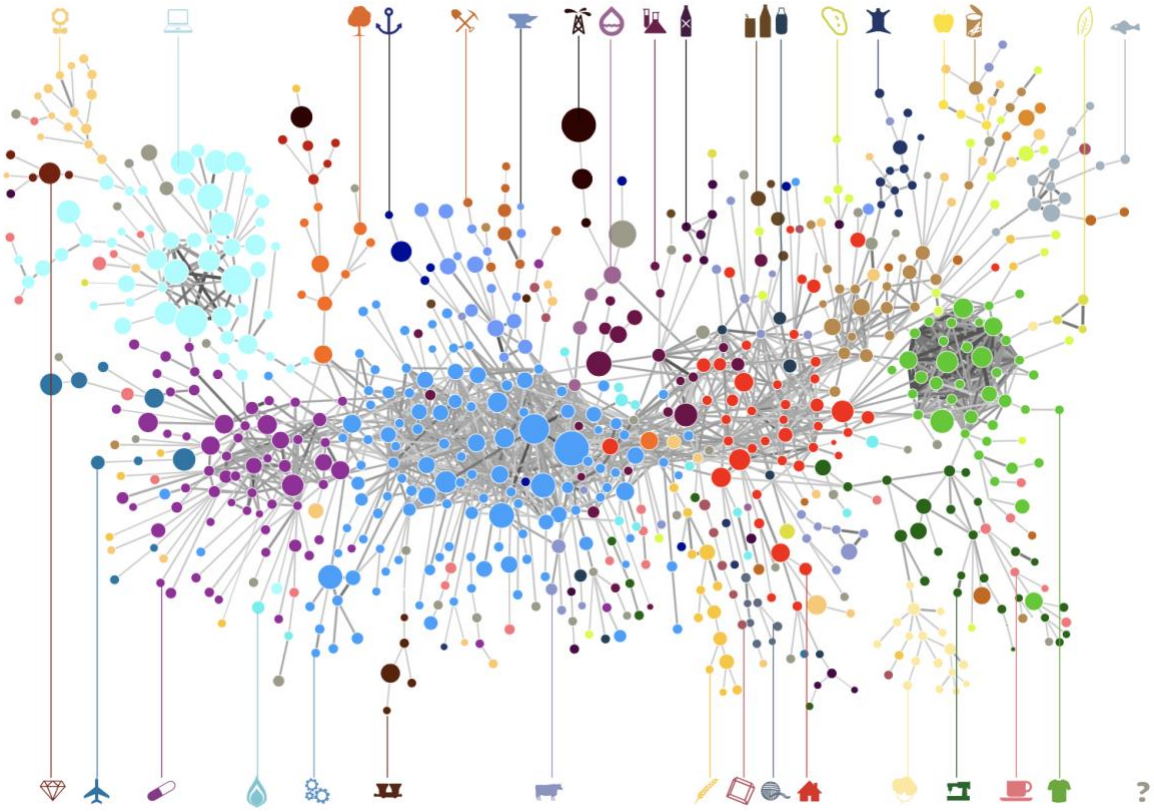

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Optimal Industry Development Strategy Using Economic and Product Complexity

Italy

The Economic Complexity Lab - Columbia University

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Optimal Industry Development Strategy for Italy

0. Executive Summary

In this report, we aim to uncover the economic path Italy went through during the period from 2013 to 2021. Specifically, we dive into the topic through a macroeconomic overview of Italy 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, Italy demonstrated a low level of economic growth with an annual GDP growth rate of 0.2% between 2013 and 2018, concurrent with a decrease in economic complexity as compared with other major economies in Europe.

The mixed level of economic progress during the first period can be partially explained through the analysis of the economic and product complexity structure of Italy 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 Italy invested heavily in Transportation, Machinery, and Construction.

Based on our analysis of the opportunity gain and sensitivity analysis of major industry groups, Italy can further its gains by prioritizing Vegetables, Fruits and Plants, Services, and Utilities in 2018. We further note that Italy has a slightly mismatched development strategy that indicates a moderate level of structural optimality on the complexity level, having an adjusted R-square of around 4.8%. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Italy indeed 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.

Between 2019 and 2021, Italy demonstrated a decreased economic complexity compared to other major comparable economies. We further note that Italy has a heavily mismatched development strategy that indicates a lower prosperity level (compared to other similar countries) of structural optimality on the complexity level, having a much lower adjusted R-square of 0.27 in 2021, demonstrating stagnation in development. Since a slight positive correlation exists between three-year GDP growth between 2019 and 2021 and the structural optimality index of an economy as we define and calculate, Italy indeed 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. It could shift its focus to more manufacturing-focused industries like High-Complexity Products, Chemicals, and Chemical Manufacturing.

The three years following showed a slight improvement in Italy's economic growth, boosting its position on the global scale. Its GDP recovered to above the pre-pandemic levels, but it saw a significant decline in the ECI, particularly compared to its peer countries. Its current strategy has a lot of the viable potential upside to increase its performance and optimize its structure further.

1. Report Overview

In this report, we aim to uncover the economic path Italy went through during the period from 2019 to 2021, before and after the COVID pandemic, compared to its performance from 2013 to 2018. Specifically, we dive into the topic through a macroeconomic overview of Italy 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 Italy during the period based on quantitative measures such as the 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 Italy, as deduced from regression models we have established on a global scale, which take into account countries' stances in their product space.

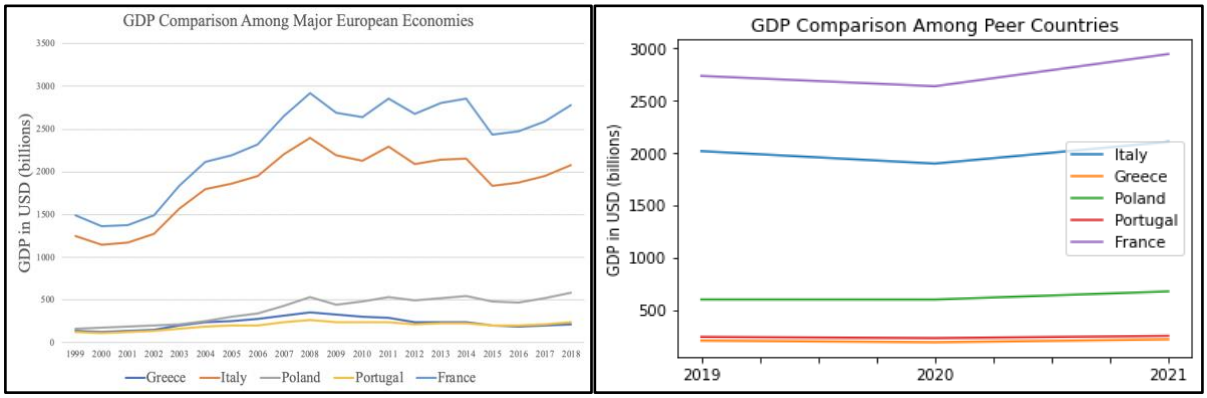
2. Macroeconomic Results

2.1 GDP Ranking and Changes

Figure 1a illustrates the time-series GDP results for Italy and some of its peer countries (Greece, Poland, Portugal, and France) from 2013 to 2018. Italy had a GDP of 2.14 trillion USD in 2013, 2.08 trillion USD in 2018, and 2.10 trillion USD, exhibiting a stable level of economic output. Similar to the other countries, Italy displayed an eventual upward trend over the period; however, its growth was consistent with France's growth, outperforming Greece, Poland, and Portugal.

During the period from 2013 to 2018, Italy exhibits an average annual GDP growth rate of 0.2%. This rate is at par with the annual growth rate of the group of major European economies in the world, which have a geometric average growth rate of 0.6% and an arithmetic average growth rate of 0.9%. The steady economic growth in Italy can be reflected through consistent ECI and PCI and can be further explained by a set of production strategies Greece adopted during the period, which we will expand on at the later stage of the report.

Figure 1b shows the GDP levels for Italy and its peer countries from 2019 to 2021. Similar to the other countries, Italy displayed a slight change in GDP from 2019 to 2020 because of the pandemic, with all GDPs approximately rebounding in 2021. Over these three years, Italy's average annual GDP growth rate (1.68%) is on the lower end among its peers, as it is greater than France's (2.69%), Greece's (2.19%), and Poland's (4.29%) rates but still higher than Portugal's rate (1.52%). It is notable that the GDP levels in Italy and France evened out and rebounded after 2018.



