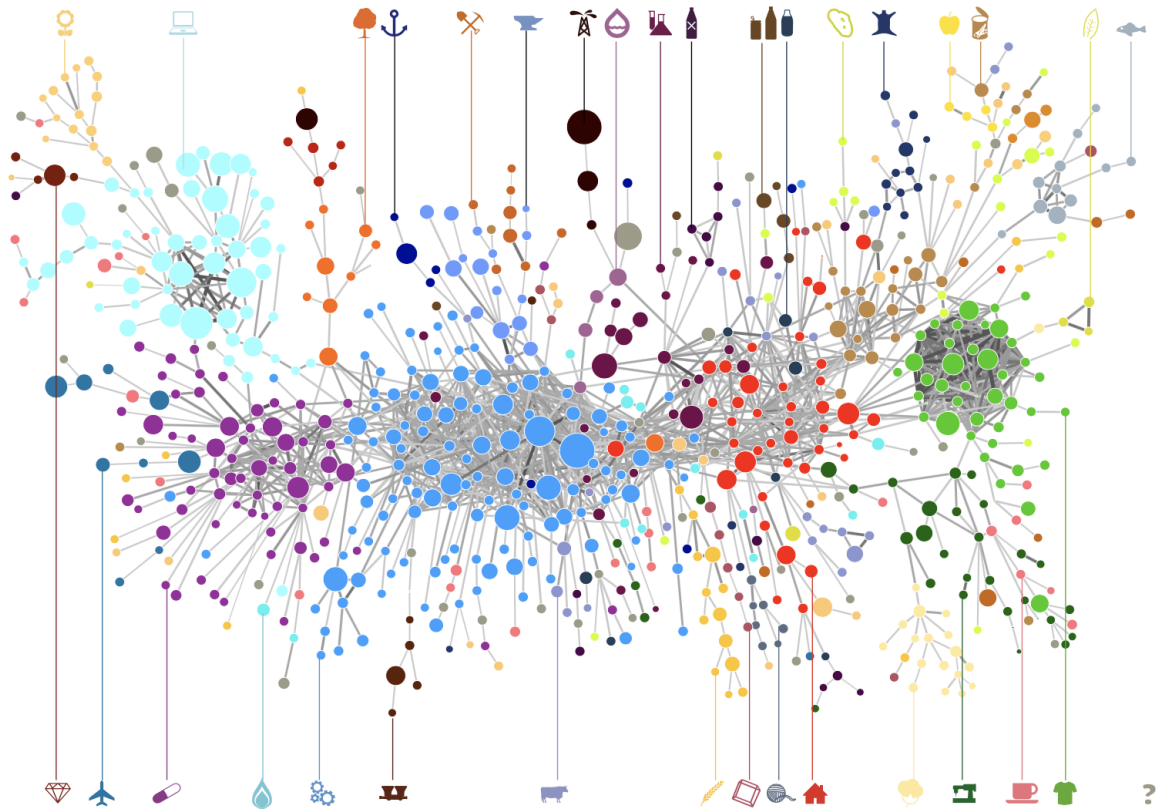




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# Optimal Industry Development Strategy Using Economic and Product Complexity

## Ireland

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# Optimal Industry Development Strategy for Ireland

## 0. Executive Summary

In this report, we aim to uncover the economic path Ireland went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Ireland 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, Ireland demonstrated a high level of economic growth with an average annual GDP growth rate of 11.16%, concurrent with an increase in economic complexity as compared with other developed economies.

The progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Ireland 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 Ireland consistently relied on developing the Vegetables, Fruits, and Plants, Services and Utilities, and Precious Stones industries during the period, while some of its developed counterparts and emerging economies around the globe adopted more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Ireland can further its gains by prioritizing High-Complexity Products, Chemical Manufacturing, and Machinery. We further note that Ireland has a slightly mismatched development strategy that indicates a high level (compared to other developed countries) of structural optimality on the complexity level, having an adjusted R-square of around 20.8%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, this explains why Ireland has a comparable growth experience as compared with fast-growing economies both on a regional scale and on a global scale. However, despite its success, Ireland still has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

## 1. Report Overview

In this report, we aim to uncover the economic path Ireland went through during the period from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Ireland from the perspective of Gross Domestic Product (GDP) and Economic Complexity Index (ECI), which reflect countries' production capability and production structure, respectively. We then analyze the industrial framework and changes of Ireland during the period based on quantitative measures such as Product Complexity Index (PCI) and Product Family Complexity Index (PfCI), followed by a detailed analysis of how such changes have matched with development strategies as quantitatively measured by opportunity gains on an industry-level. We conclude our report with macro-level results and predictions of Ireland, 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 Ireland and three of its peer countries (Finland, Denmark, New Zealand) from 2013-2018. In contrast to the other countries, which generally displayed either constant or upwards growth over all years, Ireland had volatile periods of high growth mixed in with periods of low growth. Therefore, Ireland's average annual growth rate of 11.16% over the five-year period is clearly higher than its peers, which are 2.84%, 3.57%, and 3.71% for Finland, Denmark, and New Zealand, respectively.

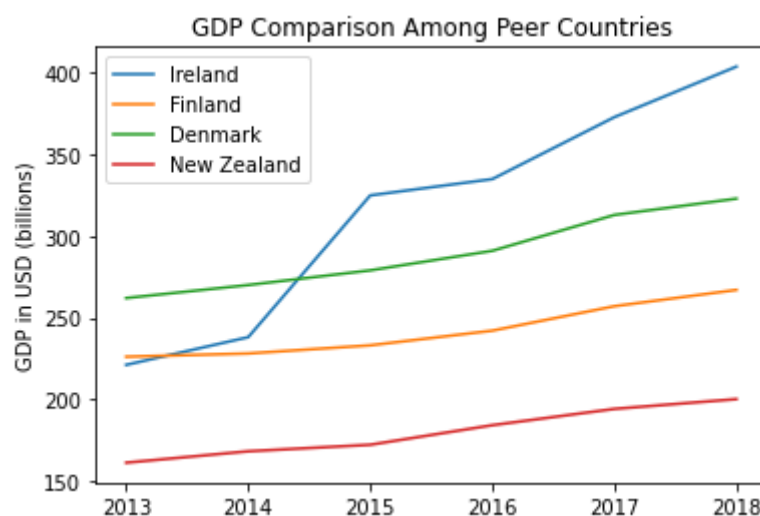


Figure 1: GDP Comparison Among Peer Countries

### 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 is illustrated in Figure 2 below. Similar to its peers, Ireland exhibits ECI volatility over the period; however, Ireland is the only peer country to see an increase (13.61% change) in terms of its production capability from 2013 to 2018, as Finland, Denmark, and New Zealand all have -15.68%, -9.25%, and -37.37% ECI changes respectively.

