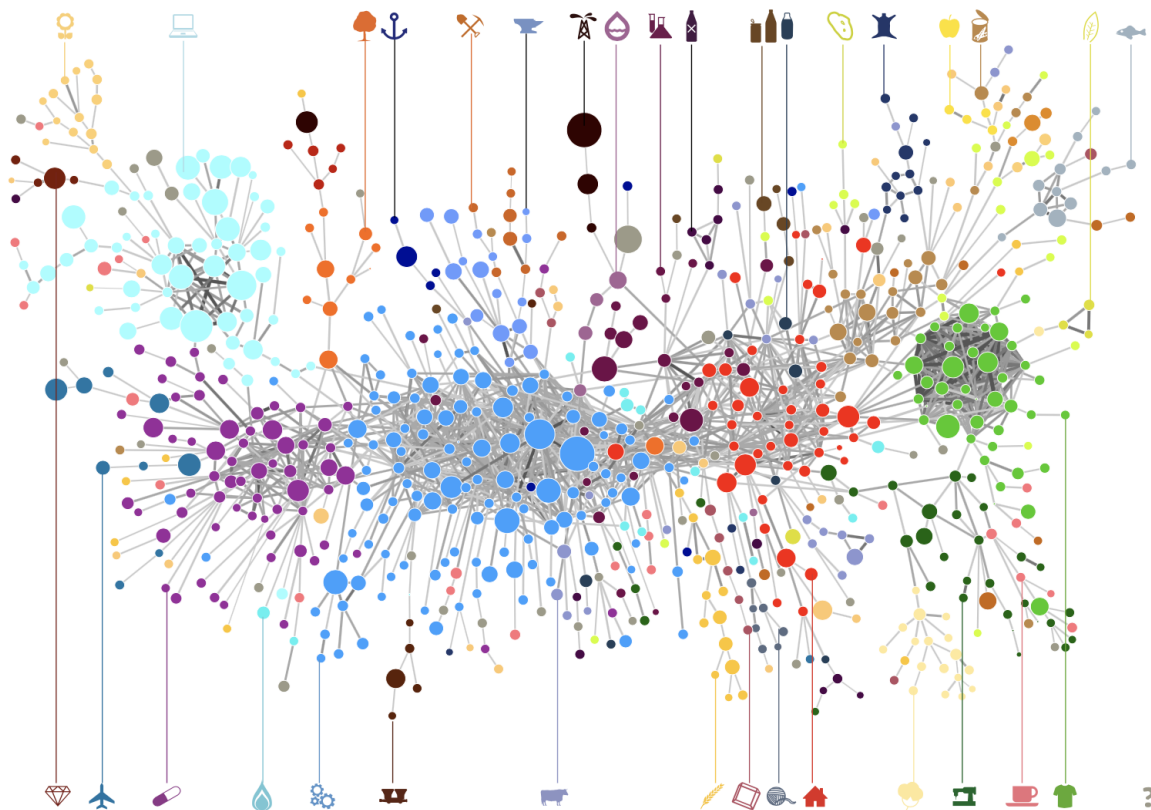




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Optimal Industry Development Strategy Using Economic and Product Complexity

Laos

—

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Optimal Industry Development Strategy for Lao People's Democratic Republic

0. Executive Summary

In this report, we uncover the economic path Laos, officially Lao People's Democratic Republic, went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Laos 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, Laos demonstrated a high level of economic growth with an average annual GDP growth rate of 7.34%, concurrent with a decrease in economic complexity.

The lack of progress during the period can be partially explained through analysis of the economic and product complexity structure of Laos on the industry group level. The product classification system we adopt allows us to measure the realized development for various industry groups and to observe that Laos consistently relied on developing the Wood Products industry during the period, while its emerging counterparts and developed 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, Laos can further its gains by prioritizing Transportation. We further note that Laos has a somewhat mismatched development strategy that indicates an average (compared to other developed and emerging economies) level of structural optimality on the complexity level, having an adjusted R-square of around 7.69%. A significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, and Laos has a moderately high growth experience as compared with emerging 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 Laos went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Laos 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 Laos 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 Laos, 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 Laos and three of its peer countries (Cambodia, Myanmar, and Viet Nam) from 2013-2018. All countries displayed constant upwards growth over all years. Lao's average annual growth rate of 7.34% over the five-year period is slightly above average relative to its peers, which are 7.45%, 7.09%, and 6.95% for Cambodia, Myanmar, and Viet Nam respectively.

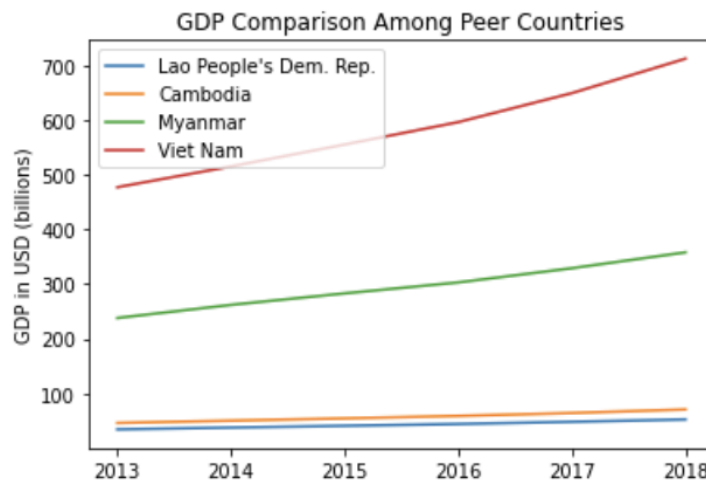


Figure 1: GDP Comparison Among Peer Countries

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 negative growth pattern for Laos. As illustrated in Figure 2 below, Laos (-54.8% ECI change) exhibited a decrease in terms of its production capability from 2013 to 2018, contrary to the positive change for Cambodia (61.97%) and Viet Nam (24.85%); but slightly above Myanmar's negative change (-58.54%). Ultimately, Laos performs suboptimally amongst its

peer country set, displaying an average GDP growth rate and a somewhat negative ECI change across the period.

