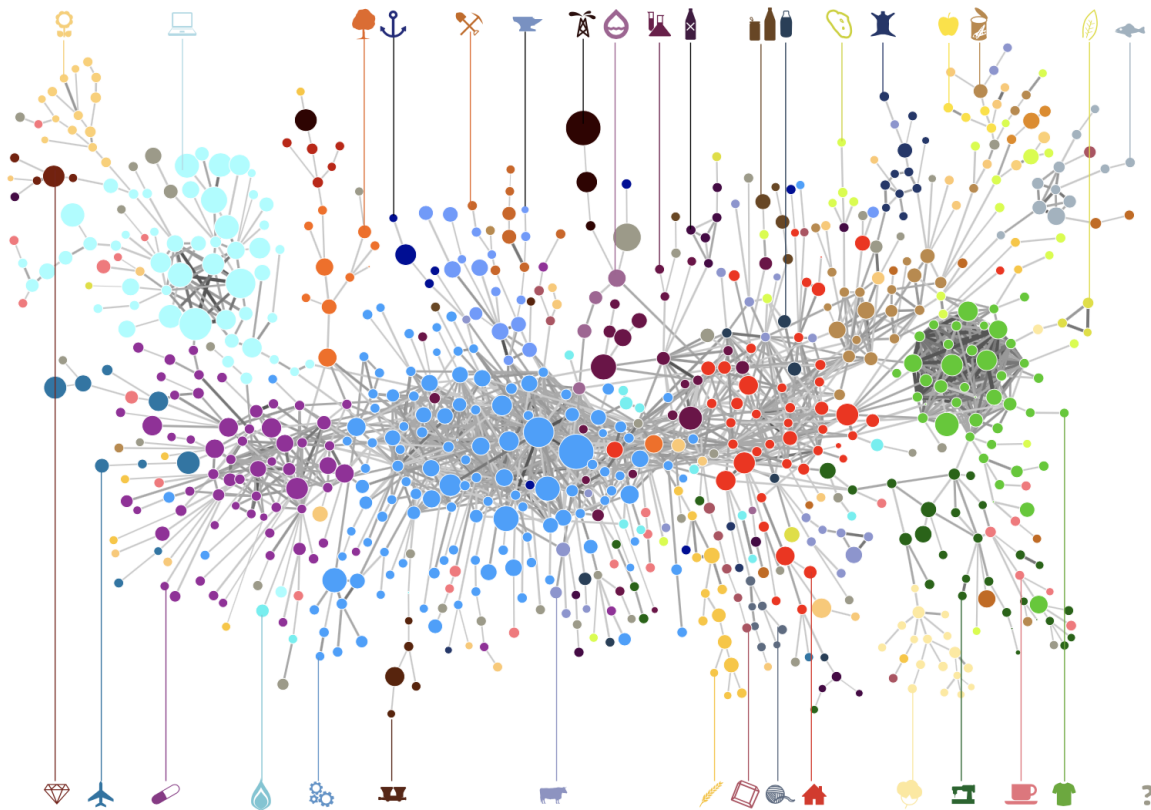




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Optimal Industry Development Strategy Using Economic and Product Complexity

Kuwait

—The Economic Complexity Lab - Columbia University

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Optimal Industry Development Strategy for Finland

0. Executive Summary

In this report, we uncover the economic path Kuwait went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Finland 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, Kuwait demonstrated a relatively low level of economic growth with an average annual GDP growth rate of 1.54%, concurrent with a decrease in economic complexity as compared with other major developed economies. Average annual GDP growth increased to 3.4% in 2021 and its economic complexity decreased as a direct result of the pandemic, in line with other major developed economies during this time period.

The lack of progress during the period can be partially explained through analysis of the economic and product complexity structure of Kuwait on the industry group level. The product classification system we adopt allows us to measure the realized development for various industry groups and to observe that Kuwait consistently relied on developing the Energy Drilling and Mining industry during the period, while its developed counterparts and emerging economies around the globe have adopted much more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Kuwait can further its gains by prioritizing High Complexity Products and Daily Instruments. We further note that Kuwait has a relatively mismatched development strategy that indicates a moderately low (compared to other developed countries such as Turkey) level of structural optimality on the complexity level, having an adjusted R-square of around 5.38%. A significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, but Kuwait has a suboptimal growth experience as compared with fast-growing economies both on a regional scale and on a global scale. However, the country has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

1. Report Overview

We aim to uncover the economic path Kuwait went through during the period from 2013 to 2018, and the impact of COVID-19 on its economic development as observed in 2021. Specifically, we dive into the topic through a macroeconomic overview of Kuwait 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 of Kuwait 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 changes to this framework 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 Kuwait, 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

Figure 1 illustrates the time-series GDP results for Kuwait and three of its peer countries (Qatar, Saudi Arabia, and the United States) from 2013-2018. In contrast to the other countries, which generally displayed either constant or upwards growth over all years, Kuwait had a noticeable dip in GDP from 2014-2015. Additionally, Kuwait's average annual growth rate of 1.54% over the five-year period is lower relative to its peers, which are 3.22%, 3.88%, and 5.41% for Sweden, Norway, and Denmark respectively.

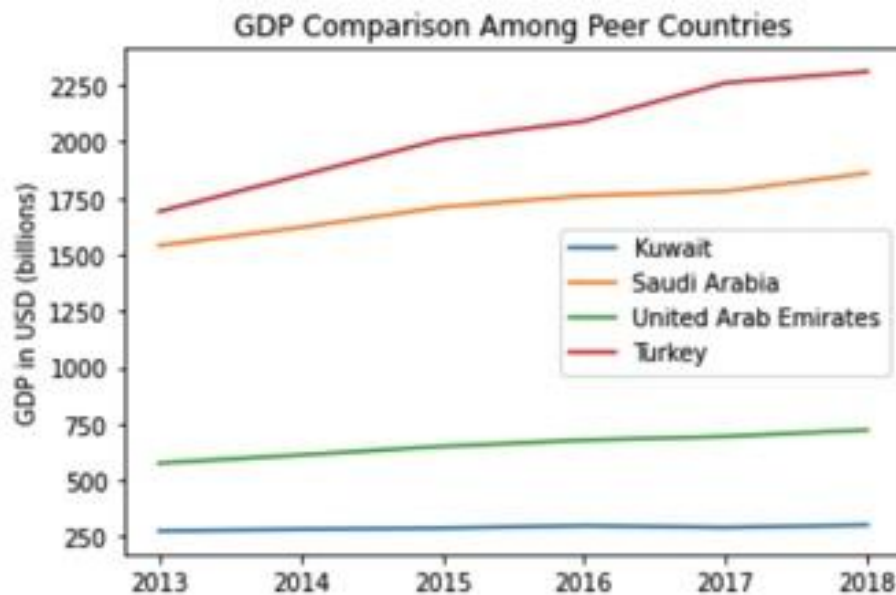


Figure 1: GDP Comparison Among Peer Countries (2013-2018)

Figure 2 illustrates the time series GDP results in 2019-2021. Both Kuwait and its comparable countries experienced a very similar trend with a slight decrease in GDP from 2019 to 2020 followed by a strong recovery by 2021. The initial decrease can be attributed to the impact of COVID-19 and the onset of the pandemic. However, all countries were able to not only recover from the initial decline seen in 2020, but to also increase their GDP to higher levels than before the pandemic. This is a strong indication that Kuwait and its comparable countries were successful in handling the economic challenges of the pandemic.

