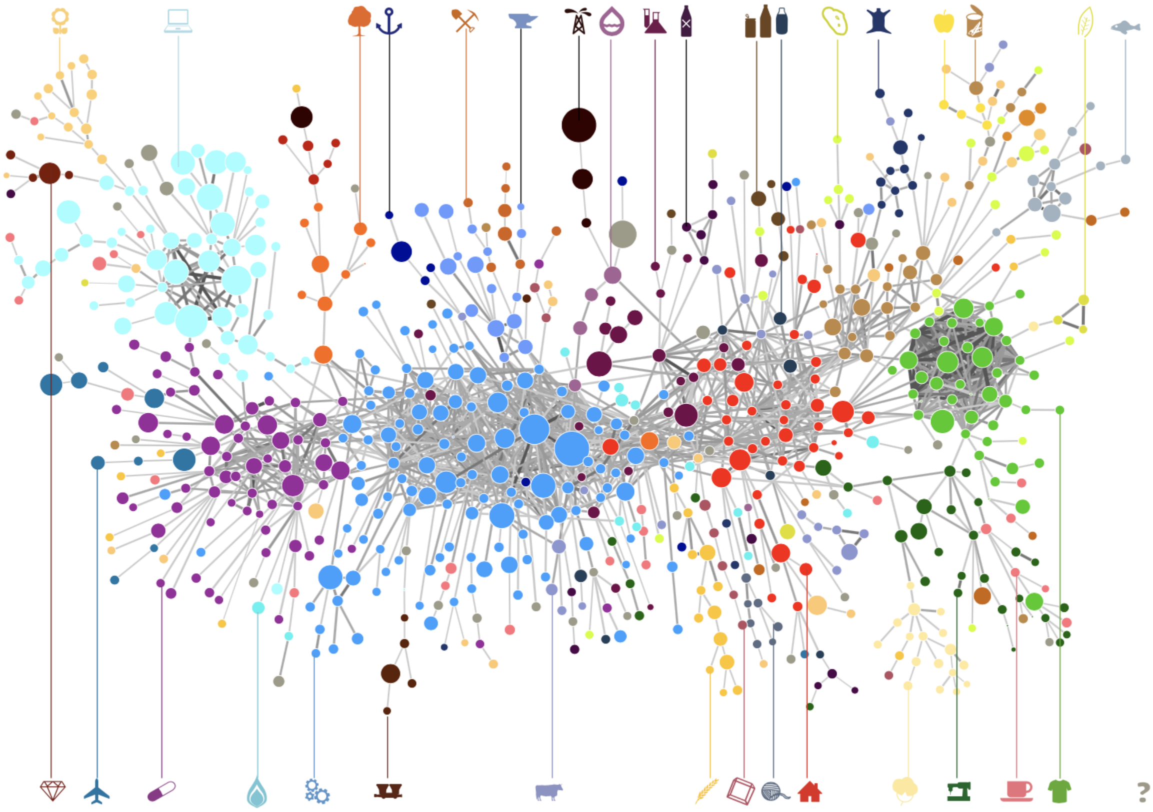

https://atlas.cid.harvard.edu/

Optimal Industry Development Strategy Using Economic and Product Complexity

Lebanon

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Optimal Industry Development Strategy for Lebanon

0. Executive Summary

In this report, we aim to uncover the economic path Lebanon went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Lebanon 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, Lebanon demonstrated a low level of economic growth with an average annual GDP growth rate of 2.19%, concurrent with a decrease in economic complexity as compared with other emerging economies.

The lack of progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Lebanon 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 Lebanon consistently relied on developing the Chemicals and Daily Instruments industries during the period, while its developed counterparts and emerging economies around the globe adopted much more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Lebanon can further its gains by prioritizing High-Complexity Products, Transportation, Machinery, and Daily Instruments. We further note that Lebanon has a heavily mismatched development strategy that indicates a low level (compared to emerging countries) of structural optimality on the complexity level, having an adjusted R-square of around -3.45%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Lebanon indeed 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.

1. Report Overview

In this report, we aim to uncover the economic path Lebanon went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Lebanon 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 Lebanon 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 Lebanon, 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 Lebanon and two of its peer countries (Jordan and Bahrain) from 2013-2018. Similar to the other countries, Lebanon displayed consistent, upward growth over the period, However, Lebanon's growth is weaker than its peers, as its average annual growth rate of 2.19% over the five-year period is lower than those of Jordan (3.36%) and Bahrain (4.15%).

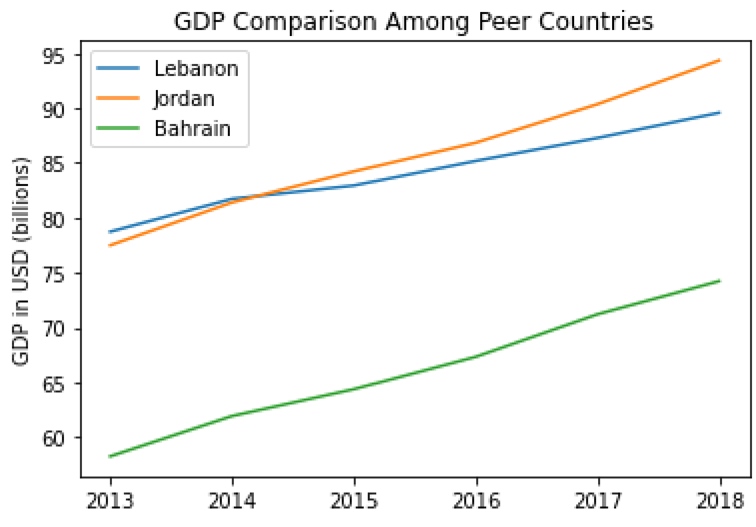


Figure 1: GDP Comparison Among Peer Countries

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 is illustrated in Figure 2. As shown, Lebanon exhibits only a slight decrease (-41.11% change) in production capability from 2013 to 2018, which is lower than both of its peers Bahrain (-53.97%) and Jordan (-4332.35%). Thus, the GDP-ECI relationship for Lebanon is contradictory, as it had the highest ECI change of the peer group, but the lowest GDP growth rate.