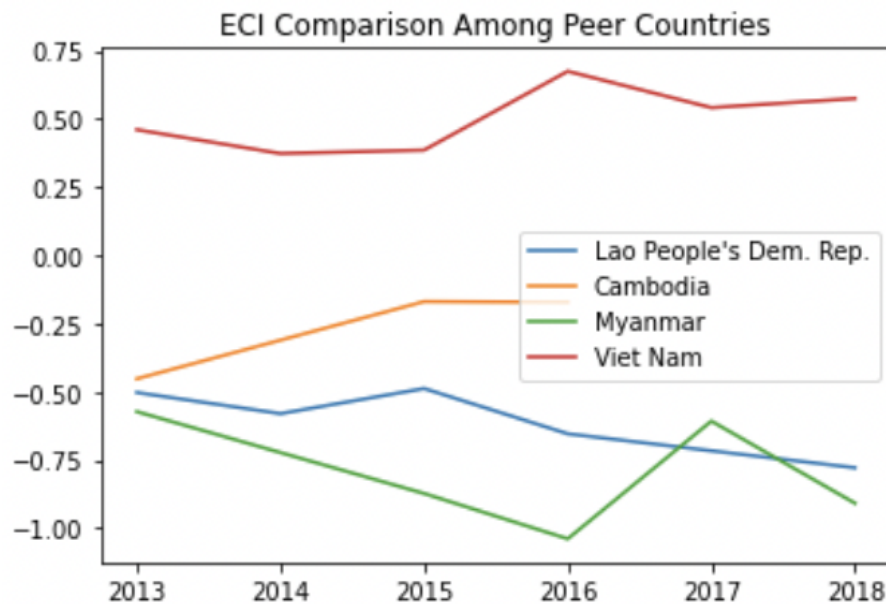


Figure 2: ECI Comparison

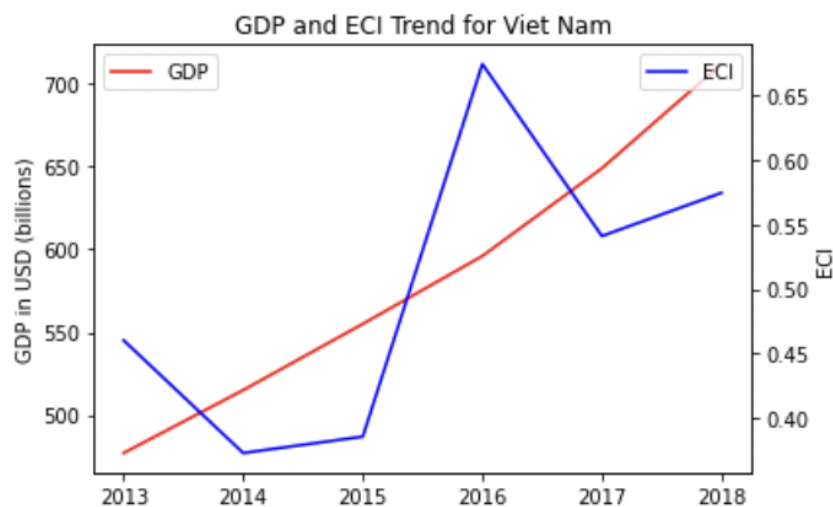


Figure 3: GDP Growth and ECI (Laos)

Figure 3 offers a further comparison of GDP Growth and ECI over the time span from 2013 to 2018 for Laos. The increase in GDP during the period from 2013 to 2018 is accompanied by an overall increase in ECI. The results show that the economic growth experienced by Laos during the period from 2013 to 2018 is consistent with the predictions by ECI and Laos effectively made strides to develop a competitive product space that helps to accumulate complicated knowledge and technology. We will dive into an analysis of Lao's production structure and its product space designs in the next few chapters.

3. Production Analysis

3.1 Product Categorization

Our main data source in this research is the UN Comtrade Website (<https://comtrade.un.org>), which provides us with valuable information on countries' export values on an annual basis, including highly specific export data for more than 5000 categories of products. In order to have a holistic vision of the product space of a country, however, a level of categorization is required. Products in our data source are labelled from 010000-999999, with the first two-digits representing a general category to which the product belongs. Based on the 99 categories as extracted from the label, we further group the products into 18 most widely-accepted industries, as summarized in Table 1.

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

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

Table 1: Categorization of Products

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

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

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

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

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

3.2 Realized Industry Development

Based on the product categorization aforementioned, we aim to capture Lao'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
Textile	-0.073386
Weapons	-0.047232
Raw Manufacturing	-0.045111
Animals and By-products	-0.030406
Clothing and Accessories	-0.022892
Precious Stones	-0.011957
Vegetables, Fruits and Plants	-0.002159
Chemicals	0.025307
Food and Preparations	0.035283
Services and Utilities	0.064024
Metals	0.077795
Machinery and Construction	0.078985
Chemical Manufacturing	0.093136
Transportation	0.116206
High-complexity Products	0.125875
Daily Instruments	0.127327
Energy Drilling and Mining	0.127373
Wood Products	0.131797

