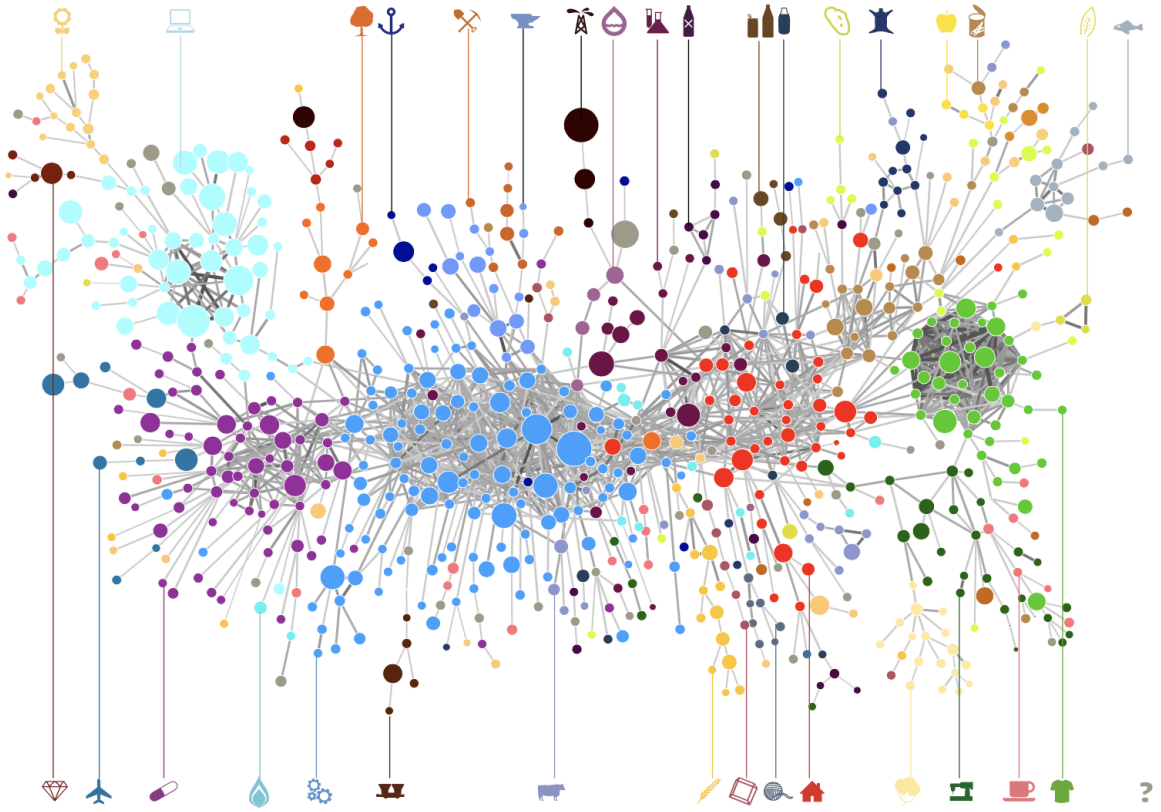

https://atlas.cid.harvard.edu/

Optimal Industry Development Strategy Using Economic and Product Complexity

Ecuador

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The Economic Complexity Lab - Columbia University

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Optimal Industry Development Strategy for Ecuador

0. Executive Summary

In this report, we uncover the economic path Ecuador went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Ecuador 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, Ecuador demonstrated a high level of economic growth with an average annual GDP growth rate of 2.47%, concurrent with a stable level of economic complexity as compared with other major developed economies.

The high level progress during the period can be partially explained through analysis of the economic complexity structure of Ecuador on the industry group level. The product classification system we adopt allows us to measure the realized development for various industry groups. We observe that Ecuador consistently relied on developing the Chemicals and Weapons 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, Ecuador can further its gains by prioritizing Daily Instruments, Chemical Manufacturing and Weapons. We further note that Ecuador has a fairly mismatched development strategy, having an adjusted R-square of around 2.7%. A significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, but Ecuador still has a suboptimal growth experience based on the metrics shown by our ECI framework. Despite having a high rate of growth, the country 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 Ecuador went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Ecuador from the perspective of Gross Domestic Product (GDP) and Economic Complexity Index (ECI), which reflect countries' production capability and production structure, respectively. We then analyze the industrial framework of Ecuador during the period based on quantitative measures such as Product Complexity Index (PCI) and Product Family Complexity Index (PfCI), followed by a detailed analysis of how changes to this framework have matched with development strategies as quantitatively measured by opportunity gains on an industry-level. We conclude our report with macro-level results and predictions of Ecuador, 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 Ecuador and three of its peer countries (Paraguay, Uruguay and Chile) from 2013-2018. Similar to the other countries, Ecuador saw a large degree of growth compared to its peers. Additionally, Ecuador's average annual growth rate of 2.47% over the five-year period is less than that of its peers, which are 3.0%, 4.94% and 3.09% for Uruguay, Paraguay and Chile, respectively.

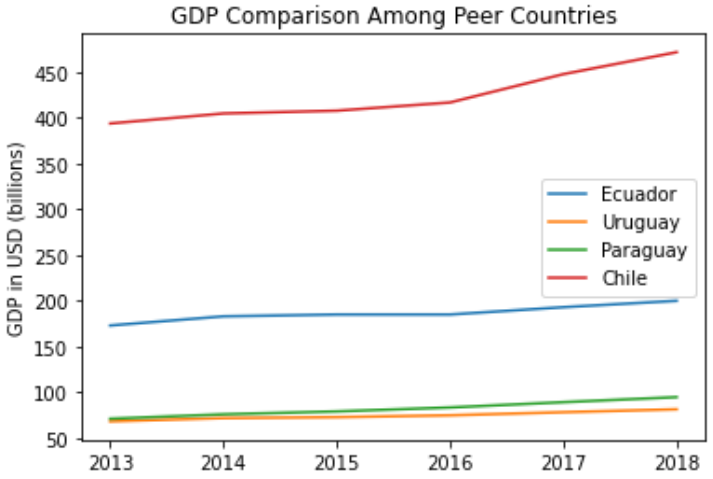


Figure 1: GDP Comparison Among Peer Countries

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, exhibits a similar growth pattern for Ecuador. As illustrated in Figure 2 below, Ecuador (1.34% ECI change) exhibited a slight increase in terms of its production capability from 2013 to 2018, which is similar to Paraguay (+1.34%), but different from both Uruguay (-173.95%) and Chile (-50.3%). Ultimately, Ecuador is among the middle in its peer group in terms of its GDP growth rate and ECI change across the period.