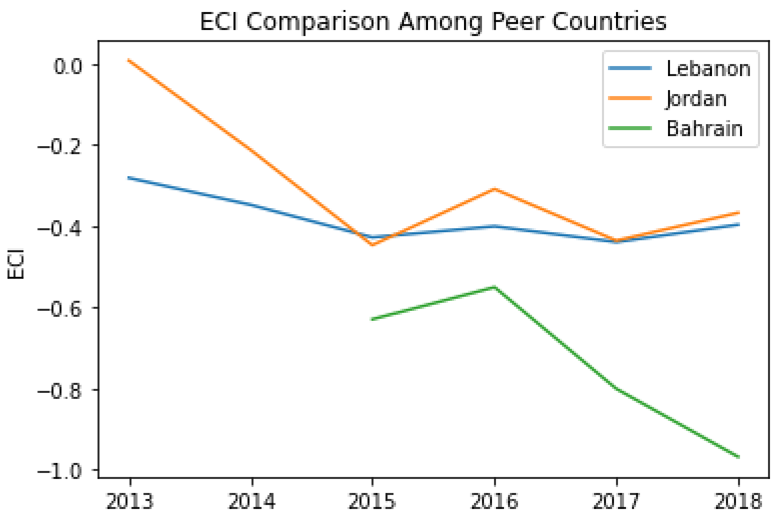


Figure 2: ECI Comparison

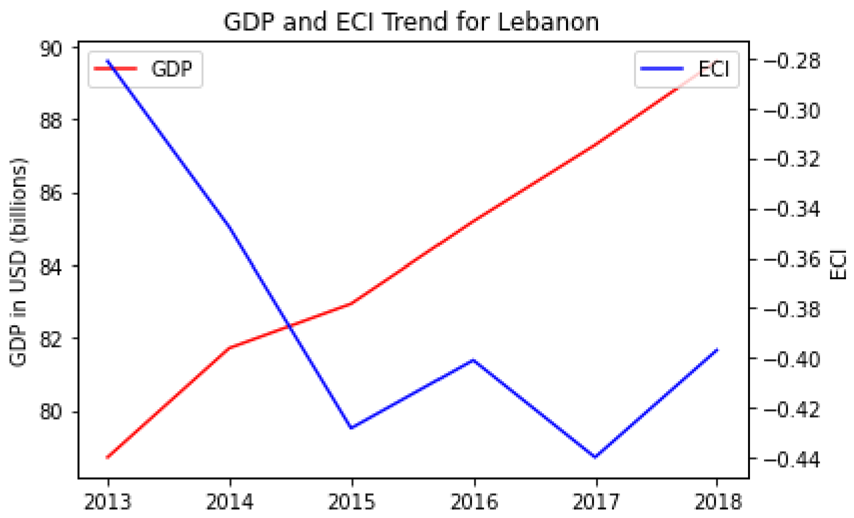


Figure 3: GDP Growth and ECI (U.S.)

Figure 3 offers a further comparison of GDP Growth and ECI over the time span from 2013 to 2018 for Lebanon.. The steady increase in GDP growth during the period from 2013 to 2018 is accompanied by an overall decrease in ECI. The results show that the economic growth experienced by Lebanon during the period from 2013 to 2018 is not very consistent with the predictions by ECI and that Lebanon had not made strides on effectively 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 Lebanon'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 Lebanon'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 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.

Category	RID
Clothing and Accessories	-0.024606
Services and Utilities	0.010562
Weapons	0.016075
High-complexity Products	0.028319
Machinery and Construction	0.043629
Animals and By-products	0.049582
Energy Drilling and Mining	0.050173
Textile	0.051654
Raw Manufacturing	0.055639
Metals	0.060493
Vegetables, Fruits and Plants	0.068295
Chemical Manufacturing	0.073582
Transportation	0.076890
Food and Preparations	0.079718
Wood Products	0.084401
Precious Stones	0.088046
Daily Instruments	0.103703
Chemicals	0.104069

Table 2: Realized Industry Development (RID) of Lebanon

3.3 Regional and Global Comparison

Table 3 and 4 below summarize how the production strategy adopted by Lebanon compares with leading economies and a selected group of emerging economies in the world, as measured in RID.

Ranking	France	US	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 Lebanon'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.

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

Ranking	China	Indonesia	Lebanon
1	Raw Manufacturing	Precious Stones	Energy Drilling and Mining
2	Clothing and Accessories	Machinery and Construction	Animals and By-products
3	Textile	Food and Preparations	High-complexity Products
4	Machinery and Construction	High-complexity Products	Machinery and Construction
5	Transportation	Services and Utilities	Transportation
6	Weapons	Metals	Weapons
7	Daily Instruments	Daily Instruments	Services and Utilities
8	High-complexity Products	Transportation	Daily Instruments
9	Precious Stones	Chemicals	Textile
10	Services and Utilities	Chemical Manufacturing	Chemicals
11	Chemicals	Animals and By-products	Vegetables, Fruits and Plants
12	Energy Drilling and Mining	Vegetables, Fruits and Plants	Food and Preparations
13	Chemical Manufacturing	Energy Drilling and Mining	Chemical Manufacturing
14	Wood Products	Raw Manufacturing	Raw Manufacturing
15	Animals and By-products	Wood Products	Wood Products
16	Vegetables, Fruits and Plants	Clothing and Accessories	Clothing and Accessories
17	Metals	Textile	Metals
18	Food and Preparations	Weapons	Precious Stones
ECI	1.96086598	-0.298641635	-0.281188359