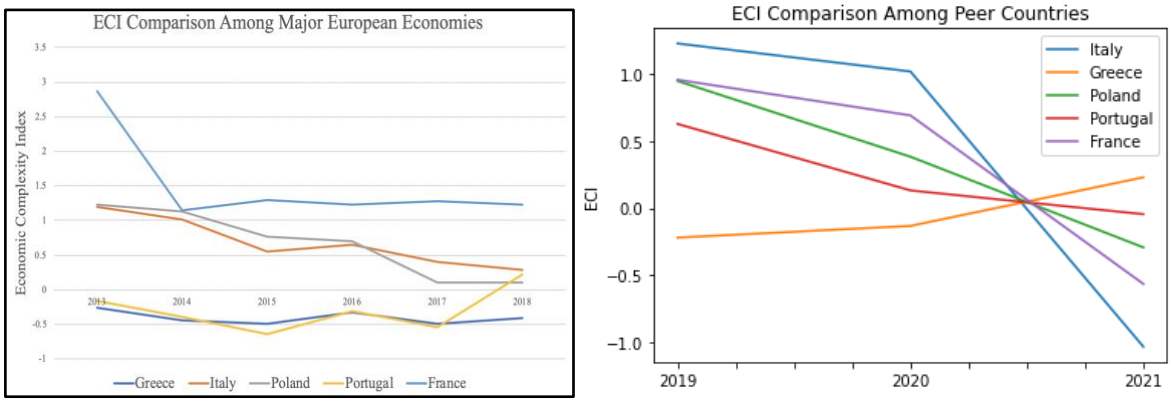
Figures 1a and 1b. GDP Comparison Among Peer Countries (left: 1999-2018; right: 2019-2021)

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 Figures 2a and 2b.

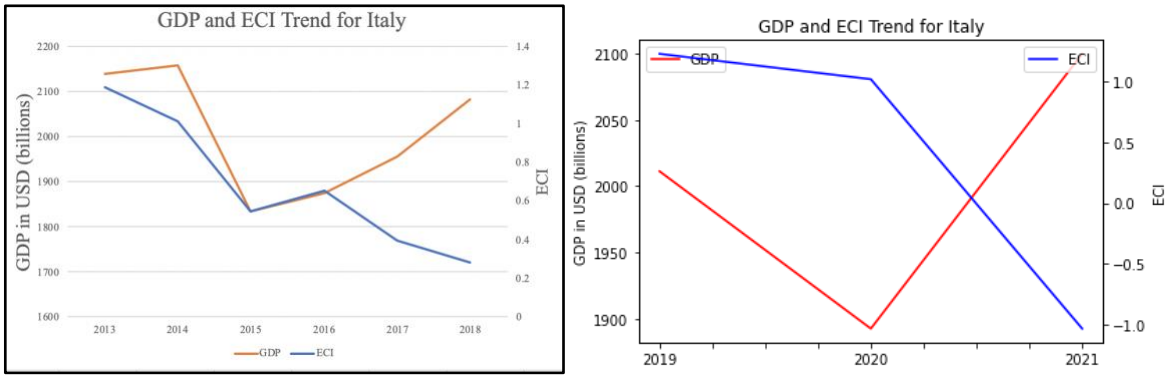
As shown, Italy exhibits a gradual decrease in production capability from 2013 to 2018. Italy is in a weak position in ECI terms but on par with its peers. The sudden drop in GDP during in the year 2014 is accompanied by a drop in ECI, indicating the potential that the slight economic growth experienced by Italy during this period might be attributed to its slow-growing ECI, or the ineffectiveness of the country in developing a competitive product space that helps to accumulate complicated knowledge and technology

The comparable countries maintain a small change in ECI level between 2019 and 2020, with a sharp change between 2020 and 2021. Italy exhibits a large decrease in production capability in 2021, exacerbated drastically by COIVD as one of the reasons. Italy has seen a -184% decrease in its ECI, which is the worst out among Greece (204%), Poland (-130%), Portugal (-107%), and France (-159%).



Figures 2a and 2b. ECI Comparison Among Peer Countries (left: 2013-2018; right: 2019-2021)

Figures 3a and 3b offer a further comparison of GDP Growth and ECI over the time span from 2013 to 2021 for Italy. Similar to the GDP drop and further increase from 2013 to 2018, the GDP growth during the period from 2019 to 2021 is accompanied by a similarly volatile increase in ECI. The results show that the economic growth experienced by Italy during the period from 2013 to 2018 is only partially consistent with the predictions by ECI and that Italy made weak progress towards effectively developing a competitive product space that helps to accumulate complicated knowledge and technology. For the period 2019 to 2021, the ECI followed GDP trends, which can be interpreted as advancements in production. In order to provide a more concrete answer to why this has happened, we will dive into an analysis of Italy's production structure and its product space designs in the next few sections.



Figures 3a and 3b. GDP Growth and ECI for Italy (left: 2013-2018; right: 2019-2021)

3. Production Analysis

3.1 Product Categorization

Our main data source in this research is the UN Comtrade Website (https://comtrade.un.org), which provides us with valuable information on countries' export values on an annual basis, including highly specific export data for more than 5000 categories of products. In order to have a holistic vision of the product space of a country, however, a level of categorization is required. Products in our data source are labeled from 010000-999999, with the first two digits representing a general category to which the product belongs. Based on the 99 categories extracted from the label, we further group the products into the 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 technological 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. Tables 2a and 2b 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

Table 2a. 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

Table 2b. OLS Regression Results of GDP against Volume of Percentage Exports

3.2 Realized Industry Development

Based on the aforementioned product categorization, we aim to capture Italy's realized industry production strategy between 2013 and 2021 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 of 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 the RID of Italy and the 18 product groups in 2021 and 2018 through the difference, where a positive RID indicates a shortening of the distance (i.e., advancement of the industry), and a negative RID indicates the reverse. It is notable that the number of industries with positive RID has increased from none to all but one from 2018 to 2021.

Category	RID (2021)	RID (2018)
Precious Stones	-0.007	-0.080
Animals and By-products	0.008	-0.118
Vegetables, Fruits and Plants	0.008	-0.120
Machinery and Construction	0.009	-0.324
Services and Utilities	0.011	-0.114
Energy Drilling and Mining	0.026	-0.082
Daily Instruments	0.027	-0.241
Food and Preparations	0.033	-0.134
Weapons	0.036	-0.114
Clothing and Accessories	0.043	-0.113
Wood Products	0.048	-0.111
High-complexity Products	0.049	-0.129
Textile	0.050	-0.147
Chemical Manufacturing	0.050	-0.095
Metals	0.069	-0.136
Raw Manufacturing	0.085	-0.086
Chemicals	0.094	-0.102
Transportation	0.126	-0.178

Table 3. Realized Industry Development (RID) of Italy

3.3 Regional and Global Comparison

Tables 4a-4b below summarize how the production strategy adopted by Italy compares with selected leading economies in the world across different years, as measured in RID. Leading economies such as France, the UK, and Germany gave a considerable level of attention to more advanced product groups, such as High-complexity Products, in 2018 and shifted toward a wider variety in groups toward more infrastructure and natural resources in 2021.

Ranking	France	the UK	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 4a. RID Comparison across Leading Economies (2018)

Ranking	France	the UK	Germany
1	Services and Utilities	Precious Stones	Daily Instruments
2	Precious Stones	High-complexity Products	Transportation
3	High-complexity Products	Services and Utilities	Chemicals
4	Energy Drilling and Mining	Energy Drilling and Mining	Chemical Manufacturing
5	Machinery and Construction	Wood Products	Clothing and Accessories

Table 4b. RID Comparison across Leading Economies (2021)

Tables 4c-4d further examine Italy's development strategy against those of emerging economies on a global scale. Reasonably, emerging economies such as China, South Korea, and Singapore have devoted the majority of their efforts to intermediate industry groups, showing drastic shifts in strategies over the course of three years.