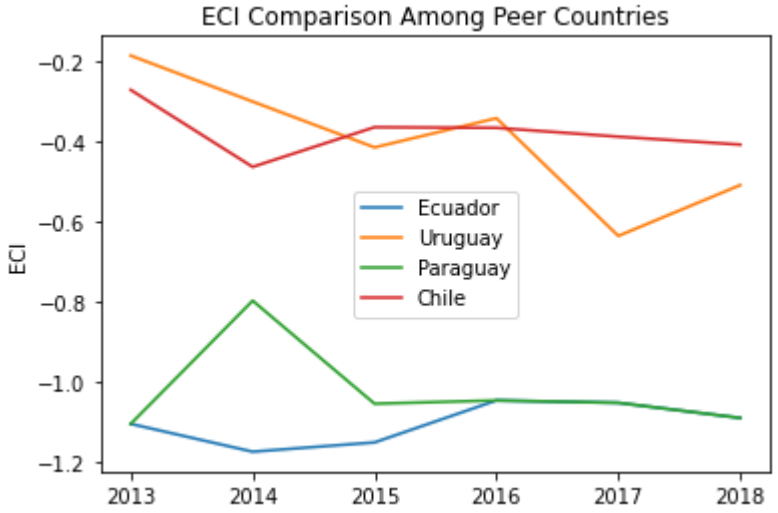


Figure 2: ECI Comparison

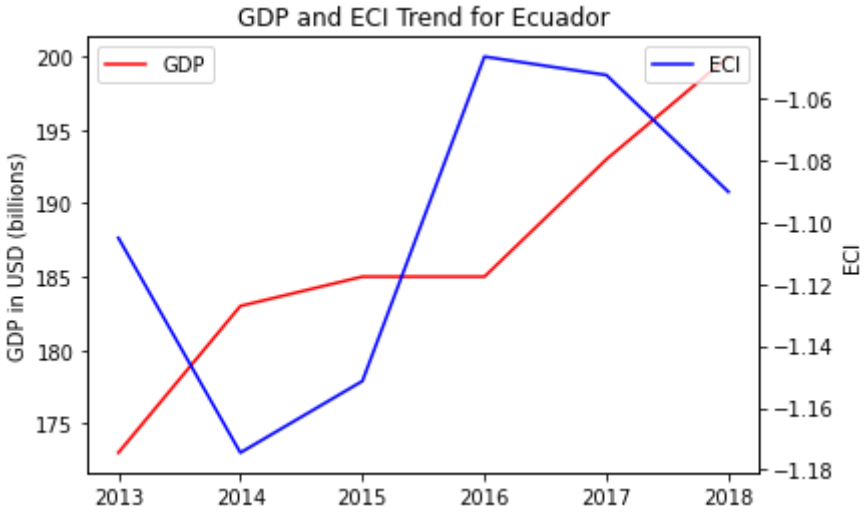


Figure 3: GDP Growth and ECI (Ecuador)

Figure 3 offers a further comparison of GDP Growth and ECI over the time span from 2013 to 2018 for Ecuador. The increase in GDP during the period from 2013 to 2018 is accompanied by a moderate growth in ECI barring 2014. The results show that the economic growth experienced by Ecuador during the period from 2013 to 2018 is partially consistent with the predictions by ECI and Ecuador did effectively make strides to develop a competitive product space that helps to accumulate complicated knowledge and technology. In order to provide a more concrete answer to why this has happened, we will dive into an analysis of Ecuador'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 labeled from 010000-999999, with the first two-digits representing a general category to which the product belongs. Based on the 99 categories as extracted from the label, we further group the products into 18 most widely-accepted industries, as summarized in Table 1.

Note that the High-complexity Products industry group is not a distinct industry but rather an aggregated industry that encompasses the most complicated products from the most technologically-advanced industries (as measured by PCI). This industry serves as an indicator for us to quantitatively evaluate how well a country has performed in developing cutting-edge technologies and closing its technical gap with advanced economies, which has become a topic of wide concern today. Indeed, when we rank the 18 categories based on PfCI (an equivalent concept of PCI as calculated based on the 18 categorized product groups), the High-complexity Products industry has the highest PfCI among all industry groups.

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

Table 1: Categorization of Products

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

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

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

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

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

3.2 Realized Industry Development

Based on the product categorization aforementioned, we aim to capture Ecuador'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 Ecuador 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
11	Machinery and Construction	-0.020991
5	Chemical Manufacturing	-0.020988
17	Services and Utilities	-0.018231
15	Precious Stones	-0.014824
0	Animals and By-products	-0.007231
8	Clothing and Accessories	-0.005077
14	Daily Instruments	0.000795
2	Food and Preparations	0.001893
10	Metals	0.002016
9	Textile	0.004838
6	Raw Manufacturing	0.010146
16	High-complexity Products	0.017691
12	Transportation	0.020664
1	Vegetables, Fruits and Plants	0.022559
7	Wood Products	0.026880
3	Energy Drilling and Mining	0.029498
13	Weapons	0.032844
4	Chemicals	0.035069

Table 2: Realized Industry Development (RID) of Ecuador

3.3 Regional and Global Comparison

Table 3 and 4 below summarize how the production strategy adopted by Ecuador 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 Ecuador'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 decrease in export of more profitable products, and therefore lead to a negative opportunity gain of product p. The opportunity gain is not the only estimator of a country's level of economic development. However, among countries with comparable economic strength, those having higher ECI, or in other words, more reasonable economic structures are often in better shape.