Table 2: Realized Industry Development (RID) of Laos

3.3 Regional and Global Comparison

Table 3 and 4 below summarize how the production strategy adopted by Laos 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 Lao'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	Finland	Sweden	Norway	Denmark
1	Transportation	Energy Drilling and Mining	High-complexity Products	Vegetables, Fruits and Plants
2	High-complexity Products	Animals and By-products	Transportation	Energy Drilling and Mining
3	Daily Instruments	Chemical Manufacturing	Machinery and Construction	Precious Stones
4	Textile	Raw Manufacturing	Daily Instruments	Textile
5	Services and Utilities	Wood Products	Weapons	Weapons
6	Weapons	Metals	Chemicals	Chemicals
7	Chemicals	Machinery and Construction	Textile	Animals and By-products
8	Raw Manufacturing	High-complexity Products	Chemical Manufacturing	Food and Preparations
9	Wood Products	Services and Utilities	Raw Manufacturing	Chemical Manufacturing
10	Metals	Vegetables, Fruits and Plants	Animals and By-products	Raw Manufacturing
11	Machinery and Construction	Textile	Energy Drilling and Mining	Clothing and Accessories
12	Chemical Manufacturing	Precious Stones	Metals	Machinery and Construction
13	Clothing and Accessories	Clothing and Accessories	Services and Utilities	Daily Instruments
14	Animals and By-products	Weapons	Wood Products	Services and Utilities
15	Energy Drilling and Mining	Food and Preparations	Vegetables, Fruits and Plants	Wood Products
16	Precious Stones	Daily Instruments	Food and Preparations	Transportation
17	Food and Preparations	Chemicals	Clothing and Accessories	Metals
18	Vegetables, Fruits and Plants	Transportation	Precious Stones	High-complexity Products
ECI	1.159	1.338	-0.247	0.904

Ranking	Finland	Sweden	Norway	Denmark
1	Transportation	Energy Drilling and Mining	High-complexity Products	Textile
2	High-complexity Products	Clothing and Accessories	Transportation	Transportation
3	Textile	Textile	Machinery and Construction	Weapons
4	Weapons	Animals and By-products	Daily Instruments	Chemicals
5	Chemicals	Chemical Manufacturing	Weapons	Energy Drilling and Mining
6	Raw Manufacturing	Raw Manufacturing	Chemicals	Precious Stones
7	Wood Products	Wood Products	Chemical Manufacturing	High-complexity Products
8	Metals	Metals	Textile	Vegetables, Fruits and Plants
9	Machinery and Construction	Machinery and Construction	Raw Manufacturing	Animals and By-products
10	Daily Instruments	Weapons	Clothing and Accessories	Food and Preparations
11	Services and Utilities	High-complexity Products	Animals and By-products	Chemical Manufacturing
12	Clothing and Accessories	Vegetables, Fruits and Plants	Energy Drilling and Mining	Clothing and Accessories
13	Chemical Manufacturing	Food and Preparations	Metals	Machinery and Construction
14	Precious Stones	Precious Stones	Wood Products	Daily Instruments
15	Energy Drilling and Mining	Chemicals	Food and Preparations	Services and Utilities
16	Animals and By-products	Services and Utilities	Vegetables, Fruits and Plants	Raw Manufacturing
17	Vegetables, Fruits and Plants	Daily Instruments	Precious Stones	Metals
18	Food and Preparations	Transportation	Services and Utilities	Wood Products
ECI	0.803	1.02	-0.928	0.541

Table 5: SDV of High 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 Brazil 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 Laos shares the characters of developing countries, with a balanced economics structure that leans towards intermediate-level industries.

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

Table 6: SDV of Other Typical Countries 2013

4.2 Budgeted Industry Development Strategy and Interpretation

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

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

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:

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

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 Laos in 2013. We can see that for different percentages of heuristic total export growth, the ECIs of Laos have different amounts of increments. 5% export growth results in an improvement pattern from -0.5 to -0.2. 10% export growth results in a slightly higher ECI of -0.05. 15%, and 20% export growth result in even more significant ECI improvement trajectories, both reaching an ECI of 0.2.

For the case of 5% export growth, Services and Utilities accounts for most of the portfolio, though Daily Instruments replaces it as the leading industry for 10% growth. For 15% and 20% export growth, more weight is awarded to Machinery & Construction, suggesting that with higher economic improvement anticipation, Laos should focus more on developing this industry. Daily Instruments, Services & Utilities, and (at a much lower percentage) Textile make up the other half of the 20% export growth portfolio. This makes sense because with more budgets, a country should focus more on the development of high-end product spaces. A more detailed numerical representation of the portfolio is shown in Table 8.

