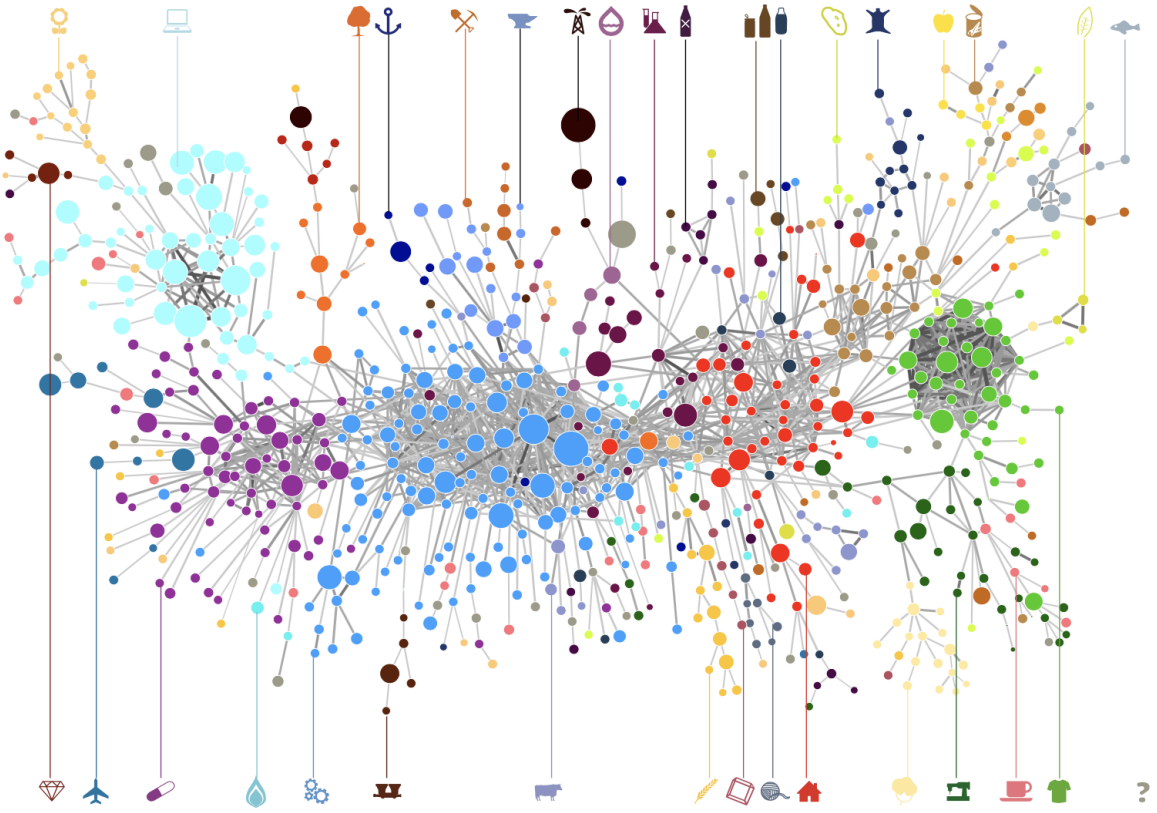

https://atlas.cid.harvard.edu/

Optimal Industry Development Strategy Using Economic and Product Complexity

Uruguay

—

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Optimal Industry Development Strategy for Uruguay

0. Executive Summary

In this report, we uncover the economic path Uruguay went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Uruguay 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, Uruguay demonstrated a high level of economic growth with an average annual GDP growth rate of 19.37%, concurrent with a rate of growth in GDP as compared with other major developed economies and fast growing economies.

The fast pace of GDP growth during the period can be partially explained through analysis of the economic complexity structure of Uruguay on an industry group level. The product classification system we adopt allows us to measure the realized development for various industry groups. We observe that Uruguay consistently relied on developing the Transportation industry 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, Uruguay can further its gains by prioritizing Metals and Precious Stones. We further note that Uruguay 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 19.5%. A significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, but Uruguay still has a suboptimal growth experience as compared with fast-growing economies both on a regional scale and on a global scale. However, the country has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

1. Report Overview

We aim to uncover the economic path Uruguay went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Uruguay 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 Uruguay 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 Uruguay, 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 Uruguay and three of its peer countries (Uruguay, Paraguay, Costa Rica) from 2013-2018. Uruguay, like other peer countries, has shown upwards growth in GDP over the years.Moreover, Uruguay's GDP has grown at a slower rate than its peer countries. Uruguay's average annual growth rate of 3.01% has been lower than its peers, which are 5.3%, 4.94% and 4.35% for Uruguay, Paraguay and Costa Rica respectively.

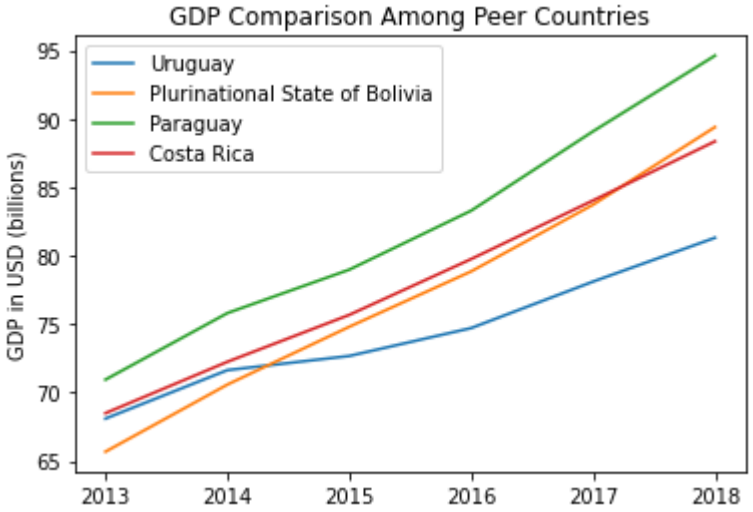


Figure 1: GDP Comparison Among Peer Countries

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 Uruguay. As illustrated in Figure 2 below, Uruguay (-183.37% ECI

change) exhibited a increase in terms of its production capability from 2013 to 2018, which is different from Bolivia (21.77%), Costa Rica (-73.57%)and the Paraguay (3.91%). Ultimately, Uruguay is the weakest of the peer country set, as it displays the lowest GDP growth rate and ECI change across the period.