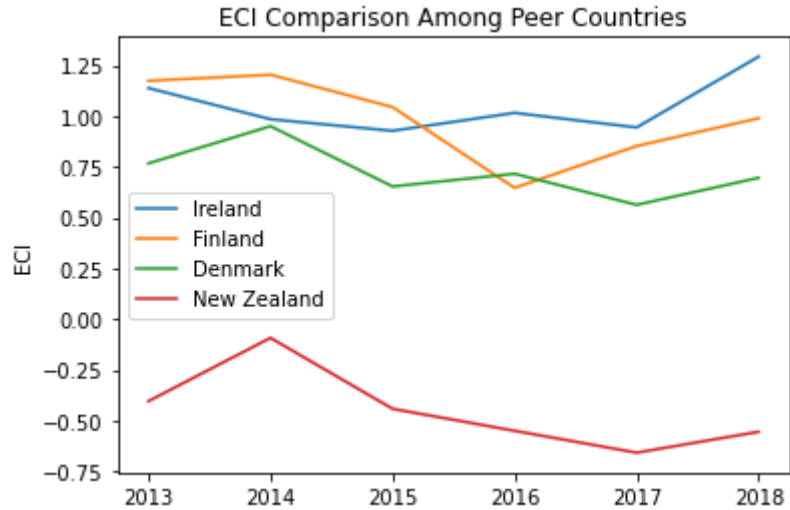


Figure 2: ECI Comparison

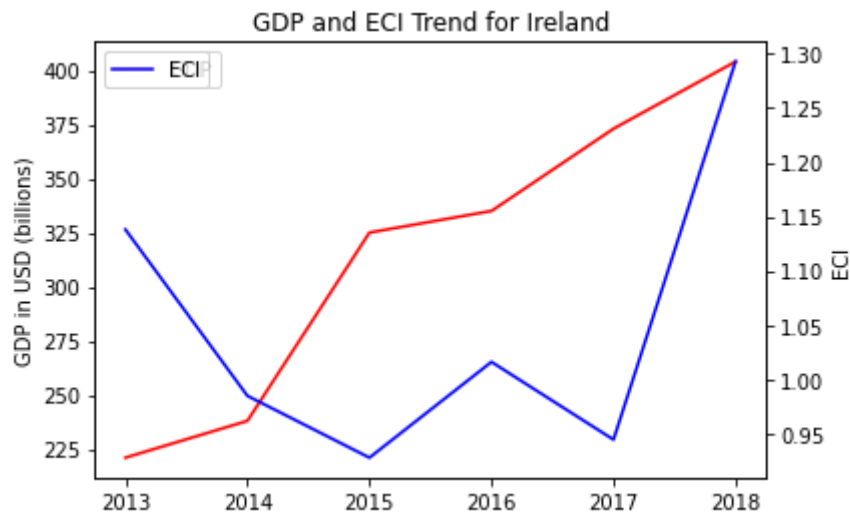


Figure 3: GDP Growth and ECI (U.S.)

Figure 3 offers a further comparison of GDP Growth and ECI over the time span from 2013 to 2018 for Ireland.. The increase in GDP growth during the period from 2013 to 2018 is accompanied by a more volatile eventual increase in ECI. The results show that the economic growth experienced by Ireland during the period from 2013 to 2018 is partially the predictions by ECI and that Ireland made strides on effectively developing a competitive product space that helps to accumulate complicated knowledge and technology. In order to provide a more concrete answer to why this has happened, we will dive into an analysis of Ireland'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                                                                    |
|--------------------------------------|--------------------------------------------------------------------------------|
| <b>Animals and By-products</b>       | All kinds of meat, livestock and related by-products                           |
| <b>Vegetables, Fruits and Plants</b> | All kinds of plants, edible vegetables and fruits                              |
| <b>Food and Preparations</b>         | Edible preparations, raw cooking materials and appliances                      |
| <b>Clothing and Accessories</b>      | All kinds of fabrics, filament, clothing and accessories                       |
| <b>Textiles</b>                      | All kinds of textile articles and related products                             |
| <b>Wood Products</b>                 | Book, paper and other elementary products related to wood                      |
| <b>Metals</b>                        | Mining of all sorts of raw Metals                                              |
| <b>Refined and Processed Stones</b>  | Refined or processed stone products such as pearl and ceramics                 |
| <b>Energy Drilling and Mining</b>    | Mining industry for energy, minerals, stone materials, etc.                    |
| <b>Daily Instruments</b>             | Basic daily instruments such as sport requisites, timing and measuring tools   |
| <b>Raw Manufacturing</b>             | Basic products made from plastic, rubber, leather, etc.                        |
| <b>Chemical Manufacturing</b>        | Advanced chemical products and pharmaceutical products                         |
| <b>Chemicals</b>                     | Raw chemical materials and by-products                                         |
| <b>Machinery and Construction</b>    | Machinery and mechanical appliances, including electrical equipment            |
| <b>Transportation</b>                | Vehicles and locomotives including aircraft, ship, railway, etc.               |
| <b>Weapons</b>                       | Explosives, arms and ammunition                                                |
| <b>Services and Utilities</b>        | Financial, business, legal, communication, travel Services and Utilities, etc. |
| <b>High-complexity Products</b>      | 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 Ireland'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      |
|-------------------------------|----------|
| Food and Preparations         | 0.011112 |
| Transportation                | 0.044972 |
| High-complexity Products      | 0.073666 |
| Machinery and Construction    | 0.081602 |
| Daily Instruments             | 0.101634 |
| Textile                       | 0.112731 |
| Chemical Manufacturing        | 0.114999 |
| Weapons                       | 0.116101 |
| Energy Drilling and Mining    | 0.119420 |
| Raw Manufacturing             | 0.132064 |
| Metals                        | 0.139328 |
| Animals and By-products       | 0.140651 |
| Chemicals                     | 0.144665 |
| Wood Products                 | 0.145889 |
| Clothing and Accessories      | 0.160278 |
| Precious Stones               | 0.178515 |
| Services and Utilities        | 0.185753 |
| Vegetables, Fruits and Plants | 0.191130 |