Ranking	Ecuador	Chile	Paraguay	Uruguay
1	High-complexity Products	Precious Stones	High-complexity Products	High-complexity Products
2	Machinery and Construction	Clothing and Accessories	Machinery and Construction	Machinery and Construction
3	Transportation	Services and Utilities	Transportation	Transportation
4	Daily Instruments	Machinery and Construction	Daily Instruments	Energy Drilling and Mining
5	Services and Utilities	Daily Instruments	Services and Utilities	Services and Utilities
6	Weapons	Textile	Weapons	Daily Instruments
7	Chemicals	High-complexity Products	Chemicals	Weapons
8	Chemical Manufacturing	Transportation	Chemical Manufacturing	Chemicals
9	Textile	Chemical Manufacturing	Textile	Textile
10	Raw Manufacturing	Animals and By-products	Raw Manufacturing	Precious Stones
11	Metals	Vegetables, Fruits and Plants	Metals	Clothing and Accessories
12	Wood Products	Food and Preparations	Wood Products	Metals
13	Precious Stones	Energy Drilling and Mining	Precious Stones	Animals and By-products
14	Clothing and Accessories	Chemicals	Clothing and Accessories	Vegetables, Fruits and Plants
15	Animals and By-products	Raw Manufacturing	Animals and By-products	Food and Preparations
16	Vegetables, Fruits and Plants	Wood Products	Vegetables, Fruits and Plants	Chemical Manufacturing
17	Food and Preparations	Metals	Food and Preparations	Raw Manufacturing
18	Energy Drilling and Mining	Weapons	Energy Drilling and Mining	Wood Products
ECI	-1.11	-0.27	-1.11	-0.19

Ranking	Ecuador	Chile	Paraguay	Uruguay
1	High-complexity Products	Precious Stones	High-complexity Products	High-complexity Products
2	Transportation	Clothing and Accessories	Transportation	Transportation
3	Machinery and Construction	High-complexity Products	Machinery and Construction	Machinery and Construction
4	Daily Instruments	Transportation	Daily Instruments	Daily Instruments
5	Weapons	Textile	Weapons	Weapons
6	Chemicals	Machinery and Construction	Chemicals	Energy Drilling and Mining
7	Chemical Manufacturing	Daily Instruments	Chemical Manufacturing	Textile
8	Raw Manufacturing	Chemical Manufacturing	Raw Manufacturing	Chemicals
9	Textile	Services and Utilities	Textile	Clothing and Accessories
10	Metals	Animals and By-products	Metals	Metals
11	Clothing and Accessories	Vegetables, Fruits and Plants	Clothing and Accessories	Chemical Manufacturing
12	Wood Products	Food and Preparations	Wood Products	Precious Stones
13	Precious Stones	Energy Drilling and Mining	Precious Stones	Animals and By-products
14	Animals and By-products	Chemicals	Animals and By-products	Vegetables, Fruits and Plants
15	Vegetables, Fruits and Plants	Raw Manufacturing	Vegetables, Fruits and Plants	Food and Preparations
16	Food and Preparations	Wood Products	Food and Preparations	Raw Manufacturing
17	Energy Drilling and Mining	Metals	Energy Drilling and Mining	Wood Products
18	Services and Utilities	Weapons	Services and Utilities	Services and Utilities
ECI	-1.11	-0.41	-1.11	-0.51

Table 5: SDV of Peer E_fCI Countries 2013(up), 2018(down)

We define the ranking of opportunity gain for a country c, as the Suggested Development Vector (SDV) of c. Table 5 and 6 summarize how the SDV of Ecuador compares with a selected group of comparable 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 peer countries have less industries with positive opportunity gain compared to Ecuador. In other words, those countries have a slightly more stable and efficient economic structure. Those countries have less industry groups with positive opportunity gain compared to Ecuador to maintain a steady and balanced economic development. Ecuador is an example of a developing country, since nearly half of its industries are those with positive opportunity gain. It can be concluded that Ecuador shares the characters of developing countries, with a balanced economics structure that leans towards intermediate-level industries.

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

Table 6: SDV of Other Typical Countries 2013

4.2 Budgeted Industry Development Strategy and Interpretation

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

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

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

If we can solve this problem, then we can know what the largest ECI that a country can improve to. Accordingly, the optimal solution x * that we obtain here is exactly our optimal allocation. However, the biggest problem is that the objective function is not convex. Therefore, we cannot apply the classical tools for convex optimization on this problem. In order to solve this problem, our idea is to use 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 Ecuador in 2013. We can see that for different percentages of heuristic total export growth, the ECIs of Ecuador have different amounts of increments. Overall, 10 and 15 percent export growth results in a similar ECI improvement pattern, which starts from around -1.1 and ends at around -0.13 and -0.10, respectively.

For the case of 5 percent export growth, Chemicals and Weapons account for most of the portfolio. For 10 percent export growth, more weights are put on other industries, such as Raw Manufacturing and Service/Utilities. As we move to 15% growth, we also notice that the largest improvement comes from Metals, suggesting that with a low economic improvement anticipation, Ecuador should focus more on developing this industry. For the case of 20 percent increment budgets, we realize that the development trajectory is in a different pattern. Different from the previous two cases, the solutions suggest that Ecuador should invest more on Daily Instruments. This makes sense because with more budgets, a country should definitely focus more on the development of high-end product spaces. A more detailed numerical representation of the portfolio is shown in Table 8.