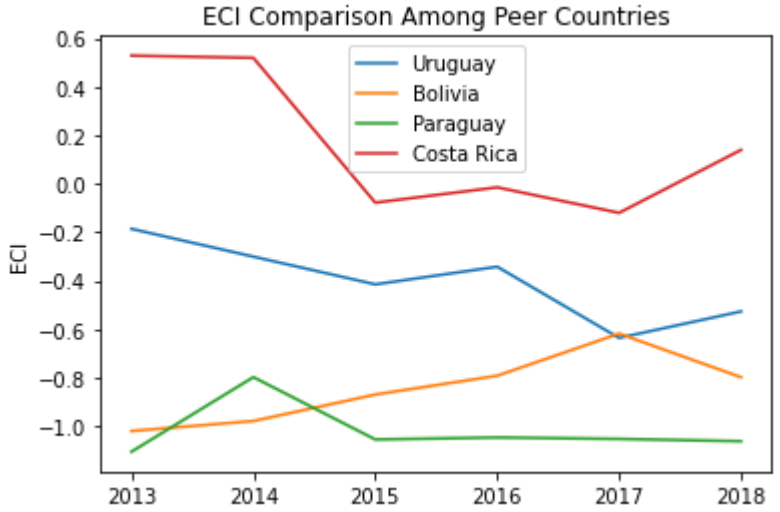


Figure 2: ECI Comparison

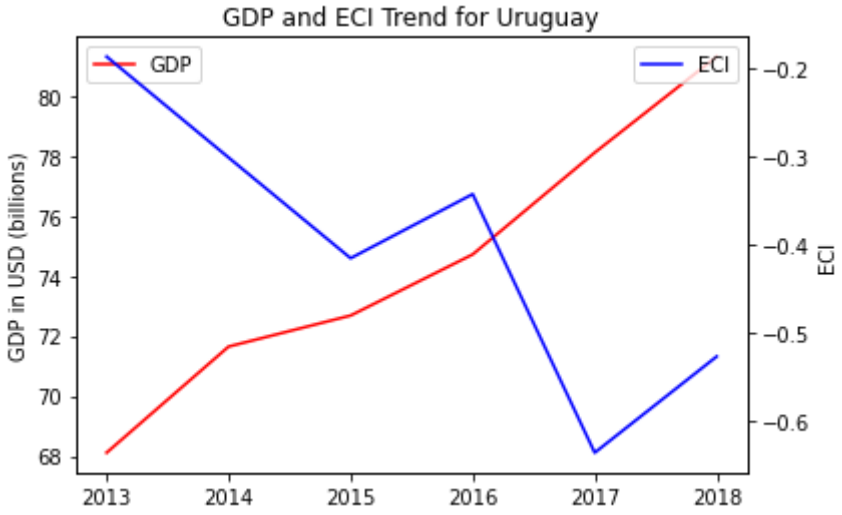


Figure 3: GDP Growth and ECI (Bolivia)

Figure 3 offers a further comparison of GDP Growth and ECI over the time span from 2013 to 2018 for Uruguay. The increase in GDP during the period from 2013 to 2018 is accompanied by a sharp decline in ECI. The results show that the economic growth experienced by Uruguay during the period from 2013 to 2018 is not very consistent with the predictions by ECI and Uruguay did not 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 Uruguay 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 Uruguay's realized industry production strategy between 2013 and 2018 on a complexity level. In Hausmann and Hidalgo (2009), distance is defined to be a measure of how far a country is from a certain product not in its product space. We extend this concept to all product groups and quantify how technically equipped a country is to develop the corresponding product groups. In other words, the shorter the distance between a country and a product group, the more capable a country is in developing products within that group. Defining this net distance change as the Realized Industry Development (RID), our export data allow us to calculate and compare RID of US and the 18 product groups in 2013 and 2018 through subtraction, where a positive RID indicates a shortening of the distance (i.e., advancement of the industry), and a negative RID indicates the reverse.

	Category	RID
5	Chemical Manufacturing	0.010554
13	Weapons	0.025714
15	Precious Stones	0.037363
8	Clothing and Accessories	0.042600
9	Textile	0.045294
0	Animals and By-products	0.048769
2	Food and Preparations	0.066664
1	Vegetables, Fruits and Plants	0.070925
7	Wood Products	0.076131
12	Transportation	0.085065
6	Raw Manufacturing	0.085312
3	Energy Drilling and Mining	0.085483
10	Metals	0.089223
14	Daily Instruments	0.094809
17	Services and Utilities	0.096046
4	Chemicals	0.111704
11	Machinery and Construction	0.111789
16	High-complexity Products	0.114798

Table 2: Realized Industry Development (RID) of Uruguay

3.3 Regional and Global Comparison

Table 3 and 4 below summarize how the production strategy adopted by Uruguay 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 Uruguay's development strategy against those of emerging economies on a global scale. Reasonably, emerging economies such as China, South Korea, Singapore and India have devoted the majority of their efforts into intermediate industry groups.