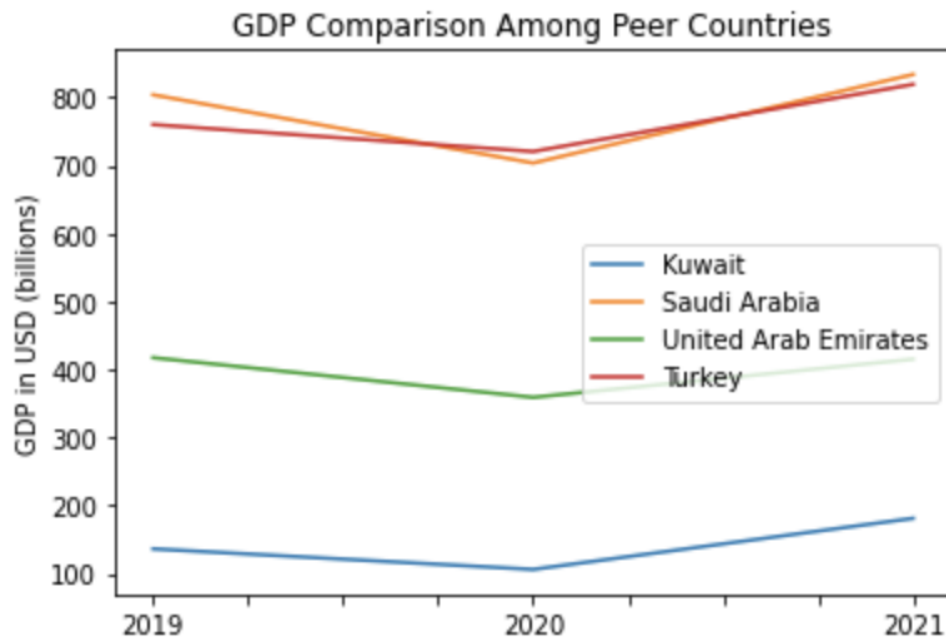


Figure 2: GDP Comparison Among Leading Economies (2019-2021)

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 growth pattern for Finland. As illustrated in Figure 3 below, Kuwait (76.91% ECI change) exhibited an increase in terms of its production capability from 2013 to 2018, to a much smaller extent than Turkey (473.18%) compared to decreases in the United Arab Emirates (-18.38%) and Turkey (-21.27%). Ultimately, Kuwait performs moderately amongst its peer country set, as it displays a low GDP growth rate and relatively median ECI change across the period.

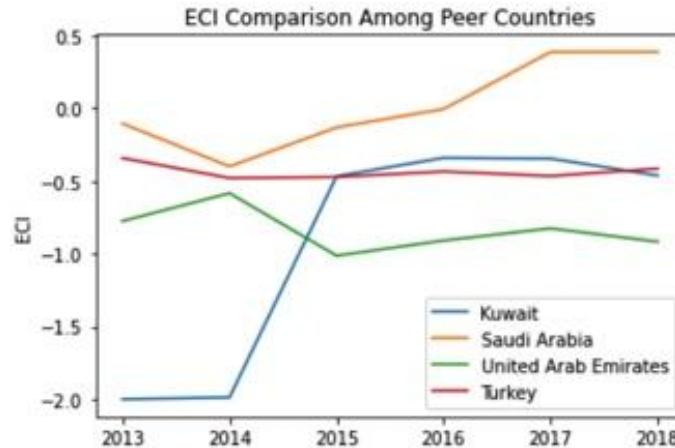


Figure 3: ECI Comparison (2013-2018)

However, as shown in Figure 4, Kuwait's ECI did not drastically change as much as the ECI did for its comparable countries. Kuwait experiences a slight decrease in its ECI index during the period between 2019 and 2020. No data was available for the ECI index for Kuwait during the year 2021. Turkey experienced a similar trend as Kuwait, with no significant change during the period. United States Arab Countries was the only one among the comparable countries group which experienced a significant increase in its ECI level. It was the only country to show positive growth during the period between 2019 and 2020 and then experienced a even more significant increase between 2020 and 2021. Saudi Arabia experienced a slight increase followed by a drastic decrease in its ECI index.

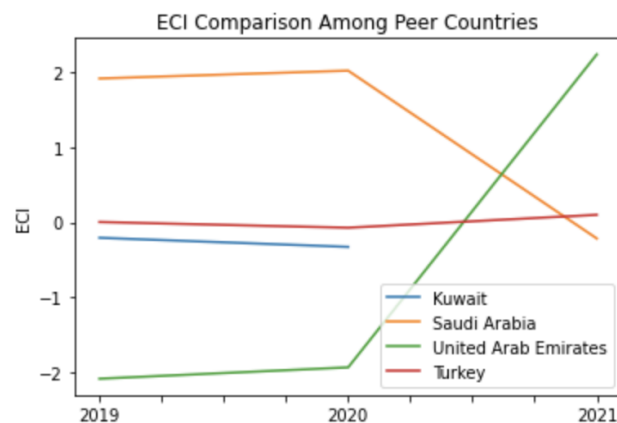


Figure 4: ECI Comparison (2019-2021)

Figure 5 offers a further comparison of GDP Growth and ECI over the time span from 2013 to 2018 for Kuwait. The increase in GDP during the period from 2013 to 2018 is accompanied by an initial period of sharp growth followed by a plateau in ECI. The results show that the economic growth experienced by Finland during the period from 2013 to 2018 is not optimally consistent with the predictions by ECI and Kuwait can make more improved strides to develop 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 Kuwait's production structure and its product space designs in the next few chapters.

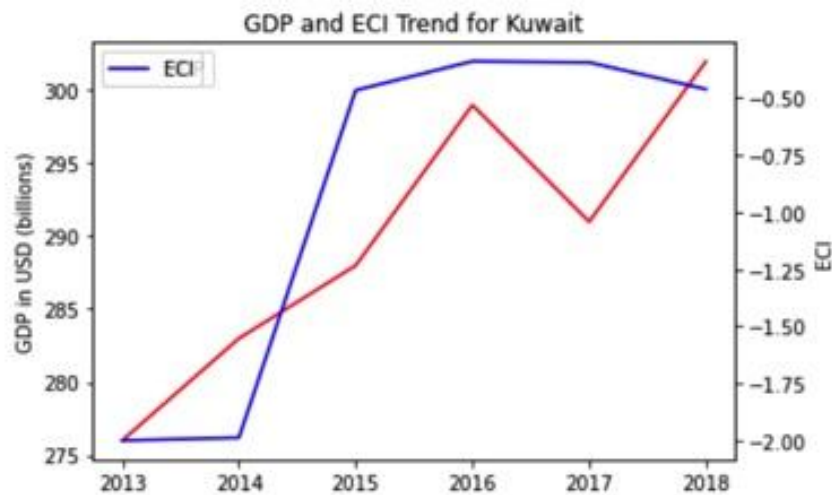


Figure 5: GDP Growth and ECI Kuwait (2013-2018)

Figure 6 compares GDP Growth and ECI between 2019 and 2021 for Kuwait. GDP increased a significant decrease in 2020 mainly due to the onset of the covid pandemic. However, Kuwait's GDP was able to recover by 2021, year in which it experienced a significant growth. Kuwait ECI decreased drastically from 2019 to 2020.

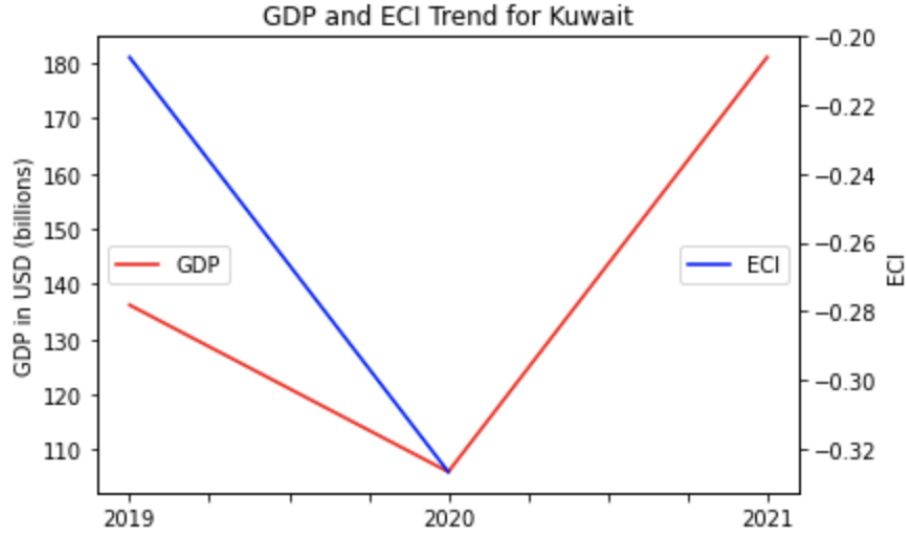


Figure 6: GDP and ECI (2019-2021)

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 labeled 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 Kuwait'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 US and the 18 product groups in 2018 and 2021 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.