Table 2: Realized Industry Development (RID) of Ireland

### 3.3 Regional and Global Comparison

Table 3 and 4 below summarize how the production strategy adopted by Ireland 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 Ireland'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 | Singapore                     | Japan                         | China                         | Germany                       | Republic of Korea             | Ireland                       |
|---------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 1       | Energy Drilling and Mining    | Chemicals                     | Chemicals                     | Chemical Manufacturing        | Services and Utilities        | Services and Utilities        |
| 2       | Chemicals                     | Metals                        | Raw Manufacturing             | Machinery and Construction    | Chemicals                     | Animals and By-products       |
| 3       | Machinery and Construction    | Machinery and Construction    | Clothing and Accessories      | Transportation                | Raw Manufacturing             | Chemicals                     |
| 4       | Transportation                | Transportation                | Textile                       | Daily Instruments             | Textile                       | Chemical Manufacturing        |
| 5       | High-complexity Products      | Weapons                       | Machinery and Construction    | High-complexity Products      | Metals                        | Daily Instruments             |
| 6       | Services and Utilities        | Daily Instruments             | Transportation                | Services and Utilities        | Transportation                | High-complexity Products      |
| 7       | Weapons                       | High-complexity Products      | Weapons                       | Chemicals                     | Daily Instruments             | Machinery and Construction    |
| 8       | Textile                       | Services and Utilities        | Daily Instruments             | Textile                       | High-complexity Products      | Weapons                       |
| 9       | Precious Stones               | Textile                       | High-complexity Products      | Weapons                       | Weapons                       | Textile                       |
| 10      | Chemical Manufacturing        | Precious Stones               | Precious Stones               | Clothing and Accessories      | Clothing and Accessories      | Clothing and Accessories      |
| 11      | Clothing and Accessories      | Clothing and Accessories      | Services and Utilities        | Precious Stones               | Precious Stones               | Transportation                |
| 12      | Daily Instruments             | Energy Drilling and Mining    | Energy Drilling and Mining    | Raw Manufacturing             | Energy Drilling and Mining    | Raw Manufacturing             |
| 13      | Animals and By-products       | Animals and By-products       | Wood Products                 | Wood Products                 | Chemical Manufacturing        | Energy Drilling and Mining    |
| 14      | Metals                        | Wood Products                 | Animals and By-products       | Energy Drilling and Mining    | Wood Products                 | Precious Stones               |
| 15      | Raw Manufacturing             | Chemical Manufacturing        | Metals                        | Animals and By-products       | Animals and By-products       | Metals                        |
| 16      | Wood Products                 | Food and Preparations         | Chemical Manufacturing        | Metals                        | Food and Preparations         | Wood Products                 |
| 17      | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants | Food and Preparations         | Vegetables, Fruits and Plants | Food and Preparations         |
| 18      | Food and Preparations         | Raw Manufacturing             | Food and Preparations         | Vegetables, Fruits and Plants | Machinery and Construction    | Vegetables, Fruits and Plants |
| ECI     | 2.112887919                   | 1.979430054                   | 1.700687855                   | 2.959929484                   | 1.648971597                   | 1.292977266                   |

| Ranking | Singapore                     | Japan                         | China                         | Germany                       | Republic of Korea             | Ireland                       |
|---------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 1       | Chemicals                     | Chemicals                     | Raw Manufacturing             | Chemical Manufacturing        | Services and Utilities        | Services and Utilities        |
| 2       | Transportation                | Metals                        | Clothing and Accessories      | Wood Products                 | Chemicals                     | Weapons                       |
| 3       | High-complexity Products      | Machinery and Construction    | Textile                       | Metals                        | Raw Manufacturing             | Animals and By-products       |
| 4       | Services and Utilities        | Transportation                | Machinery and Construction    | Machinery and Construction    | Textile                       | Food and Preparations         |
| 5       | Machinery and Construction    | Weapons                       | Transportation                | Transportation                | Metals                        | Chemicals                     |
| 6       | Daily Instruments             | Daily Instruments             | Weapons                       | Weapons                       | Transportation                | Chemical Manufacturing        |
| 7       | Weapons                       | High-complexity Products      | Daily Instruments             | High-complexity Products      | Daily Instruments             | Daily Instruments             |
| 8       | Textile                       | Services and Utilities        | High-complexity Products      | Services and Utilities        | High-complexity Products      | High-complexity Products      |
| 9       | Chemical Manufacturing        | Precious Stones               | Precious Stones               | Energy Drilling and Mining    | Weapons                       | Machinery and Construction    |
| 10      | Raw Manufacturing             | Energy Drilling and Mining    | Services and Utilities        | Precious Stones               | Energy Drilling and Mining    | Textile                       |
| 11      | Clothing and Accessories      | Textile                       | Chemicals                     | Textile                       | Chemical Manufacturing        | Energy Drilling and Mining    |
| 12      | Metals                        | Clothing and Accessories      | Energy Drilling and Mining    | Clothing and Accessories      | Precious Stones               | Precious Stones               |
| 13      | Wood Products                 | Chemical Manufacturing        | Chemical Manufacturing        | Chemicals                     | Machinery and Construction    | Vegetables, Fruits and Plants |
| 14      | Precious Stones               | Animals and By-products       | Wood Products                 | Animals and By-products       | Clothing and Accessories      | Raw Manufacturing             |
| 15      | Animals and By-products       | Wood Products                 | Animals and By-products       | Vegetables, Fruits and Plants | Wood Products                 | Clothing and Accessories      |
| 16      | Food and Preparations         | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants | Food and Preparations         | Animals and By-products       | Metals                        |
| 17      | Energy Drilling and Mining    | Food and Preparations         | Metals                        | Daily Instruments             | Food and Preparations         | Wood Products                 |
| 18      | Vegetables, Fruits and Plants | Raw Manufacturing             | Food and Preparations         | Raw Manufacturing             | Vegetables, Fruits and Plants | Transportation                |
| ECI     | 2.751108815                   | 2.170299638                   | 1.96086598                    | 1.937171566                   | 1.7759805                     | 1.138083385                   |

Table 5: SDV of High E<sub>f</sub>CI Countries 2013(up), 2018(down)

We define the ranking of opportunity gain for a country  $c$ , as the Suggested Development Vector (SDV) of  $c$ . Table 5 shows the SDV of a selected group of leading economies with outstanding economic complexity, with the industry groups ranked in decreasing order of significance. Dark blue indicates positive opportunity gain, light blue indicates zero opportunity gains, and white indicates negative opportunity gains. The result shows that leading countries barely have any industries with positive opportunity gain. In other words, those countries are already in the most stable and efficient economic structure. Without the necessity of economic transition, those countries merely need to maintain a steady and balanced economic development. In contrast, countries listed in Table 6 have nearly half of industries with positive opportunity gain. While the economies with absolute negative ECI, such as South Africa and Colombia, all need to develop High-complexity Products, Machinery and Construction and Daily Instruments, those with median ECI are facing a more complicated and diverse situation, such as Italy and Spain.

It can be concluded that Ireland is categorized to be a highly complex country as compared with the world's leading economies.

| Ranking | Thailand                      | Italy                         | Spain                         | United Arab Emirates          |
|---------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 1       | Animals and By-products       | Energy Drilling and Mining    | Energy Drilling and Mining    | High-complexity Products      |
| 2       | Food and Preparations         | Precious Stones               | Precious Stones               | Transportation                |
| 3       | Chemicals                     | Vegetables, Fruits and Plants | Weapons                       | Machinery and Construction    |
| 4       | Raw Manufacturing             | Animals and By-products       | Textile                       | Daily Instruments             |
| 5       | Textile                       | Food and Preparations         | Chemicals                     | Chemicals                     |
| 6       | Machinery and Construction    | Chemical Manufacturing        | Daily Instruments             | Weapons                       |
| 7       | Transportation                | Raw Manufacturing             | Animals and By-products       | Textile                       |
| 8       | High-complexity Products      | Wood Products                 | Vegetables, Fruits and Plants | Chemical Manufacturing        |
| 9       | Energy Drilling and Mining    | Clothing and Accessories      | Food and Preparations         | Raw Manufacturing             |
| 10      | Vegetables, Fruits and Plants | Textile                       | Chemical Manufacturing        | Energy Drilling and Mining    |
| 11      | Precious Stones               | Metals                        | Raw Manufacturing             | Precious Stones               |
| 12      | Weapons                       | Machinery and Construction    | Wood Products                 | Services and Utilities        |
| 13      | Clothing and Accessories      | Daily Instruments             | Clothing and Accessories      | Metals                        |
| 14      | Services and Utilities        | High-complexity Products      | Metals                        | Clothing and Accessories      |
| 15      | Wood Products                 | Weapons                       | Transportation                | Wood Products                 |
| 16      | Metals                        | Chemicals                     | Services and Utilities        | Animals and By-products       |
| 17      | Chemical Manufacturing        | Services and Utilities        | Machinery and Construction    | Vegetables, Fruits and Plants |
| 18      | Daily Instruments             | Transportation                | High-complexity Products      | Food and Preparations         |
| ECI     | 1.68914409                    | 1.179705915                   | 0.45830144                    | -0.734459148                  |