4. Product Space Design

4.1 Suggested Development Vector

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

Ranking	Uruguay	Bolivia	Paraguay	Costa Rica
1	High-complexity Products	High-complexity Products	High-complexity Products	Energy Drilling and Mining
2	Machinery and Construction	Machinery and Construction	Machinery and Construction	Services and Utilities
3	Transportation	Transportation	Transportation	Machinery and Construction
4	Energy Drilling and Mining	Daily Instruments	Daily Instruments	Chemicals
5	Services and Utilities	Services and Utilities	Services and Utilities	Precious Stones
6	Daily Instruments	Chemicals	Weapons	Chemical Manufacturing
7	Weapons	Animals and By-products	Chemicals	Wood Products
8	Chemicals	Chemical Manufacturing	Chemical Manufacturing	Textile
9	Textile	Textile	Textile	Animals and By-products
10	Precious Stones	Raw Manufacturing	Raw Manufacturing	Vegetables, Fruits and Plants
11	Clothing and Accessories	Wood Products	Metals	Food and Preparations
12	Metals	Metals	Wood Products	Raw Manufacturing
13	Animals and By-products	Clothing and Accessories	Precious Stones	Transportation
14	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Clothing and Accessories	Weapons
15	Food and Preparations	Food and Preparations	Animals and By-products	Daily Instruments
16	Chemical Manufacturing	Energy Drilling and Mining	Vegetables, Fruits and Plants	Clothing and Accessories
17	Raw Manufacturing	Weapons	Food and Preparations	Metals
18	Wood Products	Precious Stones	Energy Drilling and Mining	High-complexity Products
ECI	-0.185	-1.019	-1.105	0.527

Ranking	Uruguay	Bolivia	Paraguay	Costa Rica
1	High-complexity Products	High-complexity Products	High-complexity Products	Transportation
2	Transportation	Transportation	Transportation	High-complexity Products
3	Machinery and Construction	Machinery and Construction	Machinery and Construction	Energy Drilling and Mining
4	Daily Instruments	Daily Instruments	Daily Instruments	Machinery and Construction
5	Weapons	Chemicals	Weapons	Textile
6	Energy Drilling and Mining	Animals and By-products	Chemicals	Clothing and Accessories
7	Textile	Chemical Manufacturing	Chemical Manufacturing	Chemicals
8	Chemicals	Textile	Raw Manufacturing	Metals
9	Clothing and Accessories	Raw Manufacturing	Textile	Wood Products
10	Chemical Manufacturing	Clothing and Accessories	Metals	Precious Stones
11	Metals	Metals	Clothing and Accessories	Services and Utilities
12	Precious Stones	Wood Products	Wood Products	Animals and By-products
13	Animals and By-products	Services and Utilities	Precious Stones	Vegetables, Fruits and Plants
14	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Animals and By-products	Food and Preparations
15	Food and Preparations	Food and Preparations	Vegetables, Fruits and Plants	Chemical Manufacturing
16	Raw Manufacturing	Energy Drilling and Mining	Food and Preparations	Raw Manufacturing
17	Wood Products	Weapons	Energy Drilling and Mining	Weapons
18	Services and Utilities	Precious Stones	Services and Utilities	Daily Instruments
ECI	-0.526	-0.797	-1.062	0.139

Table 5: SDV of Uruguay and Comparable 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 Uruguay compares with a selected group of comparable and leading economies in the world, with the industry groups ranked in decreasing order of significance. Dark blue indicates positive opportunity gain, light blue indicates zero opportunity gains, and white indicates negative opportunity gains. The result shows that leading countries barely have any industries with positive opportunity gain. In other words, those countries are already in the most stable and efficient economic structure. Without the necessity of economic transition, those countries merely need to maintain a steady and balanced economic development. In contrast, developing countries have nearly half of industries with positive opportunity gain, and share common interests in industrial manufacturing and High-complexity Products industries. It can be concluded that Uruguay 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:

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

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 Uruguay in 2013. We can see that for different percentages of heuristic total export growth, the ECIs of Uruguay have different amounts of increments. At 5 percent export growth we see that there is a significant share of weapons manufacturing which gets replaced by Daily Instruments and Services and Utilities. Going from 5% to 10% increase results in an ECI increase from 0.09 to 0.36. Going from 15% to 20% export growth results in an added weightage towards animal and by-products however, there is no ECI increase in this case. Finally, going from 15% to 20% of export growth we see there is a significant increase in ECI from 0.36 to 0.64.

For the case of 5 percent export growth, weapons and chemicals account for most of the portfolio. For 10 percent export growth, more weights are put on other industries, such as services and utilities, and daily instruments. In these two ECI improvement trajectories, we also notice that the largest improvement comes from daily instruments, suggesting that with a low economic improvement anticipation, Bolivia should focus more on developing the industry of daily instruments. For the case of 15 percent increment budgets, other than industries mentioned in the 15% case, there is an added focus on animals and by-products. Finally, for the 20 percent increment budgets most of the portfolio is dominated by Machinery and Construction. Different from the previous scenarios, the solutions suggest that Bolivia should invest more on Machinery and Construction with a higher budget. 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.