	Category	RID
17	Services and Utilities	-0.070716
11	Machinery and Construction	-0.063555
14	Daily Instruments	-0.062216
13	Weapons	-0.061638
5	Chemical Manufacturing	-0.059736
16	High-complexity Products	-0.056496
10	Metals	-0.054319
0	Animals and By-products	-0.052378
12	Transportation	-0.047253
2	Food and Preparations	-0.046710
3	Energy Drilling and Mining	-0.046425
9	Textile	-0.046422
15	Precious Stones	-0.045972
1	Vegetables, Fruits and Plants	-0.044980
8	Clothing and Accessories	-0.044079
7	Wood Products	-0.038721
6	Raw Manufacturing	-0.037913
4	Chemicals	-0.013611

Table 2: Realized Industry Development (RID) of Kuwait (2013-2018)

3.3 Regional and Global Comparison

Tables below summarize how the production strategy adopted by Kuwait compares with leading economies and a selected group of emerging economies in the world, as measured in RID.

Ranking	France	the UK	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 4a: RID Comparison across Leading Economies (2018)

Ranking	France	the UK	Germany
1	Services and Utilities	Precious Stones	Daily Instruments
2	Precious Stones	High-complexity Products	Transportation
3	High-complexity Products	Services and Utilities	Chemicals
4	Energy Drilling and Mining	Energy Drilling and Mining	Chemical Manufacturing
5	Machinery and Construction	Wood Products	Clothing and Accessories

Table 4b: RID Comparison across Leading Economies (2021)

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 4c: RID Comparison across Emerging Economies (2018)

Ranking	China	South Korea	Singapore
1	Chemicals	Chemicals	Weapons
2	Daily Instruments	Daily Instruments	Energy Drilling and Mining
3	Transportation	Transportation	Transportation
4	Raw Manufacturing	Textile	Machinery and Construction
5	Weapons	Raw Manufacturing	High-complexity Products

Table 4d: RID Comparison across Emerging Economies (2021)

Table 4c and 4d further examines Kuwait'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 developing countries such as Kuwait should have relied more on essential or more basic 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, Kuwait is adopting a strategy that seeks development in industry groups of lower complexity. Given the economic impacts of COVID-19

this is not a out-of-phase strategy but as the economy recovers over the coming years it should shift its focus on developing a strategy to focus on industry groups with higher complexity.

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 terms 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 economic strength, those having higher ECI, or in other words, more reasonable economics structures are often in better shape.

Ranking	Kuwait	Saudi Arabia	United Arab Emirates	Turkey
1	High-complexity Products	Machinery and Construction	High-complexity Products	Energy Drilling and Mining
2	Machinery and Construction	High-complexity Products	Transportation	Machinery and Construction
3	Transportation	Transportation	Machinery and Construction	Animals and By-products
4	Daily Instruments	Services and Utilities	Daily Instruments	High-complexity Products
5	Services and Utilities	Daily Instruments	Chemicals	Daily Instruments
6	Chemicals	Weapons	Weapons	Weapons
7	Weapons	Textile	Textile	Services and Utilities
8	Textile	Chemical Manufacturing	Chemical Manufacturing	Transportation
9	Chemical Manufacturing	Energy Drilling and Mining	Raw Manufacturing	Chemicals
10	Raw Manufacturing	Chemicals	Metals	Chemical Manufacturing
11	Energy Drilling and Mining	Raw Manufacturing	Energy Drilling and Mining	Vegetables, Fruits and Plants
12	Metals	Metals	Precious Stones	Food and Preparations
13	Wood Products	Animals and By-products	Services and Utilities	Raw Manufacturing
14	Clothing and Accessories	Wood Products	Clothing and Accessories	Wood Products
15	Animals and By-products	Clothing and Accessories	Wood Products	Clothing and Accessories
16	Food and Preparations	Precious Stones	Animals and By-products	Textile
17	Precious Stones	Vegetables, Fruits and Plants	Food and Preparations	Metals
18	Vegetables, Fruits and Plants	Food and Preparations	Vegetables, Fruits and Plants	Precious Stones
ECI	-1.999	-0.104	-0.774	-0.341

Ranking	Kuwait	Saudi Arabia	United Arab Emirates	Turkey
1	High-complexity Products	High-complexity Products	High-complexity Products	Energy Drilling and Mining
2	Transportation	Transportation	Transportation	High-complexity Products
3	Machinery and Construction	Machinery and Construction	Machinery and Construction	Animals and By-products
4	Daily Instruments	Daily Instruments	Daily Instruments	Transportation
5	Weapons	Weapons	Weapons	Machinery and Construction
6	Chemical Manufacturing	Textile	Chemicals	Weapons
7	Textile	Chemical Manufacturing	Chemical Manufacturing	Daily Instruments
8	Raw Manufacturing	Chemicals	Textile	Chemicals
9	Energy Drilling and Mining	Raw Manufacturing	Raw Manufacturing	Chemical Manufacturing
10	Chemicals	Services and Utilities	Energy Drilling and Mining	Services and Utilities
11	Services and Utilities	Clothing and Accessories	Precious Stones	Vegetables, Fruits and Plants
12	Metals	Metals	Services and Utilities	Food and Preparations
13	Clothing and Accessories	Precious Stones	Clothing and Accessories	Raw Manufacturing
14	Precious Stones	Wood Products	Metals	Wood Products
15	Wood Products	Animals and By-products	Wood Products	Clothing and Accessories
16	Animals and By-products	Energy Drilling and Mining	Food and Preparations	Textile
17	Food and Preparations	Food and Preparations	Animals and By-products	Metals
18	Vegetables, Fruits and Plan	Vegetables, Fruits and Plan	Vegetables, Fruits and Plan	Precious Stones
ECI	-0.462	0.388	-0.917	-0.414

Table 5: SDV of High E_{CI} Countries 2013(up), 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 Kuwait compares with a selected group of comparable 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 Kuwait shares the characters of developing countries, with a balanced economics structure that leans towards intermediate-level industries.

Ranking	Algeria	Italy	USA	United Arab Emirates
1	High-complexity Products	Energy Drilling and Mining	Energy Drilling and Mining	High-complexity Products
2	Machinery and Construction	Precious Stones	Precious Stones	Transportation
3	Transportation	Vegetables, Fruits and Plants	Animals and By-products	Machinery and Construction
4	Services and Utilities	Animals and By-products	Vegetables, Fruits and Plants	Daily Instruments
5	Daily Instruments	Food and Preparations	Food and Preparations	Chemicals
6	Chemicals	Chemical Manufacturing	Chemicals	Weapons
7	Chemical Manufacturing	Raw Manufacturing	Chemical Manufacturing	Textile
8	Weapons	Wood Products	Raw Manufacturing	Chemical Manufacturing
9	Textile	Clothing and Accessories	Wood Products	Raw Manufacturing
10	Raw Manufacturing	Textile	Machinery and Construction	Energy Drilling and Mining
11	Energy Drilling and Mining	Metals	Weapons	Precious Stones
12	Metals	Machinery and Construction	Daily Instruments	Services and Utilities
13	Wood Products	Daily Instruments	High-complexity Products	Metals
14	Clothing and Accessories	High-complexity Products	Services and Utilities	Clothing and Accessories
15	Animals and By-products	Weapons	Clothing and Accessories	Wood Products
16	Food and Preparations	Chemicals	Metals	Animals and By-products
17	Precious Stones	Services and Utilities	Textile	Vegetables, Fruits and Plants
18	Vegetables, Fruits and Plants	Transportation	Transportation	Food and Preparations
ECI	-2.190	1.180	1.220	-0.734

Table 6: SDV of Other Typical Countries 2013

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:

$$\begin{aligned}
 & \text{Max}_{x \in \mathbf{R}^{|P|}} \left(\frac{k(x) - \langle k(x) \rangle}{stdev(k(x))} \right)_C \\
 & \text{Subject to} \\
 & \sum_{p \in P} x_p \leq B \\
 & x \succcurlyeq 0
 \end{aligned}$$

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 a 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 numbers 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).