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 4c. RID Comparison across Emerging Economies (2018)

Ranking	China	South Korea	Singapore
1	Chemicals	Chemicals	Weapons
2	Daily Instruments	Daily Instruments	Energy Drilling and Mining
3	Transportation	Transportation	Transportation
4	Raw Manufacturing	Textile	Machinery and Construction
5	Weapons	Raw Manufacturing	High-complexity Products

Table 4d. RID Comparison across Emerging Economies (2021)

4. Product Space Design

4.1 Suggested Development Vector

As outlined above, 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 of the product as compared to the 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. An unreasonable investment in a certain product p would lead to a relative decrement in the export of more profitable products and therefore lead to a negative opportunity gain of product p. The opportunity gain is not the only estimator of a country's level of economic development. However, among countries with comparable economic strength, those having higher ECI, or in other words, more reasonable economic structures, are often in better shape.

Ranking	Singapore	Japan	China	Germany	France	USA	Italy
1	Chemicals	Chemicals	Raw Manufacturing	Chemical Manufacturing	Services and Utilities	Energy Drilling and Mining	Energy Drilling and Mining
2	Transportation	Metals	Clothing and Accessories	Wood Products	Energy Drilling and Mining	Precious Stones	Precious Stones
3	High-complexity Products	Machinery and Construction	Textile	Metals	Animals and By-products	Animals and By-products	Vegetables, Fruits and Plants
4	Services and Utilities	Transportation	Machinery and Construction	Machinery and Construction	Food and Preparations	Vegetables, Fruits and Plants	Animals and By-products
5	Machinery and Construction	Weapons	Transportation	Transportation	Chemical Manufacturing	Food and Preparations	Food and Preparations
6	Daily Instruments	Daily Instruments	Weapons	Weapons	Raw Manufacturing	Chemicals	Chemical Manufacturing
7	Weapons	High-complexity Products	Daily Instruments	High-complexity Products	Transportation	Chemical Manufacturing	Raw Manufacturing
8	Textile	Services and Utilities	High-complexity Products	Services and Utilities	Weapons	Raw Manufacturing	Wood Products
9	Chemical Manufacturing	Precious Stones	Precious Stones	Energy Drilling and Mining	High-complexity Products	Wood Products	Clothing and Accessories
10	Raw Manufacturing	Energy Drilling and Mining	Services and Utilities	Precious Stones	Vegetables, Fruits and Plants	Machinery and Construction	Textile
11	Clothing and Accessories	Textile	Chemicals	Textile	Precious Stones	Weapons	Metals
12	Metals	Clothing and Accessories	Energy Drilling and Mining	Clothing and Accessories	Wood Products	Daily Instruments	Machinery and Construction
13	Wood Products	Chemical Manufacturing	Chemical Manufacturing	Chemicals	Chemicals	High-complexity Products	Daily Instruments
14	Precious Stones	Animals and By-products	Wood Products	Animals and By-products	Textile	Services and Utilities	High-complexity Products
15	Animals and By-products	Wood Products	Animals and By-products	Vegetables, Fruits and Plants	Clothing and Accessories	Clothing and Accessories	Weapons
16	Food and Preparations	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Food and Preparations	Daily Instruments	Metals	Chemicals
17	Energy Drilling and Mining	Food and Preparations	Metals	Daily Instruments	Metals	Textile	Services and Utilities
18	Vegetables, Fruits and Plants	Raw Manufacturing	Food and Preparations	Raw Manufacturing	Machinery and Construction	Transportation	Transportation
ECI	2.751108815	2.154947	1.96086598	1.937171566	1.294691459	1.220401303	1.179705915

Table 5a. Opportunity Gain Ranking on a Comparable Scale (2013)

Ranking	Singapore	Japan	China	Germany	France	USA	Italy
1	Energy Drilling and Mining	Chemicals	Chemicals	Chemical Manufacturing	Services and Utilities	Animals and By-products	Energy Drilling and Mining
2	Chemicals	Metals	Raw Manufacturing	Machinery and Construction	Animals and By-products	Clothing and Accessories	Precious Stones
3	Machinery and Construction	Machinery and Construction	Clothing and Accessories	Transportation	Food and Preparations	Metals	Animals and By-products
4	Transportation	Transportation	Textile	Daily Instruments	Chemical Manufacturing	Textile	Vegetables, Fruits and Plants
5	High-complexity Products	Weapons	Machinery and Construction	High-complexity Products	Raw Manufacturing	Raw Manufacturing	Weapons
6	Services and Utilities	Daily Instruments	Transportation	Services and Utilities	Transportation	Vegetables, Fruits and Plants	Food and Preparations
7	Weapons	High-complexity Products	Weapons	Chemicals	Weapons	Food and Preparations	Chemical Manufacturing
8	Textile	Services and Utilities	Daily Instruments	Textile	High-complexity Products	Energy Drilling and Mining	Raw Manufacturing
9	Precious Stones	Textile	High-complexity Products	Weapons	Energy Drilling and Mining	Chemicals	Wood Products
10	Chemical Manufacturing	Precious Stones	Precious Stones	Clothing and Accessories	Chemicals	Chemical Manufacturing	Clothing and Accessories
11	Clothing and Accessories	Clothing and Accessories	Services and Utilities	Precious Stones	Textile	Wood Products	Textile
12	Daily Instruments	Energy Drilling and Mining	Energy Drilling and Mining	Raw Manufacturing	Vegetables, Fruits and Plants	Machinery and Construction	Metals
13	Animals and By-products	Animals and By-products	Wood Products	Wood Products	Clothing and Accessories	Weapons	Machinery and Construction
14	Metals	Wood Products	Animals and By-products	Energy Drilling and Mining	Wood Products	Daily Instruments	Daily Instruments
15	Raw Manufacturing	Chemical Manufacturing	Metals	Animals and By-products	Precious Stones	Precious Stones	High-complexity Products
16	Wood Products	Food and Preparations	Chemical Manufacturing	Metals	Metals	Services and Utilities	Chemicals
17	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Food and Preparations	Daily Instruments	Transportation	Services and Utilities
18	Food and Preparations	Raw Manufacturing	Food and Preparations	Vegetables, Fruits and Plants	Machinery and Construction	High-complexity Products	Transportation
ECI	2.112887919	1.979430054	1.700687855	2.959929484	1.264812266	0.261724796	0.878356738

Table 5b. Opportunity Gain Ranking on a Comparable Scale (2018)

We define the ranking of opportunity gain for a country c, as the Suggested Development Vector (SDV) of c. Tables 5a-5c summarize how the SDV of Italy compares with a selected group of comparable and leading economies in the world, with the industry groups ranked in decreasing order of significance. We focus on SDV results for 2013 and 2018 because they give the most accurate changes in and a snapshot of complexity for global comparison in the absence of the irregular effects of the COVID-19 pandemic observed in 2021.

Dark blue indicates positive opportunity gains, 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 Tables 6a and 6b, have closer to half of industries with positive

opportunity gain. These countries have nearly half of the industries with positive opportunity gain and share common interests in Machinery and Construction and other industrial subcategories.

It can be concluded that Italy shares the characteristics of developing countries, with a balanced economic structure that leans towards manufacturing industries.

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

Table 6a. SDV of Other Sample Countries (2013)

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 6c. SDV of Other Sample 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:

$$\underset{x \in \mathbf{R}^{|P|}}{\text{Max}} \quad (\frac{k(x) - < k(x) >}{stdev(k(x))})_C$$

Subject to

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

$$x \succcurlyeq 0$$

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

If we can solve this problem, then we can know what the largest ECI to which a country can improve. 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 to this problem. In order to solve this problem, our idea is to use a greedy algorithm. The way that we apply the 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 equal rest parts can be done in the same way.

By definition, a greedy algorithm is a kind of local search algorithm that is possible to run into a local minimum. Therefore, for local search algorithms, one typical way 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 in the budget. To deal with the surplus, we just add it to the product which needs the least amount of dollars to make M_{cp} = 1 (i.e., the smallest amount of required export increase).

Economic Panel

As stated above, the enhanced greedy algorithm is developed mainly for solving the optimal allocation strategy. In order to visualize this allocation, an economic panel is created, consisting of a pie chart, a line chart and a table. First, a pie chart is used to show the percentage of each product in the optimal portfolio. The number located in the center of the circle denotes the heuristic growth of total export, which is also our budget. Each category in the chart has a determined percentage of the allocated budget. The lines below the pie charts show how the ECI changes during the searching process of the greedy algorithm. Even though sometimes an increase of the export by 15% or 20% does not seem reasonable to developed countries, yet it can also give a sense of how a country should develop in the long term. Eventually, the graph in the end is just for numerical explanation for the pie charts.