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:

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

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:

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

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             |

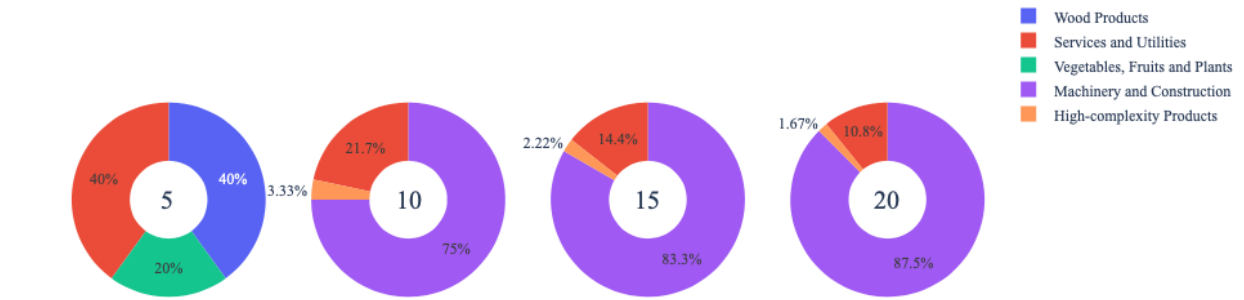
|    |                            |
|----|----------------------------|
| 8  | Wood Products              |
| 9  | Clothing and Accessories   |
| 10 | Textile                    |
| 11 | Metals                     |
| 12 | Machinery and Construction |
| 13 | Transportation             |
| 14 | Weapons                    |
| 15 | Daily Instruments          |
| 16 | Precious Stones            |
| 17 | High-complexity Products   |
| 18 | Services and Utilities     |

Table 7: Products Labeling

Below is the economic panel for Ireland in 2013. We can see that for different percentages of heuristic total export growth, the ECIs of Ireland actually have very slightly different amounts of increments. Overall, with a 5 percent growth in export, the ECI of Ireland starts growing from around 1.29 and ends at around 1.32. However, with a much larger amount of budget, such as 10, 15, and 20 percent growth, Ireland's ECI can actually achieve a much higher level, namely around 1.67.

For the case of 5 percent growth in export, wood products and services and utilities are main components of the portfolio. For the cases of 10, 15 and 20 percent increment budgets, we realize that the development trajectories are in a similar pattern, mainly consisting of machinery and construction as well as services and utilities. Similar to other developed countries, Ireland also has a relatively sparse solution, which can be reasoned by its pretty well-rounded economic structure. However, from the ECI improvement trajectories, we observe that most of the increments are resulted by services and utilities when its budget is low, and by machinery and construction when it has a high development budget. A more detailed numerical representation of the portfolio is shown in Table 8.

### Ireland ECI Growth Optimization Result



### Ireland ECI Increment

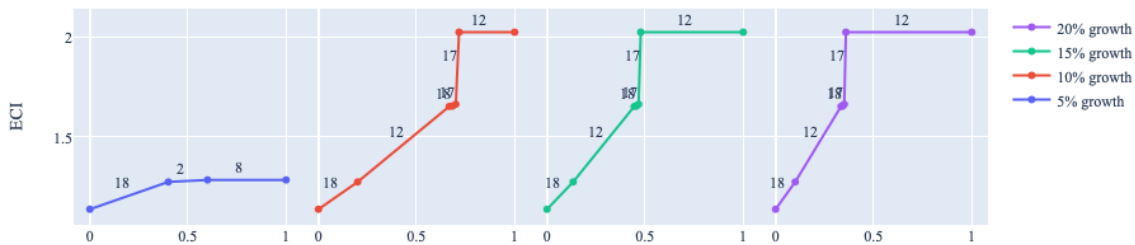


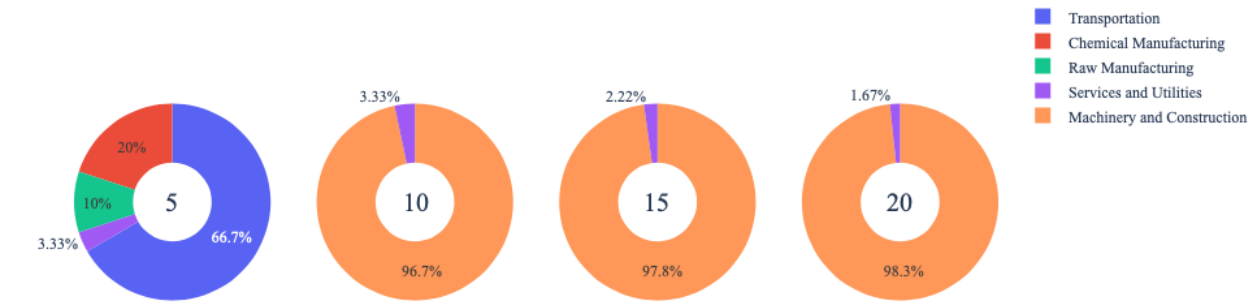
Figure 5: Greedy Based ECI Improvement Results of Ireland in 2013 with Different Budgets

| Original ECI                  | Ireland (2013) |          |          |          |
|-------------------------------|----------------|----------|----------|----------|
|                               | 5%             | 10%      | 15%      | 20%      |
| Heuristic Export Growth       | 1.29           | 1.29     | 1.29     | 1.29     |
| Vegetables, Fruits and Plants | 1.93E+09       | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Wood Products                 | 3.85E+09       | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Machinery and Construction    | 0.00E+00       | 2.41E+10 | 3.48E+10 | 4.50E+10 |
| High-complexity Products      | 0.00E+00       | 1.07E+09 | 9.28E+08 | 8.56E+08 |
| Services and Utilities        | 3.85E+09       | 6.96E+09 | 6.03E+09 | 5.57E+09 |
| Increased ECI                 | 1.32           | 2.02     | 2.02     | 2.02     |

Table 8: Portfolio of Ireland in 2013

For further suggestions on Ireland's development in the future. We also offer the optimization result based on export data in 2018. Below is the economic panel for Ireland in 2018. We can see that there is a similar pattern for the ECI improvement trajectories, which is that the improvements in 10, 15 and 20 percent export growth are similar, and all of them are greater than the one in 5 percent growth. Again, since Ireland is a pretty developed economic entity, the optimization result is very sparse and there are not so many suggestions for future development in terms of ECI improvement. With 5 percent growth in export, transportation and chemical manufacturing are the main components for ECI improvement, but as the budgets become larger, machinery and construction as well as services and utilities are still essential for ECI improvement to a great extent, which is similar to the result in 2018. A more detailed numerical representation of the portfolio is shown in Table 9.

