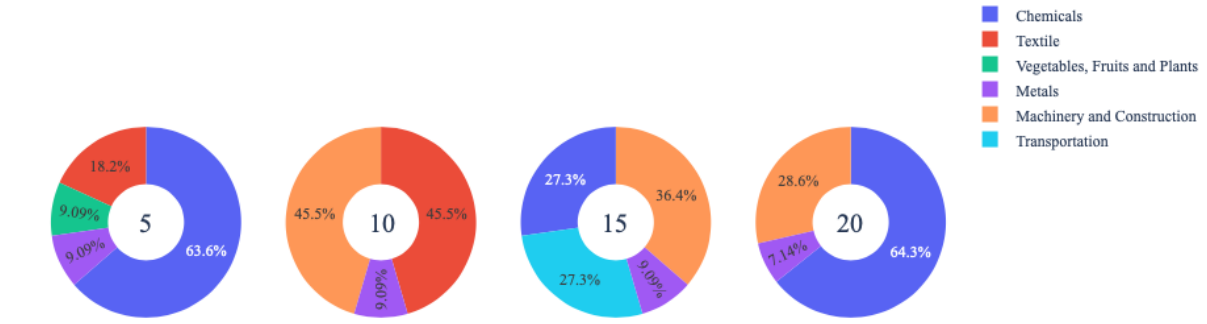
In this way, we can obtain a further sighted greedy algorithm. Also, the number of parts that we would like to separate the budget into also matters. In order to solve this problem, we added a stabilizer on top of the enhanced greedy algorithm, by running the algorithm for different number of parts and selecting the portfolio with the largest ECI increment and most complex economic structure.

Besides, it is quite common that there is a surplus for the budget. To deal with the surplus, we just add it to the product which needs the least amount of dollar to make M_{cp} = 1, (i.e., the smallest amount of required export increase).

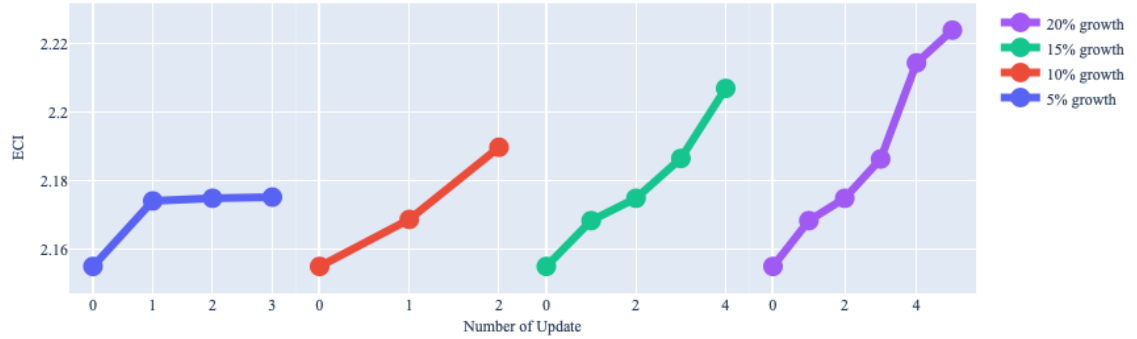
Economic Panel:

As stated above, the enhanced greedy algorithm is developed mainly for solving the optimal allocation strategy. In order to visualize this allocation, an economic panel is created, consisting of a pie chart, a line chart and a table. Firstly, a pie chart is used to show the percentage of each product in the optimal portfolio. The number located in the center of the circle denotes the heuristic growth of total export, which is also our budget. For example, for the first pie chart below, it shows we should allocate 25% for food and preparations, animals and by-products, and chemicals. In addition, we should allocate 12.5% for raw manufacturing and chemical manufacturing. The lines below the pie charts show how the ECI changes during the searching process of the greedy algorithm. For example, in the last pie chart, we can see there are three components, but there are four increments in the last line chart. That is just because many equalized amounts have been invested in high-complexity products. Even though sometimes people may feel 15% and 20% is nonsense to developed countries, yet it can also give a sense of how a country should develop in the long term. Eventually, the graph in the end is just for numerical explanation for the pie charts.