Interpretation

For the purpose of a clear explanation of the line charts, we 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	Animal 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

Figures 4a-4c show an economic panel for Italy in 2013, 2018, and 2021. We can see that for different percentages of heuristic total export growth, the ECIs of Italy actually have different increments. We can see that for different percentages of heuristic total export growth, the ECI of Italy has relatively similar performance. From all the four-line graphs, we see that Italy already obtains some great increment in terms of ECI. However, increasing the budget for too large an amount would not produce a higher and higher ECI. Also, the optimal ECI that we can achieve in all stages is not a great gain from the original one. This means that in the long term, Italy does not have a lot of room to improve. For the four-export growth budget, the increment of ECI depends on Services and Utilities, Vegetable products, and high-complexity products. A more detailed numerical representation of the portfolio is shown in Table 8a.

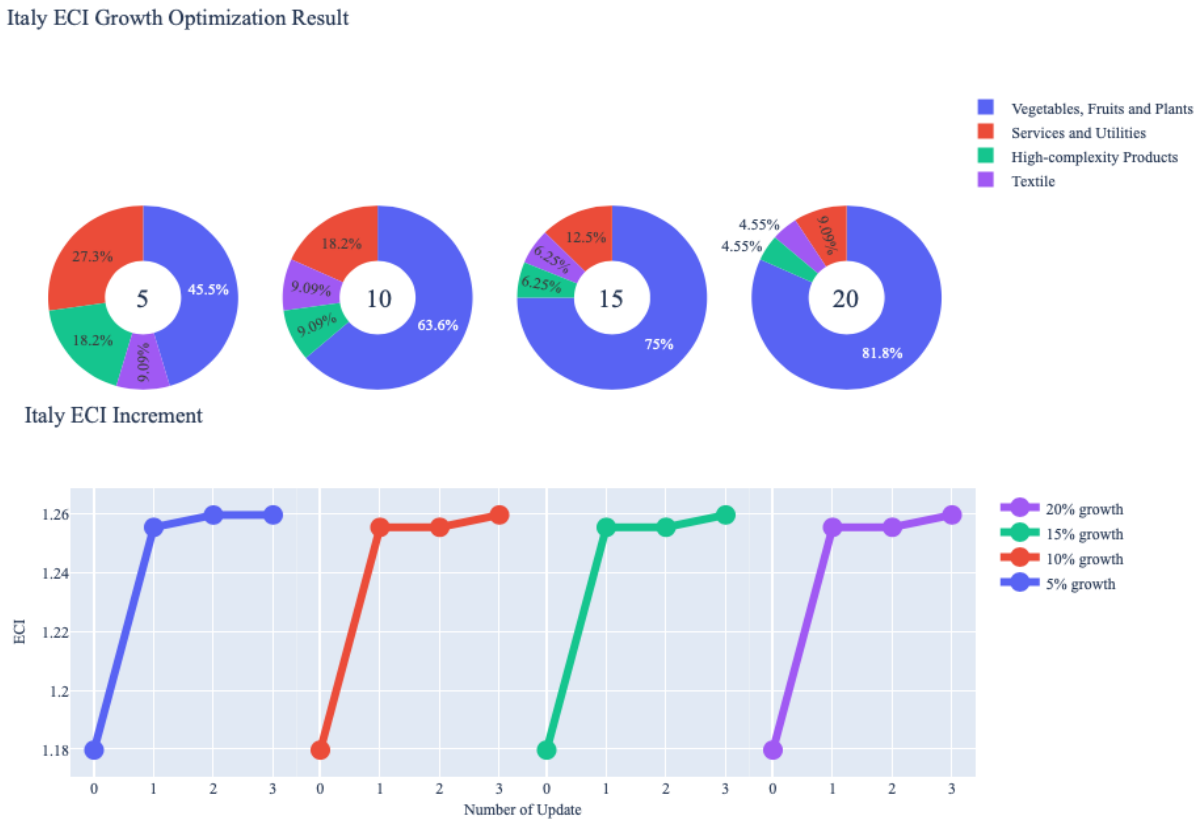


Figure 4a. Greedy-Based ECI Improvement Results of Italy with Different Budgets (2013)

Italy (2013)				
Total Export in 2013 (US. $)	7.39E+11			
Original ECI	1.180			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	3.70E+10	7.39E+10	1.11E+11	1.48E+11
Textile(US. $)	3.36E+09	6.72E+09	6.93E+09	6.72E+09
High-complexity Products(US. $)	6.72E+09	6.72E+09	6.93E+09	6.72E+09
Services and Utilities (US. $)	1.01E+10	1.34E+10	1.39E+10	1.34E+10
Vegetables, Fruits and Plants(US. $)	1.68E+10	4.70E+10	8.31E+10	1.21E+11
Increased ECI	1.260	1.260	1.260	1.260

Table 8a. Portfolio of Italy (2013)

For further suggestions on Italy's development in the future. We also offer the optimization result of Poland based on export data in 2018. Below is the economic panel for Italy in 2018. We can see that for different percentages of heuristic total export growth, the ECI growth pattern of Poland is similar to the one in 2013. From all the four-line graphs, we cannot see Italy has a great increase in ECI. This means that Italy has an even more limited space to develop. However, our optimization method shows Italy can still have gained by investing in the Services industry. Therefore, for future strategy, Italy should prioritize the development of the Services industry in order to optimize the ECI.

Figure 4b. Greedy-Based ECI Improvement Results of Italy with Different Budgets (2018)

Italy (2018)				
Total Export in 2018 (US. $)	7.94E+11			
Original ECI	0.88			
Heuristic Export Growth (%)	5%	10%	15%	20%
Heuristic Export Growth (US. $)	3.97E+10	7.94E+10	1.19E+11	1.59E+11
Precious Stones (US. $)	3.61E+10	7.58E+10	1.15E+11	1.55E+11
Services and Utilities (US. $)	3.61E+09	3.61E+09	3.97E+09	3.97E+09
Increased ECI	0.89	0.89	0.89	0.89

Table 8b. Portfolio of Italy (2018)

To compare with the performance in 2013 and 2018, we also re-examine suggested strategies for 2021. For 2021, a 5, 15, and 20 percent increase in export would emphasize Precious Stones, followed by Textiles for 10 percent export growth respectively. These strategies go in line with the suggested trajectories based on ECI. We note that the industries presented below differ from the suggested increase in investment based off SDV and ECI. A more detailed numerical representation of the portfolio for Italy is shown in Table 8c.