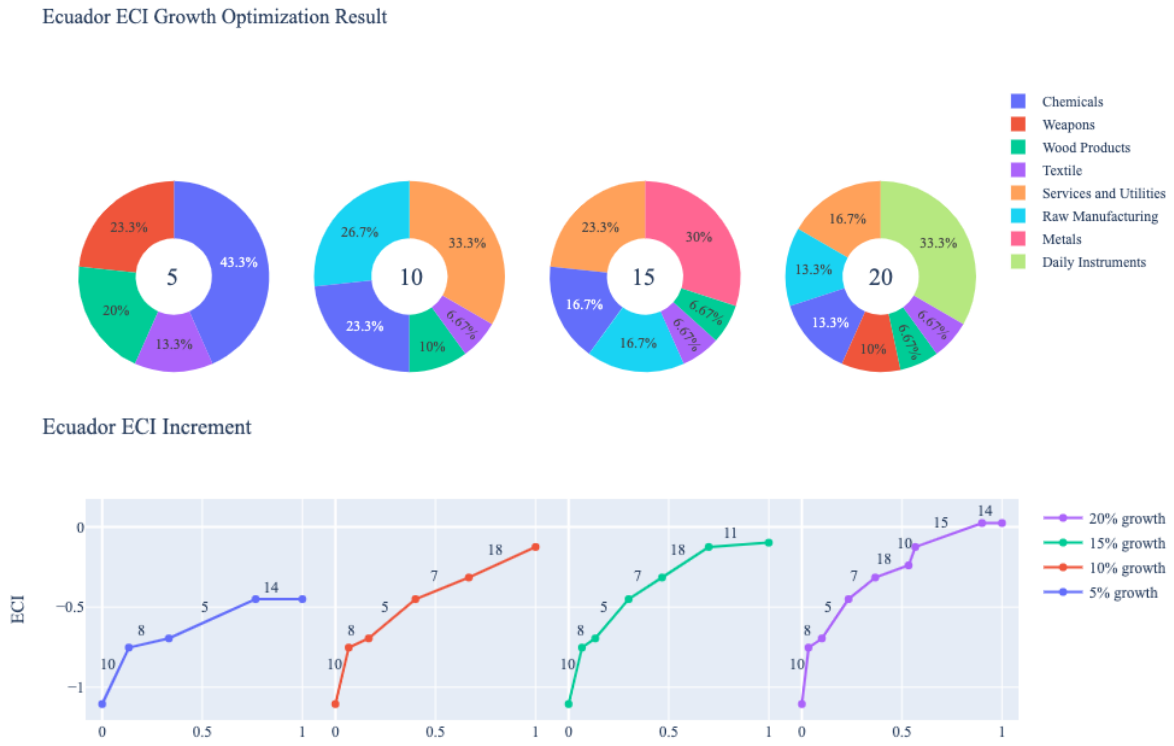


Figure 5: Greedy Based ECI Improvement Results of Ecuador in 2013 with Different Budgets

Ecuador (2013)				
Original ECI	-1.11			
Heuristic Export Growth	5%	10%	15%	20%
Chemicals	5.51E+08	5.93E+08	6.36E+08	6.78E+08
Raw Manufacturing	0.00E+00	6.78E+08	6.36E+08	6.78E+08
Wood Products	2.54E+08	2.54E+08	2.54E+08	3.39E+08
Textile	1.70E+08	1.70E+08	2.54E+08	3.39E+08
Metals	0.00E+00	0.00E+00	1.14E+09	0.00E+00
Weapons	2.97E+08	0.00E+00	0.00E+00	5.09E+08
Daily Instruments	0.00E+00	0.00E+00	0.00E+00	1.70E+09
Services and Utilities	0.00E+00	8.48E+08	8.90E+08	8.48E+08
Increased ECI	-0.45	-0.13	-0.10	0.02

Table 8: Portfolio of Ecuador in 2013

For further suggestions on Ecuador's development in the future, we also offer the optimization result of Ecuador based on export data in 2018. Below is the economic panel for Ecuador in 2018. We can see that there is a slightly different pattern for the ECI improvement trajectories, which is that the improvements across all export growth rates are different, with the jumps for 5 and 10 percent being similar, but via a different development path. For a 5 percent export growth, the main components include Raw Manufacturing and Chemicals, while for a 10 percent growth rate, the main components consist of Wood Products and Clothing and Accessories. For situations with higher budgets of investment, like 15 percent and 20 percent of growth, the portfolios are more diverse than the previous cases. In detail, for 15 percent, industries like Chemical Manufacturing, Chemicals and Clothing and Accessories contribute most towards ECI increments, and for a 20 percent rate, the Wood Products industry dominates the optimization result. A more detailed numerical representation of the portfolio is shown in Table 9.

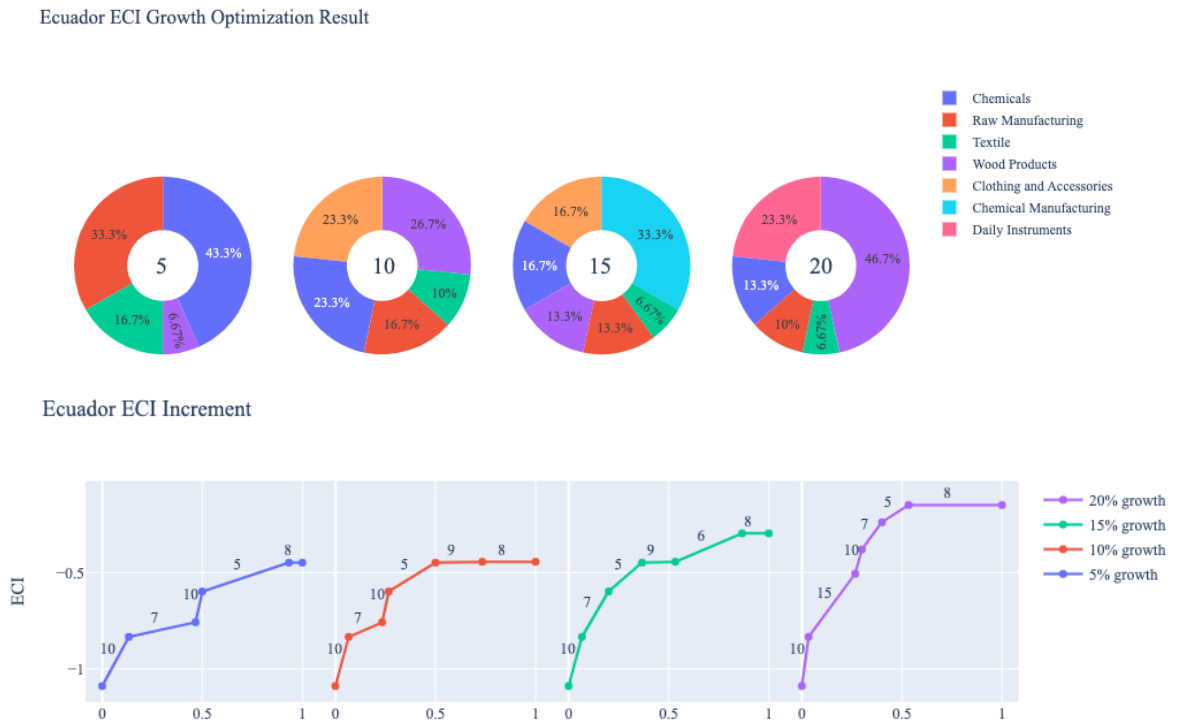


Figure 6: Greedy Based ECI Improvement Results of Ecuador in 2018 with Different Budgets

