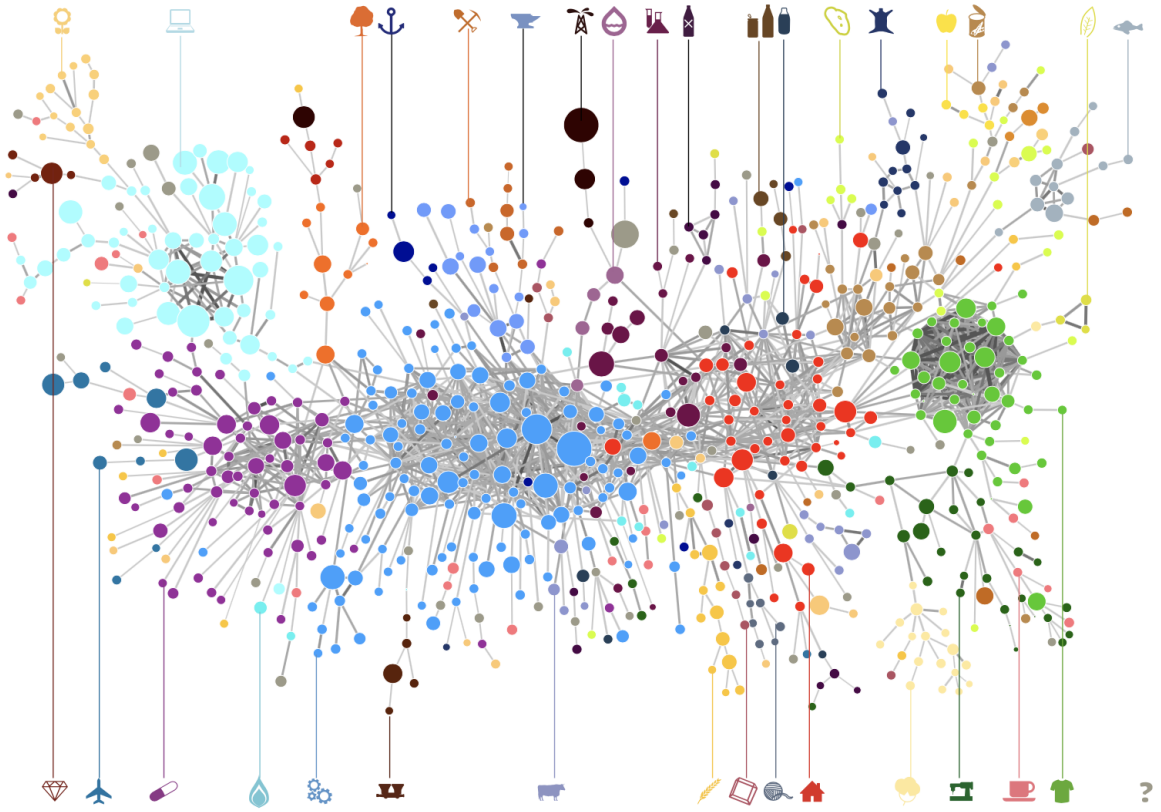

https://atlas.cid.harvard.edu/

Optimal Industry Development Strategy Using Economic and Product Complexity

Mexico

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Optimal Industry Development Strategy for Mexico

0. Executive Summary

In this report, we aim to uncover the economic path Mexico went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Mexico 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, Mexico demonstrated a moderate level of economic growth with an annual GDP growth rate of 0.5%, concurrent with a stability in economic complexity as compared with other major emerging economies.

The level of economic progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Mexico 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 Mexico invested heavily in developing basic industry groups such as Transportation, Services and Utilities, while its emerging peers and developed economies around the globe have adopted much more complex growth paths that can be potentially too aggressive and poorly-suited.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Mexico can further its gains by prioritizing Daily Instruments and Chemicals. We further note that Mexico has a well-matched development strategy that indicates a particularly high level of structural optimality on the complexity level, having an adjusted R-square of merely -6.1%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Mexico indeed has a nearly optimal 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 Mexico went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Mexico 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 Mexico 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 Mexico, as deduced from regression models we have established on a global scale, which take into account countries' stances in their product space.

2. Macroeconomic Results

2.1 GDP Ranking and Changes

As the 11th largest economy in the world by GDP in 2018, Mexico has a GDP of 1.27 trillion USD in 2013 and 1.22 trillion USD in 2018, exhibiting an steady economic output. Figure 1 illustrates the time-series GDP results for major emerging economies from 1999-2018, and Mexico demonstrates a high level of consistency in terms of both GDP and GDP growth. However, its growth rate is not significant as compared with many other emerging economies in the world, with an average annual growth of 0.5% during the period from 2013 to 2018. This number is much smaller than the annual growth rate of the other five leading emerging economies, which have a geometric average growth rates of 2.2% and an arithmetic average growth rate of 2.4%. The contrast is particularly significant with China, one of the leading emerging economies in the world, which has an average annual growth rate of 8.2% during the same period. The pace of economic growth in Mexico, we believe, can be reflected through changes in ECI and PCI, and can be further explained by a suboptimal set of production strategies adopted by Mexico from 2013 to 2018, which we will expand at the later stage of the report.

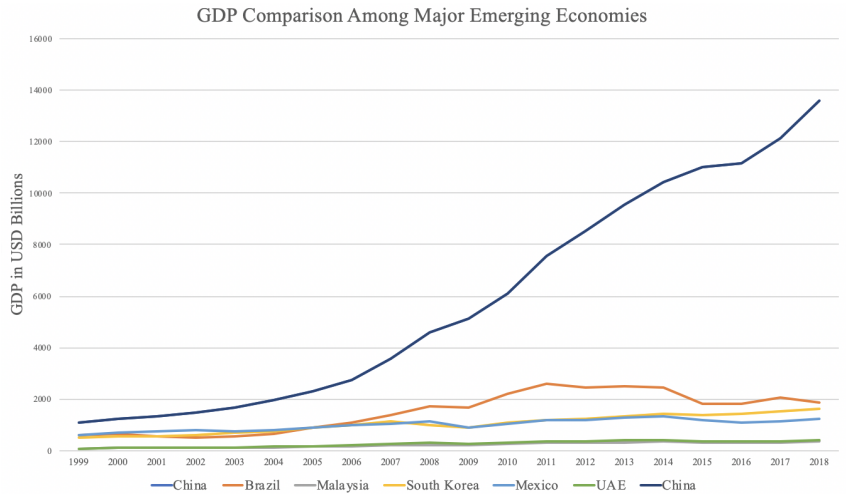


Figure 1: GDP Comparison Among Major Emerging Economies

2.2 ECI Ranking and Changes

The Economic Complexity Index (ECI), as defined by Ricardo Hausmann and Cesar Hidalgo in 2009 to explain the knowledge accumulated in a country's population, exhibits a similar pattern for Mexico. As illustrated in Figure 2 below, Mexico exhibits a huge increase in terms of its production capability from 2013 to 2018, as measured by ECI. This is in direct contrast to countries such as China and South Korea, which demonstrate a steady trend in terms of both the ECI and GDP indexes.