#### Ireland ECI Growth Optimization Result



#### Ireland ECI Increment

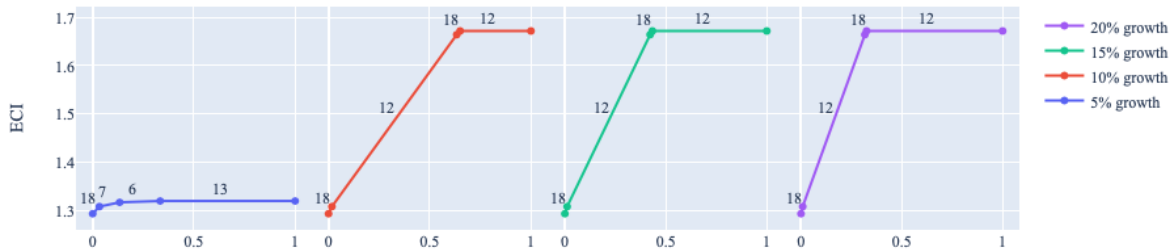


Figure 6: Greedy Based ECI Improvement Results of Ireland in 2018 with Different Budgets

| Ireland (2018)             |          |          |          |          |  |
|----------------------------|----------|----------|----------|----------|--|
| Original ECI               | 1.29     |          |          |          |  |
| Heuristic Export Growth    | 5%       | 10%      | 15%      | 20%      |  |
| Chemical Manufacturing     | 2.83E+09 | 0.00E+00 | 0.00E+00 | 0.00E+00 |  |
| Raw Manufacturing          | 1.42E+09 | 0.00E+00 | 0.00E+00 | 0.00E+00 |  |
| Machinery and Construction | 0.00E+00 | 4.47E+10 | 5.91E+10 | 7.34E+10 |  |
| Transportation             | 9.45E+09 | 0.00E+00 | 0.00E+00 | 0.00E+00 |  |
| Services and Utilities     | 4.72E+08 | 1.54E+09 | 1.34E+09 | 1.24E+09 |  |
| Increased ECI              | 1.32     | 1.67     | 1.67     | 1.67     |  |

Table 9: Portfolio of Ireland in 2018

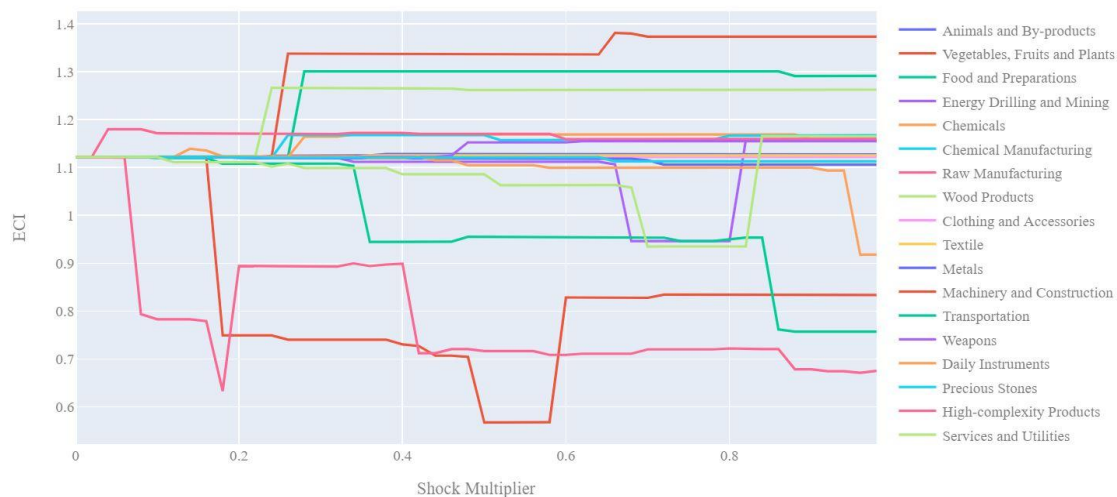
### 4.3 Sensitivity Analysis and Contingency Strategy

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

## ECI Sensitivity Graph

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

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



Example 2018 (Incremental ECI Sensitivity)

## SDV sensitivity

Secondly, we analyze the sensitivity of the SDV to changes in export levels. The goal is to understand how export level changes for a particular industry can affect the marginal

opportunity gain for other industries. We will be using specifically High Complexity Products and Food and Preparations as our base industries. We will be increasing or decreasing the absolute export level in both of these industries and observing the effects on the SDV.

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

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

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

Example High-complexity Products 2018 (Incremental SDV Sensitivity)

## Contingency Plan

The Contingency Plan aims to present a set of solutions with respect to upheavals in different industries. Instead of compensating for the declining production directly, the best strategy is to develop those incipiently profitable industries. In this manner, we can derive the contingency strategy for countries to deal with possible abrupt declines of crucial industries. In some cases, the SDV remains unchanged even when a zero-opportunity-gain industry declines to its 20% in terms of export. We can then conclude the industry is not indispensable to the country. As a clarification, the three consecutive N/As means that the country doesn't

even need to respond to a collapse in the industry. Countries tend to have distinct solutions to the up and down of the same industry. To create the contingency strategy table we decrease the export level for each industry in the country's current production space by 60% respectively. The three highest ranking industries in the new SDV are then returned.