	Ecuador (2018)			
Original ECI	-1.09			
Heuristic Export Growth	5%	10%	15%	20%
Chemicals	4.76E+08	5.12E+08	5.49E+08	5.86E+08
Chemical Manufacturing	0.00E+00	0.00E+00	1.10E+09	0.00E+00
Raw Manufacturing	3.66E+08	3.66E+08	4.39E+08	4.39E+08
Wood Products	7.32E+07	5.86E+08	4.39E+08	2.05E+09
Clothing and Accessories	0.00E+00	5.12E+08	5.49E+08	0.00E+00
Textile	1.83E+08	2.20E+08	2.20E+08	2.93E+08
Daily Instruments	0.00E+00	0.00E+00	0.00E+00	1.02E+09
Increased ECI	-0.45	-0.44	-0.30	-0.15

Table 9: Portfolio of Ecuador in 2018

4.3 Sensitivity Analysis and Contingency Strategy

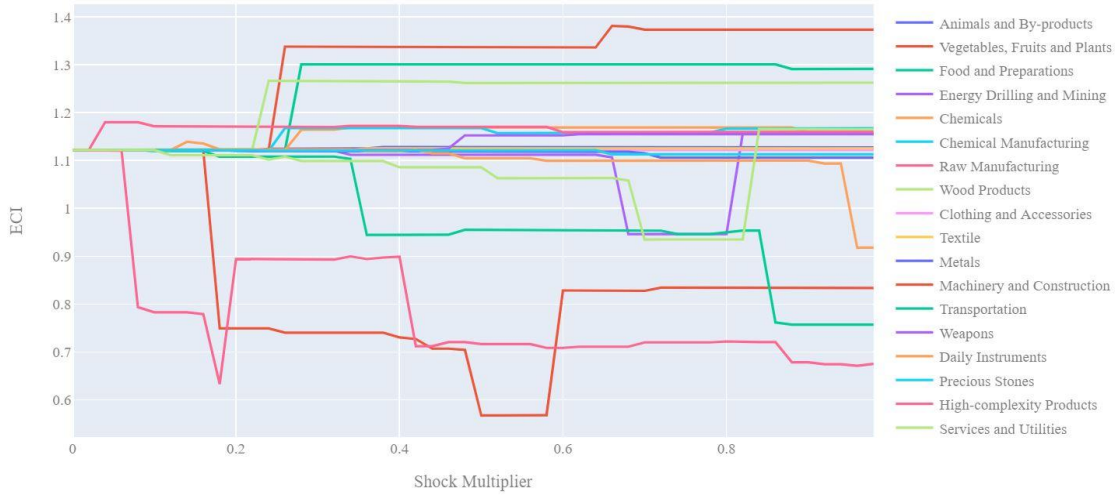
In the following section our broad aim is to understand how sensitive Ecuador is to changes in export in various industries. While the Economic Complexity Index has been shown to contain valuable information about the economic strength/capacity of a country, little has been said as to the stability of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

ECI Sensitivity Graph

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

The graphs are formulated as follows: There are four ECI Sensitivity graphs. The first two represent data from 2018. The first chart shows positive shocks in which export numbers are shocked upwards per industry. The X-axis is in terms of percentage shock per current dollar

value of export. The Y-axis is the recalculated ECI level post-shocking. The second chart follows the same format except the X-axis represents negative shocking. In other words, exports for each industry are decremented and the ECI is accordingly recomputed. The final two sensitivity graphs show the same results using 2013 data. Below is an example of an ECI sensitivity graph.



Example 2018 (Incremental ECI Sensitivity)

SDV sensitivity

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

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

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

Shocking. Industries with positive marginal opportunity gain are colored blue, neutral is colored white and negative is colored red.

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

Example High-complexity Products 2018 (Incremental SDV Sensitivity)

Contingency Plan

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

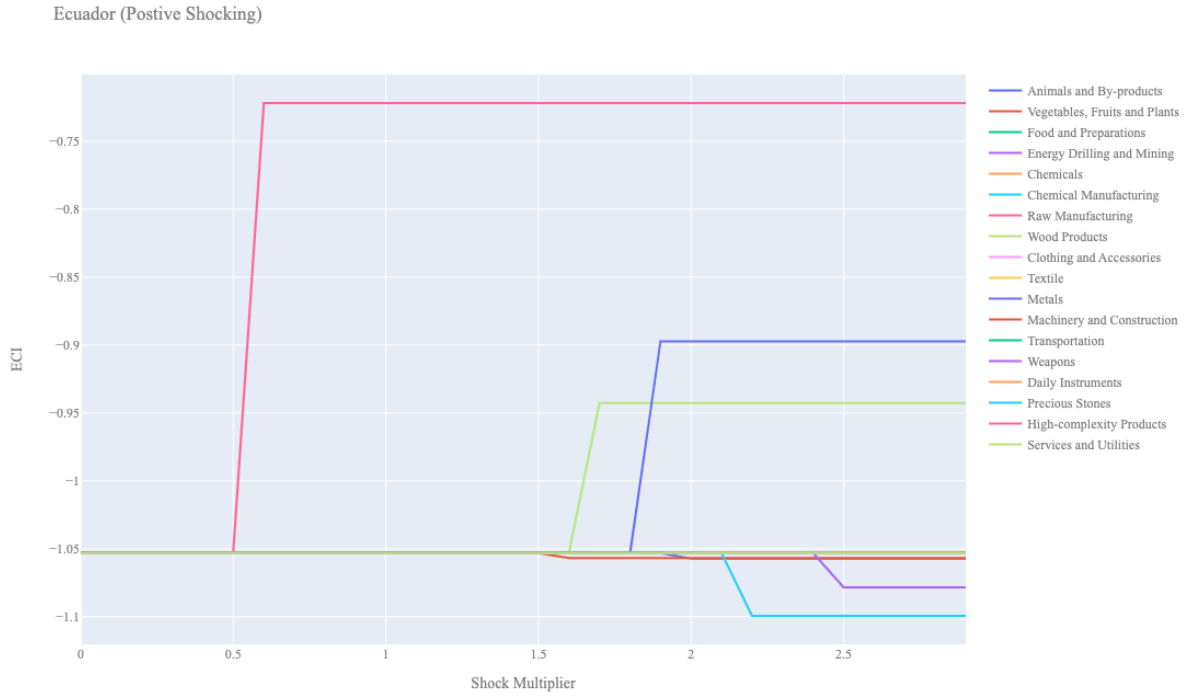
	0	1	2
Animals and By-products	Services and Utilities	Daily Instruments	Weapons
Vegetables, Fruits and Plants	Services and Utilities	Daily Instruments	Weapons
Food and Preparations	Services and Utilities	Daily Instruments	Weapons
Energy Drilling and Mining	Services and Utilities	Daily Instruments	Weapons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