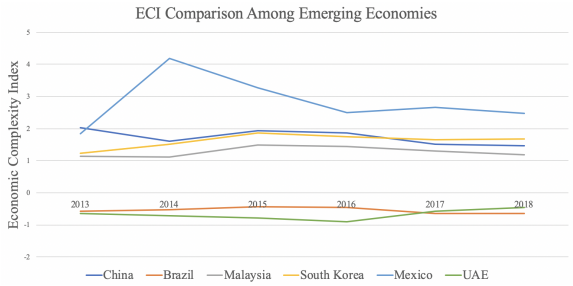


Figure 2: ECI Comparison

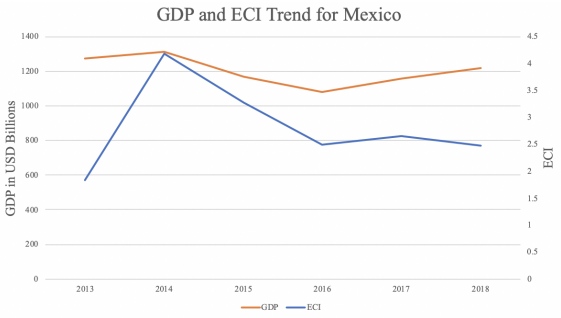


Figure 3: GDP and ECI (Mexico)

Figure 3 offers a further comparison of GDP and ECI over the entire time span from 2013 to 2018 for Mexico. Based on statistical analysis, ECI is a significant covariate for GDP with an adjusted R-square of 33.8%. In particular, the changes in GDP during the period from 2013 to 2018 are consistent with the changes in ECI, indicating great predictive power of ECI in terms of Mexico's potential economic development. The effectiveness of the country in developing a competitive product space that helps to accumulate complicated knowledge and technology can be reflected by the increase in ECI. In order to get a better insight of the relationship between ECI and the country's economy, we will dive into an analysis of Mexico'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 Mexico'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 Mexico and the 18 product groups in 2013 and 2018 through subtraction, where a positive RID indicates a shortening of the distance (i.e., advancement of the industry), and a negative RID indicates the reverse. As ranked in Table 2, during the period from 2013 to 2018, Mexico has focused on products with a moderate level of complexity and those requiring intermediate skills.

Rank	Category	RID	Rank	Category	RID
1	Transportation	-0.057	10	Textile	-0.016
2	Services and Utilities	-0.050	11	Vegetables, Fruits and Plants	-0.014
3	High-complexity Products	-0.048	12	Raw Manufacturing	-0.011
4	Precious Stones	-0.042	13	Wood Products	-0.007
5	Daily Instruments	-0.041	14	Energy Drilling and Mining	-0.006
6	Machinery and Construction	-0.028	15	Food and Preparations	-0.006
7	Clothing and Accessories	-0.025	16	Animals and By-products	-0.005
8	Chemical Manufacturing	-0.025	17	Chemicals	0.002
9	Metals	-0.018	18	Weapons	0.002

Table 2: Realized Industry Development (RID) of Mexico

3.3 Regional and Global Comparison

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

Ranking	France	The United States	Germany
1	High-complexity Products	Services and Utilities	High-complexity Products
2	Chemical Manufacturing	Weapons	Transportation
3	Daily Instruments	Raw Manufacturing	Wood Products
4	Animals and By-products	Precious Stones	Metals
5	Food and Preparations	Animals and By-products	Food and Preparations

Table 3: RID Comparison across Leading Economies

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

Table 4: RID Comparison across Emerging Economies

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

4. Product Space Design

4.1 Suggested Development Vector

As aforementioned, distance gives us an idea of how far each new product is from a country's current mix of exports. As defined in Hausmann and Hidalgo (2009), distance is "the weighted proportion of products connected to goods p that country c is not exporting, i.e., MCP=0." Based on this definition, the distance between a country and any product that the country is currently exporting (i.e., the country is a significant exporter in the product as compared to global average) is zero. Similarly, opportunity gain quantifies the contribution of a new product in 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	Mexico	Singapore	Japan	China	Germany	Republic of Korea
1	Vegetables, Fruits and Plants	Chemicals	Chemicals	Raw Manufacturing	Chemical Manufacturing	Services and Utilities
2	Machinery and Construction	Transportation	Metals	Clothing and Accessories	Wood Products	Chemicals
3	Transportation	High-complexity Products	Machinery and Construction	Textile	Metals	Raw Manufacturing
4	High-complexity Products	Services and Utilities	Transportation	Machinery and Construction	Machinery and Construction	Textile
5	Services and Utilities	Machinery and Construction	Weapons	Transportation	Transportation	Metals
6	Chemicals	Daily Instruments	Daily Instruments	Weapons	Weapons	Transportation
7	Textile	Weapons	High-complexity Products	Daily Instruments	High-complexity Products	Daily Instruments
8	Weapons	Textile	Services and Utilities	High-complexity Products	Services and Utilities	High-complexity Products
9	Daily Instruments	Chemical Manufacturing	Precious Stones	Precious Stones	Energy Drilling and Mining	Weapons
10	Chemical Manufacturing	Raw Manufacturing	Energy Drilling and Mining	Services and Utilities	Precious Stones	Energy Drilling and Mining
11	Clothing and Accessories	Clothing and Accessories	Textile	Chemicals	Textile	Chemical Manufacturing
12	Raw Manufacturing	Metals	Clothing and Accessories	Energy Drilling and Mining	Clothing and Accessories	Precious Stones
13	Food and Preparations	Wood Products	Chemical Manufacturing	Chemical Manufacturing	Chemicals	Machinery and Construction
14	Animals and By-products	Precious Stones	Animals and By-products	Wood Products	Animals and By-products	Clothing and Accessories
15	Metals	Animals and By-products	Wood Products	Animals and By-products	Vegetables, Fruits and Plants	Wood Products
16	Wood Products	Food and Preparations	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Food and Preparations	Animals and By-products
17	Precious Stones	Energy Drilling and Mining	Food and Preparations	Metals	Daily Instruments	Food and Preparations
18	Energy Drilling and Mining	Vegetables, Fruits and Plants	Raw Manufacturing	Food and Preparations	Raw Manufacturing	Vegetables, Fruits and Plants
ECI	2.753793255	2.751108815	2.154947	1.96086598	1.937171566	1.7759805