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

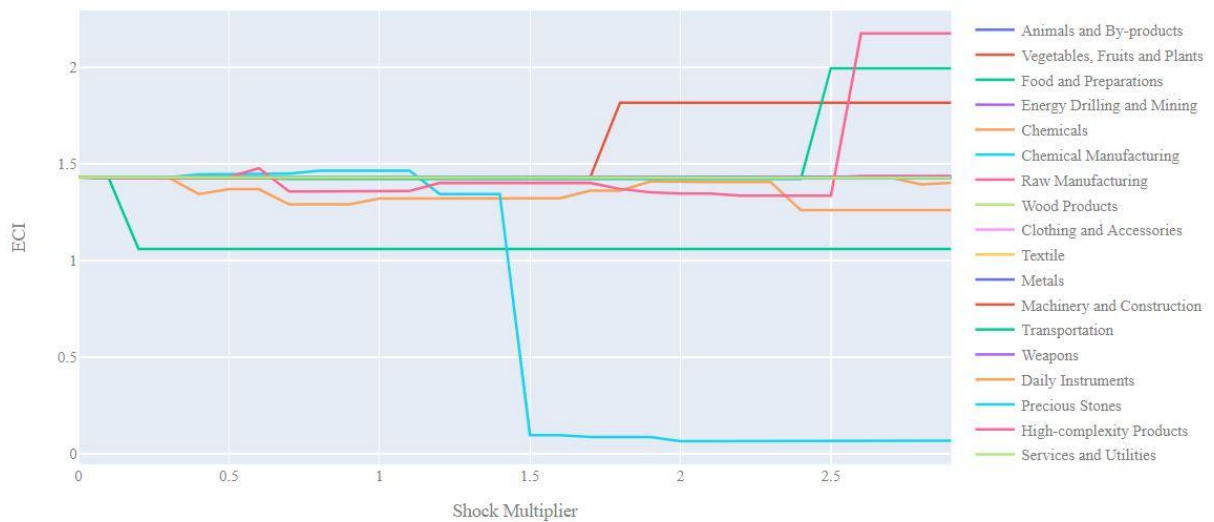
Example Contingency Strategy 2018

### 4.3 Sensitivity Analysis Results and Interpretation

Below is Ireland's 2018 ECI Sensitivity Charts. Firstly in the positive chart, we notice immediately that Ireland is quite sensitive to Food and Preparations and Chemical Manufacturing, Increases in export in either of these industries decreases ECI. Ireland is quite insensitive to increases in other industries except when very large shocks are experienced.

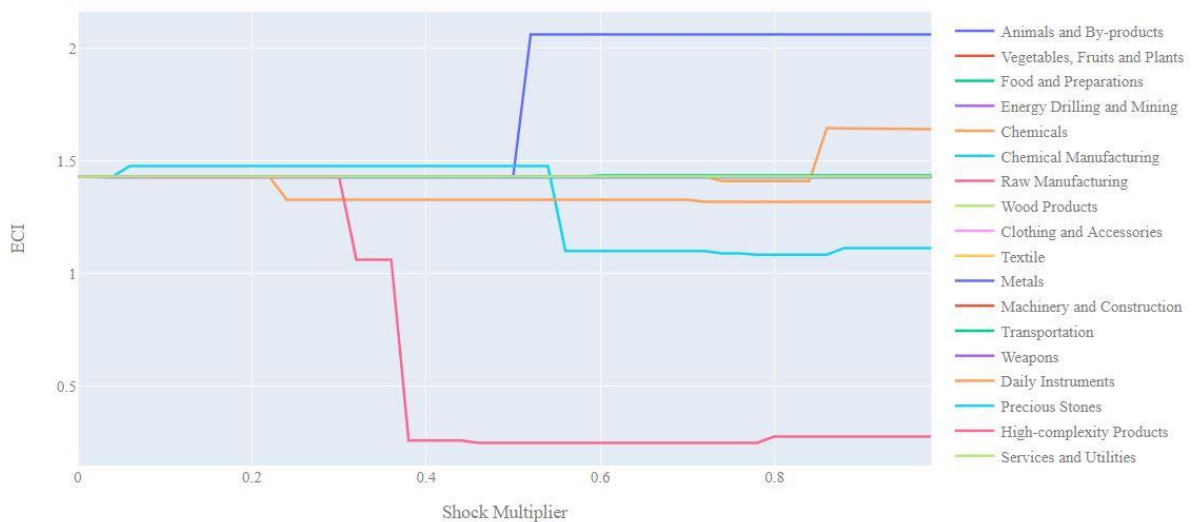
Next we consider Ireland's 2018 Negative Shock chart. We see that Ireland experiences a large drop off of ECI when there is a 30% decrease in export of High Complexity Products which suggests that this is a main supportive factor of Ireland's ECI score. Also decreases in Animals & By-products seems to increase the ECI score after about a 50% decrease.

Ireland (Postive Shocking)



Ireland 2018 (Incremental ECI Sensitivity)

Ireland (Negative Shocking)

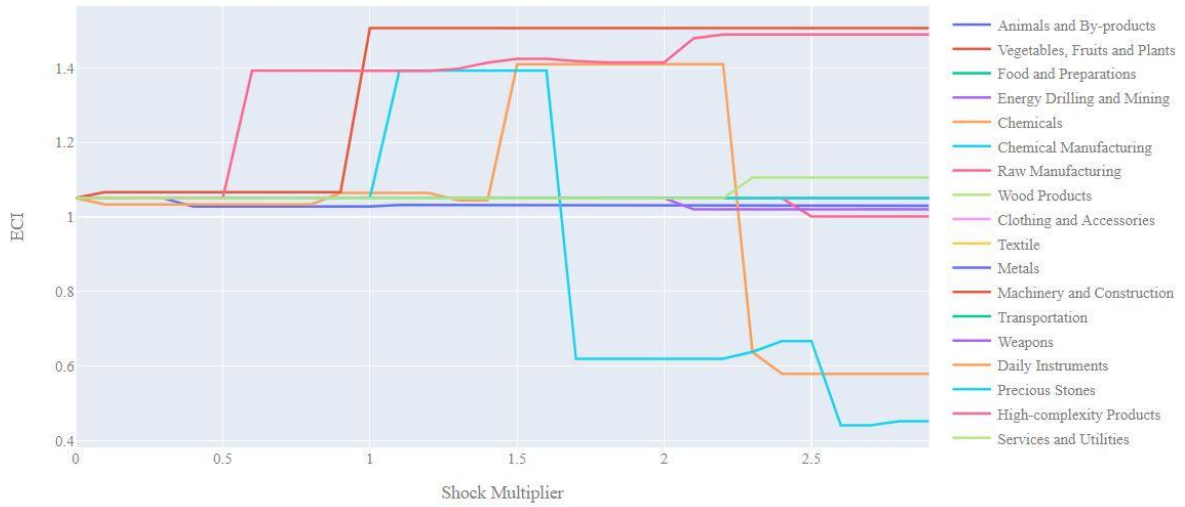


Ireland 2018 (Decremental ECI Sensitivity)

Next we consider the 2013 ECI Sensitivity graphs. Immediately we notice that Ireland has a much lower ECI score than in 2018. the 2013 positive shocking chart suggests that increases in export in industries such as High Complexity Product, Machinery, and Chemical Manufacturing could increase the ECI level to the level we see in 2018, suggesting that Ireland may have followed a similar path to achieve their 2018 ECI score.