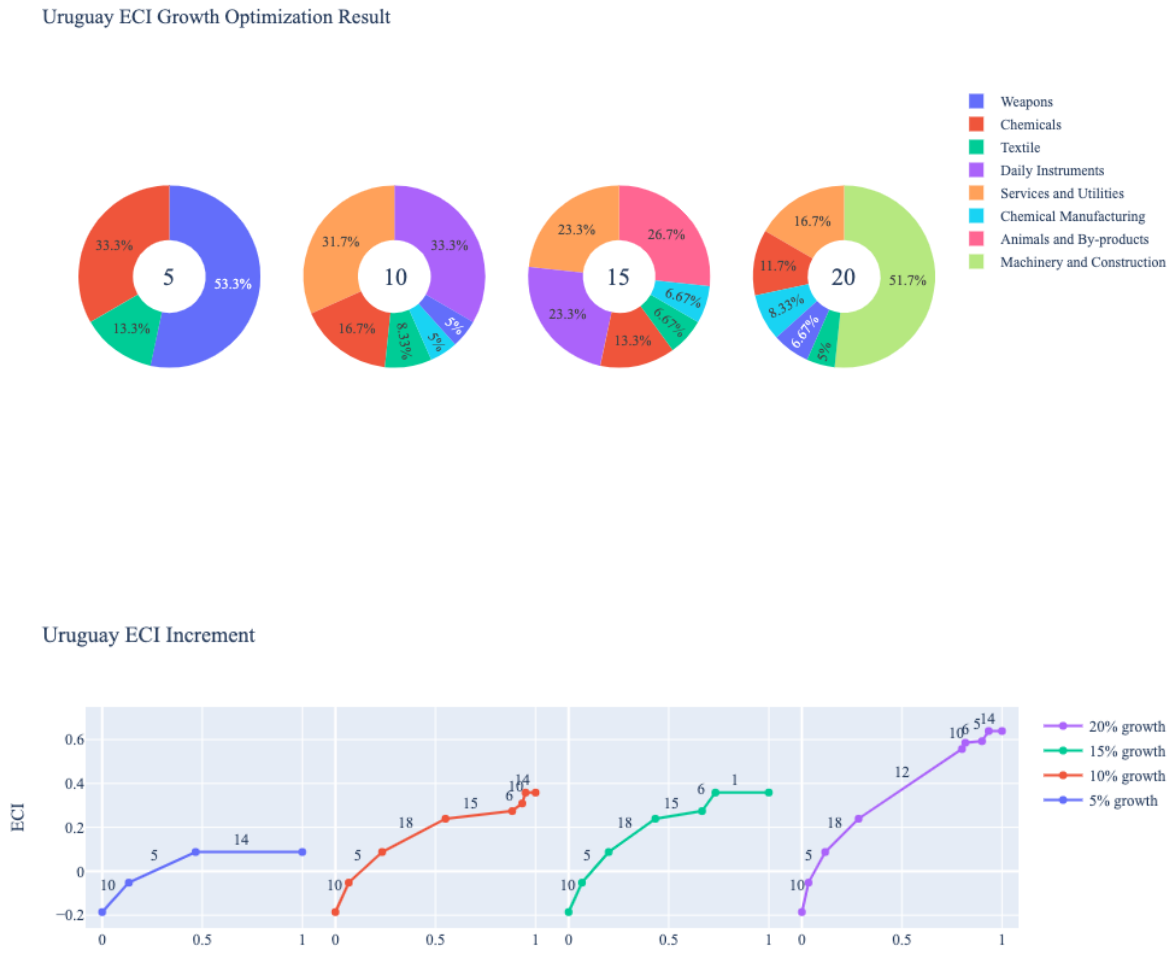


Figure 5: Greedy Based ECI Improvement Results of Uruguay in 2013 with Different Budgets

	Uruguay 2013			
Original ECI	-0.185			
Heuristic Export Growth	5%	10%	15%	20%
Animals and By-products	0.00E+00	0.00E+00	3.81E+08	0.00E+00
Chemicals	1.59E+08	1.61E+08	1.91E+08	2.33E+08
Chemical Manufacturing	0.00E+00	4.84E+07	9.53E+07	1.67E+08
Textile	6.35E+07	8.07E+07	9.53E+07	1.00E+08
Machinery and Construction	0.00E+00	0.00E+00	0.00E+00	1.03E+09
Weapons	2.54E+08	4.84E+07	0.00E+00	1.33E+08
Daily Instruments	0.00E+00	3.23E+08	3.34E+08	0.00E+00
Services and Utilities	0.00E+00	3.07E+08	3.34E+08	3.34E+08
Increased ECI	0.09	0.36	0.36	0.64

Table 8: Portfolio of Uruguay in 2013

For further suggestions on Uruguaay's development in the future. We also offer the optimization result of Bolivia based on export data in 2018. Below is the economic panel for Bolivia in 2018. We can see that the ECI improvement trajectories are much lower than in the 2013 case, the improvements in 5 percent export growth rate is higher, keeping in mind the original ECl. However, 10 percent export growth as well as the ones in 15 and 20 are also lower. Another striking difference in the growth optimization result is that for a 5 percent export growth, there is a greater emphasis on daily instruments and none on weapons. For a 10 percent growth, the main components are Daily Instruments and Weapons. For situations with higher budgets of investment, like 15 or 20 percent of growth, the portfolios are much more dominated by Weapons and Machinery and Construction, respectively. A more detailed numerical representation of the portfolio is shown in Table 9.