Japan ECI Growth Optimization Result



Japan ECI Increment

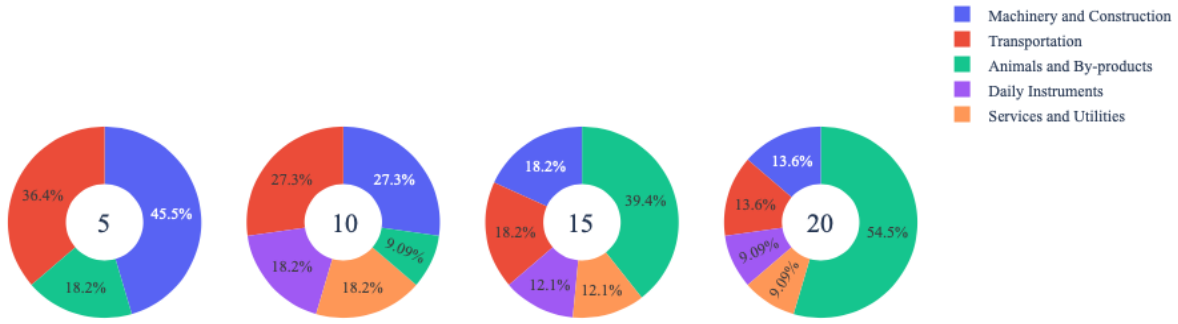


Japan (2013)				
Total Export in 2013 (US. $)	1.17E+12			
Original ECI	2.155			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	5.86E+10	1.17E+11	1.76E+11	2.35E+11
Metals(US. $)	5.33E+09	1.07E+10	1.60E+10	1.68E+10
Transportation(US. $)	0.00E+00	0.00E+00	4.80E+10	0.00E+00
Chemicals(US. $)	3.73E+10	0.00E+00	4.80E+10	1.51E+11
Machinery and Construction(US. $)	0.00E+00	5.33E+10	6.40E+10	6.70E+10
Textile(US. $)	1.07E+10	5.33E+10	0.00E+00	0.00E+00
Vegetables, Fruits and Plants(US. $)	5.33E+09	0.00E+00	0.00E+00	0.00E+00
Increased ECI	2.175	2.190	2.207	2.224

Interpretation:

Below is the economic panel for Turkey in 2013. We can see that for different percentages of heuristic total export growth, the ECI of Turkey has similar performance. From all the four line graphs, we see that Turkey already obtains some great increment in terms of ECI. However, increasing the budget for too large an amount would not produce a higher and higher ECI. One thing to notice is that, even though the growth pattern does not change a lot, the eventual ending point is quite high, which is around three times of the original ECI. This means that in short terms, Turkey still has great room to improve. For the four export growth budget, the increment primarily attributes to Transportation, machinery and construction, services and utilities and daily instruments equally. Therefore, Turkey should focus on developing machinery and construction, and transportation industry first. Afterwards, developing services and utilities, and the daily instruments industry can also result in a ECI growth.