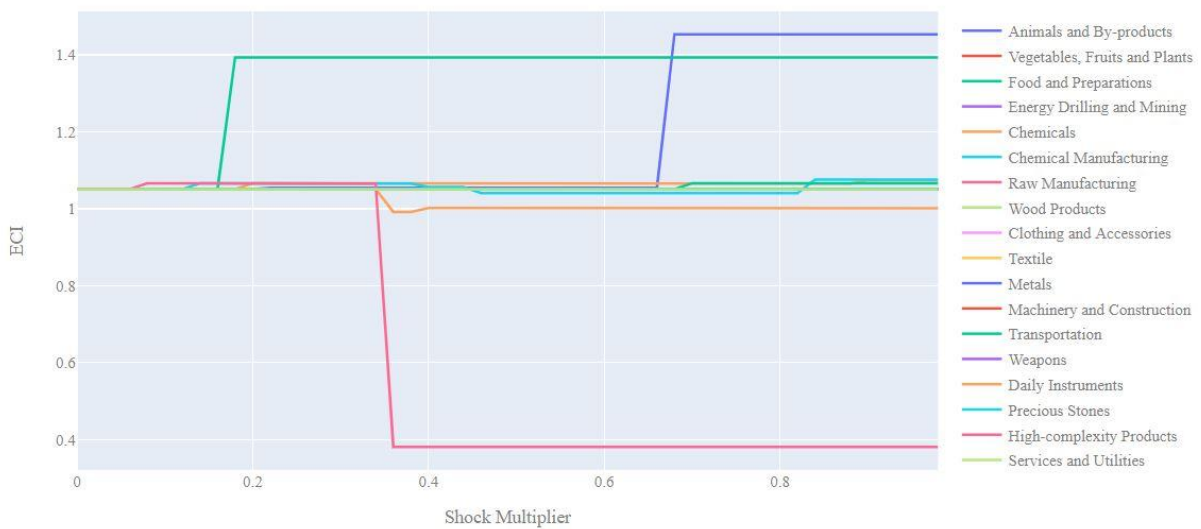
In the negative shocking case we see similar to 2018, decreases in High Complexity Products can lead to massive drop offs in ECI. We also see that decreases in Food and Preparations lead to large increases in ECI suggesting that this not an optimal industry for Ireland to expand into.

Ireland (Postive Shocking)



Ireland 2013 (Incremental ECI Sensitivity)

Ireland (Negative Shocking)



Ireland 2013 (Decremental ECI Sensitivity)

Below we see the SDV sensitivity charts for High Complexity Products. Similar to other countries that are dependent on High Complexity Products, industries such as Transportation, and Machinery are usually great opportunities to expand into as an economy it High Complexity Product footprint. Considering the negative High Complexity Product SDV sensitivity chart we observe that as the export of High Complexity Products decreases the number of industries with positive opportunity gain begin to increase. Interestingly in both the positive and negative shocking cases we see that Vegetables, Fruits, and Plants is consistently the highest opportunity gain industry.

Concerning Food and Preparations, Ireland seems to be mostly insensitive to this industry suggesting that this is not an important industry in terms of the stability of its SDV.

|     | 0.0%                          | 70.0%                         |
|-----|-------------------------------|-------------------------------|
| 0   | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants |
| 1   | Machinery and Construction    | Machinery and Construction    |
| 2   | Services and Utilities        | Services and Utilities        |
| 3   | Chemicals                     | Transportation                |
| 4   | Chemical Manufacturing        | Daily Instruments             |
| 5   | High-complexity Products      | High-complexity Products      |
| 6   | Animals and By-products       | Chemicals                     |
| 7   | Daily Instruments             | Chemical Manufacturing        |
| 8   | Transportation                | Animals and By-products       |
| 9   | Textile                       | Textile                       |
| 10  | Weapons                       | Weapons                       |
| 11  | Precious Stones               | Clothing and Accessories      |
| 12  | Clothing and Accessories      | Precious Stones               |
| 13  | Raw Manufacturing             | Raw Manufacturing             |
| 14  | Metals                        | Metals                        |
| 15  | Wood Products                 | Wood Products                 |
| 16  | Energy Drilling and Mining    | Energy Drilling and Mining    |
| 17  | Food and Preparations         | Food and Preparations         |
| ECI | 1.430696855                   | 1.356456181                   |

Ireland High-complexity Products 2018 (Incremental SDV Sensitivity)

|     | -0.0%                         | -32.0%                        | -38.0%                        |
|-----|-------------------------------|-------------------------------|-------------------------------|
| 0   | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants |
| 1   | Machinery and Construction    | Machinery and Construction    | High-complexity Products      |
| 2   | Services and Utilities        | Services and Utilities        | Machinery and Construction    |
| 3   | Chemicals                     | High-complexity Products      | Transportation                |
| 4   | Chemical Manufacturing        | Food and Preparations         | Services and Utilities        |
| 5   | High-complexity Products      | Chemicals                     | Food and Preparations         |
| 6   | Animals and By-products       | Chemical Manufacturing        | Chemicals                     |
| 7   | Daily Instruments             | Animals and By-products       | Chemical Manufacturing        |
| 8   | Transportation                | Daily Instruments             | Animals and By-products       |
| 9   | Textile                       | Transportation                | Daily Instruments             |
| 10  | Weapons                       | Textile                       | Textile                       |
| 11  | Precious Stones               | Weapons                       | Weapons                       |
| 12  | Clothing and Accessories      | Precious Stones               | Raw Manufacturing             |
| 13  | Raw Manufacturing             | Clothing and Accessories      | Precious Stones               |
| 14  | Metals                        | Raw Manufacturing             | Clothing and Accessories      |
| 15  | Wood Products                 | Metals                        | Metals                        |
| 16  | Energy Drilling and Mining    | Wood Products                 | Wood Products                 |
| 17  | Food and Preparations         | Energy Drilling and Mining    | Energy Drilling and Mining    |
| ECI | 1.430696855                   | 1.062129857                   | 0.259374027                   |

Ireland High-complexity Products 2018 (Decremental SDV Sensitivity)

|     | 0.0%                          | 20.0%                         |
|-----|-------------------------------|-------------------------------|
| 0   | Vegetables, Fruits and Plants | Vegetables, Fruits and Plants |
| 1   | Machinery and Construction    | Machinery and Construction    |
| 2   | Services and Utilities        | Services and Utilities        |
| 3   | Chemicals                     | High-complexity Products      |
| 4   | Chemical Manufacturing        | Food and Preparations         |
| 5   | High-complexity Products      | Chemicals                     |
| 6   | Animals and By-products       | Chemical Manufacturing        |
| 7   | Daily Instruments             | Animals and By-products       |
| 8   | Transportation                | Daily Instruments             |
| 9   | Textile                       | Transportation                |
| 10  | Weapons                       | Textile                       |
| 11  | Precious Stones               | Weapons                       |
| 12  | Clothing and Accessories      | Precious Stones               |
| 13  | Raw Manufacturing             | Clothing and Accessories      |
| 14  | Metals                        | Raw Manufacturing             |
| 15  | Wood Products                 | Metals                        |
| 16  | Energy Drilling and Mining    | Wood Products                 |
| 17  | Food and Preparations         | Energy Drilling and Mining    |
| ECI | 1.430696855                   | 1.059158986                   |

Ireland Food and Preparations 2018 (Incremental SDV Sensitivity)

|     | -0.0%                         |
|-----|-------------------------------|
| 0   | Vegetables, Fruits and Plants |
| 1   | Machinery and Construction    |
| 2   | Services and Utilities        |
| 3   | Chemicals                     |
| 4   | Chemical Manufacturing        |
| 5   | High-complexity Products      |
| 6   | Animals and By-products       |
| 7   | Daily Instruments             |
| 8   | Transportation                |
| 9   | Textile                       |
| 10  | Weapons                       |
| 11  | Precious Stones               |
| 12  | Clothing and Accessories      |
| 13  | Raw Manufacturing             |
| 14  | Metals                        |
| 15  | Wood Products                 |
| 16  | Energy Drilling and Mining    |
| 17  | Food and Preparations         |
| ECI | 1.430696855                   |