Ranking	Germany	Mexico	Singapore	Japan	China	Republic of Korea
1	Chemical Manufacturing	Vegetables, Fruits and Plants	Energy Drilling and Mining	Chemicals	Chemicals	Services and Utilities
2	Machinery and Construction	Machinery and Construction	Chemicals	Metals	Raw Manufacturing	Chemicals
3	Transportation	Transportation	Machinery and Construction	Machinery and Construction	Clothing and Accessories	Raw Manufacturing
4	Daily Instruments	High-complexity Products	Transportation	Transportation	Textile	Textile
5	High-complexity Products	Services and Utilities	High-complexity Products	Weapons	Machinery and Construction	Metals
6	Services and Utilities	Chemicals	Services and Utilities	Daily Instruments	Transportation	Transportation
7	Chemicals	Weapons	Weapons	High-complexity Products	Weapons	Daily Instruments
8	Textile	Textile	Textile	Services and Utilities	Daily Instruments	High-complexity Products
9	Weapons	Daily Instruments	Precious Stones	Textile	High-complexity Products	Weapons
10	Clothing and Accessories	Clothing and Accessories	Chemical Manufacturing	Precious Stones	Precious Stones	Clothing and Accessories
11	Precious Stones	Chemical Manufacturing	Clothing and Accessories	Clothing and Accessories	Services and Utilities	Precious Stones
12	Raw Manufacturing	Precious Stones	Daily Instruments	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining
13	Wood Products	Energy Drilling and Mining	Animals and By-products	Animals and By-products	Wood Products	Chemical Manufacturing
14	Energy Drilling and Mining	Animals and By-products	Metals	Wood Products	Animals and By-products	Wood Products
15	Animals and By-products	Raw Manufacturing	Raw Manufacturing	Chemical Manufacturing	Metals	Animals and By-products
16	Metals	Food and Preparations	Wood Products	Food and Preparations	Chemical Manufacturing	Food and Preparations
17	Food and Preparations	Wood Products	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
18	Vegetables, Fruits and Plants	Metals	Food and Preparations	Raw Manufacturing	Food and Preparations	Machinery and Construction
ECI	2.959929484	2.527893051	2.112887919	1.979430054	1.700687855	1.648971597

Table 5: SDV of High ECI 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 shows the SDV of a selected group of leading economies with outstanding economic complexity, 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, countries listed in Table 6 have nearly half of industries with positive opportunity gain. While the economies with absolute negative E_fCI, such as Tunisia, South Africa and Mexico, all need to develop High-complexity Products, Machinery and Construction and daily instruments, those with median E_fCI are facing a more complicated and diverse situation, such as Italy, Spain and the United States.

It can be concluded that Mexico is categorized to be a highly complexed country as compared with the world's leading economies and other major economies in Europe.

Ranking	Italy	Tunisia	South Africa	Colombia
1	Energy Drilling and Mining	Machinery and Construction	High-complexity Products	High-complexity Products
2	Precious Stones	Services and Utilities	Machinery and Construction	Machinery and Construction
3	Vegetables, Fruits and Plants	Daily Instruments	Animals and By-products	Transportation
4	Animals and By-products	High-complexity Products	Transportation	Services and Utilities
5	Food and Preparations	Weapons	Services and Utilities	Daily Instruments
6	Chemical Manufacturing	Chemical Manufacturing	Daily Instruments	Chemicals
7	Raw Manufacturing	Precious Stones	Clothing and Accessories	Weapons
8	Wood Products	Textile	Chemicals	Chemical Manufacturing
9	Clothing and Accessories	Raw Manufacturing	Chemical Manufacturing	Textile
10	Textile	Animals and By-products	Raw Manufacturing	Raw Manufacturing
11	Metals	Food and Preparations	Textile	Metals
12	Machinery and Construction	Metals	Vegetables, Fruits and Plants	Food and Preparations
13	Daily Instruments	Vegetables, Fruits and Plants	Food and Preparations	Animals and By-products
14	High-complexity Products	Energy Drilling and Mining	Energy Drilling and Mining	Wood Products
15	Weapons	Chemicals	Wood Products	Clothing and Accessories
16	Chemicals	Clothing and Accessories	Metals	Vegetables, Fruits and Plants
17	Services and Utilities	Transportation	Weapons	Energy Drilling and Mining
18	Transportation	Wood Products	Precious Stones	Precious Stones
ECI	1.179705915	0.239091536	-0.80405844	-1.752771623

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:

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

Subject to

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

$$x \succcurlyeq 0$$

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

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

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

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

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

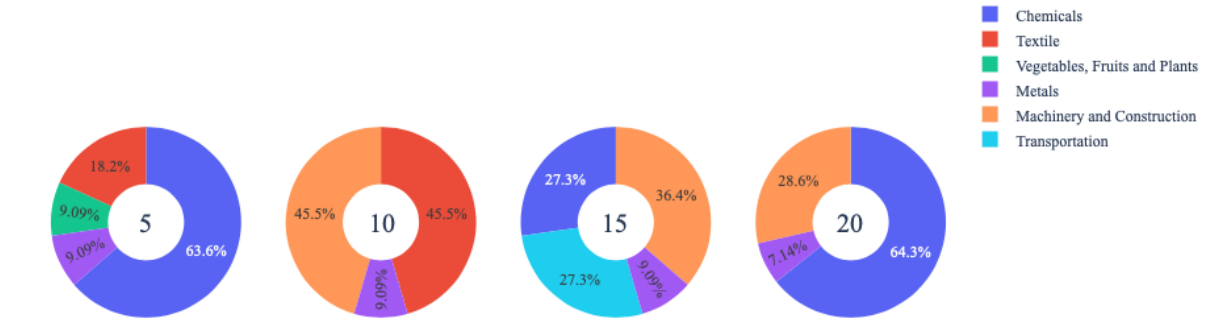
In this way, we can obtain a further sighted greedy algorithm. Also, the number of parts that we would like to separate the budget into also matters. In order to solve this problem, we added a stabilizer on top of the enhanced greedy algorithm, by running the algorithm for different number of parts and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

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

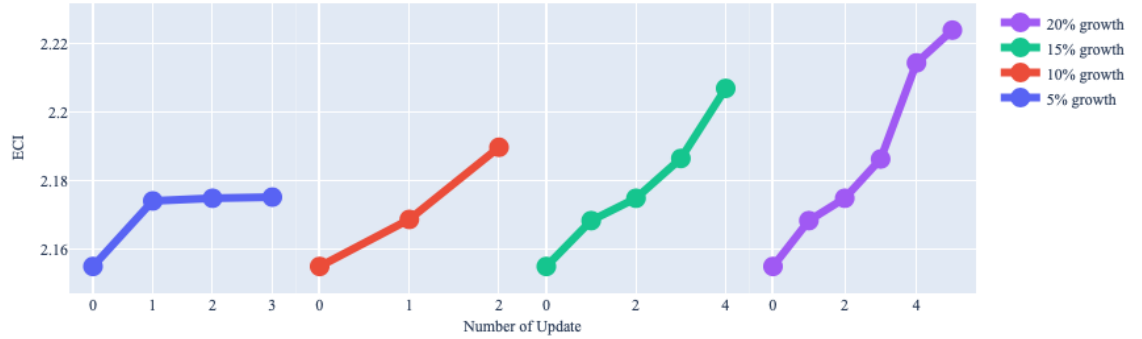
Economic Panel:

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

Japan ECI Growth Optimization Result



Japan ECI Increment

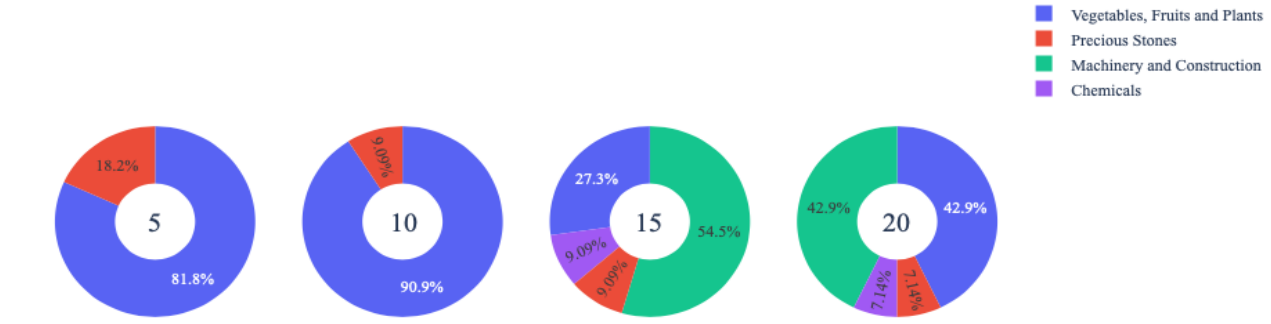


Japan (2013)				
Total Export in 2013 (US. $)	1.17E+12			
Original ECI	2.155			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	5.86E+10	1.17E+11	1.76E+11	2.35E+11
Metals(US. $)	5.33E+09	1.07E+10	1.60E+10	1.68E+10
Transportation(US. $)	0.00E+00	0.00E+00	4.80E+10	0.00E+00
Chemicals(US.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

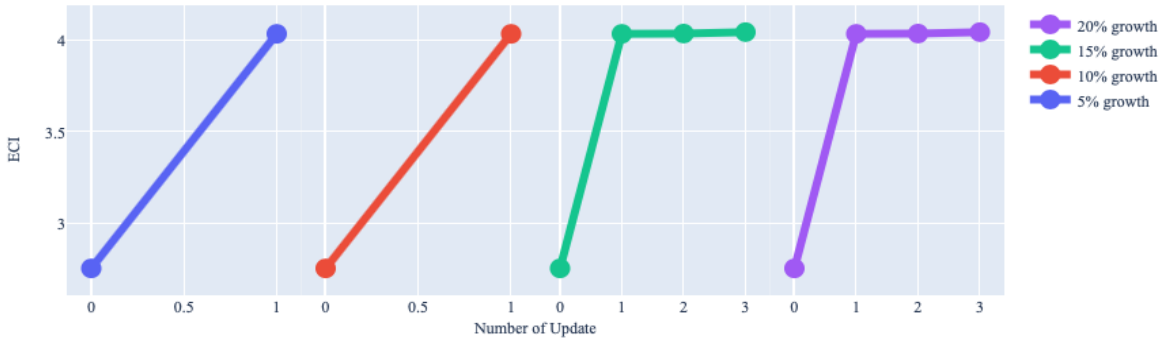
Interpretation:

Below is the economic panel for Mexico in 2013. We can see that for different percentages of heuristic total export growth, the ECI of Mexico will have a different amount of increments. From all the four graphs, we see that Mexico already obtains some great increment in terms of ECI, but eventually the ECIs are not so much different. This means that in terms of export, Mexico has already achieved a well-balanced stage. For the case of 5 and 10 percent increment, precious stones is the only one product that can boost the ECI optimally. For the case of 15 and 20 percent increment, the ECI does not change a lot, but there are still some tiny gains by increasing the export of machinery and chemicals. However, the additional investment in these industries offer a small amount of ECI gains, therefore, under budgeted constraints, the growth of the export of precious stones can optimize the ECI.