Turkey ECI Growth Optimization Result

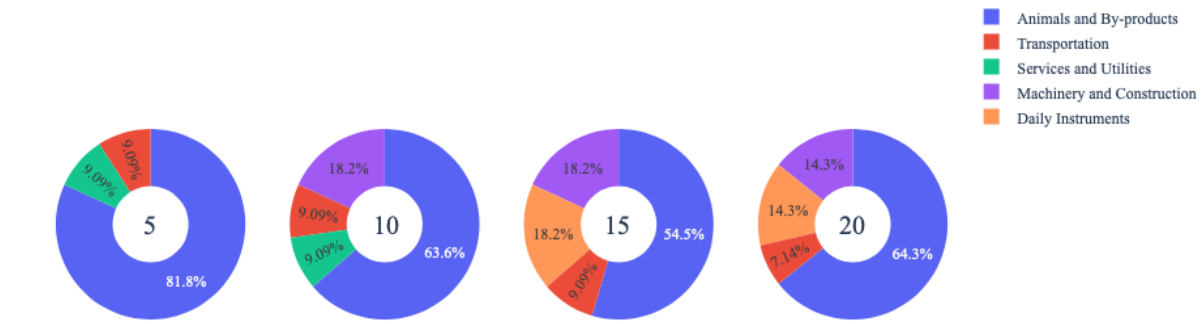


Turkey ECI Increment

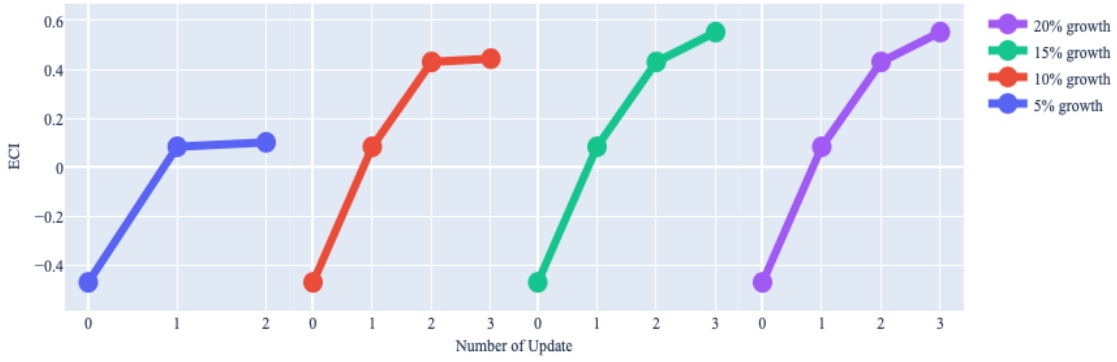
Turkey (2013)				
Total Export in 2013 (US. $)	1.95E+11			
Original ECI	- 0.314			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	9.76E+09	1.95E+10	2.93E+10	3.90E+10
Daily Instruments(US. $)	0.00E+00	3.55E+09	3.55E+09	3.55E+09
Machinery and Construction(US. $)	4.43E+09	5.32E+09	5.32E+09	5.32E+09
Animals and By-products(US. $)	1.77E+09	1.77E+09	1.15E+10	2.13E+10
Services and Utilities (US. $)	0.00E+00	3.55E+09	3.55E+09	3.55E+09
Transportation(US. $)	3.55E+09	5.32E+09	5.32E+09	5.32E+09
Increased ECI	0.538	0.742	0.742	0.742

For further suggestions on Turkey's development in the future. We also offer the optimization result of Turkey based on export data in 2018. Below is the economic panel for Turkey in 2018. We can see that for different percentages of heuristic total export growth, the ECI growth pattern of Turkey is different from the one in 2013. From all the four line graphs, we see that Turkey obtains a different extent of great increment in terms of ECI. This means that Turkey still has great room to improve. For the case of 5 percent export growth budget, transportation and services industry accounts for the ECI increment, For the case of 10 percent, machinery and construction can also increase a little for ECI. For the case of 15 and 20 percent of export growth budget, the result shows that adding daily instruments as a growth component can bring lots of gains. Therefore, for future strategy, Turkey should prioritize development of transportation, which causes the first jump in all line graphs, and then transportation and machinery. in order to optimize ECI.

Turkey ECI Growth Optimization Result



Turkey ECI Increment



Turkey (2018)				
Total Export in 2018 (US. $)	2.24E+11			
Original ECI	- 0.47			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	1.12E+10	2.24E+10	3.36E+10	4.48E+10
Animals and Byproducts (US. $)	9.16E+09	1.42E+10	1.83E+10	2.88E+10
Machinery and Construction (US. $)	0.00E+00	4.07E+09	6.11E+09	6.40E+09
Transportation (US. $)	1.02E+09	2.04E+09	3.05E+09	3.20E+09
Daily Instruments (US. $)	0.00E+00	0.00E+00	6.11E+09	6.40E+09
Services and Utilities (US. $)	1.02E+09	2.04E+09	0.00E+00	0.00E+00
Increased ECI	0.10	0.44	0.55	0.55