Ranking	China	Indonesia	Lebanon
1	Chemicals	Precious Stones	Transportation
2	Raw Manufacturing	High-complexity Products	High-complexity Products
3	Clothing and Accessories	Machinery and Construction	Machinery and Construction
4	Textile	Chemicals	Energy Drilling and Mining
5	Machinery and Construction	Chemical Manufacturing	Animals and By-products
6	Transportation	Transportation	Clothing and Accessories
7	Weapons	Services and Utilities	Weapons
8	Daily Instruments	Daily Instruments	Services and Utilities
9	High-complexity Products	Animals and By-products	Daily Instruments
10	Precious Stones	Vegetables, Fruits and Plants	Textile
11	Services and Utilities	Food and Preparations	Chemicals
12	Energy Drilling and Mining	Energy Drilling and Mining	Vegetables, Fruits and Plants
13	Wood Products	Raw Manufacturing	Food and Preparations
14	Animals and By-products	Wood Products	Chemical Manufacturing
15	Metals	Clothing and Accessories	Raw Manufacturing
16	Chemical Manufacturing	Textile	Wood Products
17	Vegetables, Fruits and Plants	Metals	Metals
18	Food and Preparations	Weapons	Precious Stones
ECI	1.700687855	-0.4615811	-0.396791954

Table 5: Opportunity Gain Ranking on a Comparable 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 Lebanon 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 Lebanon shares the characteristics of developing countries, with a premature economics structure that leans towards intermediate-level industries.

Ranking	Singapore	Japan	Germany	United Kingdom
1	Chemicals	Chemicals	Chemical Manufacturing	Transportation
2	Transportation	Metals	Wood Products	High-complexity Products
3	High-complexity Products	Machinery and Construction	Metals	Daily Instruments
4	Services and Utilities	Transportation	Machinery and Construction	Textile
5	Machinery and Construction	Weapons	Transportation	Weapons
6	Daily Instruments	Daily Instruments	Weapons	Chemicals
7	Weapons	High-complexity Products	High-complexity Products	Food and Preparations
8	Textile	Services and Utilities	Services and Utilities	Chemical Manufacturing
9	Chemical Manufacturing	Precious Stones	Energy Drilling and Mining	Machinery and Construction
10	Raw Manufacturing	Energy Drilling and Mining	Precious Stones	Precious Stones
11	Clothing and Accessories	Textile	Textile	Services and Utilities
12	Metals	Clothing and Accessories	Clothing and Accessories	Clothing and Accessories
13	Wood Products	Chemical Manufacturing	Chemicals	Raw Manufacturing
14	Precious Stones	Animals and By-products	Animals and By-products	Energy Drilling and Mining
15	Animals and By-products	Wood Products	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
16	Food and Preparations	Vegetables, Fruits and Plants	Food and Preparations	Metals
17	Energy Drilling and Mining	Food and Preparations	Daily Instruments	Wood Products
18	Vegetables, Fruits and Plants	Raw Manufacturing	Raw Manufacturing	Animals and By-products
ECI	2.751108815	2.170299638	1.937171566	0.922251037

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:

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

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 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 Lebanon in 2013. We can see that for different percentages of heuristic total export growth, the ECIs of Lebanon actually have different amounts of increments. Overall, 5 percent export growth results in a ECI improvement pattern starting from around -0.28 and ends at around 0.17. As the budget is increased to 10 percent export growth, the ECI of Lebanon can achieve a slightly higher level, which is around 0.56. With much more growth budget, including 15 and 20 percent growth, Lebanon is able to achieve an even much higher stage, which is around 0.63.

For the case of 5 percent export growth, services and utilities, and daily instruments account for most of the portfolio. For 10 percent export growth, the portfolio becomes more diverse. In addition to the products mentioned before, machinery and construction are added as one of the main components as well. For the cases of 15 and 20 percent growth budgets, the solved portfolios are even more comprehensive. Not only do they follow similar ECI improvement trajectories but also they share a pretty close investment portfolio, which are mainly made up of machinery and construction, services and utilities, chemicals animals and by-products, and daily instruments etc. In these four ECI improvement trajectories, we also notice that the largest improvement comes from textile and daily instruments, suggesting that with a low economic improvement anticipation, Lebanon should focus more on developing these products. A more detailed numerical representation of the portfolio is shown in Table 8.