Mexico ECI Growth Optimization Result

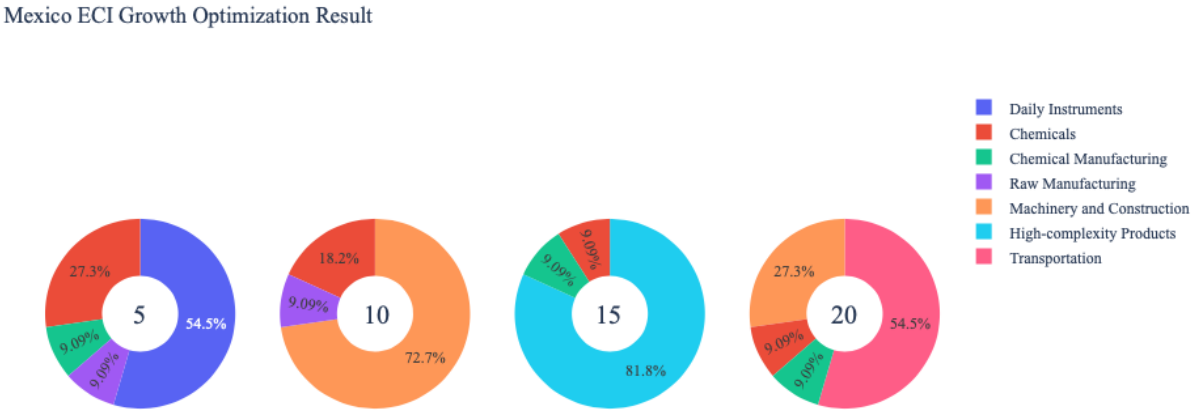


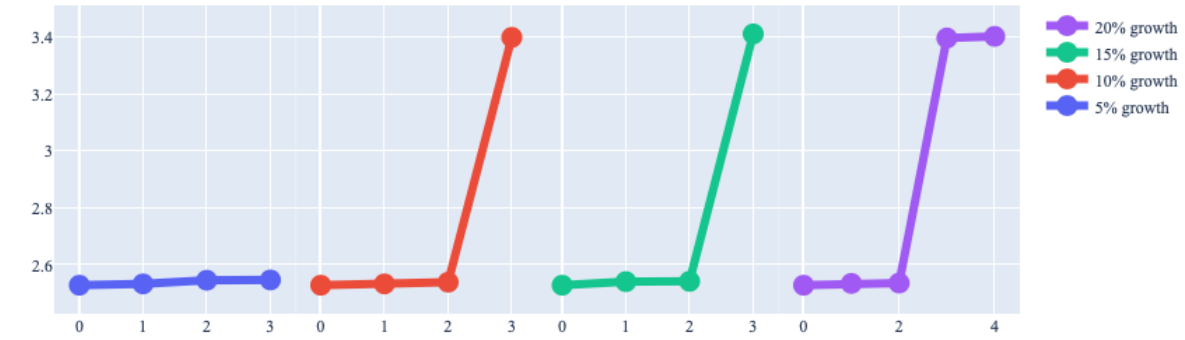
Mexico ECI Increment



Mexico (2013)				
Total Export in 2013 (US. $)	6.01E+11			
Original ECI	2.754			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	3.00E+10	6.01E+10	9.01E+10	1.20E+11
Machinery and Construction(US. $)	0.00E+00	0.00E+00	4.92E+10	5.15E+10
Precious Stones(US. $)	5.46E+09	5.46E+09	8.19E+09	8.58E+09
Chemicals(US. $)	0.00E+00	0.00E+00	8.19E+09	8.58E+09
Vegetables, Fruits and Plants(US. $)	2.46E+10	5.46E+10	2.46E+10	5.15E+10
Increased ECI	4.035	4.035	4.044	4.044

For further suggestions on Mexico's development in the future. We also offer the optimization result of Mexico based on export data in 2018. Below is the economic panel for Mexico in 2018. We can see that for different percentages of heuristic total export growth, the ECI growth pattern of Mexico is tiny for 5 percent export growth budget, but relatively large for 10 percent or more. For the case of 5, some fundamental products stimulate only a small amount of ECI increment, including daily instruments, chemicals etc. For the case of 10, 15 and 20 percent growth, their ECIs are not so much different, meaning that economic complexity structure is pretty well rounded. However, the products that caused the growth are different. These products are machinery and construction, high-complexity products, and transportations, respectively for 10, 15, and 20 growth situations. Therefore, for optimal future strategy, Mexico should select one of these three industries to prioritize, and then develop chemicals and chemical manufacturing.





Mexico (2018)				
Total Export in 2018 (US. $)	7.23E+11			
Original ECI	2.53			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	3.62E+10	7.23E+10	1.08E+11	1.45E+11
Chemicals (US. $)	9.86E+09	1.31E+10	9.86E+09	1.31E+10
Chemical Manufacturing (US. $)	3.29E+09	0.00E+00	9.86E+09	1.31E+10
Raw Manufacturing (US. $)	3.29E+09	6.57E+09	0.00E+00	0.00E+00
Machinery and Construction (US. $)	0.00E+00	5.26E+10	0.00E+00	3.94E+10
Transportation (US. $)	0.00E+00	0.00E+00	0.00E+00	7.89E+10
Daily Instruments (US. $)	1.97E+10	0.00E+00	0.00E+00	0.00E+00
High-complexity Products (US. $)	0.00E+00	0.00E+00	8.87E+10	0.00E+00
Increased ECI	2.55	3.4	3.41	3.41

4.3 Sensitivity Analysis and Contingency Strategy

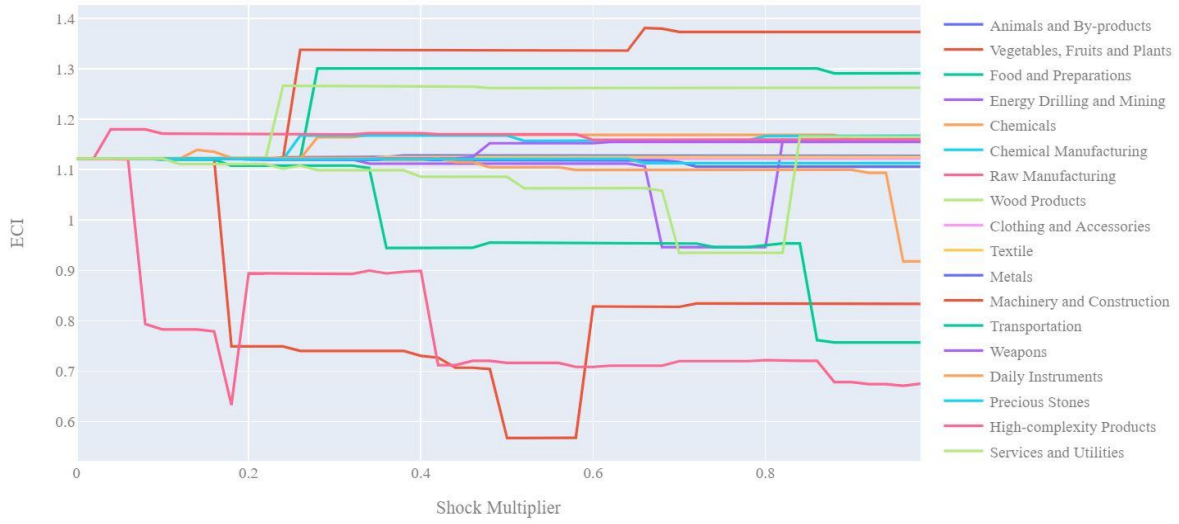
In the following section our broad aim is to understand how sensitive Mexico is to changes in export in various industries. While the Economic Complexity Index has been shown to contain valuable information about the economic strength/capacity of a country, little has been said as to the stability of the measure itself. We seek to uncover the main drivers of

stability under a country's ECI score and better understand longer-term projections for ECI growth. Additionally, gaining an intuition on the industries that are bolstering an economy and the industries that offer the greatest return per unit of investment is best done through visualization of industry specific sensitivity.

ECI Sensitivity Graph

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

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



Example 2018 (Incremental ECI Sensitivity)

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.

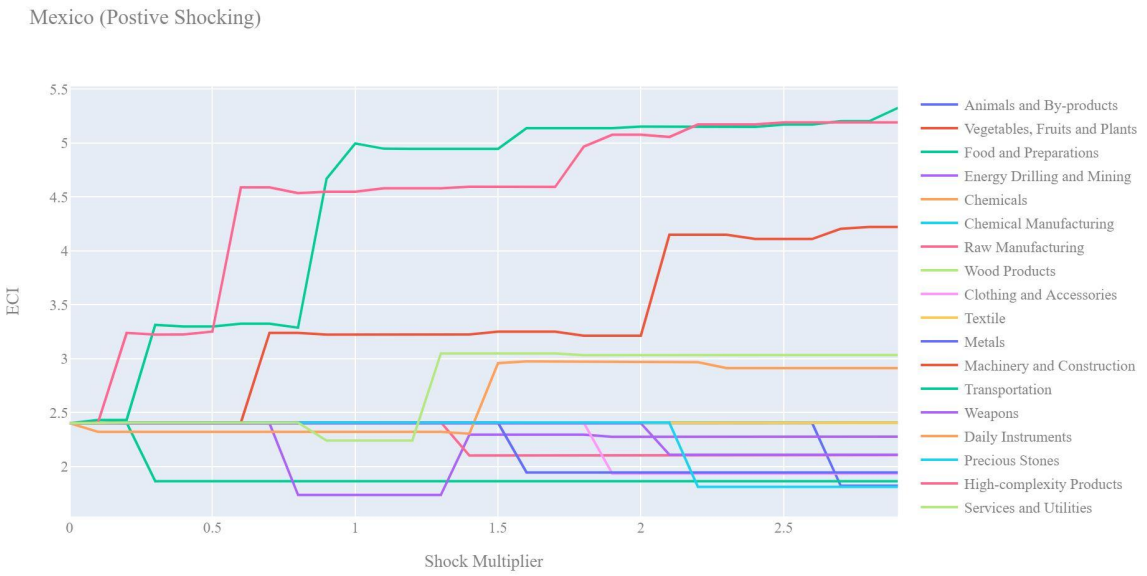
	0	1	2
Animals and By-products	Services and Utilities	Daily Instruments	Weapons
Vegetables, Fruits and Plants	Services and Utilities	Daily Instruments	Weapons
Food and Preparations	Services and Utilities	Daily Instruments	Weapons
Energy Drilling and Mining	Services and Utilities	Daily Instruments	Weapons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