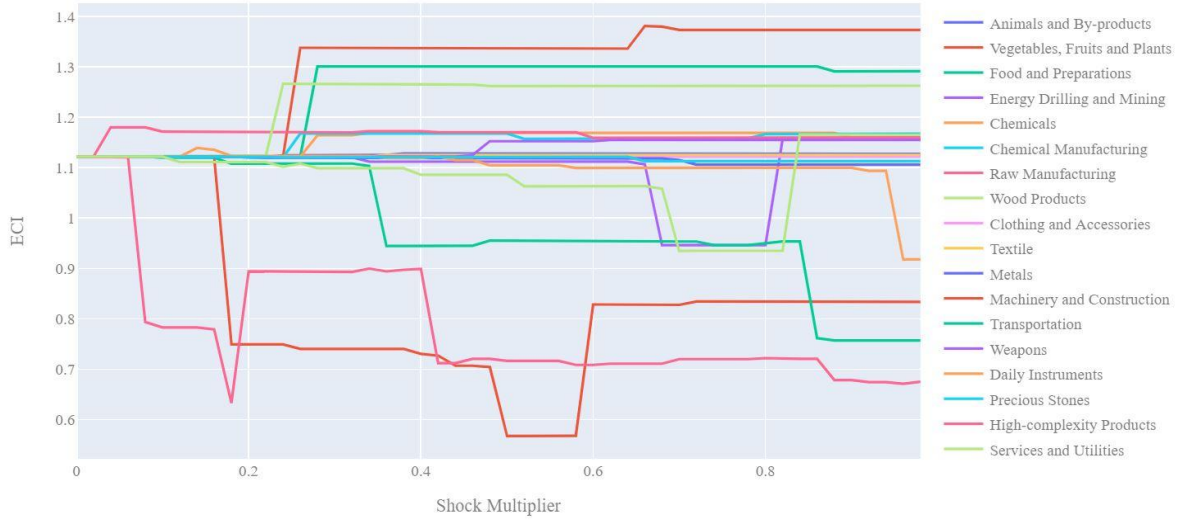
4.3 Sensitivity Analysis

In the following section our broad aim is to understand how sensitive Turkey is to changes in export in various industries. While the Economic Complexity Index has been shown to contain valuable information about the economic strength/capacity of a country, little has been said as to the stability of the measure itself. We seek to uncover the main drivers of stability under a country's ECI score and better understand longer-term projections for ECI growth. Additionally, gaining an intuition on the industries that are bolstering an economy and the industries that offer the greatest return per unit of investment is best done through visualization of industry specific sensitivity.

ECI Sensitivity Graph

Firstly, in order to assess the effect particular industries have on each respective country, we developed ECI Sensitivity graphs. We use shocking methodology to increment or decrement an industry's export level by a certain percentage and recalculate the ECI all else being equal. While freezing the export dynamics of the rest of the world and enacting an instantaneous shock in export for a particular industry and country may not reflect real-life dynamics, what it does offer us is an understanding of a country's level of dependency on an industry in the context of ECI. The shocking is done in small percentage increments in order to smooth out the resulting curve. Additionally, a recurring theme one will see is that for most industries, a breaking point occurs where the ECI either jumps upwards or downwards, creating a hockey stick shape rather than a linear trend. While the inflection point may not be accurate in context of real life, comparing the various inflection points across industries can give us valuable insight.

The graphs are formulated as follows: There are four ECI Sensitivity graphs. The first two represent data from 2018. The first chart shows positive shocking in which export numbers are shocked upwards per industry. The X-axis is in terms of percentage shock per current dollar value of export. The Y-axis is the recalculated ECI level post-shocking. The second chart follows the same format except the X-axis represents negative shocking. In other words, exports for each industry are decremented and the ECI is accordingly recomputed. The final two sensitivity graphs show the same results using 2013 data. Below is an example of an ECI sensitivity graph.