Example Contingency Strategy 2018

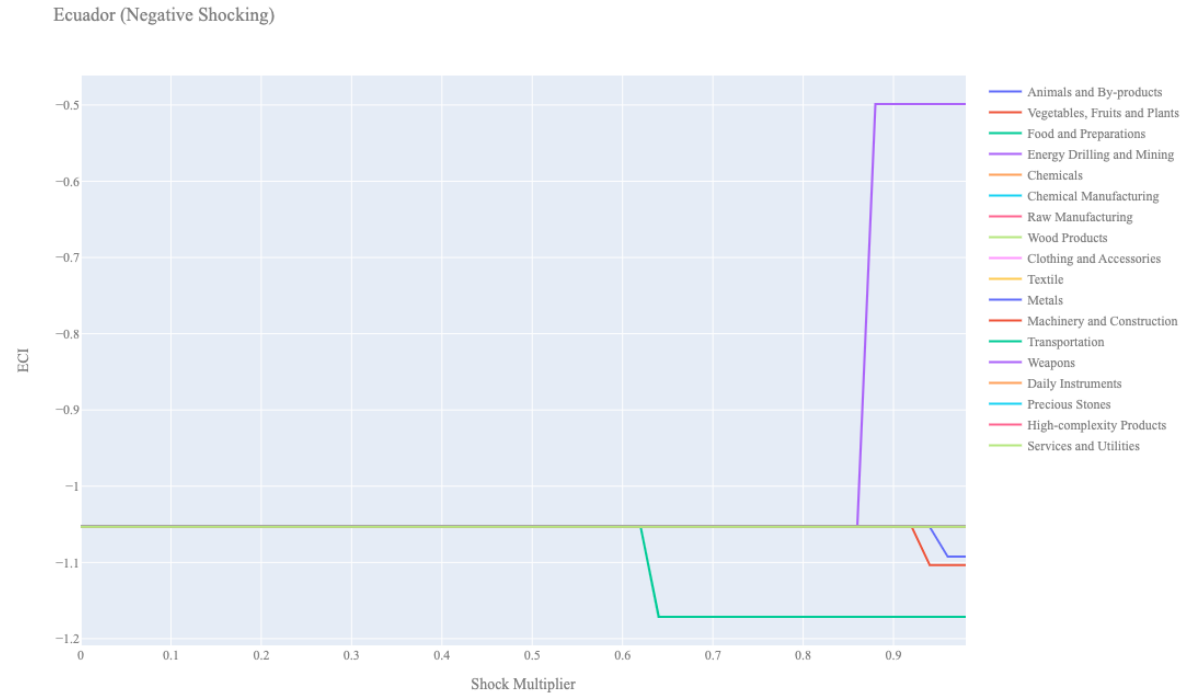
4.3 Sensitivity Analysis Results and Interpretation

Below is Ecuador's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that increases in Raw Manufacturing and Metals lead to an uptrend in ECI. Raw Manufacturing offers the best ECI growth per unit of export increase.

Next we consider Ecuador's 2018 Negative Shock chart. We see that Ecuador's ECI is slightly sensitive to drawdowns in Food & Preparations and Animals & By-products. More interestingly we see that large decreases in Energy Drilling & Mining seems to greatly increase the ECI score. This industry is very important for Ecuador's economy and thus the results that are reflected in the chart may be suggesting that there is another industry that could be very beneficial for Ecuador that is far in proximity from the Energy & Drilling industry.



Ecuador 2018 (Incremental ECI Sensitivity)

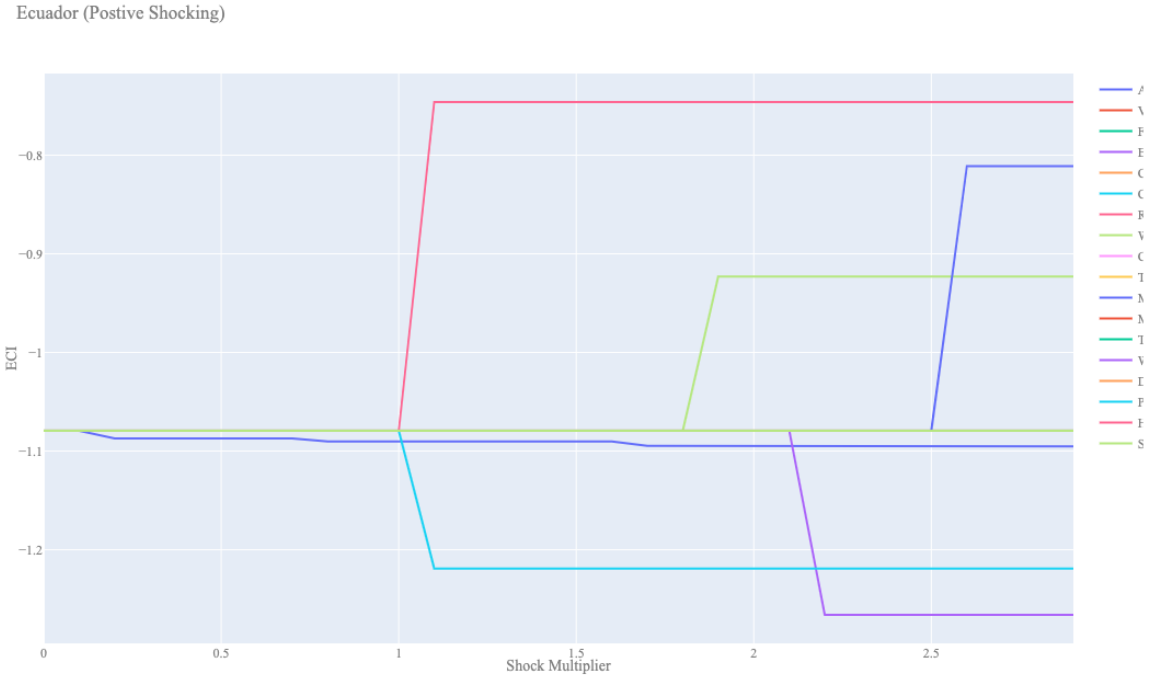


Ecuador 2018 (Decremental ECI Sensitivity)