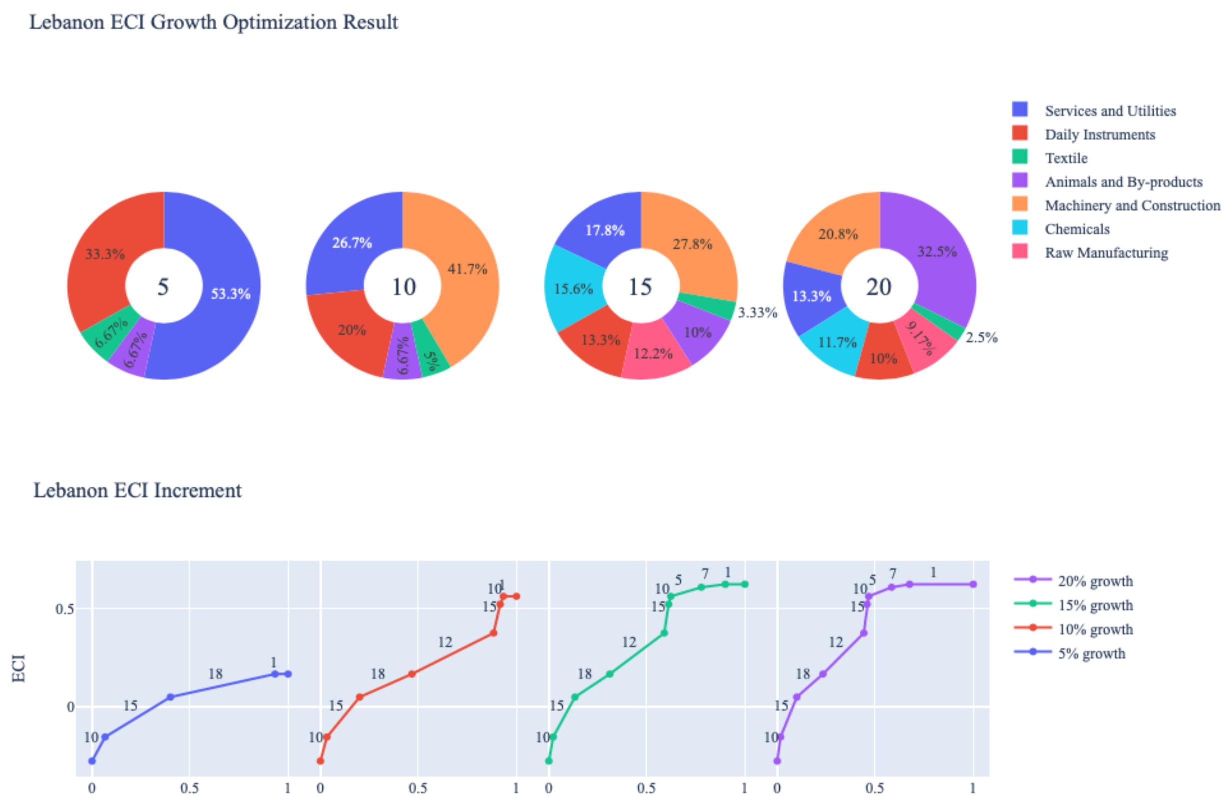


Figure 5: Greedy Based ECI Improvement Results of Lebanon in 2013 with Different Budgets

	Lebanon (2013)			
Original ECI	-0.28			
Heuristic Export Growth	5%	10%	15%	20%
Animals and By-products	1.51E+07	3.37E+07	6.80E+07	2.95E+08
Chemicals	0.00E+00	0.00E+00	1.06E+08	1.06E+08
Raw Manufacturing	0.00E+00	0.00E+00	8.31E+07	8.31E+07
Textile	1.51E+07	2.53E+07	2.27E+07	2.27E+07
Machinery and Construction	0.00E+00	2.11E+08	1.89E+08	1.89E+08
Daily Instruments	7.55E+07	1.01E+08	9.06E+07	9.06E+07
Services and Utilities	1.21E+08	1.35E+08	1.21E+08	1.21E+08
Increased ECI	0.17	0.56	0.63	0.63

Table 8: Portfolio of Lebanon in 2013

For further suggestions on Lebanon's development in the future. We also offer the optimization result based on its export data in 2018. Below is the economic panel for Lebanon in 2018. We can see that there are two patterns for the ECI improvement trajectories in four cases, which is that the improvements in 5 and 10 percent export growth share one pattern, and the improvements in 15 and 20 share another one. For 5 and 10 percent growth, the main components include machinery and construction and high complexity products. For situations with higher budgets of investment, like 15 or 20 percent growth, industries like transportation and high complexity products are the ones that contribute a lot in ECI increments. A more detailed numerical representation of the portfolio is shown in Table 9.

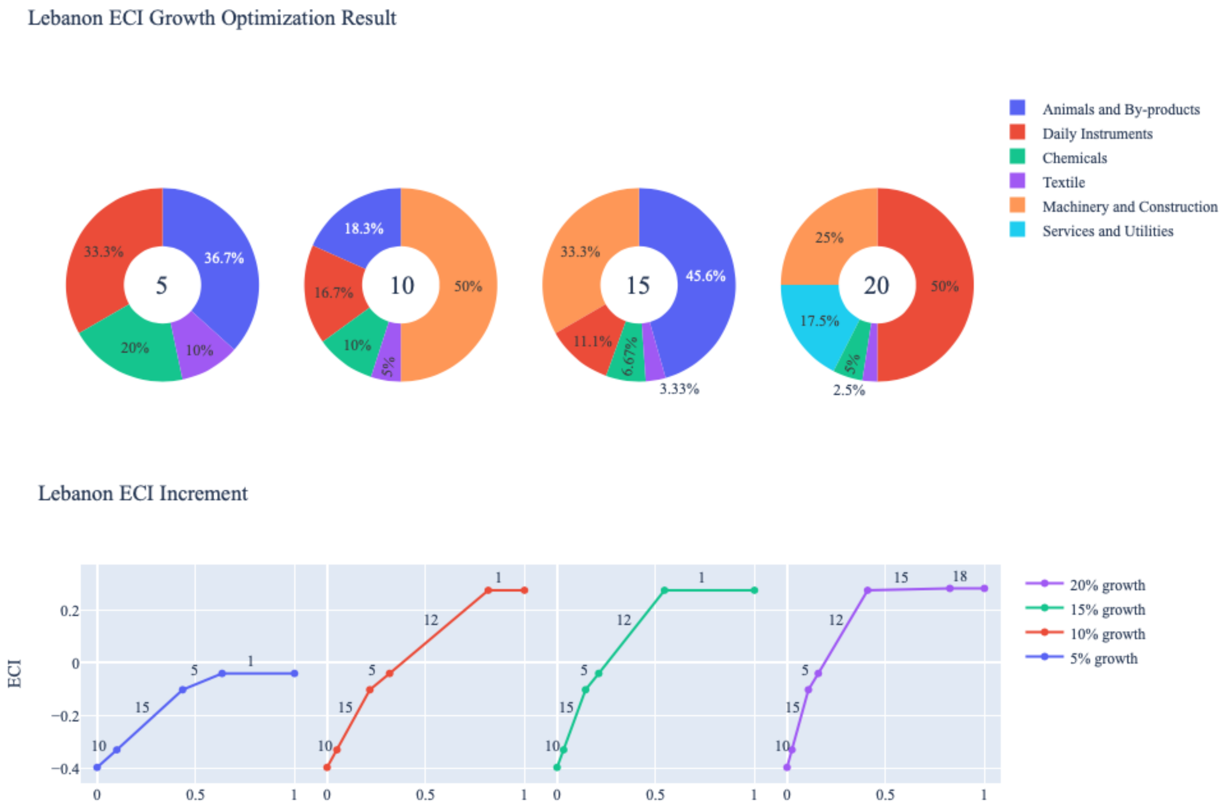


Figure 6: Greedy Based ECI Improvement Results of Lebanon in 2018 with Different Budgets