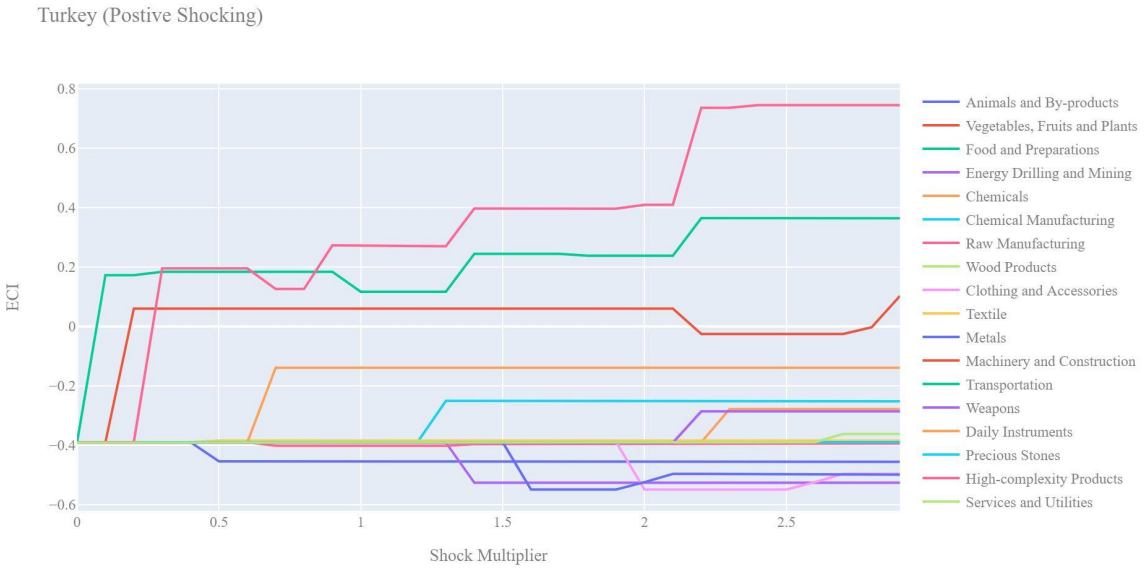


Example 2018 (Incremental ECI Sensitivity)

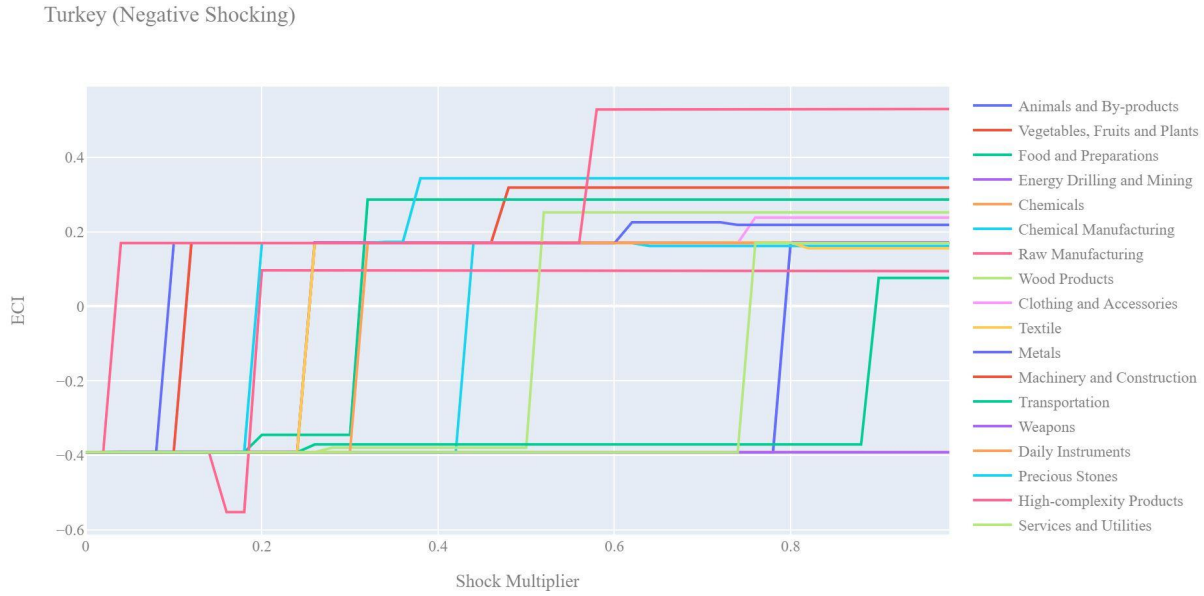
4.3 Sensitivity Analysis Results and Interpretation