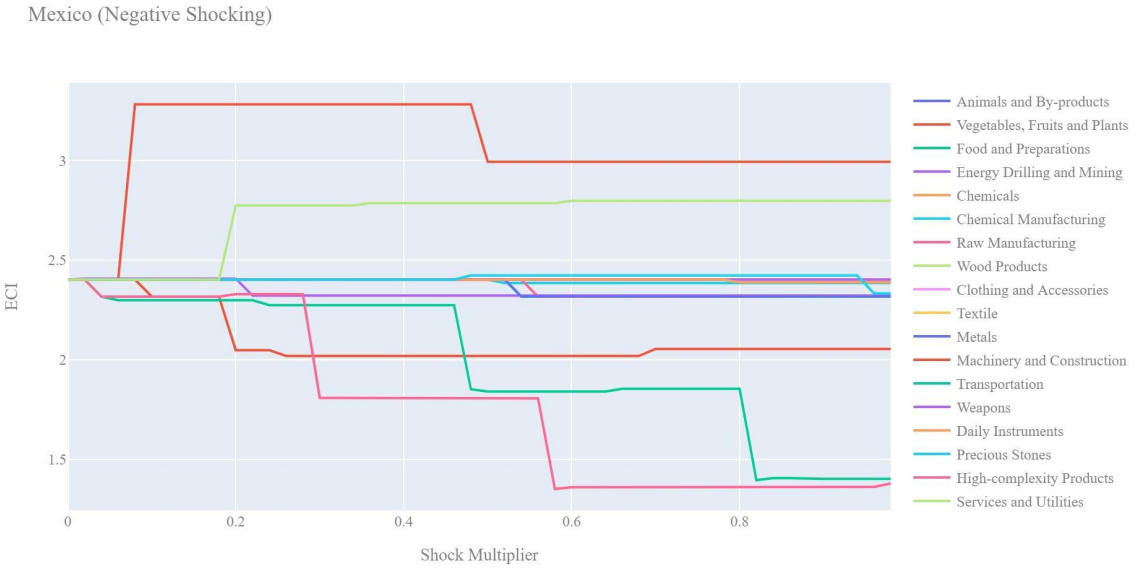
4.3 Sensitivity Analysis Results and Interpretation

Below is Mexico's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that High Complexity Products, Transportation and Machinery give fairly significant increases in ECI with only a 15-50% increase net export value. Services and Utilities, as well as Daily Instrument also lead to larger ECI levels however over 100% increase in exports are needed in order to experience the ECI expansion. All other industries tend to not greatly affect the ECI level making it fairly clear which industries to pursue.

Next we consider Mexico's 2018 Negative Shock chart. We can see that Mexico is fairly sensitive to the three industries listed above as expected from a country that relies on these industries to bolster its ECI level. Interestingly, even small decreases in export of Vegetables, Fruits and Plants can lead to vast increases in ECI suggesting that this industry is not worthwhile for the Mexican economy in the ECI context.



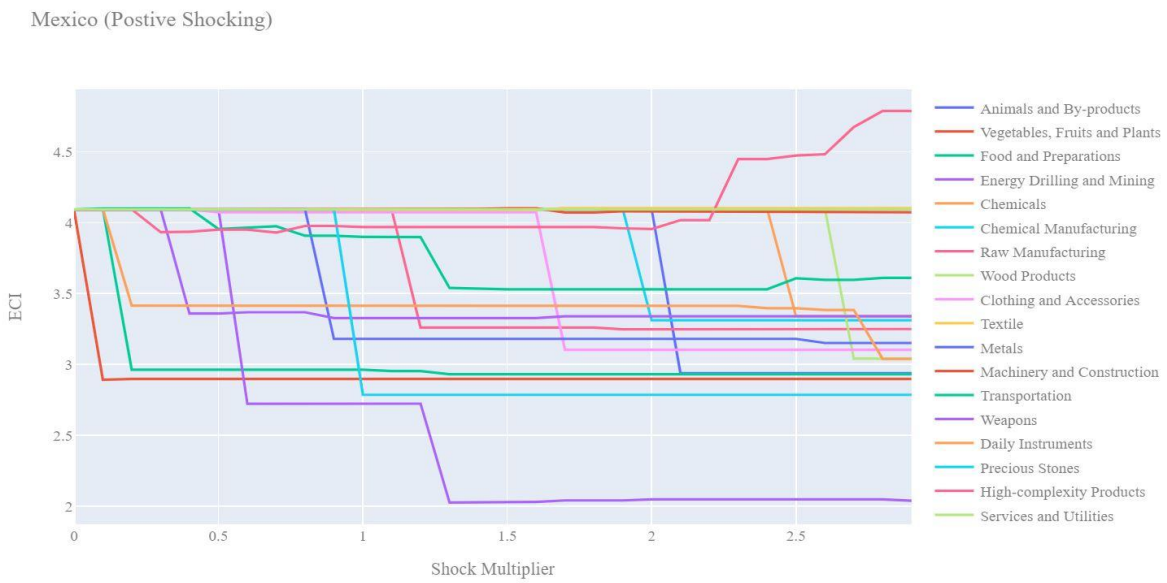
Mexico 2018 (Incremental ECI Sensitivity)