	Lebanon (2018)			
Original ECI	-0.40			
Heuristic Export Growth	5%	10%	15%	20%
Animals and By-products	6.23E+07	6.23E+07	2.32E+08	0.00E+00
Chemicals	3.40E+07	3.40E+07	3.40E+07	3.40E+07
Textile	1.70E+07	1.70E+07	1.70E+07	1.70E+07
Machinery and Construction	0.00E+00	1.70E+08	1.70E+08	1.70E+08
Daily Instruments	5.67E+07	5.67E+07	5.67E+07	3.40E+08
Services and Utilities	0.00E+00	0.00E+00	0.00E+00	1.19E+08
Increased ECI	-0.04	0.27	0.27	0.28

Table 9: Portfolio of Lebanon in 2018

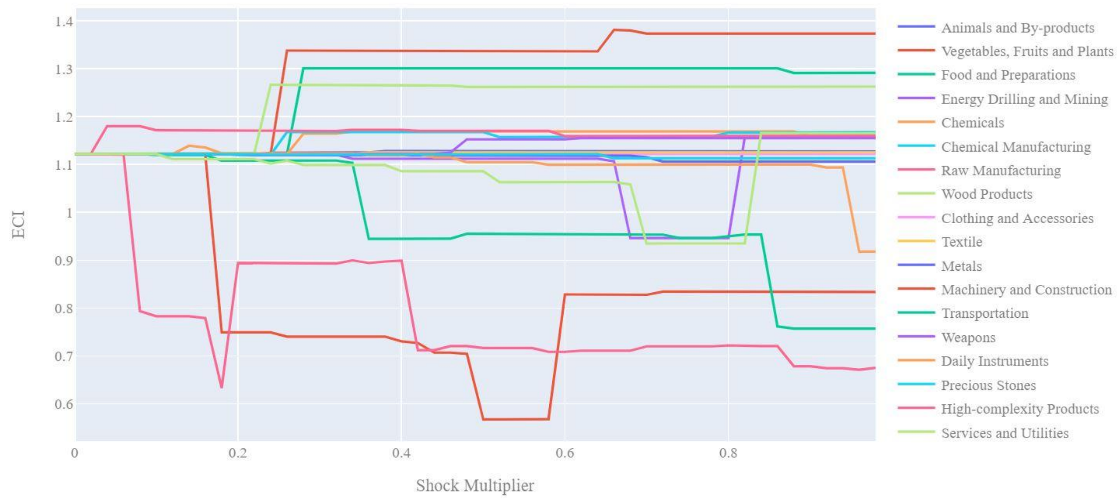
4.3 Sensitivity Analysis and Contingency Strategy

In the following section our broad aim is to understand how sensitive Lebanon 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 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)

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 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.

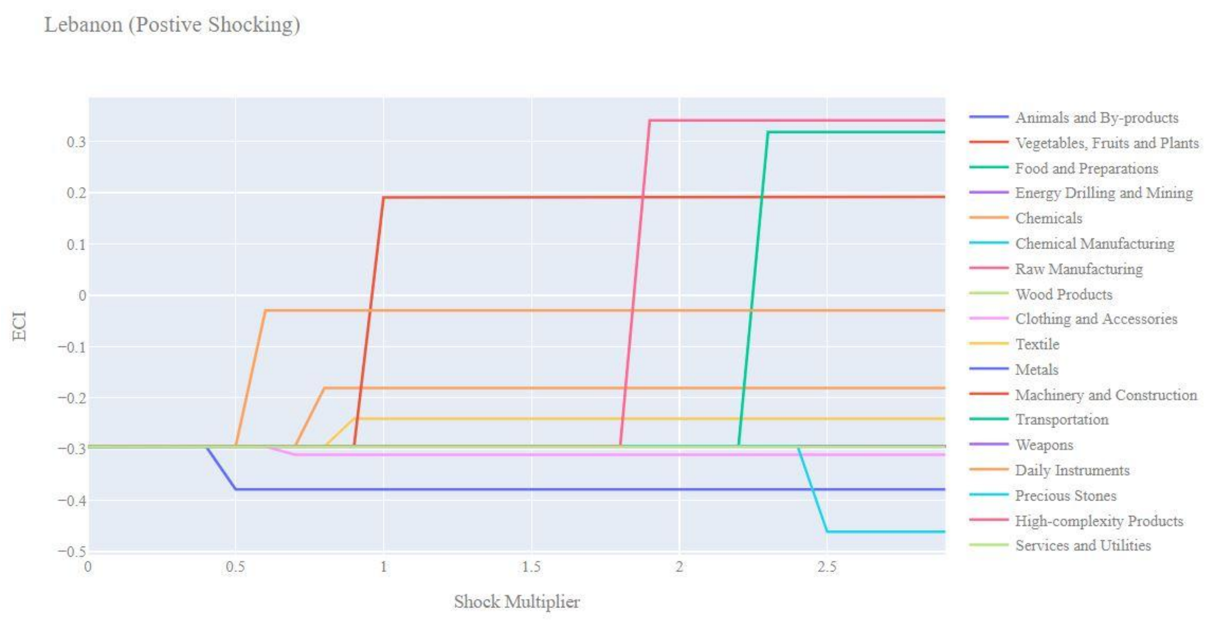
	0	1	2
Animals and By-products	Services and Utilities	Daily Instruments	Weapons
Vegetables, Fruits and Plants	Services and Utilities	Daily Instruments	Weapons
Food and Preparations	Services and Utilities	Daily Instruments	Weapons
Energy Drilling and Mining	Services and Utilities	Daily Instruments	Weapons
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