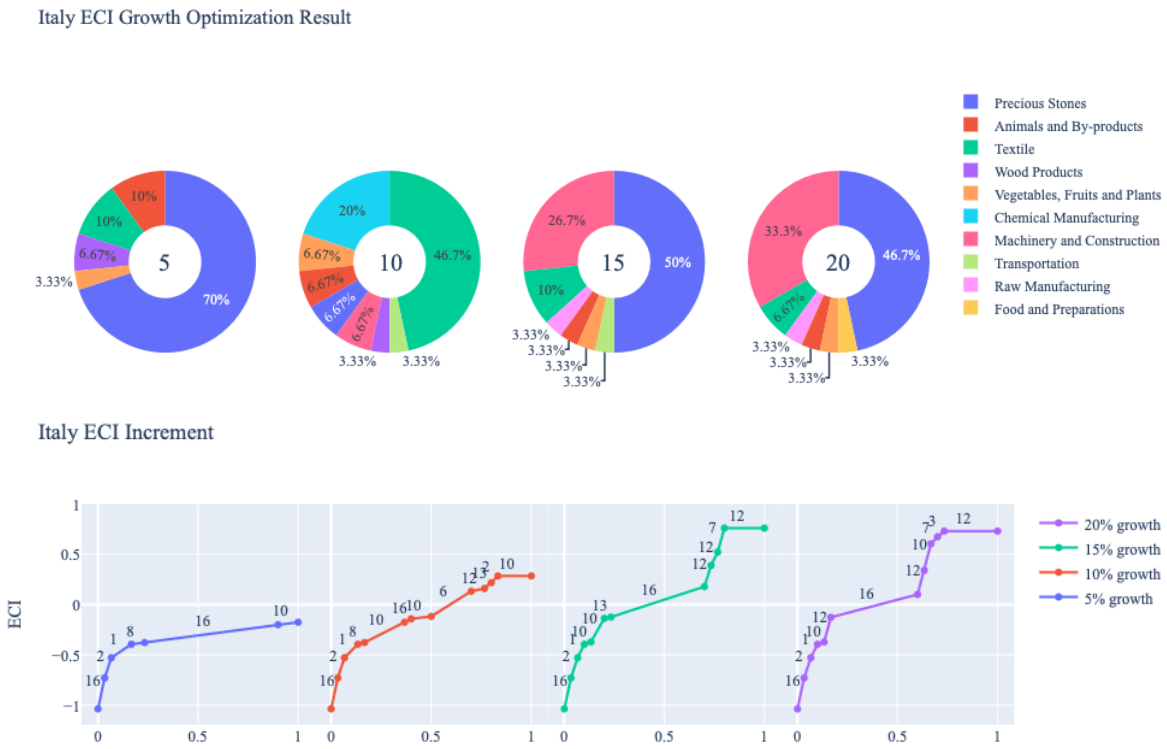


Figure 4c. Greedy-Based ECI Improvement Results of Italy with Different Budgets (2021)

Italy (2021)				
Original ECI		**1.23**		
Heuristic Export Growth	**5%**	**10%**	**15%**	**20%**
Animals and By-products	3.68E+09	9.17E+09	9.21E+09	8.84E+09
Vegetables, Fruits and Plants	1.23E+09	9.17E+09	9.21E+09	8.84E+09
Food and Preparations	0.00E+00	0.00E+00	0.00E+00	8.84E+09
Chemical Manufacturing	0.00E+00	2.75E+10	0.00E+00	0.00E+00
Raw Manufacturing	0.00E+00	0.00E+00	9.21E+09	8.84E+09
Wood Products	2.45E+09	4.58E+09	0.00E+00	0.00E+00
Textile	3.68E+09	6.42E+10	2.76E+10	1.77E+10
Machinery and Construction	0.00E+00	9.17E+09	7.36E+10	8.84E+10
Transportation	0.00E+00	4.58E+09	9.21E+09	0.00E+00
Precious Stones	2.58E+10	9.17E+09	1.38E+11	1.24E+11
Increased ECI	**-1.75E-01**	**2.86E-01**	**7.61E-01**	**7.31E-01**

Table 8c. Portfolio of Italy (2021)

4.3 Sensitivity Analysis and Contingency Strategy

In the following section, our broad aim is to understand how sensitive Italy 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

First, in order to assess the effect particular industries have on each respective country, we developed ECI Sensitivity graphs (Figure 5). We use the 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.

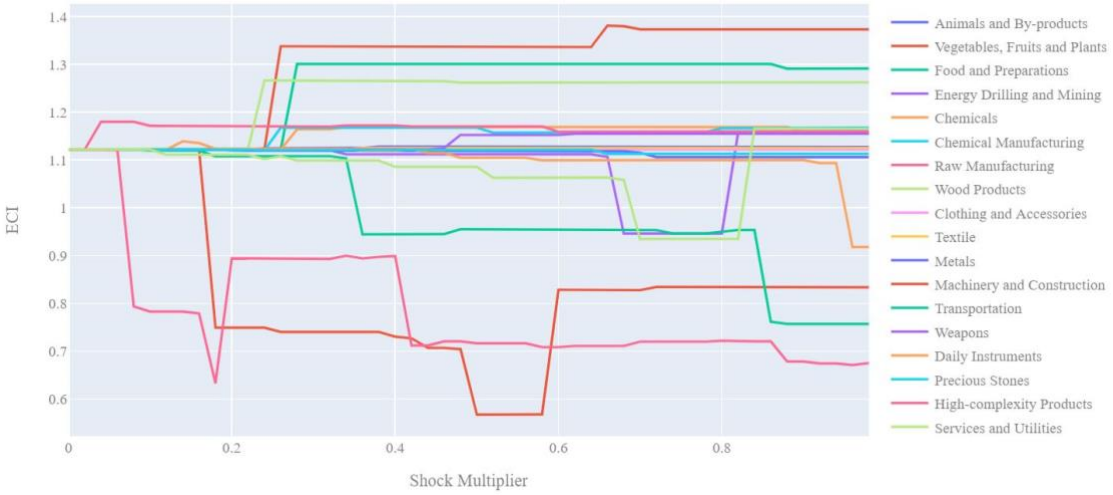


Figure 5. Sample ECI Sensitivity Graph (2018)

The graphs are formulated as follows. There are six ECI Sensitivity graphs, two for each of the following years: 2021, 2018, and 2013. The first chart, Incremental ECI Sensitivity, 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, Decremental ECI Sensitivity, follows the same format except the X-axis represents negative shock. In other words, exports for each industry are decremented, and the ECI is accordingly recomputed.

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 an 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

Table 9. Sample Incremental SDV Sensitivity for High-Complexity Products (2018)

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 a 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 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 mean that the country doesn't even need to respond to a collapse in the industry. Countries tend to have distinct solutions to the

ups and downs 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.

Product Names	0	1	2
Animal 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 Constructions	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
Daily Instruments	Services and Utilities	Daily Instruments	Weapons
Services and Utilities	Daily Instruments	Weapons	Transportation

Table 10. Sample Contingency Strategy (2019)

Sensitivity Analysis Results and Interpretation

We examine Italy's ECI Decremental and Incremental Sensitivity Charts for 2021. An increase in Highest-Complexity Products will lead to the highest change in ECI, followed by Chemicals and Chemical Manufacturing. The strong sensitivity effect of manipulating the Highest-Complexity Products category remains the same as in 2018. For the negative shock cases, Vegetables, Fruits and Plants and Chemical Manufacturing become the most impactful, a mix of old and new trends across the data emerging from the previous years. The rest of the industries do not appear to have the same level of sensitivity.

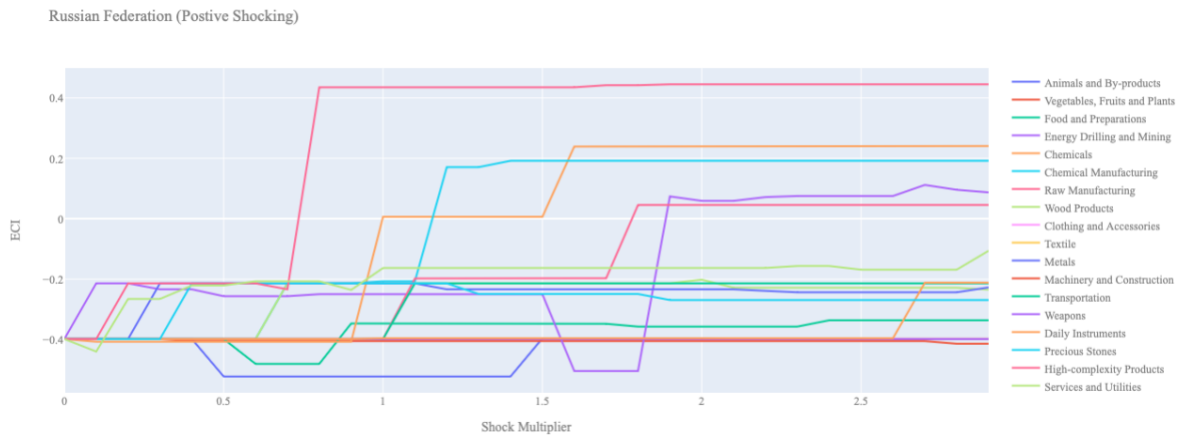


Figure 6a. Incremental ECI Sensitivity for Italy (2021)