Lao People's Dem. Rep. ECI Growth Optimization Result

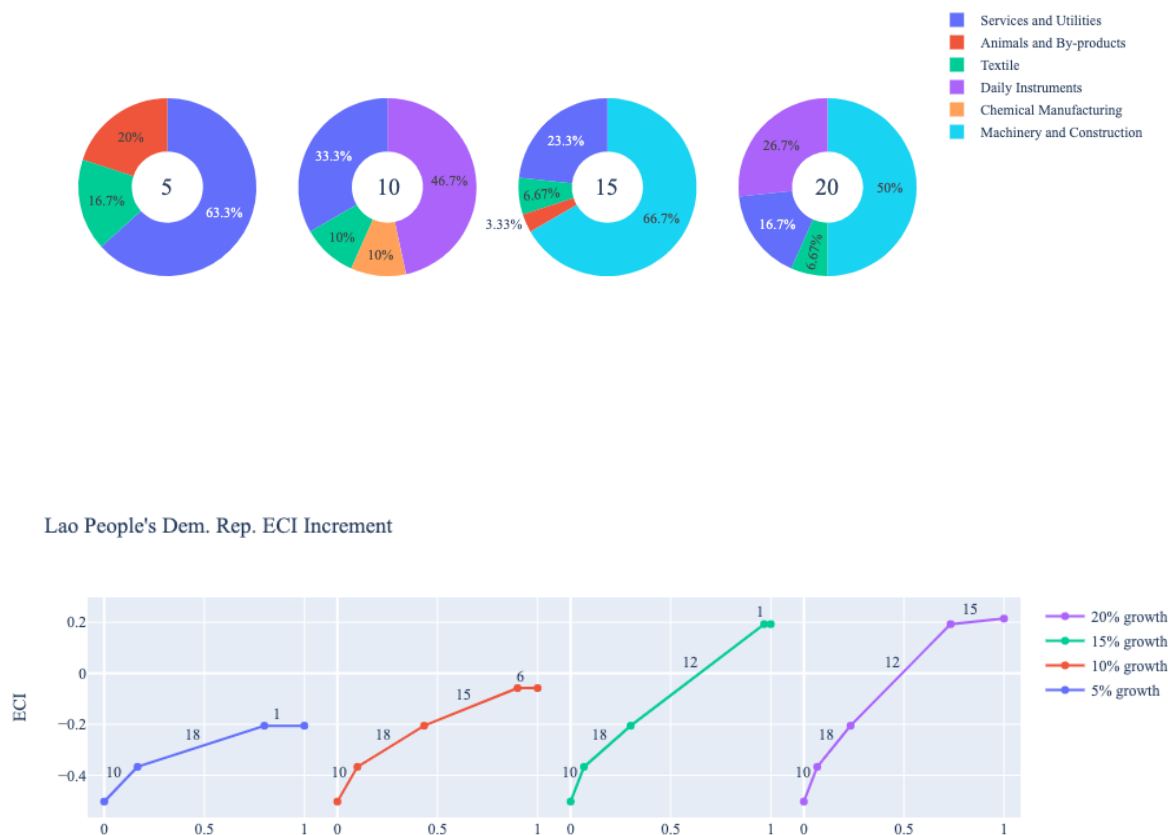


Figure 5: Greedy Based ECI Improvement Results of Laos in 2013 with Different Budgets

Lao PDR (2013)				
Original ECI	-0.5031			
Heuristic Export Growth	5%	10%	15%	20%
Animals and By-products	31094710.51	0	15547355.26	0
Chemical Manufacturing	0	31094710.51	0	0
Textile	25912258.76	31094710.51	31094710.51	41459614.01
Machinery and Construction	0	0	310947105.1	310947105.1
Daily Instruments	0	145108649	0	165838456.1
Services and Utilities	98466583.28	103649035	108831486.8	103649035
Increased ECI	-0.2057480194	-0.05829017754	0.1923331308	0.214154111

Table 8: Portfolio of Laos in 2013

For further suggestions on Lao's development in the future, we also offer the optimization result for Laos based on export data in 2018. Below is the economic panel for Laos in 2018. Starting at a lower ECI than in 2013, (-0.9), 5% growth gets ECI up to -0.4. 10% growth

manages a slightly higher ECI of -0.25. 15% and 20% growth show a significantly greater improvement up to 0 and 0.4, respectively, demonstrating an overall steeper trajectory up to a higher ECI than in 2013. One key difference is that the main components that result in ECI improvements are not quite similar. For the cases of 5% and 10% export growth, Animals & By-products account for most of the portfolio, though Chemical Manufacturing replaces Raw Manufacturing as the second leading industry for 10% growth. For 15% export growth, more weight is awarded to Daily Instruments, suggesting that with a moderate economic improvement anticipation, Laos should focus more on developing this industry. For the case of a 20% increment budget, Transportation is emphasized, with Daily Instruments in second place. This makes sense because with more budgets, a country should focus more on the development of high-end product spaces. A more detailed numerical representation of the portfolio is shown in Table 9.