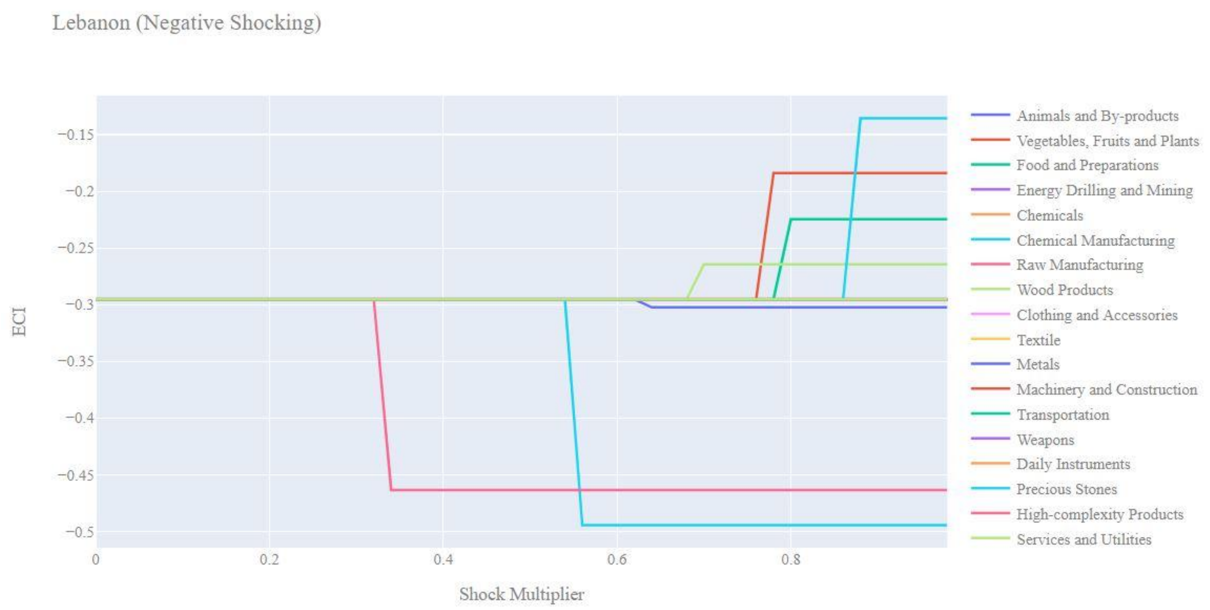
4.3 Sensitivity Analysis Results and Interpretation

Below is Lebanon's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that increases in High Complexity Products, Transportation, and Machinery, and Daily Instruments lead to significant increases in ECI. Daily Instruments seems to be the most realistic industry to expand in given that a 50% increase in export in this space leads to almost a positive absolute level of ECI. The other industries listed above require more than 100% increase in export level to experience any benefit of ECI increase.

Next we consider Lebanon's 2018 Negative Shock chart. We see that Lebanon's ECI is quite sensitive to drawdowns in Raw Manufacturing and Chemical Manufacturing. Very large decreases in export level for a handful of industries actually lead to an increase in ECI however a decrease of 70%+ is required for this effect.



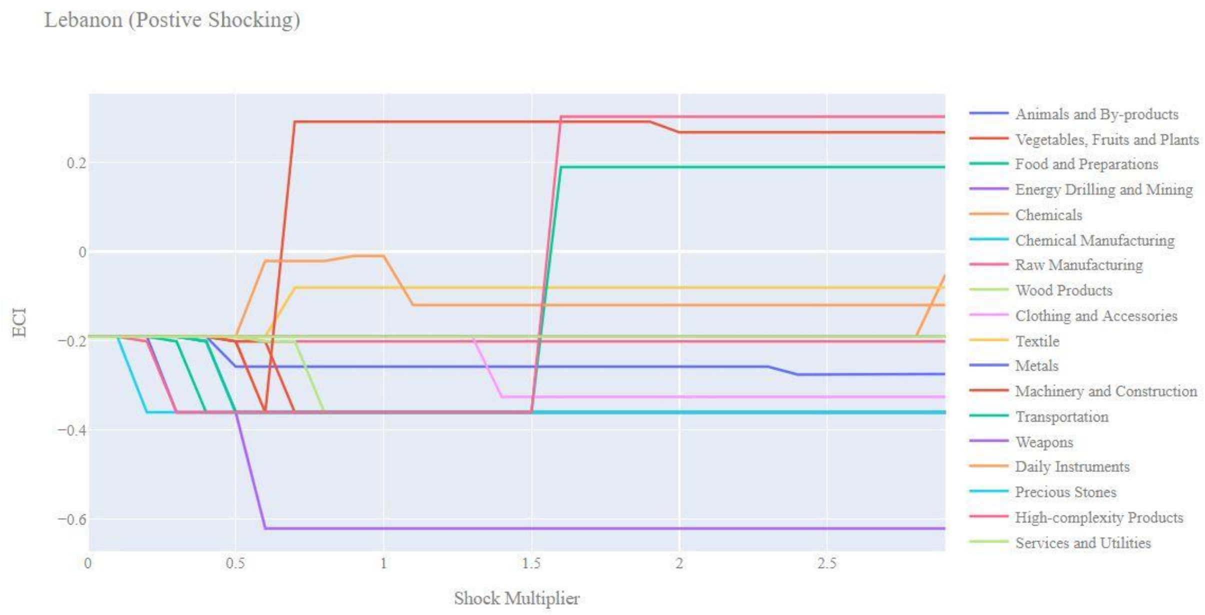
Lebanon 2018 (Incremental ECI Sensitivity)