Below is Turkey's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that increase in exports in High Complexity Products, Machinery and Construction, and Transportation lead to very fast expansion in ECI. Increases in export of Daily Instrument can also boost ECI however over 50% of export expansion is required and the ECI level plateaus a bit above the -0.2 level. All other industries tend to not greatly affect the ECI level making it fairly clear which industries to pursue.

Next we consider Turkey's 2018 Negative Shock chart. Interestingly decreases in exports from quite a few industries actually increase the ECI level. This may suggest that Turkey is not operating at an optimal blend of export types. A better course of action could be to pursue one of three industries listed above that lead to immediate ECI improvements.



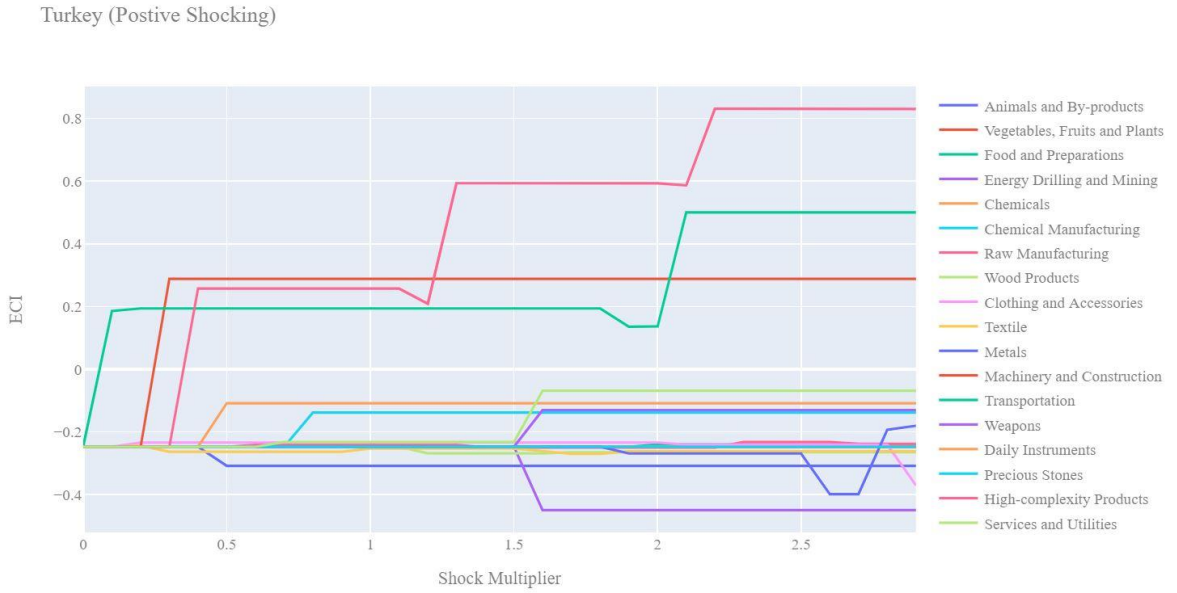
Turkey 2018 (Incremental ECI Sensitivity)