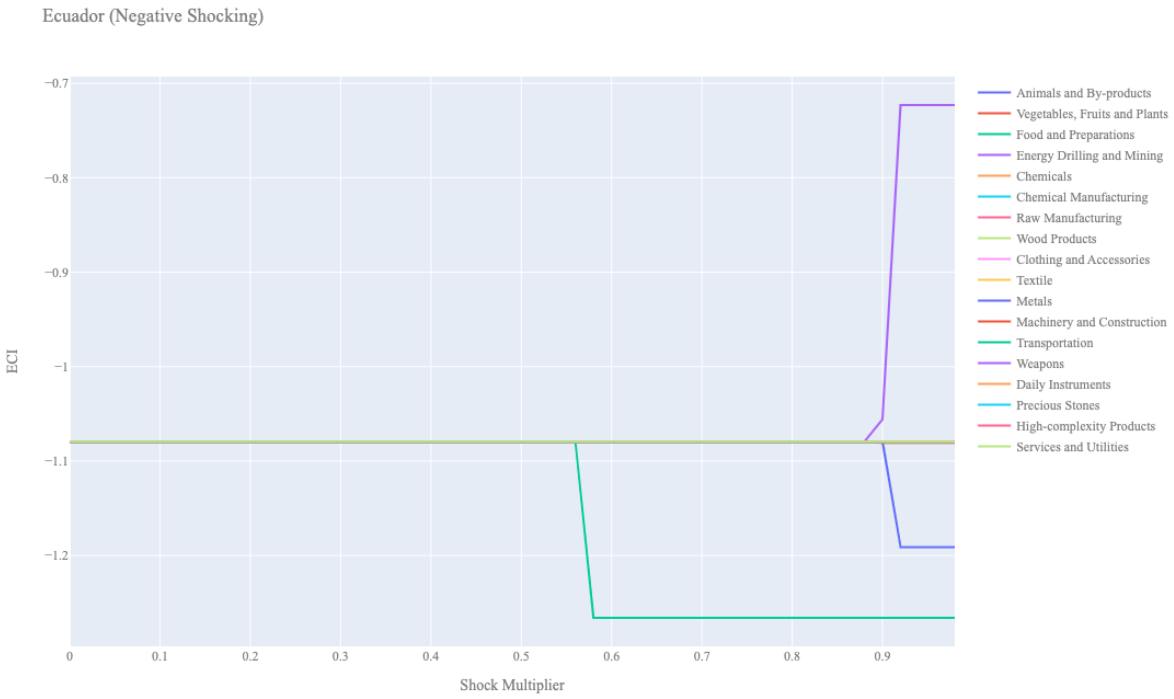
Next we consider the 2013 ECI Sensitivity graphs. We see that in the positive shocking case, the landscape of ECI sensitivity has not altered significantly over the five year period. Raw

Manufacturing and Metals seem to offer the best ECI growth prospects, with Energy & Drilling actually decreasing the ECI.

In the 2013 negative shocking case, we see that Ecuador is similarly most sensitive to drawdowns in Energy & Drilling and Animals & Byproducts industries.



Ecuador 2013 (Incremental ECI Sensitivity)



Ecuador 2013 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for High-Complexity Products. We see that both increasing and decreasing the export of High-Complexity Products does not open that much positive opportunity gain .

For Food and Preparations, on the other hand, while we do not see much impact based on an increase in the exports of this commodity, we do see a slight increase in the number of positive-opportunity gain industries upon a decrease in Food and Preparations exports, suggesting a potential shift away from this industry could lead to beneficial development results.

	0%
0	High-complexity Products
1	Daily Instruments
2	Machinery and Construction
3	Transportation
4	Raw Manufacturing
5	Chemical Manufacturing
6	Textile
7	Clothing and Accessories
8	Weapons
9	Wood Products
10	Chemicals
11	Metals
12	Services and Utilities
13	Precious Stones
14	Vegetables, Fruits and Plants
15	Energy Drilling and Mining
16	Food and Preparations
17	Animals and By-products
ECI	-1.053287966

Ecuador High-complexity Products 2018 (Incremental & Decremental SDV Sensitivity)

	0%
0	High-complexity Products
1	Daily Instruments
2	Machinery and Construction
3	Transportation
4	Raw Manufacturing
5	Chemical Manufacturing
6	Textile
7	Clothing and Accessories
8	Weapons
9	Wood Products
10	Chemicals
11	Metals
12	Services and Utilities
13	Precious Stones
14	Vegetables, Fruits and Plants
15	Energy Drilling and Mining
16	Food and Preparations
17	Animals and By-products
ECI	-1.053287966

Ecuador Food and Preparations 2018 (Incremental SDV Sensitivity)

	-0%	-64%
0	High-complexity Products	Daily Instruments
1	Daily Instruments	High-complexity Products
2	Machinery and Construction	Machinery and Construction
3	Transportation	Raw Manufacturing
4	Raw Manufacturing	Transportation
5	Chemical Manufacturing	Chemical Manufacturing
6	Textile	Wood Products
7	Clothing and Accessories	Clothing and Accessories
8	Weapons	Textile
9	Wood Products	Metals
10	Chemicals	Weapons
11	Metals	Chemicals
12	Services and Utilities	Food and Preparations
13	Precious Stones	Precious Stones
14	Vegetables, Fruits and Plants	Services and Utilities
15	Energy Drilling and Mining	Vegetables, Fruits and Plants
16	Food and Preparations	Energy Drilling and Mining
17	Animals and By-products	Animals and By-products
ECI	-1.053287966	-1.171396757