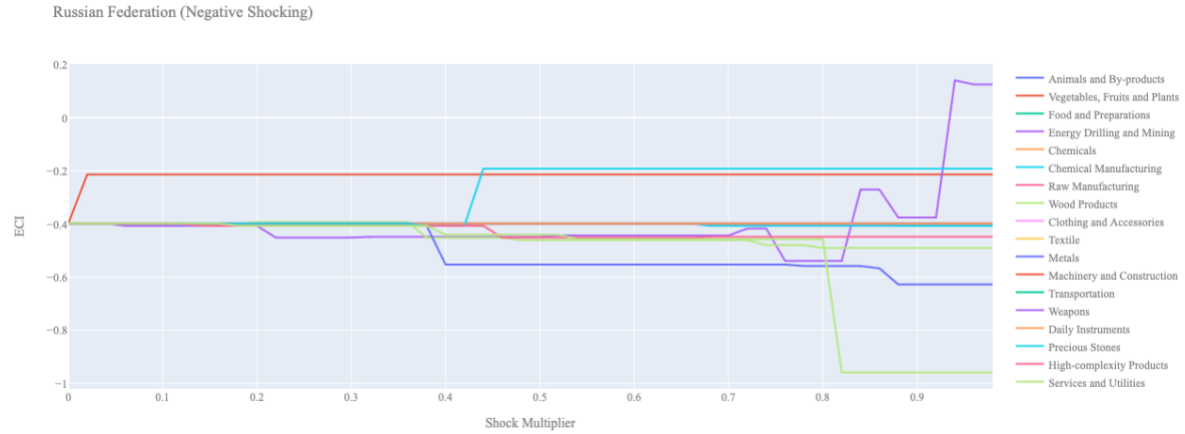


Figure 6b. Decremental ECI Sensitivity for Italy (2021)

Below are Italy's 2018 ECI Sensitivity Charts. In the positive chart, we notice that only High Complexity products lead to any positive gain in ECI. However, over 100% expansion in High Complexity Product export is needed to experience this gain. Italy is mildly insensitive to the majority of the other industries.

Italy's 2018 Negative Shock chart shows that Italy is fairly sensitive to High Complexity Products and Machinery. Italy is fairly insensitive to the majority of other industries, although there seems to be a trend of small ECI drawdowns with small decreases in exports.

Next, we consider Italy's 2018 Negative Shock chart. Interestingly, Italy is highly insensitive to changes in most industries suggesting that Italy has a good blend of industries that complement each other and can compensate for reductions in some of them.

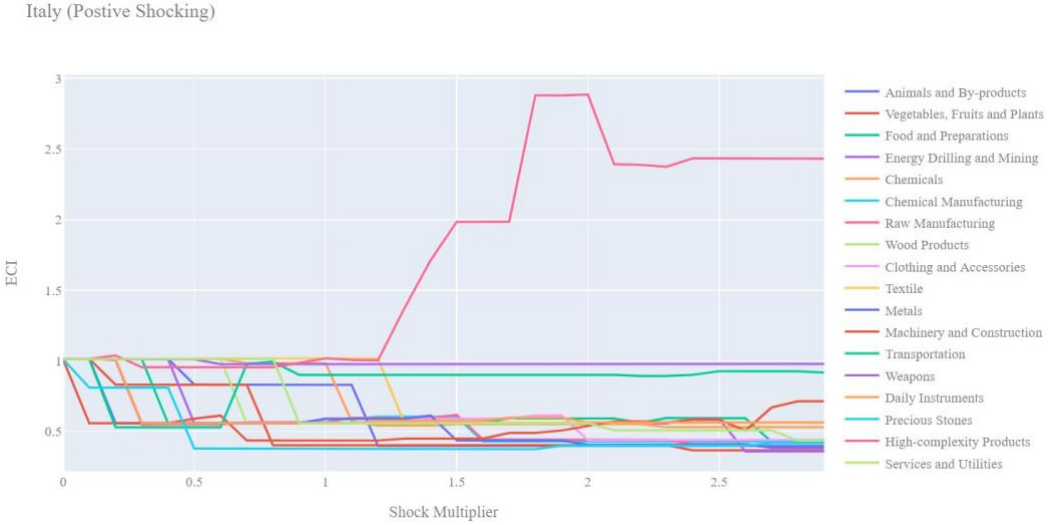


Figure 7a. Incremental ECI Sensitivity for Italy (2018)

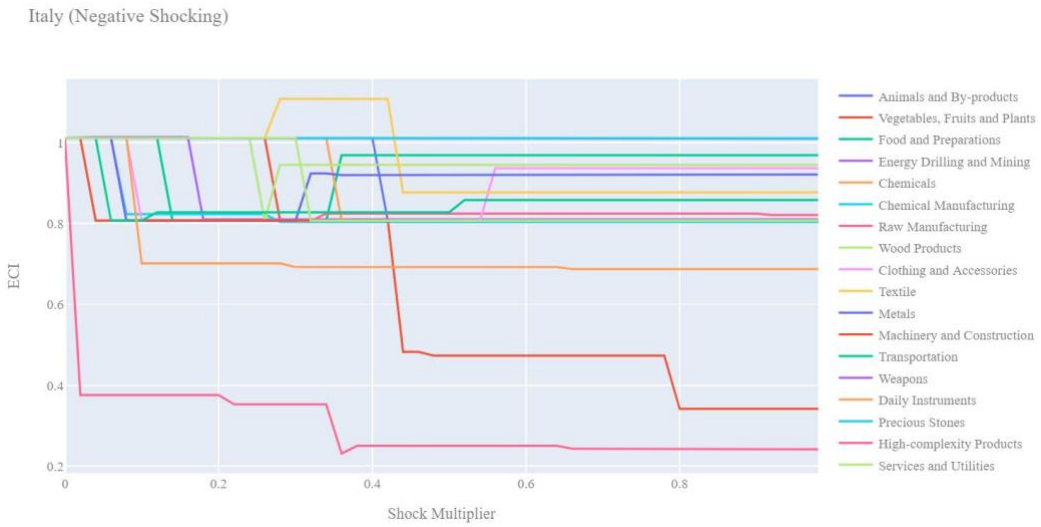


Figure 7b. Decremental ECI Sensitivity for Italy (2018)

Next, we consider the 2013 ECI Sensitivity graphs (Figures 8a and 8b). We see that in the positive shocking case, we have a similar sensitivity profile to the 2018 graph. Most industries give either little or no benefit to ECI. However, High Complexity Products offer significant increases in ECI.

In the 2013 negative shocking case, we see that Italy is once again fairly sensitive to High Complexity Products as well as Machinery. Other industries lead to small ECI gains after around 30% decreases in export values.

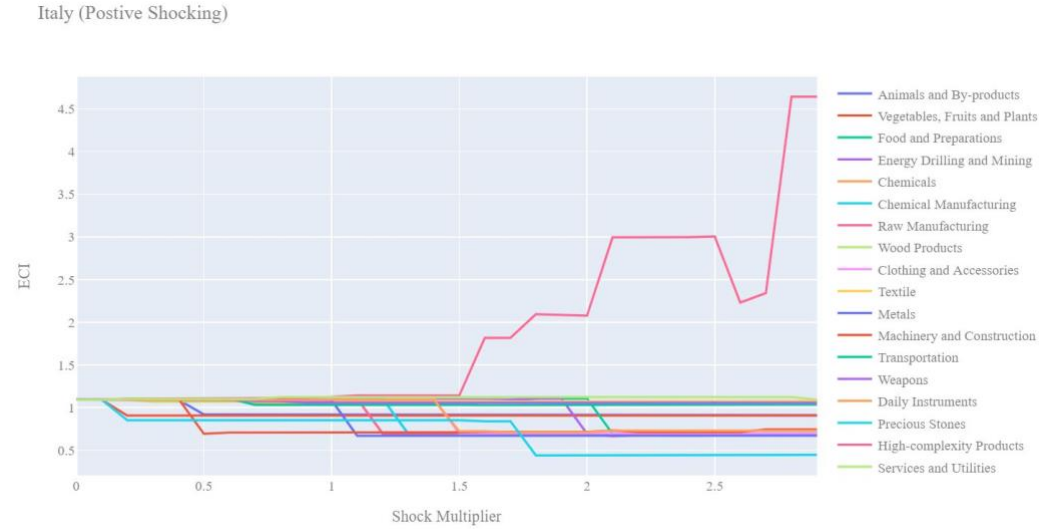


Figure 8a. Incremental ECI Sensitivity for Italy (2013)