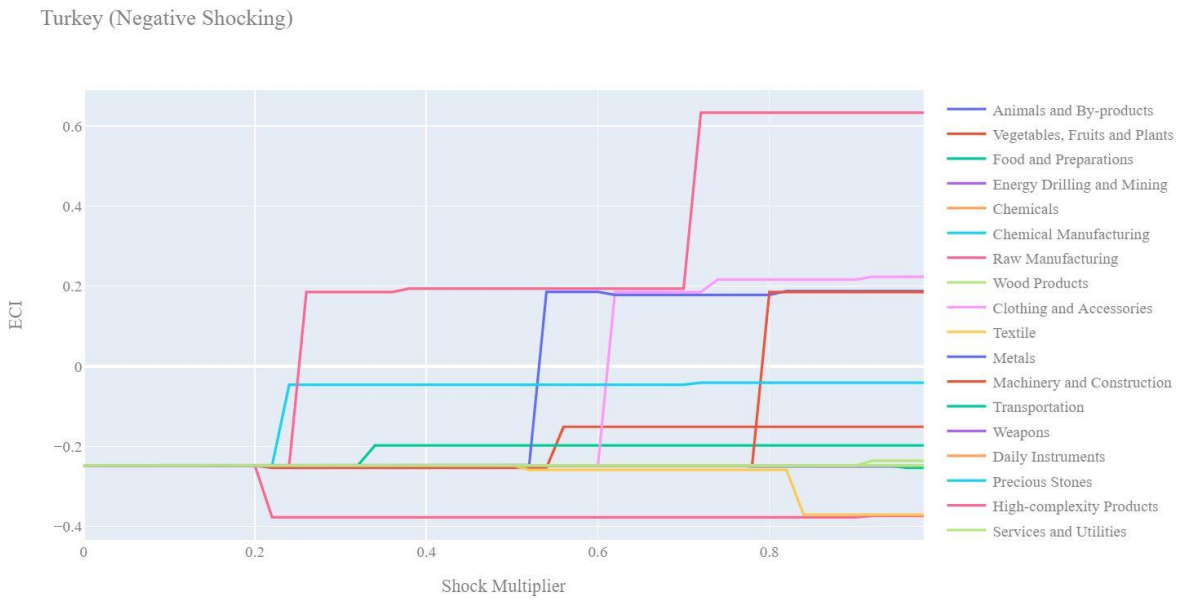
Turkey 2018 (Decremental ECI Sensitivity)

Next we consider the 2013 ECI Sensitivity graphs. We see that the profile in the positive shocking case is very similar to the 2018 case. Increase in exports in High Complexity Products, Machinery and Construction, and Transportation lead to very fast expansion in ECI.

More interestingly, in the 2013 negative shocking case, we see that Turkey seems to much less sensitive to economic downturns than in the 2018 case. Drops of over 20% are required to see any effect in the ECI level. That being said, we still see quite a few industries that increase ECI as export levels decrease.



Turkey 2013 (Incremental ECI Sensitivity)



Turkey 2013 (Decremental ECI Sensitivity)

5. Macro-level Predictions

5.1 Structural Optimality Index

Indeed, such choice of prioritization has proven to be a significant factor in deciding the economic outcomes of countries. In order to quantitatively evaluate how effective our development strategies are and how deviations from the suggested developmental path will lead to suboptimal growth results, we define the measure – Structural Optimality Index (SOI) – on a country level as the Adjusted R-Square obtained from regressing the country's realized industry development over the suggested development strategy. Both strategies are quantified in nature, with the realized development represented by export increase in every major industry group and the suggested development strategy represented by the opportunity gains of developing the corresponding industry groups as calculated in previous sections. The adjusted R-square from the regression thus provides us with a quantified measure of how the development path adopted by the country has fitted with/differed from calculations on a complexity level.

After obtaining this measure for all countries in our database, we further regress countries' five-year economic growth, which is defined as the percent increase in GDP (USD), over their SOI. Figure 6 illustrates the regression output, which shows a strong positive correlation between countries' SOI and their five-year GDP growth, significant at the 1% level and achieving an adjusted R^2 of 4.5%. In other words, the more a country develops as suggested by calculations on a complexity level, the better economic outcomes it achieves.