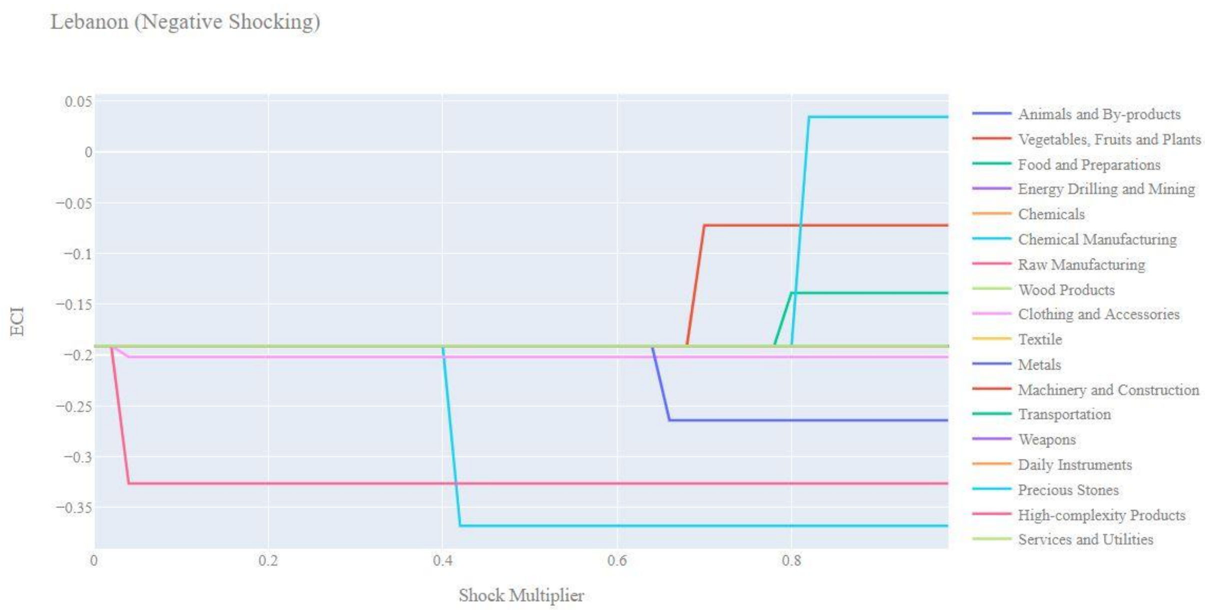
Lebanon 2018 (Decremental ECI Sensitivity)

Next we consider the 2013 ECI Sensitivity graphs. We see that in the positive shocking case, increases in High Complexity Products, Transportation, and Machinery, and Daily Instruments lead to increases in ECI as in 2018. Interestingly we see even though Lebanon has a higher ECI in 2013 it seems to be more sensitive to positive shocks in the majority of the remaining industries, Energy, Drilling, and Mining especially so.

In the 2013 negative shocking case, we see that again Lebanon is fairly sensitive to drawdowns in Raw Manufacturing and Chemical Manufacturing. In fact in 2013 Lebanon was extremely sensitive to even small drawdowns in Raw Manufacturing as compared to 2018.



Lebanon 2013 (Incremental ECI Sensitivity)



Lebanon 2013 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for High Complexity Products. Lebanon's SDV is quite insensitive to changes in High Complexity Products since this does not seem to be a key industry for the Russian economy. In both the positive negative SDV sensitivity chart we see that the SDV barely changes for any level of shock to the export level of High Complexity Products.

Similarly for the Food and Preparations SDV sensitivity chart we see that Lebanon is fairly insensitive to the Food and Preparations Industry. The set of industries that offer positive opportunity gain are quite stable in the face of changes in export level of High Complexity Products and Food and Preparations.

	0.0%	190.0%
0	Transportation	Machinery and Construction
1	High-complexity Products	Chemicals
2	Machinery and Construction	Daily Instruments
3	Daily Instruments	Services and Utilities
4	Chemicals	Transportation
5	Services and Utilities	Weapons
6	Weapons	Textile
7	Textile	Clothing and Accessories
8	Clothing and Accessories	Animals and By-products
9	Animals and By-products	Energy Drilling and Mining
10	Energy Drilling and Mining	Metals
11	Metals	High-complexity Products
12	Wood Products	Wood Products
13	Raw Manufacturing	Raw Manufacturing
14	Chemical Manufacturing	Chemical Manufacturing
15	Precious Stones	Precious Stones
16	Food and Preparations	Food and Preparations
17	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
ECI	-0.295376489	0.34084865

Lebanon High-complexity Products 2018 (Incremental SDV Sensitivity)

	-0.0%
0	Transportation
1	High-complexity Products
2	Machinery and Construction
3	Daily Instruments
4	Chemicals
5	Services and Utilities
6	Weapons
7	Textile
8	Clothing and Accessories
9	Animals and By-products
10	Energy Drilling and Mining
11	Metals
12	Wood Products
13	Raw Manufacturing
14	Chemical Manufacturing
15	Precious Stones
16	Food and Preparations
17	Vegetables, Fruits and Plants
ECI	-0.295376489

Lebanon High-complexity Products 2018 (Decremental SDV Sensitivity)

	0.0%
0	Transportation
1	High-complexity Products
2	Machinery and Construction
3	Daily Instruments
4	Chemicals
5	Services and Utilities
6	Weapons
7	Textile
8	Clothing and Accessories
9	Animals and By-products
10	Energy Drilling and Mining
11	Metals
12	Wood Products
13	Raw Manufacturing
14	Chemical Manufacturing
15	Precious Stones
16	Food and Preparations
17	Vegetables, Fruits and Plants
ECI	-0.295376489

Lebanon Food and Preparations 2018 (Incremental SDV Sensitivity)

	-0.0%	-80.0%
0	Transportation	Transportation
1	High-complexity Products	High-complexity Products
2	Machinery and Construction	Machinery and Construction
3	Daily Instruments	Daily Instruments
4	Chemicals	Chemicals
5	Services and Utilities	Weapons
6	Weapons	Services and Utilities
7	Textile	Textile
8	Clothing and Accessories	Clothing and Accessories
9	Animals and By-products	Food and Preparations
10	Energy Drilling and Mining	Animals and By-products
11	Metals	Energy Drilling and Mining
12	Wood Products	Metals
13	Raw Manufacturing	Wood Products
14	Chemical Manufacturing	Raw Manufacturing
15	Precious Stones	Chemical Manufacturing
16	Food and Preparations	Precious Stones
17	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
ECI	-0.295376489	-0.224528204

Lebanon Food and Preparations 2018 (Decremental SDV Sensitivity)