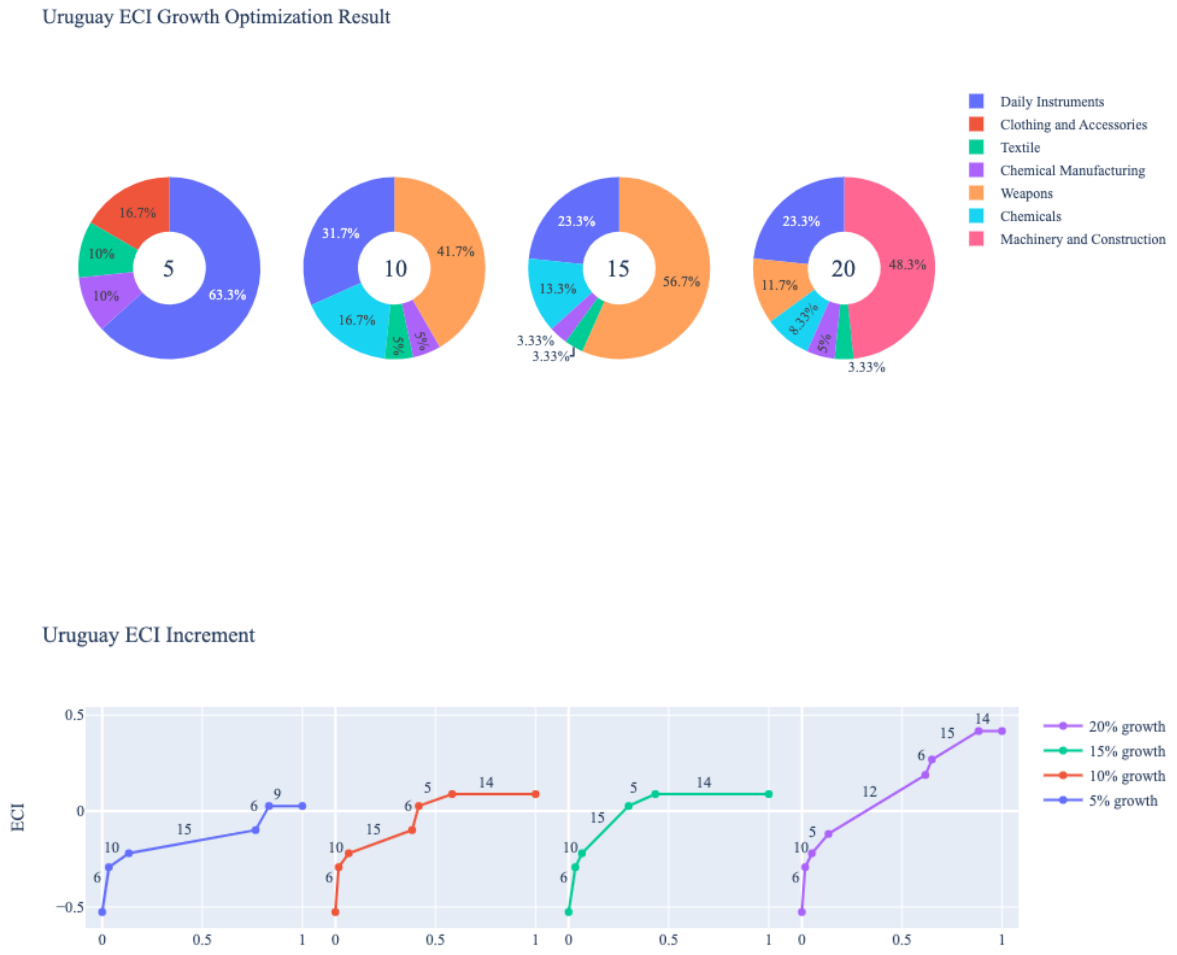


Figure 6: Greedy Based ECI Improvement Results of Bolivia in 2018 with Different Budgets

Uruguay 2018				
Original ECI	-0.526			
Heuristic Export Growth	5%	10%	15%	20%
Chemicals	0.00E+00	1.30E+08	1.56E+08	1.30E+08
Chemical Manufacturing	3.91E+07	3.91E+07	3.91E+07	7.81E+07
Clothing and Accessories	6.51E+07	0.00E+00	0.00E+00	0.00E+00
Textile	3.91E+07	3.91E+07	3.91E+07	5.21E+07
Machinery and Construction	0.00E+00	0.00E+00	0.00E+00	7.55E+08
Weapons	0.00E+00	3.25E+08	6.64E+08	1.82E+08
Daily Instruments	2.47E+08	2.47E+08	2.73E+08	3.65E+08
Increased ECI	0.03	0.09	0.09	0.42

Table 9: Portfolio of Uruguay in 2018

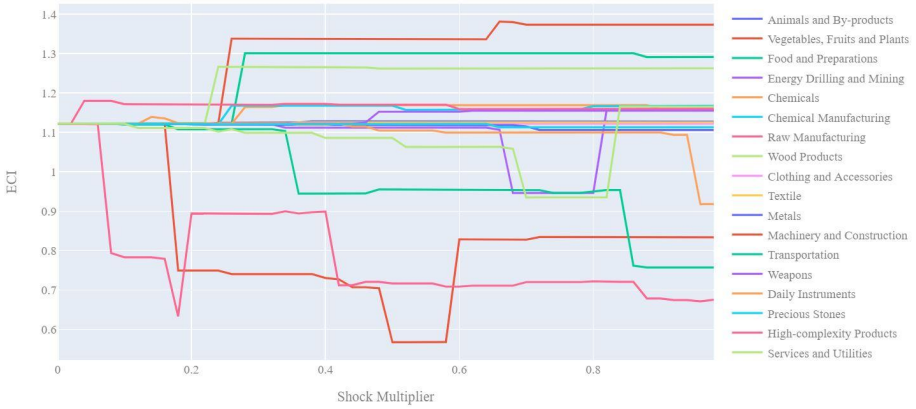
4.3 Sensitivity Analysis and Contingency Strategy

In the following section our broad aim is to understand how sensitive Uruguay 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.

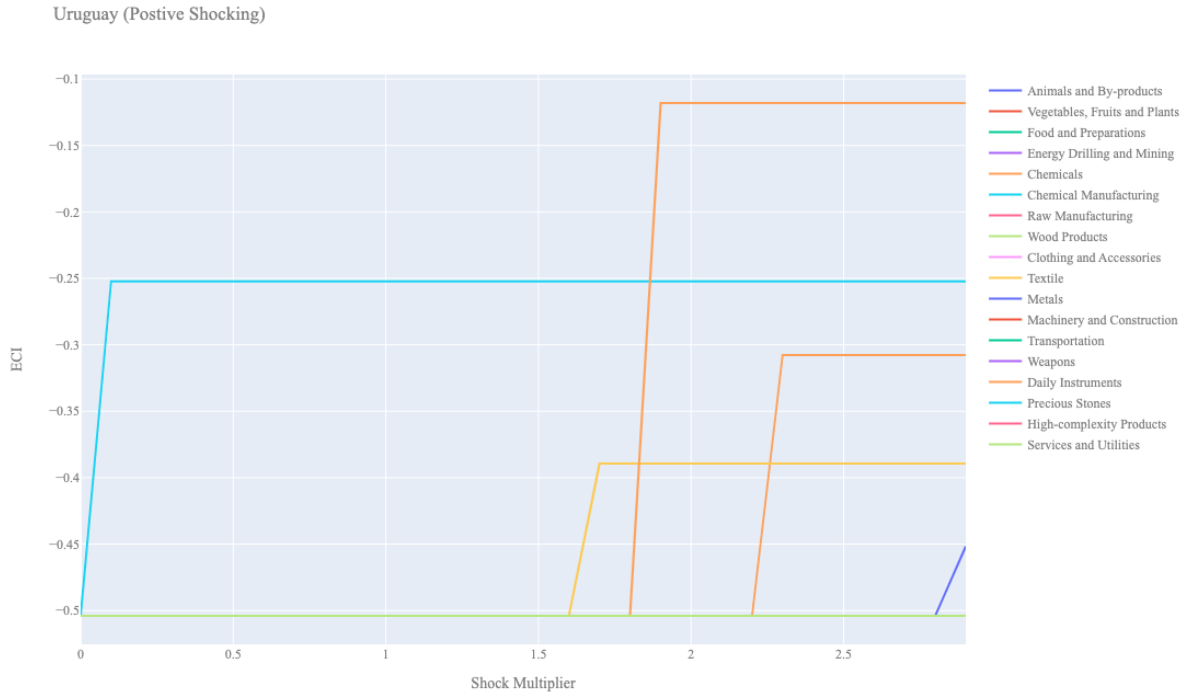
	0	1	2
Animals and By-products	High-complexity Products	Machinery and Construction	Transportation
Vegetables, Fruits and Plants	High-complexity Products	Machinery and Construction	Transportation
Food and Preparations	High-complexity Products	Machinery and Construction	Transportation
Energy Drilling and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