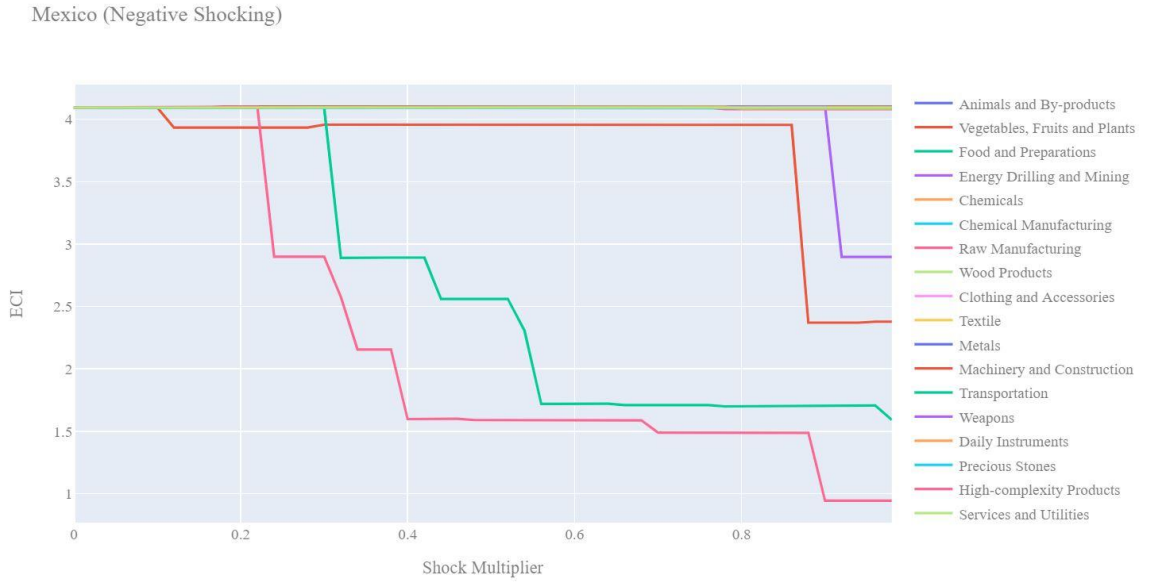
Mexico 2018 (Decremental ECI Sensitivity)

Next we consider the 2013 ECI Sensitivity graphs. We see notice immediately that Mexico had a significantly higher ECI in 2013 than 2018. Interestingly positive shocks in almost all industries lead to declines in ECI suggesting that Mexico already has a fairly well-balanced economy. Large increases in export in particularly High Complexity Products can increase ECI however.

In the 2013 negative shocking case, we see that again Mexico is fairly insensitive to decreases in export in most industries. High Complexity Products and Transportation however can greatly decrease ECI levels even with only 20-30% decreases in export. It is in Mexico's best interest then to protect these two industries in particular.



Mexico 2013 (Incremental ECI Sensitivity)



Mexico 2013 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for High Complexity Products. We see that everything held at current levels results in an SDV that contains 13 positive opportunity gain industries. Increases in the export of High Complexity Products leads to the conversion of many positive opportunity gain industries into negative opportunity fain industries since it would be more beneficial to continue to focus on High Complexity Products and industries related to High Complexity Products.

Considering the Negative SDV sensitivity chart we observe that as exports of High COmplexity Products decrease the SDV is not very affected. This is because many other industries already begin with a positive opportunity gain and so the export level of High Complexity products does not significantly affect their potential benefits.

	0.0%	20.0%	60.0%	180.0%
0	Wood Products	Chemicals	Machinery and Construction	Machinery and Construction
1	Metals	Textile	Services and Utilities	Daily Instruments
2	Food and Preparations	Services and Utilities	Chemicals	Chemicals
3	Animals and By-products	High-complexity Products	Daily Instruments	Services and Utilities
4	Raw Manufacturing	Transportation	Textile	Transportation
5	Clothing and Accessories	Machinery and Construction	Chemical Manufacturing	Textile
6	Energy Drilling and Mining	Daily Instruments	Weapons	Chemical Manufacturing
7	Chemical Manufacturing	Chemical Manufacturing	High-complexity Products	Weapons
8	Precious Stones	Weapons	Transportation	High-complexity Products
9	Textile	Clothing and Accessories	Clothing and Accessories	Clothing and Accessories
10	Weapons	Precious Stones	Precious Stones	Raw Manufacturing
11	Daily Instruments	Raw Manufacturing	Raw Manufacturing	Precious Stones
12	Chemicals	Metals	Wood Products	Metals
13	Machinery and Construction	Wood Products	Metals	Wood Products
14	Transportation	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining
15	High-complexity Products	Animals and By-products	Animals and By-products	Animals and By-products
16	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Food and Preparations	Food and Preparations
17	Services and Utilities	Food and Preparations	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
ECI	2.401979343	3.239206706	4.588340409	4.96528296

Mexico High-complexity Products 2018 (Incremental SDV Sensitivity)

	-0.0%	-4.0%	-30.0%	-58.0%
0	Wood Products	Wood Products	Wood Products	Metals
1	Metals	Metals	Metals	Wood Products
2	Food and Preparations	Food and Preparations	Food and Preparations	Raw Manufacturing
3	Animals and By-products	Animals and By-products	Raw Manufacturing	Clothing and Accessories
4	Raw Manufacturing	Raw Manufacturing	Animals and By-products	Chemical Manufacturing
5	Clothing and Accessories	Energy Drilling and Mining	Clothing and Accessories	Energy Drilling and Mining
6	Energy Drilling and Mining	Clothing and Accessories	Energy Drilling and Mining	Animals and By-products
7	Chemical Manufacturing	Precious Stones	Chemical Manufacturing	Textile
8	Precious Stones	Chemical Manufacturing	Precious Stones	Precious Stones
9	Textile	Textile	Textile	Chemicals
10	Weapons	Weapons	Weapons	Weapons
11	Daily Instruments	Chemicals	Chemicals	High-complexity Products
12	Chemicals	Machinery and Construction	High-complexity Products	Machinery and Construction
13	Machinery and Construction	High-complexity Products	Machinery and Construction	Transportation
14	Transportation	Transportation	Transportation	Daily Instruments
15	High-complexity Products	Daily Instruments	Daily Instruments	Food and Preparations
16	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
17	Services and Utilities	Services and Utilities	Services and Utilities	Services and Utilities
ECI	2.401979343	2.31699847	1.808648834	1.351817423

Mexico High-complexity Products 2018 (Decremental SDV Sensitivity)

Below we see the SDV sensitivity charts for Food and Preparations. As expected for a fairly developed country, Mexico is not very sensitive in both the positive shocking and negative shocking case to Food and Preparations. The country's SDV is largely unaffected by this particular industry.