Ireland Food and Preparations 2018 (Decremental SDV Sensitivity)

## 4.4 Contingency Strategy

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

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

## Ireland 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 |                              |
|----------------------------------|------------------------------|
| <b>Dep. Variable: GDP</b>        | <b>F-Statistic: 5.963</b>    |
| <b>R<sup>2</sup>: 0.054</b>      | <b>Prob (F-Stat): 0.0163</b> |

|                            |                       |
|----------------------------|-----------------------|
| Adj R <sup>2</sup> : 0.045 | No. Observations: 106 |
|----------------------------|-----------------------|

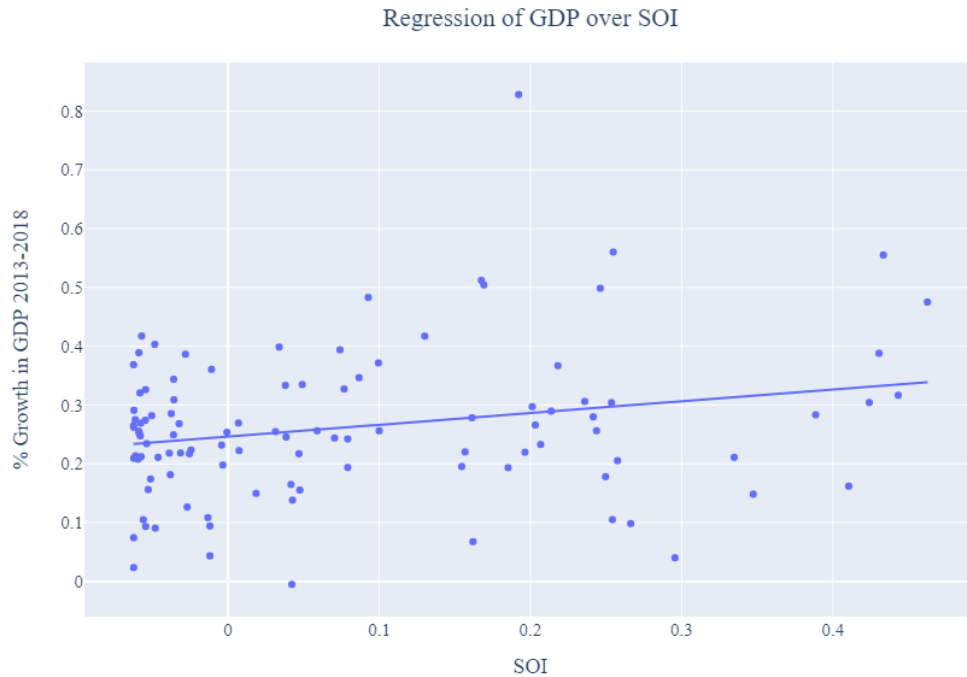


Figure 2: Regression of Five-year GDP Growth over SOI

## 5.2 SOI of Ireland and Its Implications

Ireland, for instance, has a higher 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), Ireland demonstrates an above-average level of correlation with the suggested developmental path, having an adjusted R-square of around 20.8%. Ireland ranks in the top quartile among all countries in terms of SOI and has made a high rate of economic progress among its emerging peers from 2013 to 2018 with a 5-year GDP growth rate of 82.8%, 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 moderate SOI of around -4.8% and a corresponding 5-year growth rate of 9.0%, ranking it a slow-developing economy during the period. In sum, Ireland's rapid economic progress from 2013 to 2018 can be at least partially explained by a development strategy that demonstrates a good level of similarity with our suggested developmental path. Particularly, Ireland invested heavily in the Precious Stone and Metals industries, and decreased investment in the Transportation and High-complexity industries.

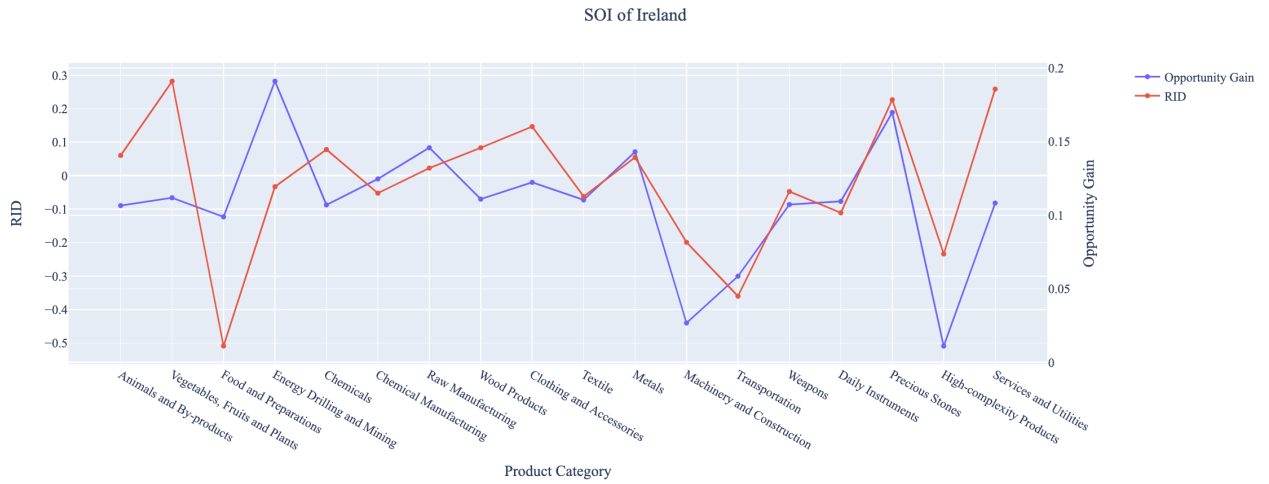


Figure 7: SOI of Ireland (2013-2018)

## 6. Concluding Remarks

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

The progress during the period, we believe, can be partially explained through analysis of the economic and product complexity structure of Ireland 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 Ireland consistently relied on developing the Vegetables, Fruits, and Plants, Services and Utilities, and Precious Stones industries during the period, while some of its developed counterparts and emerging economies around the globe adopted more complex and progressive paths.

Based on our analysis of the opportunity gain and a sensitivity analysis of major industry groups, Ireland can further its gains by prioritizing High-Complexity Products, Chemical Manufacturing, and Machinery. We further note that Ireland has a slightly mismatched development strategy that indicates a high level (compared to other developed countries) of structural optimality on the complexity level, having an adjusted R-square of around 20.8%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, this explains why Ireland has a comparable growth experience as compared with fast-growing economies both on a regional scale and on a global scale. However, despite its success, Ireland still has the potential to further its economic gains through industrial structure optimization as suggested in the paper.

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