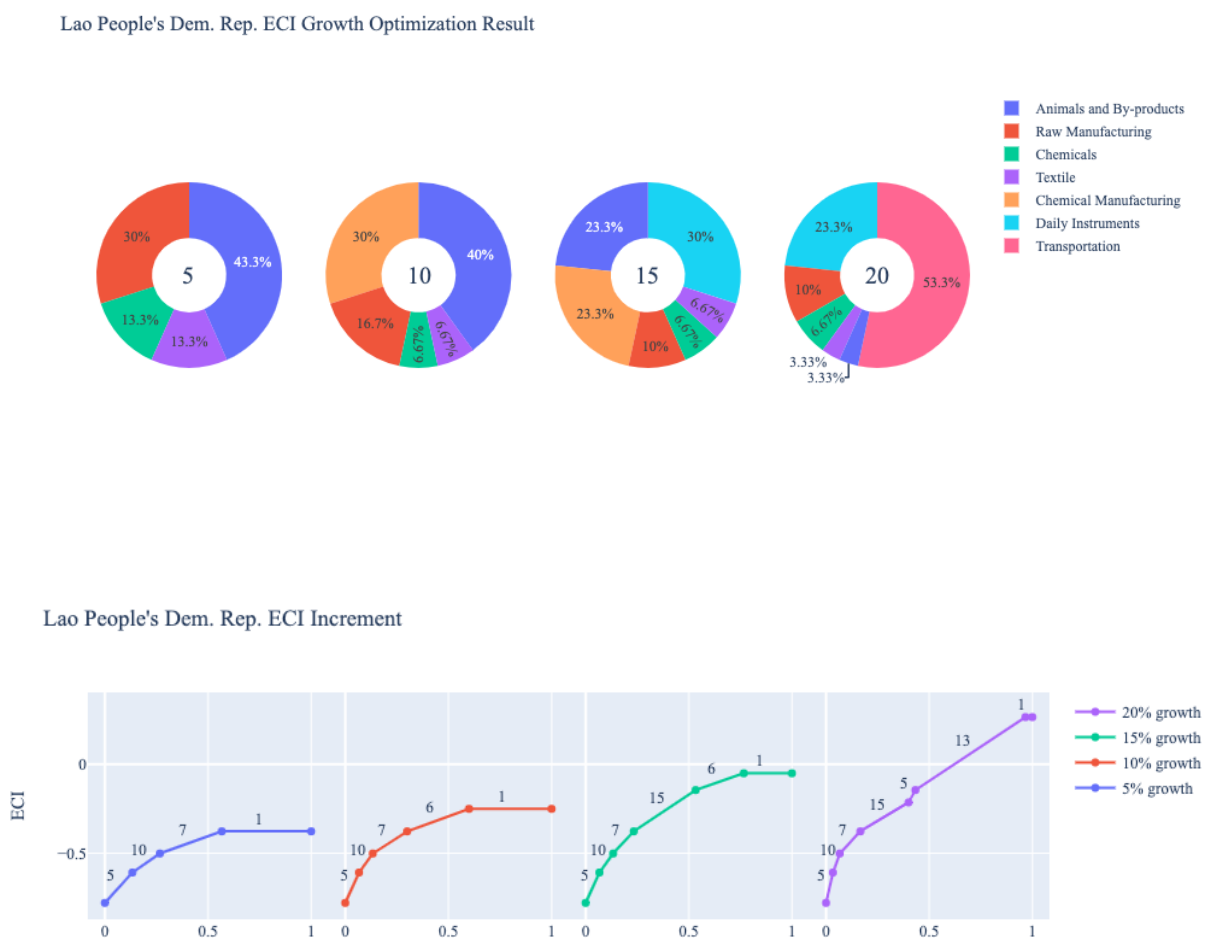


Figure 6: Greedy Based ECI Improvement Results of Laos in 2018 with Different Budgets

Lao PDR (2018)				
Original ECI	-0.7787			
Heuristic Export	5%	10%	15%	20%
Animals and By-p	146011256.5	269559242.8	235864337.5	44926540.47
Chemicals	44926540.47	44926540.47	67389810.7	89853080.93
Chemical Manufa	0	202169432.1	235864337.5	0
Raw Manufacturi	101084716.1	112316351.2	101084716.1	134779621.4
Textile	44926540.47	44926540.47	67389810.7	44926540.47
Transportation	0	0	0	718824647.5
Daily Instruments	0	0	303254148.2	314485783.3
Increased ECI	-0.3768998875	-0.2505793778	-0.05102059509	0.2645704703

Table 9: Portfolio of Laos in 2018

4.3 Sensitivity Analysis and Contingency Strategy

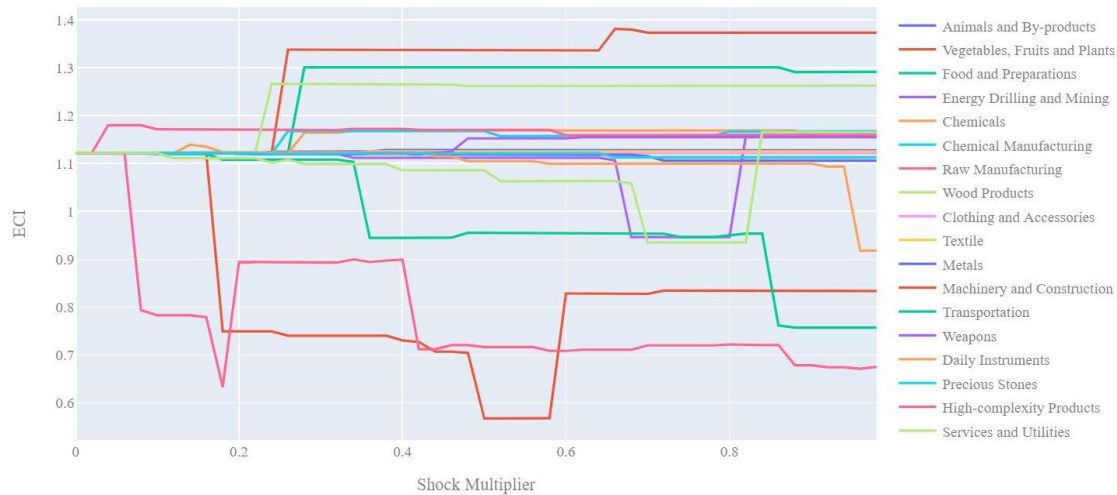
In the following section our broad aim is to understand how sensitive Laos is to changes in export in various industries. While the Economic Complexity Index has been shown to contain valuable information about the economic strength/capacity of a country, little has been said as to the stability of the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