Interpretation:

For the purpose of a clear explanation of the line charts, we try to label all the products in Table 7. Please refer to this table when trying to understand the investment trajectories in the line charts.

Label	Product Names
1	Animals and By-products
2	Vegetables, Fruits and Plants
3	Food and Preparations
4	Energy Drilling and Mining
5	Chemicals

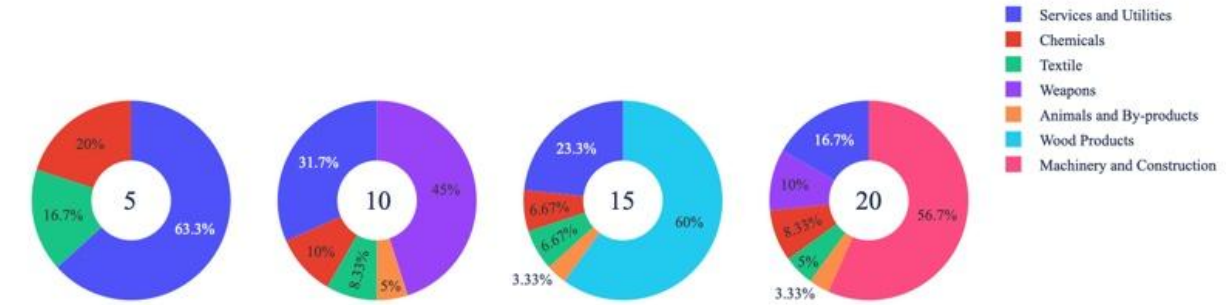
6	Chemical Manufacturing
7	Raw Manufacturing
8	Wood Products
9	Clothing and Accessories
10	Textile
11	Metals
12	Machinery and Construction
13	Transportation
14	Weapons
15	Daily Instruments
16	Precious Stones
17	High-complexity Products
18	Services and Utilities

Table 7: Products Labeling

Below is the economic panel for Kuwait in 2013. We can see that for different percentages of heuristic total export growth, the ECIs of Kuwait have different amounts of increments. A 5% export growth results in an ECI improvement pattern of around -1.999 and ends at around 0.361. The ECI improvement pattern is similarly positive for a bit and then plateaus for export growth of 10%, 15%, and 20%. In particular, the ECI for 10% export growth ends at around 0.374. For the 15% growth budget, the ECI of Kuwait ends at around 0.359, and for the 20% growth budget, the ECI ends at around 0.871.

For the case of 5 percent export growth, Services and Utilities accounts for the majority of the portfolio. For 10 percent export growth, more weight is awarded to Weapons, suggesting that with a low economic improvement anticipation, Finland should focus more on developing this industry. Going to 15 percent export growth, we see that Wood Products is now the heavily recommended strategy, while 20 percent growth recommends the majority in Machinery and Construction. Thus, there is a very different distribution for each level of export growth. A more detailed numerical representation of the portfolio is shown in Table 8.

Kuwait ECI Growth Optimization Result



Kuwait ECI Increment

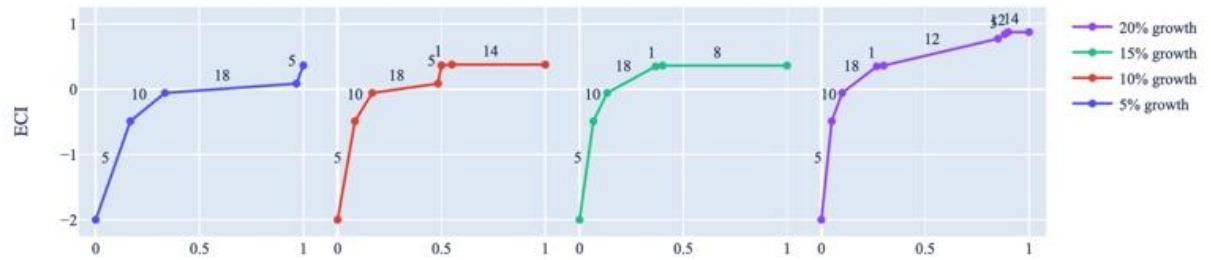


Figure 5: Greedy Based ECI Improvement Results of Kuwait in 2013 with Different Budgets

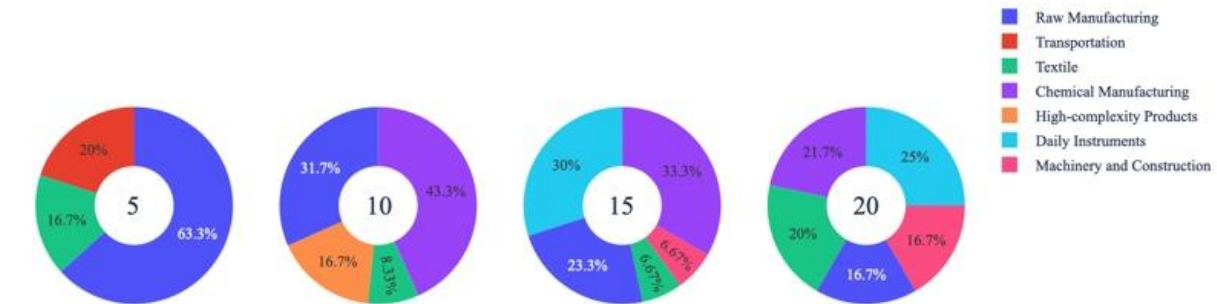
Kuwait (2018)				
Original ECI		-1.999		
Heuristic Export Growth	5%	10%	15%	20%
Animals and By-products	0	5.86E+08	5.86E+08	1.37E+09
Chemicals	1.37E+09	1.17E+09	1.17E+09	3.42E+09
Wood Products	0	0	1.0545E+10	0
Textile	1.14E+09	9.76E+08	1.17E+09	2.05E+09
Machinery and Construction	0	0	0	2.3239E+10
Weapons	0	5.27	0	4.10E+09
Services and Utilities	4.33E+09	3.71E+09	4.10E+09	6.83E+09
Increased ECI	3.61E-01	3.75E-01	3.59E-01	8.71E-01

Table 8: Portfolio of Kuwait in 2013

For further suggestions on Kuwait's development in the future, we also offer the optimization result of Kuwait based on export data in 2018. Below is the economic panel for Kuwait in 2018. We can see that there is a similar pattern for the ECI improvement trajectories, but the growth

trajectories do not plateau as they did previously, instead continuing to trend upwards continuously for all percentages of growth. Also, we notice that the main components that result in ECI improvements are not similar. For a 5 percent export growth, the improvement is now concentrated in Raw Manufacturing, while for 10, 15, and 20 percent growth, it is increasingly concentrated in Chemical Manufacturing and Daily Instruments. A more detailed numerical representation of the portfolio is shown in Table 9.