Example Contingency Strategy 2018

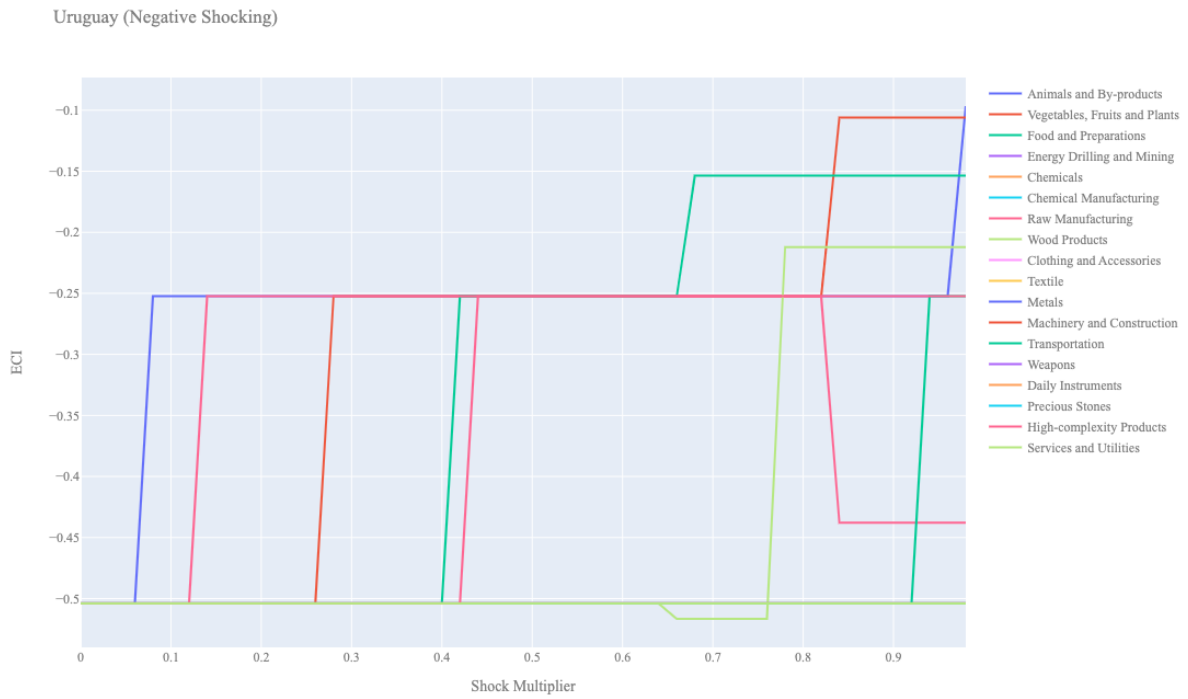
4.3 Sensitivity Analysis Results and Interpretation

Below is Uruguay's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that increases in Daily Instruments lead to an uptrend in ECI. Daily Instruments offer the best ECI growth per unit of export increase. Metals also help in increasing the ECI greatly.

Next we consider Bolivia's 2018 Negative Shock chart. We see that Bolivia's ECI is slightly sensitive to drawdowns in Weapons. More interestingly we see that large decreases in Precious Stones and Energy, Mining and Drilling seem to greatly increase the ECI score. These industries are two very important industries for Bolivia'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 Bolivia that is far in proximity from them.

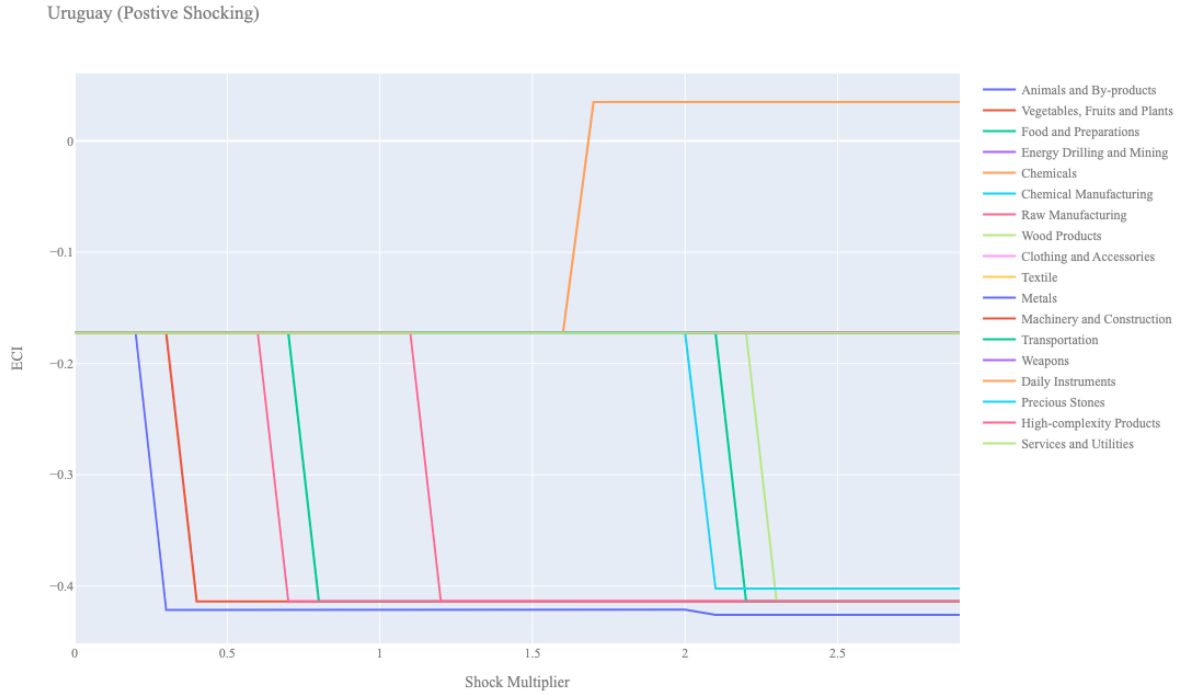


Uruguay 2018 (Incremental ECI Sensitivity)