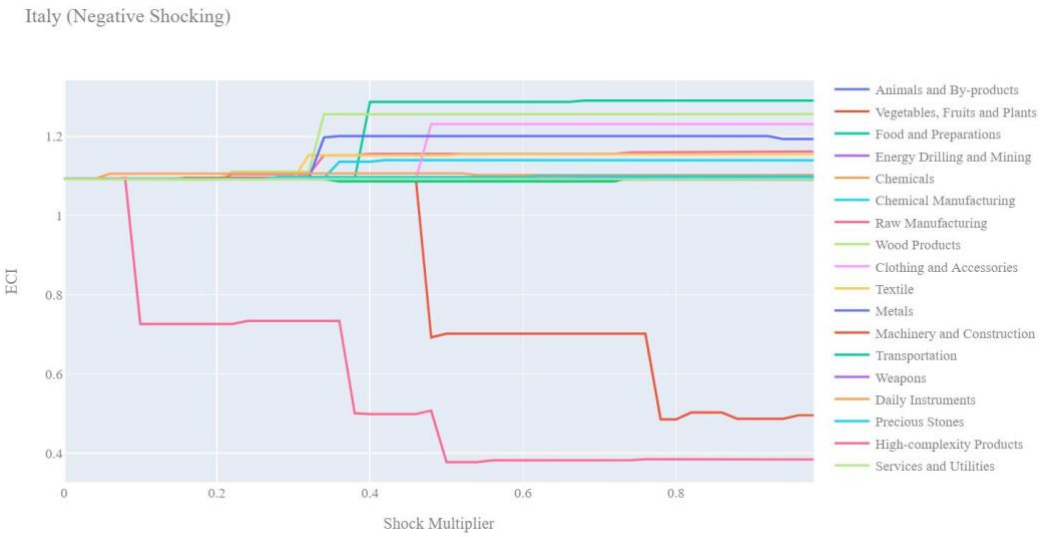


Figure 8b. Decremental ECI Sensitivity for Italy (2013)

Decreasing the export of each industry in Italy's current production space by 60% respectively, we derive the contingency strategy shown below. Below we see the SDV sensitivity charts for High Complexity Products. We see that large increases in the export of High Complexity Products make room for other industries to shift into positive opportunity gain territory. A 130% increase in export leads to 2 new industries that offer positive opportunity gain: Chemicals, Services and Utilities

Considering the Negative SDV sensitivity chart, we observe that as the export of High Complexity products decreases, a few other industries become attractive with positive opportunity gains, namely Transportation, Services and Utilities, and Chemicals.

	0.0%	30.0%	120.0%	130.0%	140.0%	150.0%	180.0%	210.0%
0	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Chemicals	Machinery and Construction
1	Clothing and Accessories	Clothing and Accessories	Clothing and Accessories	Chemicals	Chemicals	Chemicals	Services and Utilities	Chemicals
2	Raw Manufacturing	Wood Products	High-complexity Products	Services and Utilities	Services and Utilities	Services and Utilities	Daily Instruments	Services and Utilities
3	Daily Instruments	Food and Preparations	Food and Preparations	Metals	High-complexity Products	Daily Instruments	Textile	Transportation
4	Food and Preparations	Chemical Manufacturing	Raw Manufacturing	Food and Preparations	Food and Preparations	High-complexity Products	Transportation	Daily Instruments
5	Chemical Manufacturing	Raw Manufacturing	Wood Products	Raw Manufacturing	Raw Manufacturing	Food and Preparations	High-complexity Products	Weapons
6	Machinery and Construction	Machinery and Construction	Machinery and Construction	High-complexity Products	Clothing and Accessories	Clothing and Accessories	Clothing and Accessories	Textile
7	Metals	Metals	Metals	Clothing and Accessories	Machinery and Construction	Machinery and Construction	Machinery and Construction	Chemical Manufacturing
8	Textile	Textile	Textile	Machinery and Construction	Daily Instruments	Transportation	Weapons	High-complexity Products
9	High-complexity Products	High-complexity Products	Services and Utilities	Daily Instruments	Transportation	Textile	Chemical Manufacturing	Clothing and Accessories
10	Wood Products	Services and Utilities	Chemicals	Transportation	Textile	Weapons	Vegetables, Fruits and Plants	Raw Manufacturing
11	Services and Utilities	Chemicals	Daily Instruments	Textile	Weapons	Chemical Manufacturing	Raw Manufacturing	Precious Stones
12	Chemicals	Transportation	Transportation	Weapons	Chemical Manufacturing	Precious Stones	Precious Stones	Vegetables, Fruits and Plants
13	Transportation	Daily Instruments	Weapons	Chemical Manufacturing	Precious Stones	Raw Manufacturing	Metals	Metals
14	Weapons	Weapons	Chemical Manufacturing	Precious Stones	Energy Drilling and Mining	Metals	Wood Products	Wood Products
15	Precious Stones	Precious Stones	Precious Stones	Energy Drilling and Mining	Metals	Wood Products	Energy Drilling and Mining	Energy Drilling and Mining
16	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining	Wood Products	Wood Products	Energy Drilling and Mining	Animals and By-products	Animals and By-products
17	Animals and By-products	Animals and By-products	Animals and By-products	Animals and By-products	Animals and By-products	Animals and By-products	Food and Preparations	Food and Preparations
ECI	1.011372932	0.955141709	1.003079674	1.369172816	1.711185286	1.984137204	2.880149366	2.392221757

Table 11a. Italy's Incremental SDV Sensitivities for High-Complexity Products (2018)

	-0.0%	-2.0%	-36.0%
0	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Transportation
1	Clothing and Accessories	Clothing and Accessories	High-complexity Products
2	Raw Manufacturing	Food and Preparations	Services and Utilities
3	Daily Instruments	Precious Stones	Chemicals
4	Food and Preparations	Daily Instruments	Vegetables, Fruits and Plants
5	Chemical Manufacturing	Machinery and Construction	Food and Preparations
6	Machinery and Construction	Metals	Chemical Manufacturing
7	Metals	Textile	Raw Manufacturing
8	Textile	Wood Products	Wood Products
9	High-complexity Products	Raw Manufacturing	Clothing and Accessories
10	Wood Products	Chemical Manufacturing	Textile
11	Services and Utilities	High-complexity Products	Metals
12	Chemicals	Transportation	Machinery and Construction
13	Transportation	Services and Utilities	Daily Instruments
14	Weapons	Chemicals	Precious Stones
15	Precious Stones	Weapons	Weapons
16	Energy Drilling and Mining	Energy Drilling and Mining	Energy Drilling and Mining
17	Animals and By-products	Animals and By-products	Animals and By-products
ECI	1.011372932	0.376008889	0.231565119

Table 11b. Italy's Decremental SDV Sensitivities for High-Complexity Products (2018)

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

	-0.0%	-14.0%	-36.0%
0	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
1	Clothing and Accessories	Clothing and Accessories	Clothing and Accessories
2	Raw Manufacturing	Chemical Manufacturing	Raw Manufacturing
3	Daily Instruments	Precious Stones	Precious Stones
4	Food and Preparations	Daily Instruments	Daily Instruments
5	Chemical Manufacturing	Food and Preparations	Chemical Manufacturing
6	Machinery and Construction	Machinery and Construction	Machinery and Construction
7	Metals	Metals	Metals
8	Textile	Textile	Textile
9	High-complexity Products	High-complexity Products	High-complexity Products
10	Wood Products	Wood Products	Wood Products
11	Services and Utilities	Raw Manufacturing	Services and Utilities
12	Chemicals	Services and Utilities	Chemicals
13	Transportation	Chemicals	Transportation
14	Weapons	Transportation	Weapons
15	Precious Stones	Weapons	Energy Drilling and Mining
16	Energy Drilling and Mining	Energy Drilling and Mining	Animals and By-products
17	Animals and By-products	Animals and By-products	Food and Preparations
ECI	1.011372932	0.80728868	0.968891476

Table 12a. Italy's SDV Decremental Sensitivities for Food and Preparations (2018)

	0.0%	40.0%
0	Vegetables, Fruits and Plants	Vegetables, Fruits and Plants
1	Clothing and Accessories	Clothing and Accessories
2	Raw Manufacturing	Chemical Manufacturing
3	Daily Instruments	Daily Instruments
4	Food and Preparations	Food and Preparations
5	Chemical Manufacturing	Machinery and Construction
6	Machinery and Construction	Metals
7	Metals	Textile
8	Textile	Wood Products
9	High-complexity Products	Raw Manufacturing
10	Wood Products	High-complexity Products
11	Services and Utilities	Transportation
12	Chemicals	Services and Utilities
13	Transportation	Chemicals
14	Weapons	Weapons
15	Precious Stones	Precious Stones
16	Energy Drilling and Mining	Energy Drilling and Mining
17	Animals and By-products	Animals and By-products
ECI	1.011372932	0.558595981

Table 12b. Italy's SDV Incremental Sensitivities for Food and Preparations (2018)

5. Macro-level Predictions

5.1 Structural Optimality Index

ECI sensitivity described in the section before 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 increasing export 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 9 illustrates the regression output, which shows a strong positive correlation between countries' SOI and their five-year GDP growth, significant at the 1.68% level and achieving an adjusted R^2 of 0.27. In other words, the more a country develops as suggested by calculations on a complexity level, the better economic outcomes it achieves.