Kuwait ECI Growth Optimization Result



Kuwait ECI Increment

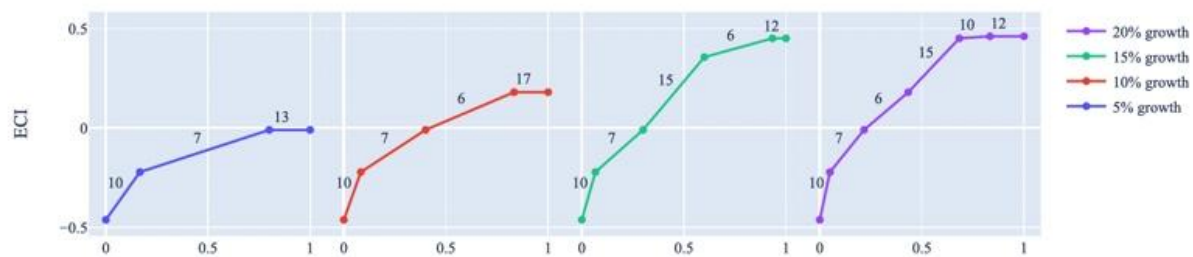


Figure 6: Greedy Based ECI Improvement Results of Kuwait in 2018 with Different Budgets

Kuwait (2018)				
Original ECI	-0.462			
Heuristic Export Growth	5%	10%	15%	20%
Chemical Manufacturing	0	3.28E+09	3.79E+09	3.28E+09
Raw Manufacturing	2.40E+09	2.40E+09	2.65E+09	2.53E+09
Textile	6.31E+08	6.31E+08	7.58E+08	3.03E+09
Machinery and Construction	0	0	7.58E+08	2.53E+09
Transportation	7.58E+08	0	0	0
Daily Instruments	0	0	3.41E+09	3.79E+09
High-complexity Products	0	1.26E+09	0	0
Increased ECI	-9.62E-03	1.80E-01	4.51E-01	4.61E-01

Table 9: Portfolio of Kuwait in 2018

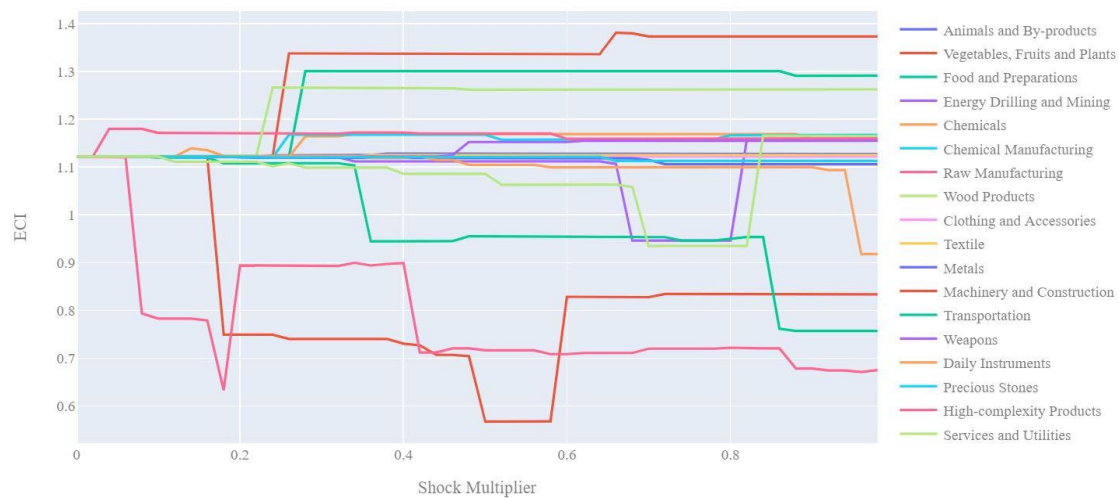
4.3 Sensitivity Analysis and Contingency Strategy

In the following section our broad aim is to understand how sensitive Kuwait 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. To this end, we have developed two categories of sensitivity analysis.

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 the 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 shocks 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)

SDV sensitivity

Secondly, we analyze the sensitivity of the SDV to changes in export levels. The goal is to understand how export level changes for a particular industry can affect the marginal opportunity gain for other industries. We will be using specifically High Complexity Products and Food and Preparations as our base industries. We will be increasing or decreasing the absolute export level in both of these industries and observing the effects on the SDV.

When the opportunity gain of an industry is negative, the SDV sensitivity approximates how an over-development of the industry jeopardizes the economic structure of a country. When the opportunity gain of the industry is zero, the SDV sensitivity determines whether the further development of the industry shapes the country with a better economic structure and predicts how the SDV would change accordingly. Specifically, as we reduce the export of such an industry to 25%-50% of its original value, a few other industries originally with negative opportunity gain could likely become profitable.

Similar to the ECI sensitivity graphs above, we will be shocking the export of High Complexity Products and Food and Preparations in small percentage increments. A new SDV, represented by a new column in the charts, is recorded only when a certain level of shock changes the structure of the SDV. In effect we are incrementing or decrementing export levels of two industries until the marginal opportunity gain of any industry changes in category (positive, negative, or neutral). Below is an example of a SDV Sensitivity chart with Positive Shocking. Industries with positive marginal opportunity gain are colored blue, neutral is colored white and negative is colored red.

	0.0%	10.0%	30.0%	50.0%	80.0%	100.0%	120.0%
0	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Chemicals	Chemicals	Chemicals	Machinery and Construction
1	Daily Instruments	Daily Instruments	Daily Instruments	Services and Utilities	Services and Utilities	Daily Instruments	Chemicals
2	Weapons	Weapons	Weapons	Textile	Textile	Textile	Daily Instruments
3	Transportation	Transportation	Transportation	Weapons	Daily Instruments	Services and Utilities	Services and Utilities
4	Machinery and Construction	Machinery and Construction	Machinery and Construction	Transportation	High-complexity Products	Transportation	Transportation
5	Metals	Metals	High-complexity Products	Machinery and Construction	Transportation	Chemical Manufacturing	Textile
6	High-complexity Products	High-complexity Products	Chemicals	High-complexity Products	Machinery and Construction	Weapons	Chemical Manufacturing
7	Chemicals	Services and Utilities	Services and Utilities	Daily Instruments	Chemical Manufacturing	High-complexity Products	Weapons
8	Services and Utilities	Chemicals	Textile	Chemical Manufacturing	Weapons	Machinery and Construction	High-complexity Products
9	Textile	Textile	Chemical Manufacturing	Precious Stones	Clothing and Accessories	Clothing and Accessories	Clothing and Accessories
10	Chemical Manufacturing	Chemical Manufacturing	Precious Stones	Clothing and Accessories	Precious Stones	Precious Stones	Raw Manufacturing
11	Precious Stones	Precious Stones	Clothing and Accessories	Vegetables, Fruits and Plants	Raw Manufacturing	Raw Manufacturing	Precious Stones
12	Clothing and Accessories	Clothing and Accessories	Raw Manufacturing	Raw Manufacturing	Wood Products	Metals	Wood Products
13	Raw Manufacturing	Raw Manufacturing	Metals	Metals	Metals	Wood Products	Metals
14	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining	Wood Products	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining
15	Wood Products	Wood Products	Wood Products	Energy Drilling and Mining	Animals and By-products	Animals and By-products	Animals and By-products
16	Animals and By-products	Animals and By-products	Animals and By-products	Animals and By-products	Vegetables, Fruits and Plants	Food and Preparations	Food and Preparations
17	Food and Preparations	Food and Preparations	Food and Preparations	Food and Preparations	Food and Preparations	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
ECI	2.261503667	2.520234671	3.08896214	3.452901685	4.299466299	4.439916975	5.069638102

Example High-complexity Products 2018 (Incremental SDV Sensitivity)

Contingency Plan

The Contingency Plan aims to present a set of solutions with respect to upheavals in different industries. Instead of compensating for the declining production directly, the best strategy is to develop those incipiently profitable industries. In this manner, we can derive the contingency strategy for countries to deal with possible abrupt declines of crucial industries. In some cases, the SDV remains unchanged even when a zero-opportunity-gain industry declines to its 20% in terms of export. We can then conclude the industry is not indispensable to the country. As a clarification, the three consecutive N/As means that the country doesn't even need to respond to a collapse in the industry. Countries tend to have distinct solutions to the up and down of the same industry. To create the contingency strategy table we decrease the export level for each industry in the country's current production space by 60% respectively. The three highest ranking industries in the new SDV are then returned.