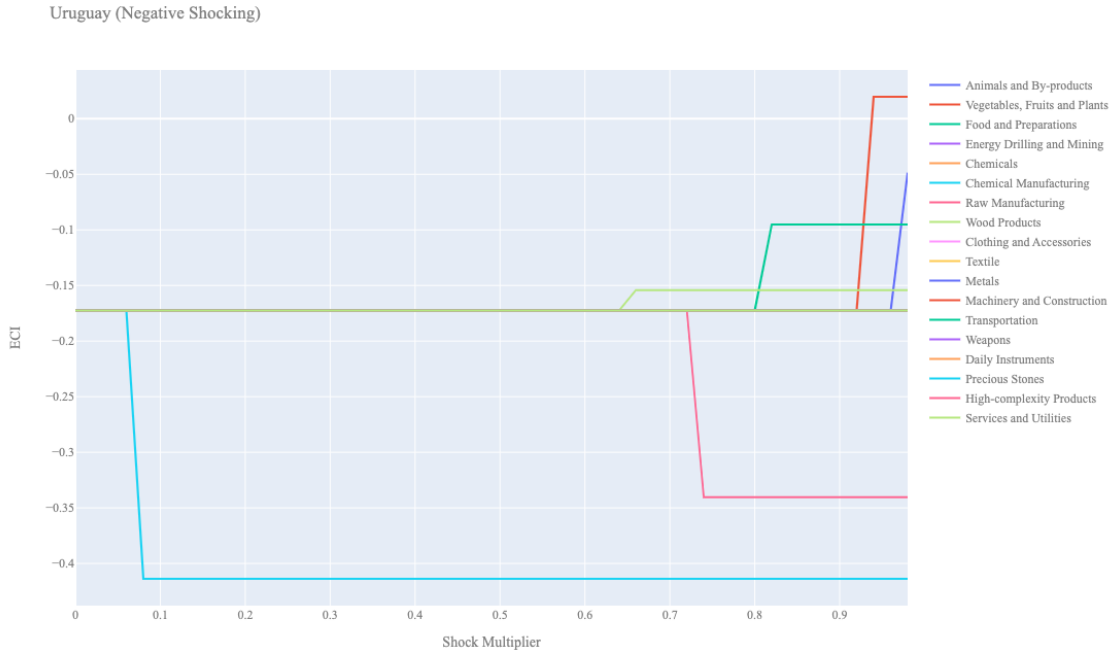


Uruguay 2018 (Decremental ECI Sensitivity)

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. High complexity products seem to offer the best ECI growth prospects. Transportation and Machinery do not affect ECI levels as positively as in 2018.



Uruguay 2013 (Incremental ECI Sensitivity)



Uruguay 2013 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for Metals. We see that after increasing the export of Metals by 20% there is no additional gain to ECI even by increasing the export more. As to start with, after 20% increase in export of metals no industries within the SDV have negative opportunity gain.

In the negative SDV chart, we see that as we decrease the export of Metals the ECI does not change. Additionally, it is not optimal to decrease the export of metals at all.

Concerning Precious Stones, Bolivia seems to be mostly insensitive towards increasing this However, decreasing exports in this sector leads to gains in ECI. Decreasing export by 82% leads to optimum ECI increase.

	0%	20%
0	High-complexity Products	High-complexity Products
1	Machinery and Construction	Machinery and Construction
2	Transportation	Transportation
3	Daily Instruments	Daily Instruments
4	Raw Manufacturing	Chemical Manufacturing
5	Chemical Manufacturing	Textile
6	Textile	Raw Manufacturing
7	Clothing and Accessories	Chemicals
8	Wood Products	Clothing and Accessories
9	Metals	Services and Utilities
10	Chemicals	Wood Products
11	Services and Utilities	Animals and By-products
12	Animals and By-products	Metals
13	Weapons	Weapons
14	Precious Stones	Precious Stones
15	Energy Drilling and Mining	Energy Drilling and Mining
16	Food and Preparations	Food and Preparations
17	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
ECI	-0.7698746255	-0.6865290472

Bolivia Metals 2018 (Incremental SDV Sensitivity)

	0%
0	High-complexity Products
1	Machinery and Construction
2	Transportation
3	Daily Instruments
4	Raw Manufacturing
5	Chemical Manufacturing
6	Textile
7	Clothing and Accessories
8	Wood Products
9	Metals
10	Chemicals
11	Services and Utilities
12	Animals and By-products
13	Weapons
14	Precious Stones
15	Energy Drilling and Mining
16	Food and Preparations
17	Vegetables, Fruits and Plants
ECI	-0.7698746255

Bolivia Metals 2018 (Decremental SDV Sensitivity)

	-0%
0	High-complexity Products
1	Machinery and Construction
2	Transportation
3	Daily Instruments
4	Raw Manufacturing
5	Chemical Manufacturing
6	Textile
7	Clothing and Accessories
8	Wood Products
9	Metals
10	Chemicals
11	Services and Utilities
12	Animals and By-products
13	Weapons
14	Precious Stones
15	Energy Drilling and Mining
16	Food and Preparations
17	Vegetables, Fruits and Plants
ECI	-0.7698746255

Bolivia Precious Stones 2018 (Incremental SDV Sensitivity)

	-0%	-60%	-82%
0	High-complexity Products	High-complexity Products	High-complexity Products
1	Machinery and Construction	Machinery and Construction	Machinery and Construction
2	Transportation	Transportation	Transportation
3	Daily Instruments	Daily Instruments	Daily Instruments
4	Raw Manufacturing	Chemical Manufacturing	Chemical Manufacturing
5	Chemical Manufacturing	Textile	Textile
6	Textile	Raw Manufacturing	Raw Manufacturing
7	Clothing and Accessories	Chemicals	Clothing and Accessories
8	Wood Products	Clothing and Accessories	Chemicals
9	Metals	Services and Utilities	Services and Utilities
10	Chemicals	Wood Products	Wood Products
11	Services and Utilities	Animals and By-products	Precious Stones
12	Animals and By-products	Metals	Animals and By-products
13	Weapons	Weapons	Metals
14	Precious Stones	Precious Stones	Weapons
15	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining
16	Food and Preparations	Food and Preparations	Food and Preparations
17	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
ECI	-0.7698746255	-0.6865290472	-0.5821567762