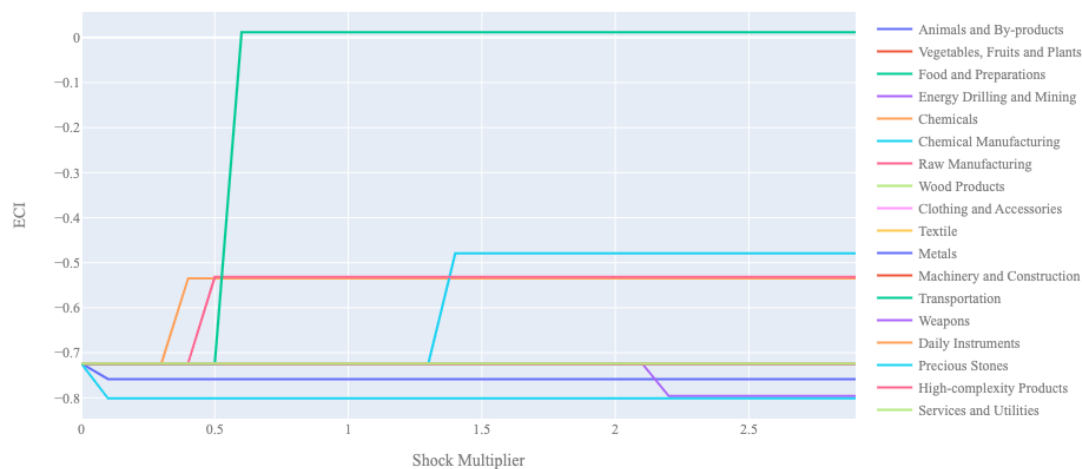
Example Contingency Strategy 2018

4.3 Sensitivity Analysis Results and Interpretation

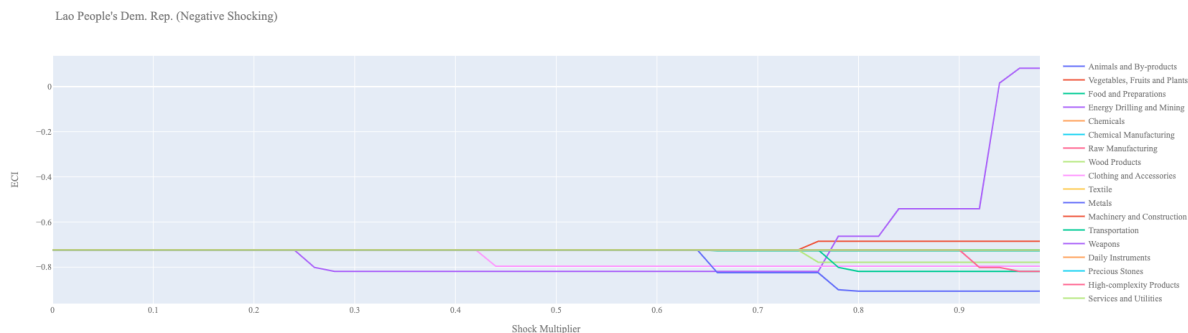
Below is Lao's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that increases in Transportation and Chemical Manufacturing lead to an uptrend in ECI. Transportation offers the best ECI growth per unit of export increase, with Chemical Manufacturing, Raw Manufacturing, and Chemicals providing a lower (but still significant) growth prospect. All other industries tend to not greatly affect the ECI level, making it fairly clear which industries to pursue.

Next we consider Lao's 2018 Negative Shock chart. We see that Lao's ECI is highly sensitive to drawdowns in Metals. More interestingly, we see that large decreases in Energy Drilling & Mining seems to greatly increase the ECI score. These industries are very important for Lao'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 Laos that is far in proximity from the Energy Drilling & Mining industry.

Lao People's Dem. Rep. (Postive Shocking)



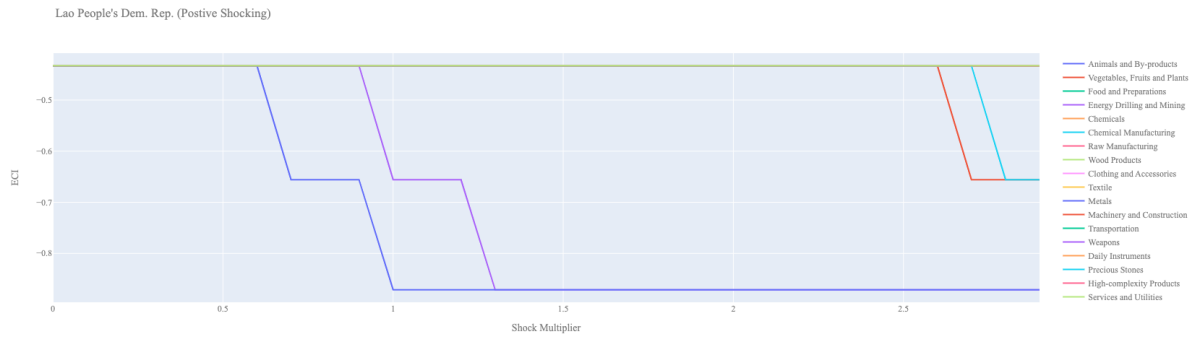
Laos 2018 (Incremental ECI Sensitivity)



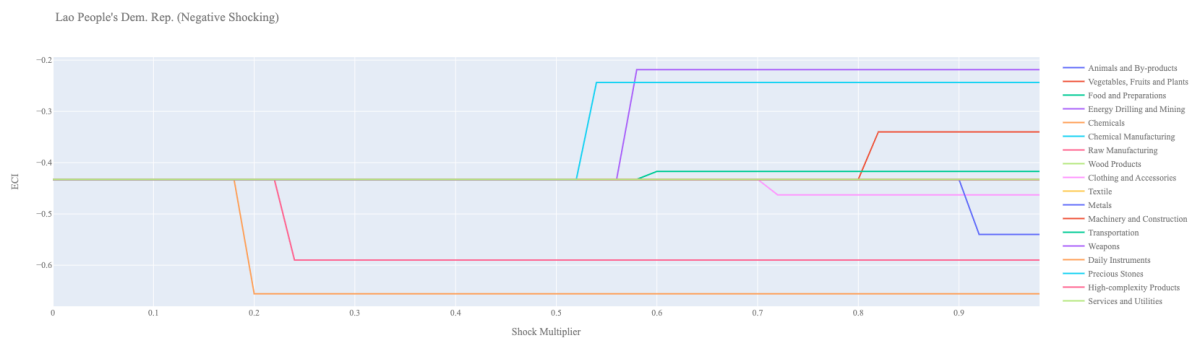
Laos 2018 (Decremental ECI Sensitivity)

Next we consider the 2013 ECI Sensitivity graphs. We see that in the positive shocking case, the landscape of ECI sensitivity has somewhat altered over the five year period. Services & Utilities seemed to offer the best ECI growth prospects in 2013 as a neutral alternative to the negative reaction observed for all other industries.