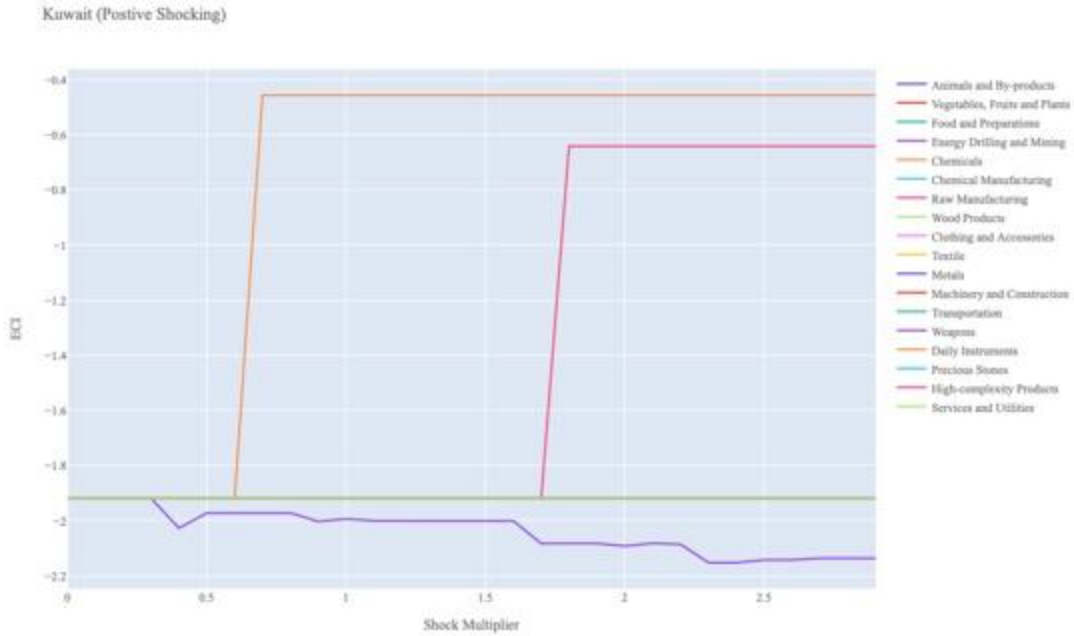
	0	1	2
Animals and By-products	Services and Utilities	Daily Instruments	Weapons
Vegetables, Fruits and Plants	Services and Utilities	Daily Instruments	Weapons
Food and Preparations	Services and Utilities	Daily Instruments	Weapons
Energy Drilling and Mining	Services and Utilities	Daily Instruments	Weapons
Chemicals	Services and Utilities	Daily Instruments	Weapons
Chemical Manufacturing	Services and Utilities	Daily Instruments	Weapons
Raw Manufacturing	Services and Utilities	Daily Instruments	Weapons
Wood Products	Services and Utilities	Daily Instruments	Weapons
Clothing and Accessories	Services and Utilities	Daily Instruments	Weapons
Textile	Services and Utilities	Daily Instruments	Weapons
Metals	Services and Utilities	Daily Instruments	Weapons
Machinery and Construction	Services and Utilities	Daily Instruments	Weapons
Transportation	Services and Utilities	Raw Manufacturing	Daily Instruments
Weapons	Services and Utilities	Daily Instruments	Transportation
Daily Instruments	Services and Utilities	Weapons	Transportation
Precious Stones	Services and Utilities	Daily Instruments	Weapons
High-complexity Products	Services and Utilities	Daily Instruments	Weapons
Services and Utilities	Daily Instruments	Weapons	Transportation

Example Contingency Strategy 2018

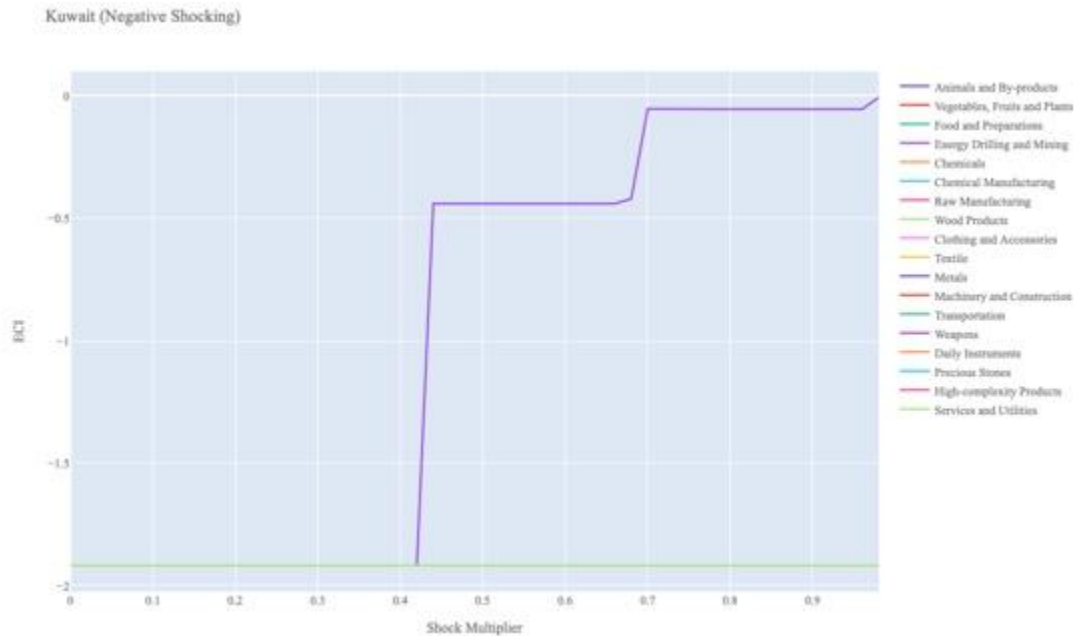
4.3 Sensitivity Analysis Results and Interpretation

Below is Kuwait's 2013 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that increases in High Complexity Products and Daily Instruments lead to an uptrend in ECI. In particular, Daily Instruments offer the best ECI growth per unit of export increase. All other industries besides the two mentioned above tend to not greatly affect the ECI level making it fairly clear which industries to pursue.

Next we consider Kuwait's 2013 Negative Shock chart. We see that Kuwait's ECI is not very highly sensitive to drawdowns in any particular category, but we see that large decreases in Energy Drilling and Mining seems to greatly increase the ECI score. These industries are very important industries for Kuwait's economy and thus the results that are reflected in the chart may be suggesting that there is another industry that could be very beneficial for Kuwait that is far in proximity from the Energy Drilling and Mining industries.



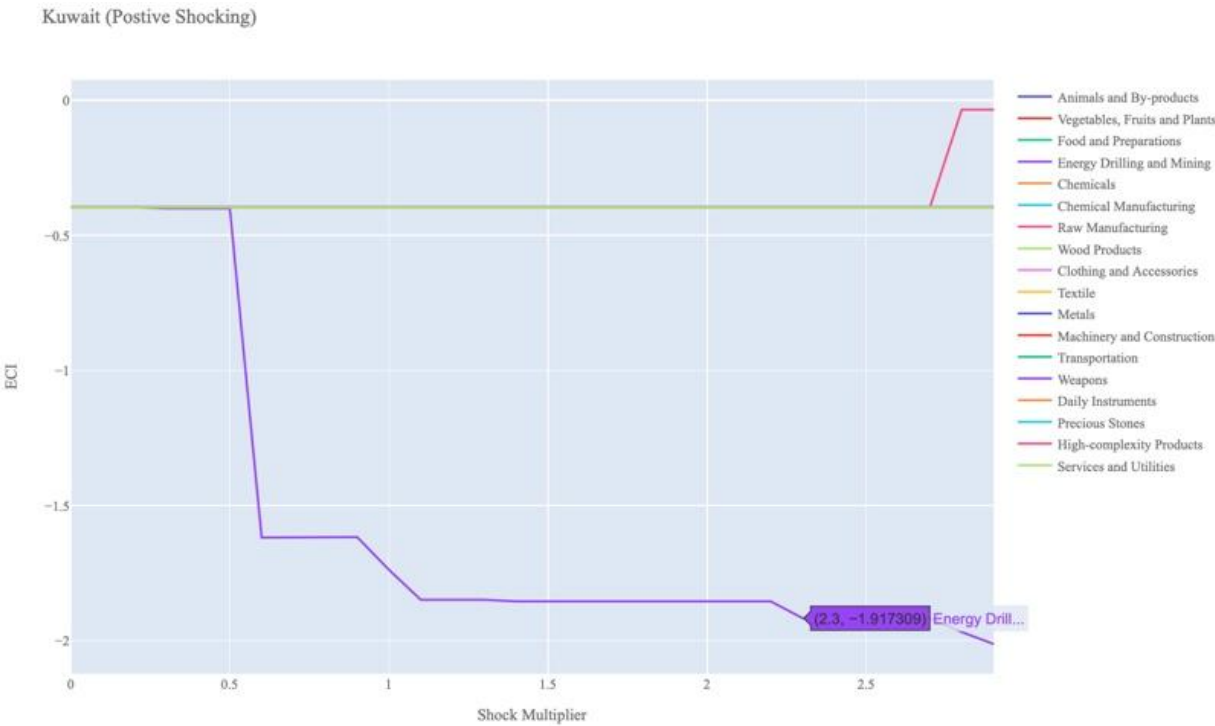
Kuwait 2013 (Incremental ECI Sensitivity)