Table 14: OLS Regression Results	
Dep. Variable: GDP	**F-Statistic:** 5.963
R^2: 0.054	**Prob (F-Stat):** 0.0163
Adj R^2: 0.045	**No. Observations:** 106

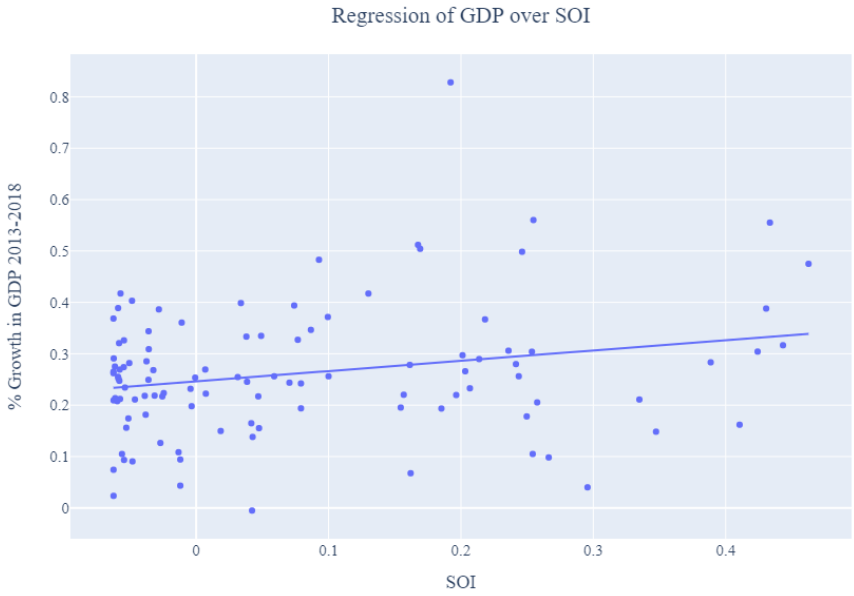


Figure 9. Regression of Five-Year GDP Growth over SOI (2013-2018)

5.2 SOI of Italy and Its Implications

Italy, for instance, has a relatively low level of structural optimality as compared with its developed peers. As the regression in Figure 7 suggests (the orange curve represents export increase, and the blue curve stands for opportunity gain of the corresponding industry), France demonstrates a low level of correlation with the suggested developmental path, having an adjusted R-square of around 4.7%. France ranks 48th place among all countries in terms of SOI and has a 5-year growth rate of 15.5% from 2013 to 2018, which is consistent with the regression result in Figure 6. These data points are very similar to that of France. This is in direct contrast to emerging economies such as Turkey, where there is a high SOI of around 21.8% and corresponding GDP growth of 36.7% from 2013 to 2018, making it one of the fastest-developing economies during the period. In sum, Italy's slower economic progress from 2013 to 2018 can be at least partially explained by a mismatched development strategy that demonstrates a considerable level of deviations from our suggested developmental path. For example, Italy invested heavily in High-Complexity Products despite a lower opportunity gain, while it should have focused more on industry groups such as Services and Utilities.

Figure 10a. SOI of Italy (2013-2018)

For the 2019-2021 years, Italy has a strong presence in the Transportation, Chemicals, and Raw Manufacturing industries, which do not seem to possess a higher potential for future development level when considering their negative opportunity gain relative to RID. It also could consider Energy Drilling and Mining and Precious Stones to improve its growth. Italy has seen an average growth in GDP over those three years of 1.68% compared to 0.9% for the average yearly growth for the five years prior.

Lower than before, its adjusted R-squared value of 0.27 now indicates a lower correlation between the GDP growth and the implemented development path. Progress is slow on a global scale during this period, but Italy demonstrates a moderate ability to adjust to negative economic shocks by improving SOI and increasing GDP growth than it did between 2013 and 2018.

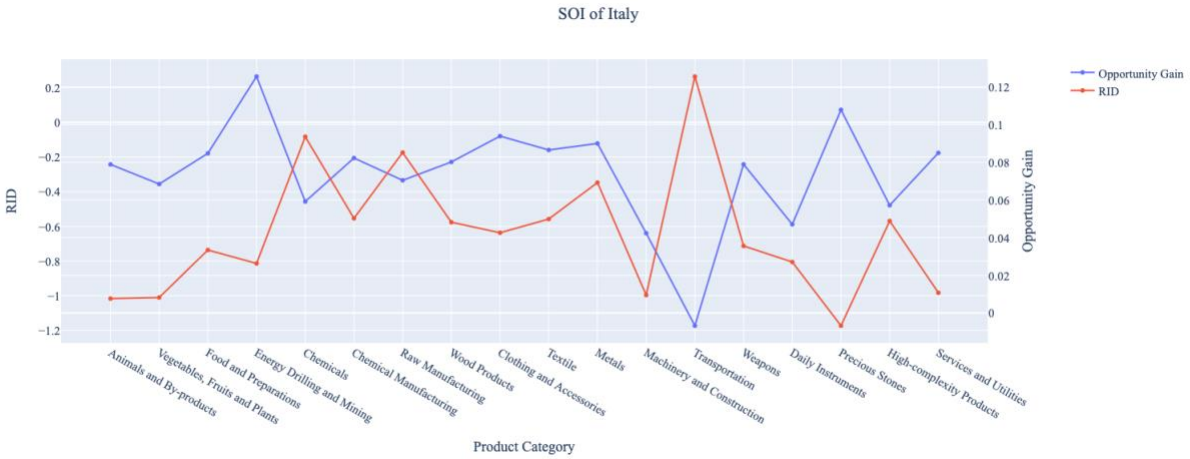


Figure 10b. SOI of Italy (2019-2021)

6. Concluding Remarks

In conclusion, Italy has demonstrated a low level of economic growth in terms of GDP during the period from 2013 to 2018, concurrent with stagnation in economic complexity as compared with other major European economies.

The level of economic progress during the period, we believe, can be partially explained through the analysis of the economic and product complexity structure of Italy 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 Italy invested heavily in Transportation, Machinery, and Construction.

Based on our analysis of the opportunity gain and sensitivity analysis of major industry groups, Italy could further its gains by prioritizing Vegetables, Fruits and Plants, and Services and Utilities between 2013 and 2018. We further note that Italy has a slightly mismatched development strategy that indicates a moderate level of structural optimality on the complexity level, having an adjusted R-square of around 0.048. Since a significant positive correlation exists between five-year GDP growth and the structural optimality index of an economy as we define and calculate, Italy indeed 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.

During the second examined period, from 2019 to 2021, the growth in GDP has increased alongside a large decline in ECI. Overall, Italy performed less successfully than before and was weaker than other countries, particularly France and Poland. We infer that during the COVID-19 period, Italy slightly shifted its focus on developing higher-complexity industries despite a lower demand for these industries, given the global economic downturn. We also note that Italy has increased its investment in the sectors identified earlier, leading to a boost from Highest-Complexity Products, Chemicals, and Chemical Manufacturing industries, leaving some room for strategic improvement. It invested in the industries which did not contribute the most to its advancements, such as Transportation. The ECI suggests greater growth could have been achieved through Energy Drilling, followed by Mining and Precious Stones. The surprising growth also increased the adjusted R-squared value to 0.27 in 2021 from 0.048 in 2018, demonstrating that the pursued strategies contributed to the GDP. With the revised focus, Italy has further potential to advance its economic growth to maintain its position among other countries to continue its post-pandemic recovery.

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