In the 2013 negative shocking case, we see that Laos is very sensitive to drawdowns in Chemicals and Raw Manufacturing.



Laos 2013 (Incremental ECI Sensitivity)



Laos 2013 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for High Complexity Products. We see that increasing the export of High Complexity Products does not affect the number of positive opportunity gain industries for Laos to move into.

In the negative Transportation SDV chart, we see that as we decrease the export of Transportation, nothing happens. The number of industries with positive opportunity gain stays the same, suggesting that the opportunities available to Laos are independent of its High Complexity Products footprint.

Concerning Food and Preparations, Laos seems to be somewhat sensitive to this industry in the case of decrement. Interestingly, decreasing the export of Food and Preparations positively affects the Chemical Manufacturing industry, suggesting that Laos is somewhat dependent on this industry in terms of the stability of its SDV.

	-0%
0	Animals and By-products
1	Machinery and Construction
2	High-complexity Products
3	Wood Products
4	Transportation
5	Daily Instruments
6	Weapons
7	Services and Utilities
8	Textile
9	Chemical Manufacturing
10	Clothing and Accessories
11	Vegetables, Fruits and Plants
12	Metals
13	Raw Manufacturing
14	Chemicals
15	Energy Drilling and Mining
16	Precious Stones
17	Food and Preparations
ECI	-0.4326636589

Laos High Complexity Products 2018 (Decremental SDV Sensitivity)

	0%
0	Animals and By-products
1	Machinery and Construction
2	High-complexity Products
3	Wood Products
4	Transportation
5	Daily Instruments
6	Weapons
7	Services and Utilities
8	Textile
9	Chemical Manufacturing
10	Clothing and Accessories
11	Vegetables, Fruits and Plants
12	Metals
13	Raw Manufacturing
14	Chemicals
15	Energy Drilling and Mining
16	Precious Stones
17	Food and Preparations
ECI	-0.4326636589

Laos High Complexity Products 2018 (Incremental SDV Sensitivity)

	-0%	-60%
0	Animals and By-products	Machinery and Construction
1	Machinery and Construction	High-complexity Products
2	High-complexity Products	Transportation
3	Wood Products	Animals and By-products
4	Transportation	Daily Instruments
5	Daily Instruments	Food and Preparations
6	Weapons	Services and Utilities
7	Services and Utilities	Weapons
8	Textile	Wood Products
9	Chemical Manufacturing	Textile
10	Clothing and Accessories	Chemical Manufacturing
11	Vegetables, Fruits and Plants	Clothing and Accessories
12	Metals	Vegetables, Fruits and Plants
13	Raw Manufacturing	Metals
14	Chemicals	Raw Manufacturing
15	Energy Drilling and Mining	Chemicals
16	Precious Stones	Precious Stones
17	Food and Preparations	Energy Drilling and Mining
ECI	-0.4326636589	-0.4169401785

Laos Food and Preparations 2018 (Decremental SDV Sensitivity)

	0%
0	Animals and By-products
1	Machinery and Construction
2	High-complexity Products
3	Wood Products
4	Transportation
5	Daily Instruments
6	Weapons
7	Services and Utilities
8	Textile
9	Chemical Manufacturing
10	Clothing and Accessories
11	Vegetables, Fruits and Plants
12	Metals
13	Raw Manufacturing
14	Chemicals
15	Energy Drilling and Mining
16	Precious Stones
17	Food and Preparations
ECI	-0.4326636589

Laos Food and Preparations 2018 (Incremental SDV Sensitivity)

4.4 Contingency Strategy

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

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

Laos Contingency Strategy 2018

5. Macro-level Predictions

5.1 Structural Optimality Index

Indeed, such choice of prioritization has proven to be a significant factor in deciding the economic outcomes of countries. In order to quantitatively evaluate how effective our development strategies are and how deviations from the suggested developmental path will lead to suboptimal growth results, we define the measure – Structural Optimality Index (SOI) – on a country level as the Adjusted R-Square obtained from regressing the country's realized industry development over the suggested development strategy. Both strategies are quantified in nature, with the realized development represented by export increase in every major industry group and the suggested development strategy represented by the opportunity gains of developing the corresponding industry groups as calculated in previous sections. The adjusted R-square from the regression thus provides us with a quantified measure of how the development path adopted by the country has fitted with/differed from calculations on a complexity level.

After obtaining this measure for all countries in our database, we further regress countries' five-year economic growth, which is defined as the percent increase in GDP (USD), over their SOI. Figure 6 illustrates the regression output, which shows a strong positive correlation between countries' SOI and their five-year GDP growth, significant at the 1% level and achieving an adjusted R^2 of 4.5%. In other words, the more a country develops as suggested by calculations on a complexity level, the better economic outcomes it achieves.