	-0.0%	-54.0%
0	Wood Products	Wood Products
1	Metals	Metals
2	Food and Preparations	Food and Preparations
3	Animals and By-products	Animals and By-products
4	Raw Manufacturing	Raw Manufacturing
5	Clothing and Accessories	Energy Drilling and Mining
6	Energy Drilling and Mining	Clothing and Accessories
7	Chemical Manufacturing	Precious Stones
8	Precious Stones	Chemical Manufacturing
9	Textile	Textile
10	Weapons	Weapons
11	Daily Instruments	Chemicals
12	Chemicals	Machinery and Construction
13	Machinery and Construction	High-complexity Products
14	Transportation	Transportation
15	High-complexity Products	Daily Instruments
16	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
17	Services and Utilities	Services and Utilities
ECI	2.401979343	2.31699847

Mexico Food and Preparations 2018 (Incremental SDV Sensitivity)

	0.0%	30.0%
0	Wood Products	Wood Products
1	Metals	Metals
2	Food and Preparations	Clothing and Accessories
3	Animals and By-products	Raw Manufacturing
4	Raw Manufacturing	Chemical Manufacturing
5	Clothing and Accessories	Animals and By-products
6	Energy Drilling and Mining	Energy Drilling and Mining
7	Chemical Manufacturing	Precious Stones
8	Precious Stones	Textile
9	Textile	Chemicals
10	Weapons	Daily Instruments
11	Daily Instruments	Weapons
12	Chemicals	Machinery and Construction
13	Machinery and Construction	Transportation
14	Transportation	High-complexity Products
15	High-complexity Products	Food and Preparations
16	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
17	Services and Utilities	Services and Utilities
ECI	2.401979343	1.864857868

Mexico Food and Preparations 2018 (Decremental SDV Sensitivity)

4.4 Contingency Strategy

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

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

Mexico Contingency Strategy 2018

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

Mexico Contingency Strategy 2013

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

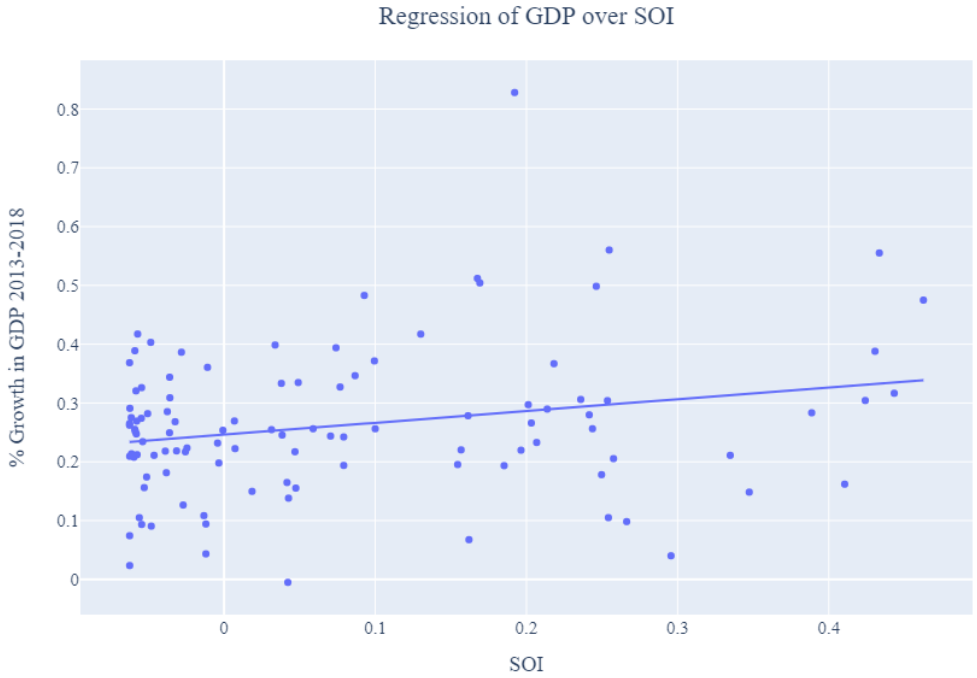


Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Mexico and Its Implications

Mexico, for instance, stands out among the countries in terms of structural optimality. 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), Mexico demonstrates a high level of correlation with the suggested developmental path, having an adjusted R-square of around -6.1%. Mexico ranks 103rd place among all countries in terms of SOI and has an 5-year GDP growth rate of 21.3% from 2013 to 2018. This is in direct contrast to developed economies such as the United States, where there is moderate SOI of around 15.7% and a corresponding annual growth rate of 22.1% similar to that of Mexico. Despite such a difference in SOI, Mexico seems to be growing at the same rate as the USA. As has been expressed, this is likely due to other political and economic factors not covered by the SOI index. It can be said that, Mexico's growth rate would have likely been higher had it followed a more optimal development strategy. For example, larger investment in High Complexity Products would be a positive factor.

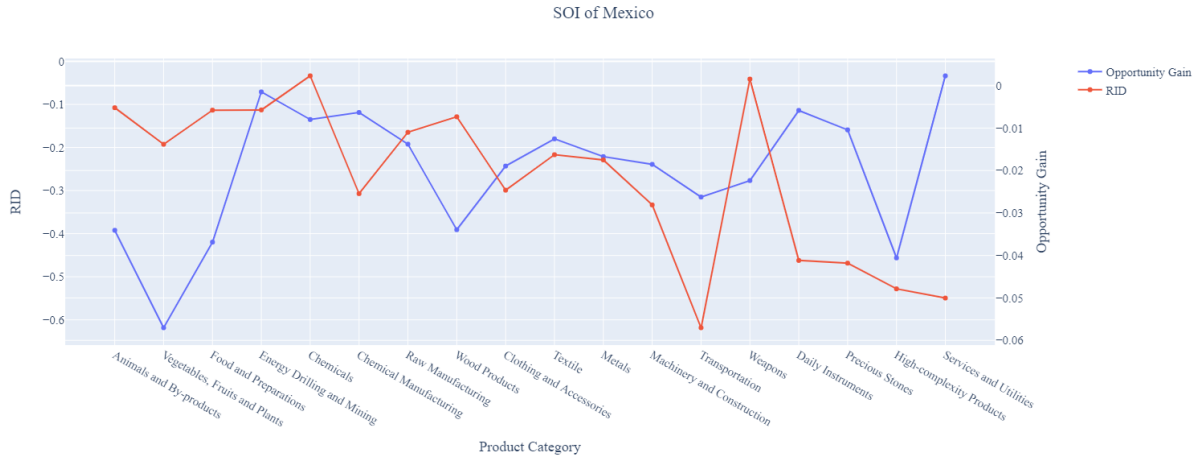


Figure 7: SOI of Mexico (2009-2014)

6. Concluding Remarks

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

The level of economic progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Mexico 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 Mexico invested heavily in developing basic industry groups such as Transportation, Services and Utilities, while its emerging peers and developed economies around the globe have adopted much more complex growth paths that can be potentially too aggressive and poorly-suited.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Mexico can further its gains by prioritizing Daily Instruments and Chemicals. We further note that Mexico has a well-matched development strategy that indicates a particularly high level of structural optimality on the complexity level, having an adjusted R-square of merely -6.1%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Mexico indeed has a nearly optimal 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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