Ecuador Food and Preparations 2018 (Decremental SDV Sensitivity)

4.4 Contingency Strategy

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

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

Ecuador 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

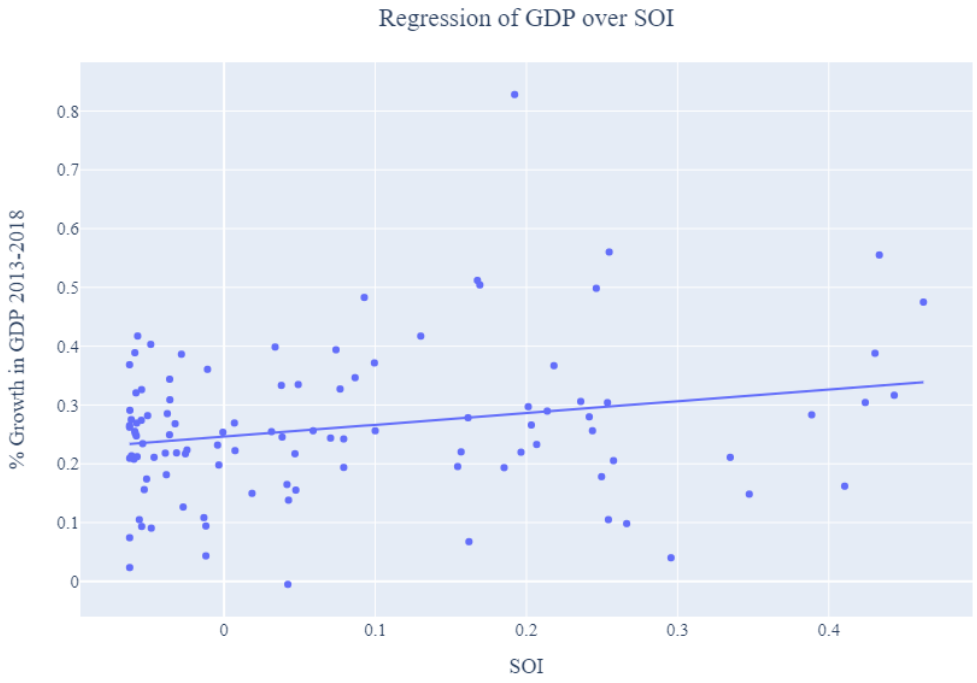


Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Ecuador and Its Implications

Ecuador for instance, has a low level of structural optimality as compared with its developed peers. As the regression in Figure 7 suggests (the orange curve represents export increase and the blue curve stands for opportunity gain of the corresponding industry), Ecuador demonstrates a low level of correlation with the suggested developmental path, having an adjusted R-square of around 2.7%. Ecuador ranks in the bottom half among all countries in terms of SOI, yet has made a high rate of economic progress above its developed peers from 2013 to 2018 with a 5-year GDP growth rate of 15.6%. This is in direct contrast to other developed economies such as Japan, where there is low SOI of around -5.7% and a corresponding GDP growth of 9.05% from 2013 to 2018, making it a much slower developing economy during the period. In sum, Ecuador's high economic progress from 2013 to 2018 does not seem to be correlated with the optimal development strategy, as it does not demonstrate a high level of matches with our suggested developmental path. In specific, Ecuador invested heavily in the Weapons, Wood Products and Chemicals industries, while it should have focused more on more complex industry groups such as Energy & Drilling to maximize ECI.

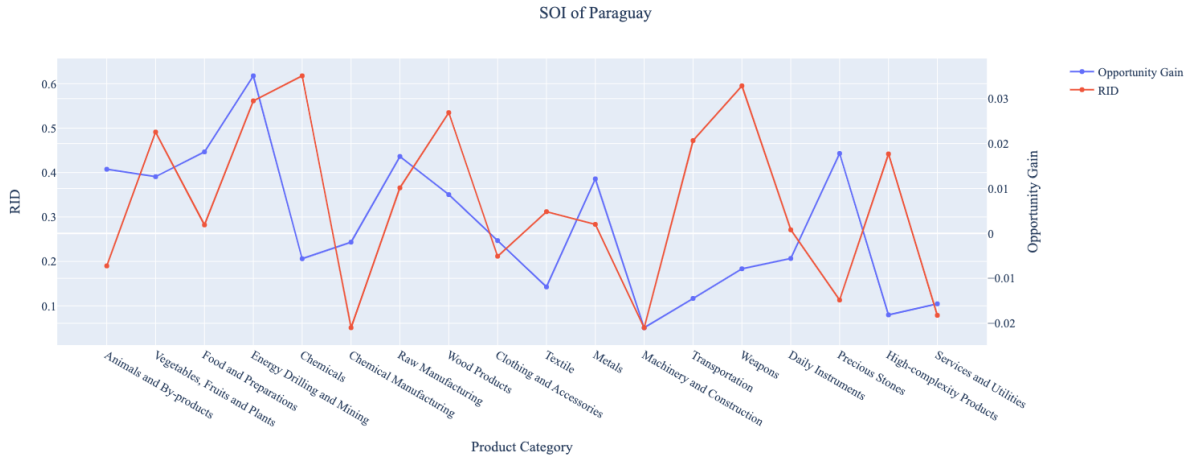


Figure 7: SOI of Ecuador (2009-2014)

6. Concluding Remarks

In conclusion, Ecuador has demonstrated a high level of economic growth in terms of annual GDP increase during the period from 2013 to 2018, although this does not fully line up with a relatively stable level of economic complexity as compared with other major developed economies.

The high level of progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Ecuador 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 Ecuador consistently relied on developing the Chemicals and Weapons industries during the period, while its developed counterparts and emerging economies around the globe have adopted other more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Ecuador can further its gains by prioritizing Energy & Drilling and Raw Manufacturing. We further note that Ecuador has a slightly mismatched development strategy that indicates a moderately high (compared to other developed countries) level of structural optimality on the complexity level, having an adjusted R-square of around 2.7%. Despite the fact a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Ecuador still has a high growth experience as compared with fast-growing economies both on a regional scale and on a global scale, but still has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

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