4.4 Contingency Strategy

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

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

Lebanon 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
R^2: 0.054	**Prob (F-Stat):** 0.0163
Adj R^2: 0.045	**No. Observations:** 106

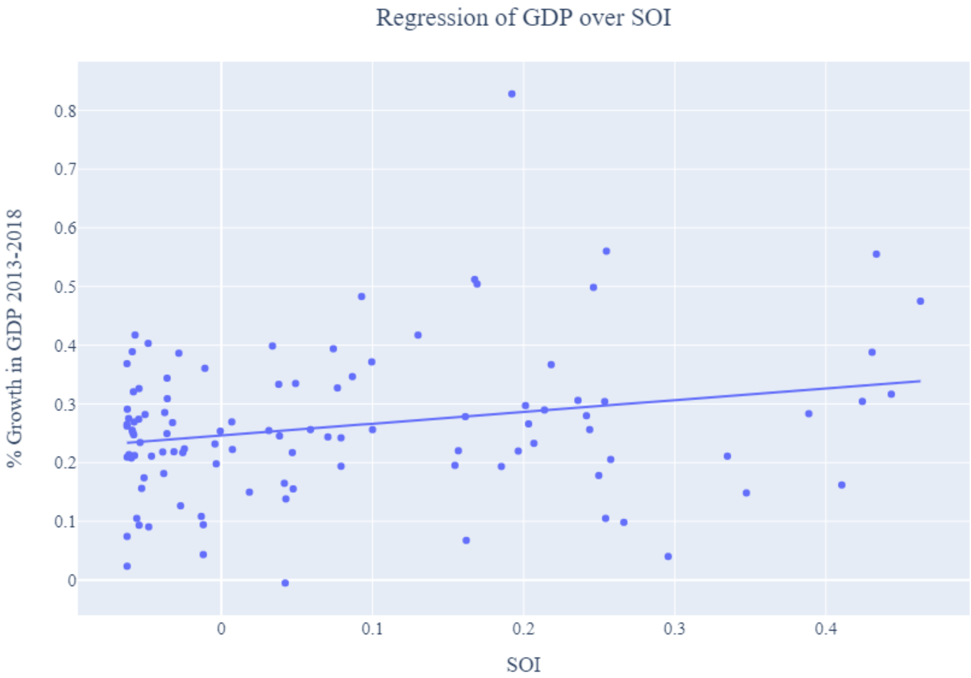


Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Lebanon and Its Implications

Lebanon, for instance, has a low level of structural optimality as compared with its emerging 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), Lebanon demonstrates a low level of correlation with the suggested developmental path, having an adjusted R-square of around -3.45%. Lebanon ranks in the third quartile among all countries in terms of SOI and made a low rate of economic progress among its emerging peers from 2013 to 2018 with a 5-year GDP growth rate of 13.8%, which is consistent with the regression result in Figure 6. This is in direct contrast to emerging economies such as Turkey, where there is high SOI of around 21.8% and a corresponding GDP growth of 36.7% from 2013 to 2018, making it one of the fastest developing economies during the period. In sum, Lebanon's slow economic progress from 2013 to 2018 can be at least partially explained by a development strategy that demonstrates a low level of matches with our suggested developmental path. In specific, Lebanon invested heavily in the Daily Instruments industry, while it should have focused more on less complex industry groups such as Clothing/Accessories and Precious Stones.

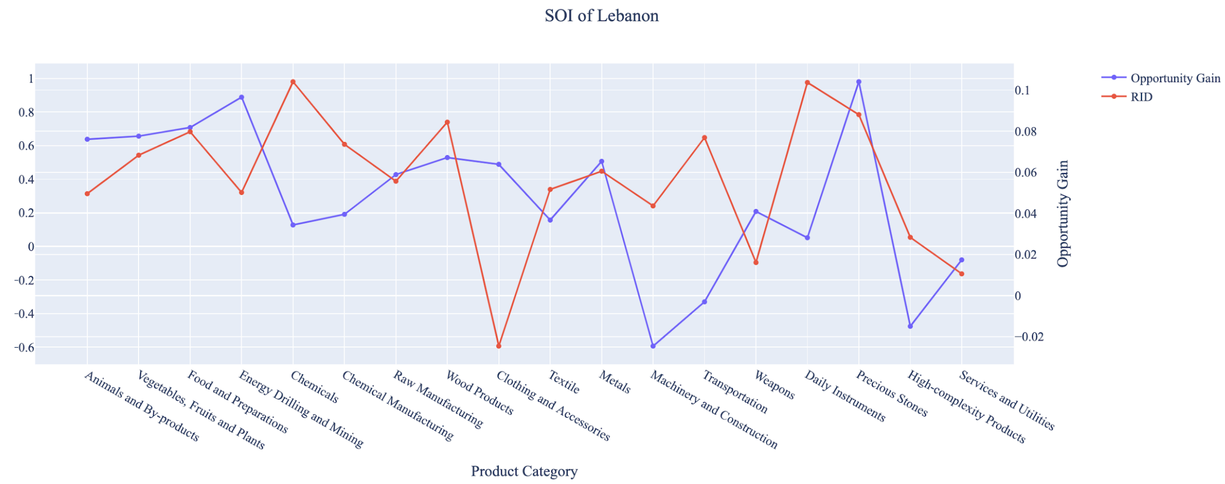


Figure 7: SOI of Lebanon (2013-2018)

6. Concluding Remarks

In conclusion, Lebanon has demonstrated a 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 emerging economies.

The lack of progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Lebanon 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 Lebanon consistently relied on developing the Chemicals and Daily Instruments industries during the period, while its developed counterparts and emerging economies around the globe adopted much more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Lebanon can further its gains by prioritizing High-Complexity Products, Transportation, Machinery, and Daily Instruments. We further note that Lebanon has a heavily mismatched development strategy that indicates a low level (compared to emerging countries) of structural optimality on the complexity level, having an adjusted R-square of around -3.45%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Lebanon indeed 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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