Table 18: OLS Regression Results	
Dep. Variable: GDP	F-Statistic: 5.963
R²: 0.054	Prob (F-Stat): 0.0163

Adj R²: 0.045

No. Observations: 106

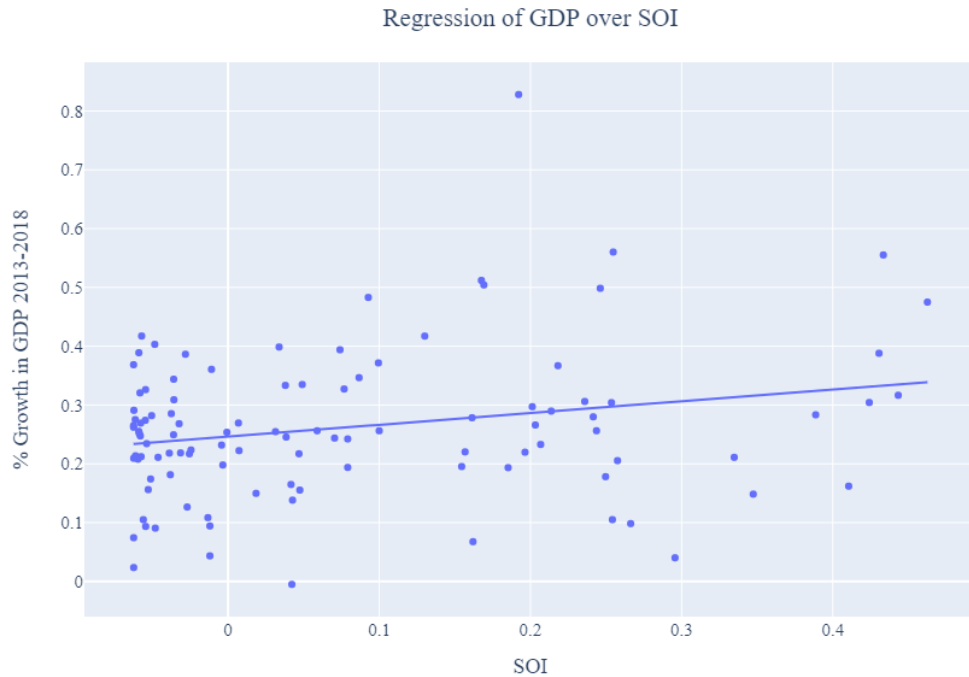


Figure 2: Regression of Five-year GDP Growth over SOI

5.2 SOI of Laos and Its Implications

Laos, for instance, has a low level of structural optimality as compared with its emerging peers. As the regression in Figure 7 suggests (the orange curve represents export increase and the blue curve stands for opportunity gain of the corresponding industry), Laos demonstrates a low level of correlation with the suggested developmental path, having an adjusted R-square of around 7.69%. Laos ranks in the median quartile among all countries in terms of SOI, with an SOI of 1.68%, and has made an average rate of economic progress compared to its developing peers from 2013 to 2018, with a 5-year GDP growth rate of 7.34%, which is consistent with the regression result in Figure 6. The disparity in SOI and GDP growth is not as great as for leading 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 Laos an only slightly slower developing economy during the period. In sum, Lao's mixed economic progress from 2013 to 2018 can be at least partially explained by a development strategy that demonstrates a suboptimal level of matches with our suggested developmental path. In specific, Laos invested heavily in the Wood Products industry, while it should have focused more on more complex industry groups such as Precious Stones. That being said, it stayed fairly in line with our expectations in the Energy Drilling and Mining industry.

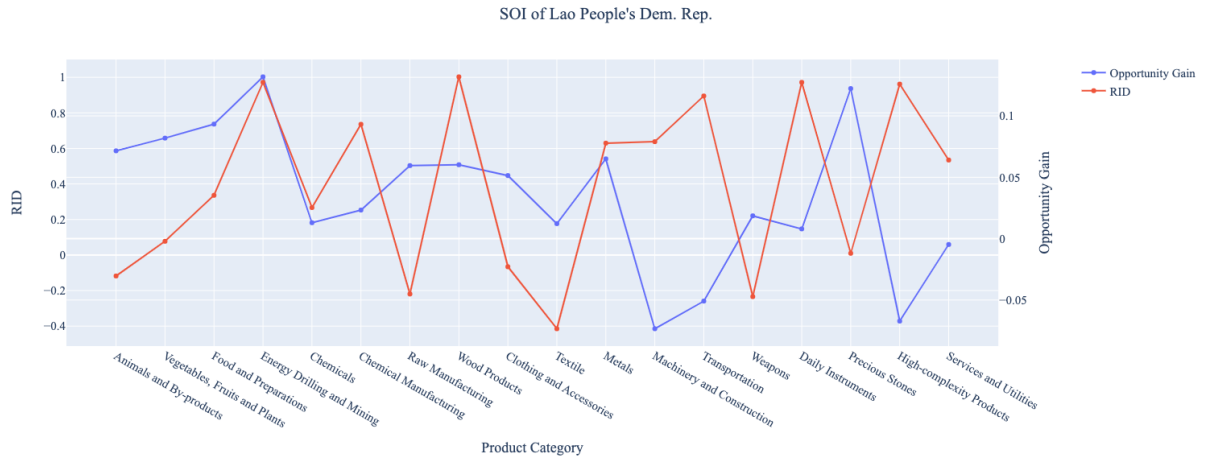


Figure 7: SOI of Laos (2009-2014)

6. Concluding Remarks

In conclusion, Laos has demonstrated a moderately high level of economic growth in terms of annual GDP increase during the period from 2013 to 2018, concurrent with an decrease in economic complexity.

The moderate progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Laos 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 Laos consistently relied on developing the Wood Products and Transportation industries during the period, while its emerging counterparts and developed 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, Laos can further its gains by prioritizing Transportation and Daily Instruments. We further note that Laos has a slightly mismatched development strategy that indicates an average (compared to other developing countries) level of structural optimality on the complexity level, having an adjusted R-square of around 7.69%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Laos, 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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