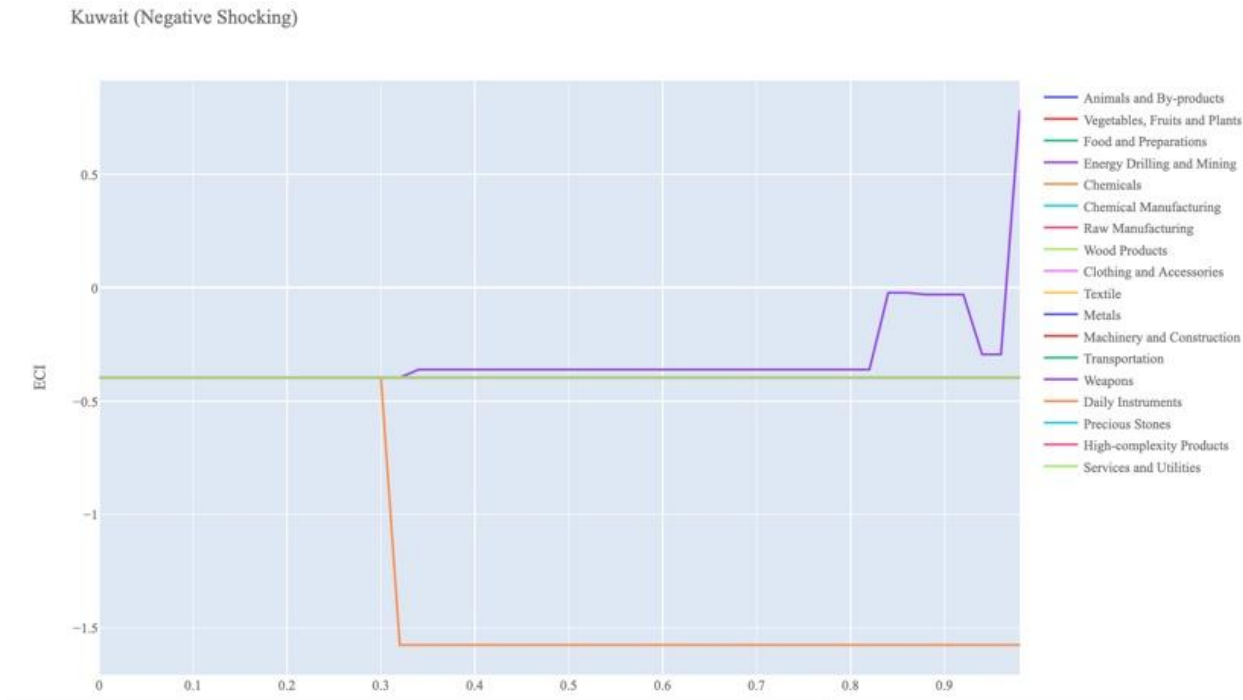
Kuwait 2013 (Decremental ECI Sensitivity)

Next we consider the 2018 ECI Sensitivity graphs. We see that in the positive shocking case, the landscape of ECI sensitivity has altered a bit over the five year period. Daily Instruments still seem to offer positive ECI growth prospects, and Kuwait is sensitive to negative ECI growth due to Energy Drilling and Mining.

In the 2018 negative shocking case, we see that Kuwait is sensitive to drawdowns in Chemicals and would benefit in ECI growth from Energy Drilling and Mining.



Kuwait 2018 (Incremental ECI Sensitivity)



Kuwait 2018 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for Energy Drilling and Mining. We see that increasing the export of Energy Drilling and Mining opens up many positive opportunity gain industries for Kuwait to move into.

In the negative Energy Drilling and Mining SDV chart, we see that as we decrease the export of Energy Drilling and Mining products, the exact opposite happens. The number of industries with positive opportunity gain shrink suggesting that the opportunities available to Kuwait are highly dependent on its Energy Drilling and Mining footprint.

Concerning Food and Preparations, Kuwait seems to be mostly insensitive to this industry suggesting that this is not an important industry in terms of the stability of its SDV.

	0%	100%
0	Machinery and Construction	Machinery and Construction
1	High-complexity Products	High-complexity Products
2	Transportation	Transportation
3	Daily Instruments	Daily Instruments
4	Services and Utilities	Chemicals
5	Textile	Services and Utilities
6	Chemical Manufacturing	Textile
7	Weapons	Chemical Manufacturing
8	Chemicals	Weapons
9	Energy Drilling and Mining	Energy Drilling and Mining
10	Vegetables, Fruits and Plants	Raw Manufacturing
11	Raw Manufacturing	Clothing and Accessories
12	Clothing and Accessories	Precious Stones
13	Precious Stones	Metals
14	Metals	Vegetables, Fruits and Plants
15	Wood Products	Wood Products
16	Animals and By-products	Animals and By-products
17	Food and Preparations	Food and Preparations
ECI	-0.457321992	-1.712843984

Kuwait High-complexity Products 2018 (Incremental SDV Sensitivity)

	0%	-84%	-94%	-98%
0	Machinery and Construction	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
1	High-complexity Products	Machinery and Construction	Machinery and Construction	Machinery and Construction
2	Transportation	High-complexity Products	High-complexity Products	Services and Utilities
3	Daily Instruments	Transportation	Transportation	Transportation
4	Services and Utilities	Daily Instruments	Services and Utilities	Raw Manufacturing
5	Textile	Services and Utilities	Daily Instruments	High-complexity Products
6	Chemical Manufacturing	Textile	Animals and By-products	Animals and By-products
7	Weapons	Raw Manufacturing	Raw Manufacturing	Chemicals
8	Chemicals	Chemicals	Chemicals	Energy Drilling and Mining
9	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining	Daily Instruments
10	Vegetables, Fruits and Plants	Chemical Manufacturing	Textile	Textile
11	Raw Manufacturing	Weapons	Chemical Manufacturing	Chemical Manufacturing
12	Clothing and Accessories	Clothing and Accessories	Weapons	Weapons
13	Precious Stones	Precious Stones	Clothing and Accessories	Clothing and Accessories
14	Metals	Metals	Precious Stones	Precious Stones
15	Wood Products	Wood Products	Metals	Metals
16	Animals and By-products	Animals and By-products	Wood Products	Wood Products
17	Food and Preparations	Food and Preparations	Food and Preparations	Food and Preparations
ECI	-0.457321992	-0.072163611	-0.31276344	0.750214508

Kuwait High-complexity Products 2018 (Decremental SDV Sensitivity)

	0%
0	Machinery and Construction
1	High-complexity Products
2	Transportation
3	Daily Instruments
4	Services and Utilities
5	Textile
6	Chemical Manufacturing
7	Weapons
8	Chemicals
9	Energy Drilling and Mining
10	Vegetables, Fruits and Plants
11	Raw Manufacturing
12	Clothing and Accessories
13	Precious Stones
14	Metals
15	Wood Products
16	Animals and By-products
17	Food and Preparations
ECI	-0.457321992

Kuwait Chemicals 2018 (Incremental SDV Sensitivity)

	0%	-32%
0	Machinery and Construction	Machinery and Construction
1	High-complexity Products	High-complexity Products
2	Transportation	Transportation
3	Daily Instruments	Daily Instruments
4	Services and Utilities	Chemicals
5	Textile	Services and Utilities
6	Chemical Manufacturing	Textile
7	Weapons	Chemical Manufacturing
8	Chemicals	Weapons
9	Energy Drilling and Mining	Energy Drilling and Mining
10	Vegetables, Fruits and Plants	Raw Manufacturing
11	Raw Manufacturing	Clothing and Accessories
12	Clothing and Accessories	Precious Stones
13	Precious Stones	Metals
14	Metals	Vegetables, Fruits and Plants
15	Wood Products	Wood Products
16	Animals and By-products	Animals and By-products
17	Food and Preparations	Food and Preparations
ECI	-0.457321992	-1.66574213

Kuwait Chemicals 2018 (Decremental SDV Sensitivity)

4.4 Contingency Strategy

Decreasing export of each industry in Kuwait's current production space by 60% respectively, we derive the contingency strategy shown below.