Table 18: OLS Regression Results	
Dep. Variable: GDP	**F-Statistic:** 5.963
R^2: 0.054	**Prob (F-Stat):** 0.0163
Adj R^2: 0.045	**No. Observations:** 106

Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Turkey and Its Implications

Turkey, for instance, has a moderate level of structural optimality as compared with its emerging peers. As the regression in Figure 7 suggests (the orange curve represents RDI and the blue curve stands for opportunity gain of the corresponding industry), Turkey in various industries demonstrates a high level of correlation with the opportunity gains of those industries, having an adjusted R-square (i.e., SOI) of around 21.8%. In fact, Turkey ranks among the fastest growing countries, 36.7% GDP Growth from 2013 to 2018, and has one of the highest SOI's, which is consistent with the regression result in Figure 6. The situation in Turkey is in direct contrast to that in developed economies such as Japan, where there is a small SOI of around -4.8% and a corresponding 5-year growth rate of merely 9.0%, ranking it a slow-developing economy during the period. In sum, Turkey's stable economic progress from 2013 to 2018 can be at least partially explained by a development strategy that demonstrates a considerable level of matching with our suggested developmental path. In specific, Turkey should have focused more on moderately complex industry groups such as Chemical Manufacturing and Daily Instruments.

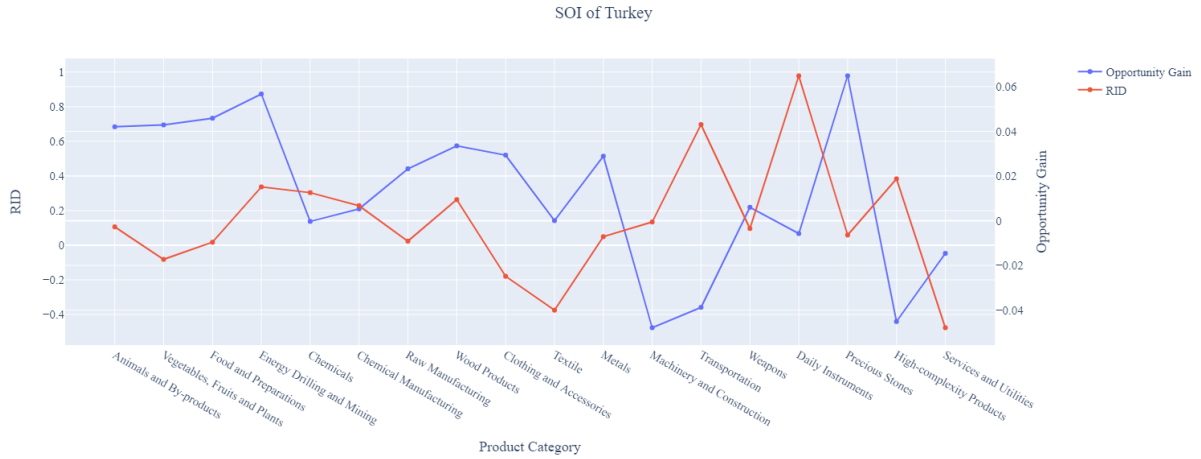


Figure 7: SOI of Turkey (2013-2018)

6. Concluding Remarks

In conclusion, Turkey has demonstrated a promising level of economic growth in terms of GDP during the period from 2013 to 2018, concurrent with a stability in economic complexity as compared with other emerging economies in the world.

The level of economic progress made during the period, we believe, can be largely explained through analysis of the economic and product complexity structure of Turkey on the industry group level. The product classification system we adopt allows us to measure the realized industry development for various industry groups and to observe that Turkey strategically invested in developing Services and Utilities, Textile and Clothing and Accessories industries during the period, while its regional peers and emerging economies around the globe have adopted much more progressive growth paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Turkey can further its gains by focusing on Machinery and Construction, and

Transportation. We further note that Turkey has a slightly mismatched development strategy that indicates a moderate but not perfect level of fitness with the strategy calculated on a complexity level, having an adjusted R-square of around 21.8%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Turkey indeed adopted a more complex development plan as compared with other emerging economies both on a regional scale and on a global scale, and has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

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