Bolivia Precious Stones 2018 (Decremental SDV Sensitivity)

4.4 Contingency Strategy

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

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

Uruguay 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

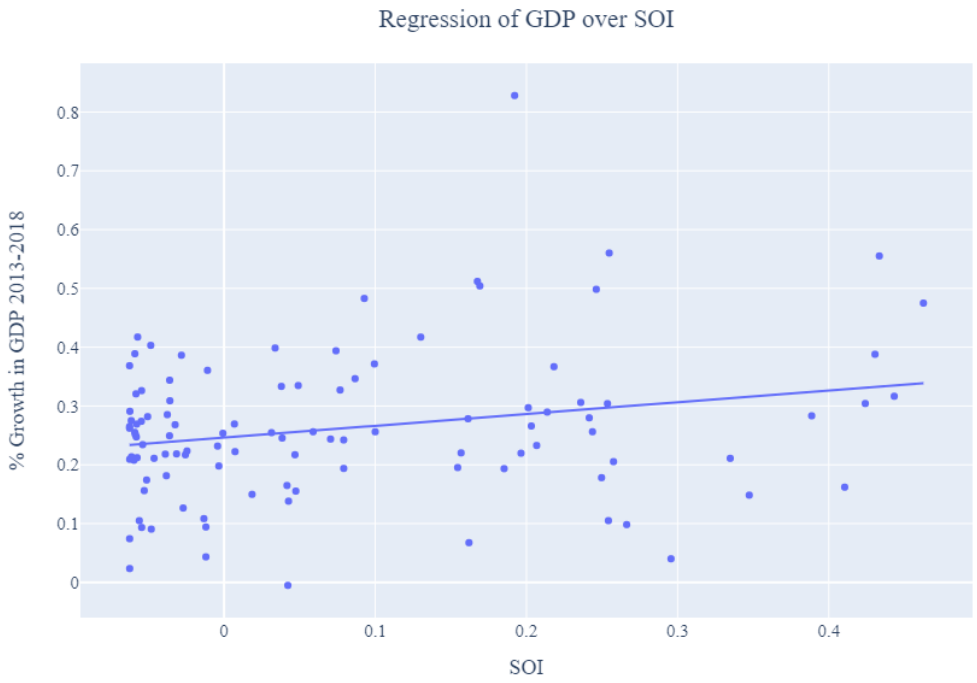


Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Bolivia and Its Implications

Bolivia for instance, has a high 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), Bolivia demonstrates an average level of correlation with the suggested developmental path, having an adjusted R-square of around 19.5%. Bolivia ranks in top quartile among all countries in terms of SOI and has made a medium rate of economic progress below its developed peers from 2013 to 2018 with a 5-year GDP growth rate of 5.26%, which is consistent with the regression result in Figure 6. This is in direct contrast to other developed economies such as Japan, where there is low SOI of around -5.7% and a corresponding GDP growth of 9.05% from 2013 to 2018, making it a much faster developing economy during the period. In sum, Bolivia's mixed economic progress from 2013 to 2018 can be at least partially explained by a development strategy that demonstrates a decent, but not perfect, level of matches with our suggested developmental path. In specific, Bolivia invested heavily in the Machinery and Construction industry, while it should have focused more on more industry groups such as Precious Stones and metals. That being said, it stayed fairly in line with our expectations in the raw manufacturing and animals and by-products industry.

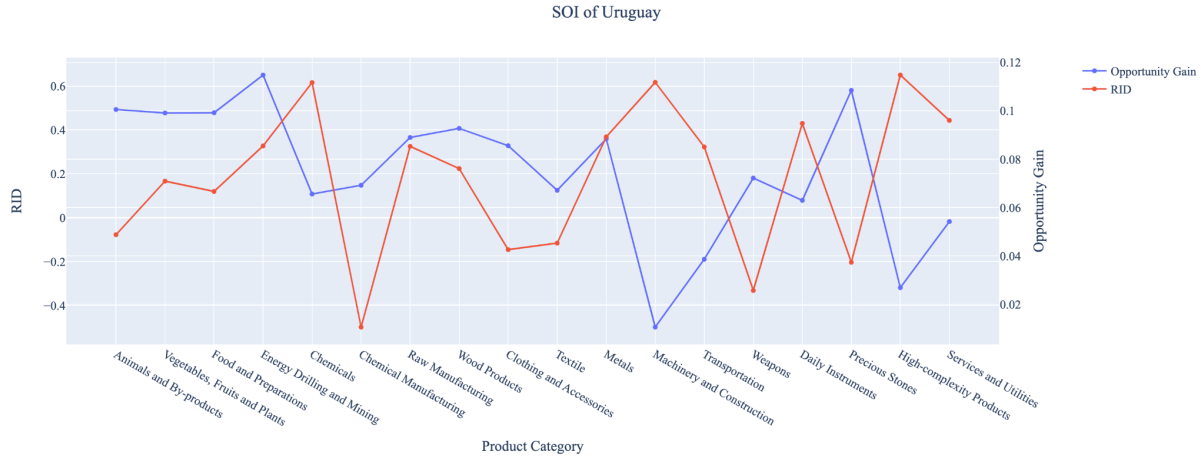


Figure 7: SOI of Uruguay (2009-2014)

6. Concluding Remarks

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

The lack of progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Bolivia 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 Bolivia consistently relied on developing the Transportation industry during the period, while its developed counterparts

and emerging economies around the globe have adopted much more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Bolivia can further its gains by prioritizing Metals and Precious Stones. We further note that Bolivia 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 19.5%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Bolivia, however, still has a suboptimal growth experience as compared with fast-growing economies both on a regional scale and on a global scale, and has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

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