	0	1	2
Animals and By-products	High-complexity Products	Machinery and Construction	Transportation
Vegetables, Fruits and Plants	High-complexity Products	Machinery and Construction	Transportation
Food and Preparations	High-complexity Products	Machinery and Construction	Transportation
Energy Drilling and Mining	High-complexity Products	Machinery and Construction	Transportation
Chemicals	High-complexity Products	Machinery and Construction	Transportation
Chemical Manufacturing	High-complexity Products	Machinery and Construction	Transportation
Raw Manufacturing	High-complexity Products	Machinery and Construction	Transportation
Wood Products	High-complexity Products	Machinery and Construction	Transportation
Clothing and Accessories	High-complexity Products	Machinery and Construction	Transportation
Textile	High-complexity Products	Machinery and Construction	Transportation
Metals	High-complexity Products	Machinery and Construction	Transportation
Machinery and Construction	High-complexity Products	Machinery and Construction	Transportation
Transportation	High-complexity Products	Machinery and Construction	Transportation
Weapons	High-complexity Products	Machinery and Construction	Transportation
Daily Instruments	High-complexity Products	Machinery and Construction	Transportation
Precious Stones	High-complexity Products	Machinery and Construction	Transportation
High-complexity Products	High-complexity Products	Machinery and Construction	Transportation
Services and Utilities	High-complexity Products	Machinery and Construction	Transportation

Kuwait Contingency Strategy 2018

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
R²: 0.054	Prob (F-Stat): 0.0163

Adj R ² : 0.045	No. Observations: 106
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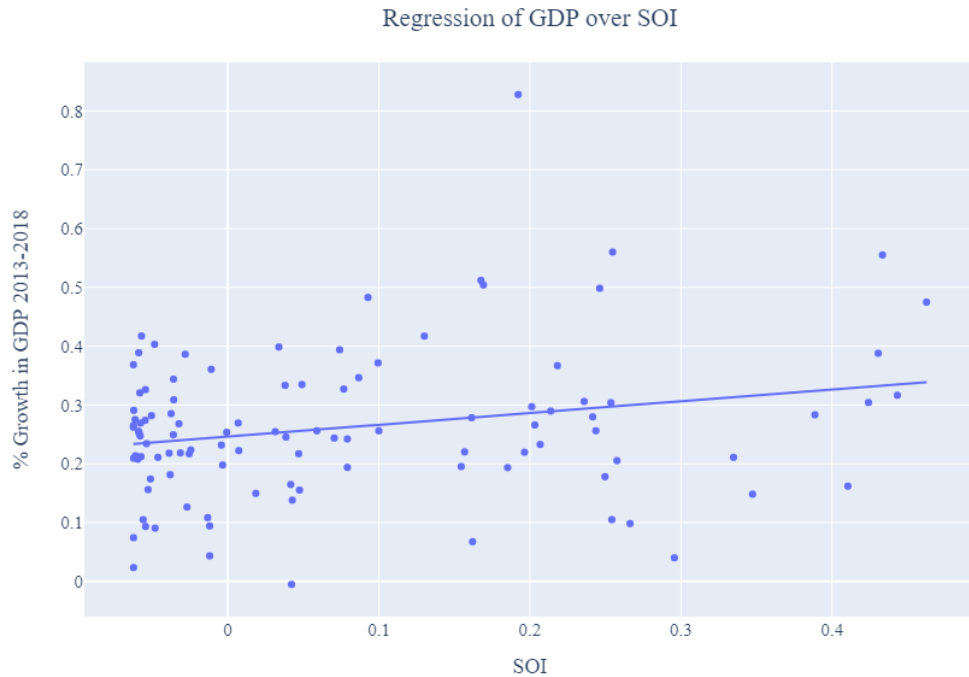


Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Kuwait and Its Implications

Kuwait for instance, has a low level of structural optimality as compared with its developed peers. As the regression in Figure 7 suggests (the orange curve represents export increase and the blue curve stands for opportunity gain of the corresponding industry), Kuwait demonstrates a low level of correlation with the suggested developmental path, having an adjusted R-square of around 5.38%. Kuwait ranks in the lower quartile among all countries in terms of SOI and has made a low rate of economic progress below its developed peers from 2013 to 2018 with a 5-year GDP growth rate of 1.54%, which is consistent with the regression result in Figure 6. This is in direct contrast to other developed economies such as Japan, where there is low SOI of around -5.7% and a corresponding GDP growth of 9.05% from 2013 to 2018, making Kuwait a much slower developing economy during the period. In sum, Kuwait's mixed economic progress from 2013 to 2018 can be at least partially explained by a development strategy that demonstrates a suboptimal level of matches with our suggested developmental path. In specific, Kuwait invested heavily in the Chemicals and Raw Manufacturing industry, while it should have focused more on more complex industry groups such as Energy Drilling and Mining. That being said, it stayed fairly in line with our expectations in the Precious Stones industry.

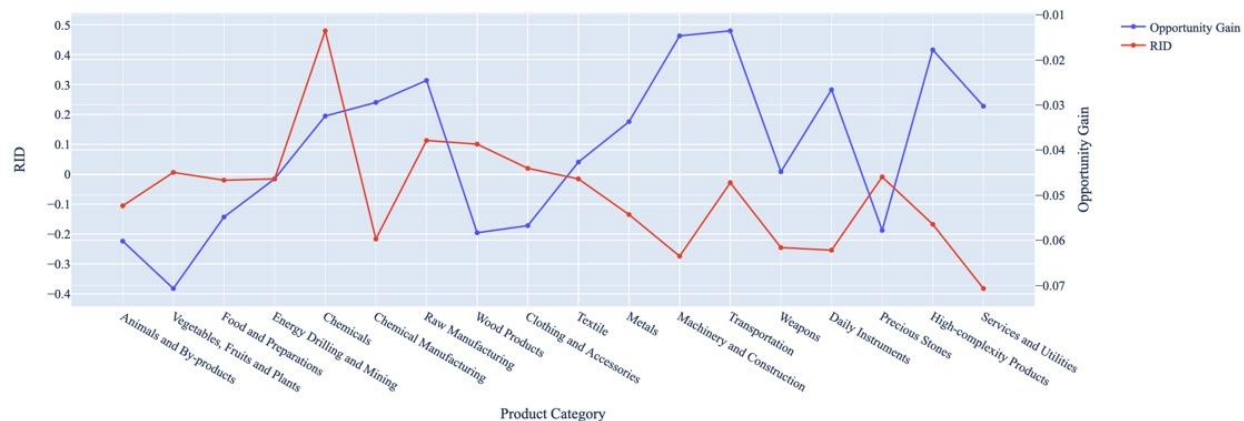


Figure 7: SOI of Kuwait (2013-2018)

6. Concluding Remarks

In conclusion, Kuwait has demonstrated a moderately low level of economic growth in terms of annual GDP increase during the period from 2013 to 2018, concurrent with a decrease in economic complexity as compared with other major developed economies.

The lack of progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Kuwait 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 Kuwait consistently relied on developing the Energy Drilling and Mining industry during the period, while its developed counterparts and emerging economies around the globe have adopted much more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Kuwait can further its gains by prioritizing Chemical Manufacturing and Daily Instruments. We further note that Kuwait has a slightly mismatched development strategy that indicates a moderately low (compared to other developed countries) level of structural optimality on the complexity level, having an adjusted R-square of around 0.64%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Kuwait, however, still has a suboptimal growth experience as compared with fast-growing 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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