Economic impact of the COVID-19 pandemic on production industry: a nonparametric comparative analysis

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Abstract

The outbreak of COVID-19 and containment measures introduced by the EU Member States had a significant impact on the EU's industrial production. Being the industry sector plays an essential role in the economy of any country, it is important to study in details the factors that influencing positive/negative in the behavior.

The data from Eurostat indicate that the value of sold production registered a small decrease in 2019, then dropped more sharply in 2020 and the year 2021 showed increases in production in all the industrial activity groups.

In this work, is adopted a non-parametric approach that combines mathematics tools and techniques for benchmarking analysis for to analyze the behavior of the industry of European countries. In addition, some metrics/indexes are introduced for a comparative analysis of the manufacturing sector, before, during and after the pandemic. The results allow a characterization of the financial structure of the countries, in terms of economic performance.

Keywords: non-parametric model; benchmarking; manufacturing sector; European countries.

JEL Codes : C14, L60, 047

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1. Introduction

The infectious disease Coronavirus (COVID-19) caused by the SARS-CoV-2 virus, is an unprecedented global phenomenon, negatively affected global economic growth in 2020 beyond anything experienced in nearly a century. Estimates indicate the virus reduced global economic growth in 2020 to an annualized rate of around -3.2%, (see [1], [2]).

Major advanced economies, comprising 60% of global economic activity, are projected to operate below their potential output level through at least 2024, which indicates lower national and individual economic welfare relative to pre-pandemic levels.

As some developed economies start recovering, central banks and national governments are weighing the impact and timing of tapering off monetary and fiscal support as a result of concerns over potential inflationary pressures against the prospect of slowing the pace of the recovery, [1].

However, the impact of the pandemic is not only affecting global economic growth. The human costs in terms of lives lost will permanently in addition to the cost of elevated levels of poverty, lives upended, careers derailed, and increased social unrest.

All of the above led to aspects such as social, family and psychological, also strongly influencing the deterioration of a global economy. The most decisive economic sectors, such as the productive one, faced multiple challenges to survive. In that sense, the containment measures introduced by the EU Member States had a significant impact on industrial production.

This work adopted a non-parametric approach that combines mathematics tools and techniques for benchmarking analysis, for examining the behavior of the industry of European countries, under three approaches: (A1)-Analysis for Portuguese manufacturing sector. A review for Portuguese manufacturing sector, before COVID-19 and during financial crisis, (2006-2013); (A2)-Economic analysis for European countries. A general analysis on industrial production for 32 European countries, during COVID-19, (2019-2022); (A3)-Particular efficiency analysis. A particular analysis for 5 European countries, during the last phase of COVID-19, (2021-2022).

The approach (A2) examines the evolution of production industrial examining 32 European countries: Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Norway, Montenegro, North Macedonia, Serbia, Turkey, Bosnia and Herzegovina. The approach (A3) study the efficiency, during nine months (2021M10 -2022M06) to examine five European countries: Germany, Luxembourg, Malta, Austria y Portugal.

The mathematical model is based on two important efficiency models DEA (Data envelopment Analysis), and MEA (Multidirectional efficiency analysis), in combination with other mathematical techniques. In general terms nonparametric efficiency models, calculate the amount of inefficiency for every Decision-Making Unit (DMU), according to the best unit, and puts others on the efficiency frontier or under it. In DEA, introduced in [3], we may apply radial contractions of the inputs and undesirable outputs and/or apply radial expansions of the desirable outputs. In contrast to DEA, in the MEA model, introduce in [4], the input reduction and output expansion benchmarks are selected proportional to the potential improvements in efficiency identified by considering the improvement potential separately in each input variable and output variable.

Given the conditions of this study, the model selected for the analysis under the approach (A1) is MEA/VRS and under the approach (A3) is the DEA/CRS, see Section 2. Additionally, some mathematical techniques with significant indicators are defined: a growth rate with the percentage change compared with the same month of the previous year, a recovery rate with the percentage change compared with the next month and previous year, inefficiency index by input and NC-value to compare different levels of efficiency.

In the literature are widely used, DEA models for the efficiency measurement of decision-making units, see [5], [6] and [7]. Some interesting studies in MEA are [8], [9] and [10].

With the study's years, different approaches and countries considered in this article (Portugal in approach A1, 32 European countries in approach A2, and five European countries in A3) it is possible to assess the real difference in the strategies adopted by the countries, before and after the covid-19.

The remainder of the paper is laid out as follows. In the next section, is introduced the non-parametric model, used in this study. Section 3 is presented the data of the study. Section 4 are discussed the main results obtained in each approach and, in Section 5, some concluding remarks are formulated.

2. Mathematical non-parametric model

In this work, is adopted a non-parametric approach that combines mathematics tools and techniques for benchmarking analysis for to analyze the behavior of the industry of 32 European countries.

Some notations used in this article, is fixed: Months are denoted by M0X, where X represents the month number (i.e M01 refers to the first month: January; M02 represents the second month: February, etc).

Consider $\boldsymbol{t_{max-k}}$_$\mathbf{k = 0, 1, 2, 3}$, the years of study distribuited in periods $\boldsymbol{I_{t_{max-k}}}$ and $\boldsymbol{II_{t_{max-k}}}$, for $\mathbf{k = 0, 1, 2, 3}$ such that $\boldsymbol{I_{t_{max-k}}}$: first semester year k, (M01-M06) and $\boldsymbol{II_{t_{max-k}}}$: second semester year k, (M07-M12). For the analysis in Section 4, are considered three years, distributed in six periods of study $\boldsymbol{II_{t_{max-3}}}$, $\boldsymbol{I_{t_{max-2}}}$, $\boldsymbol{II_{t_{max-2}}}$, $\boldsymbol{I_{t_{max-1}}}$, $\boldsymbol{II_{t_{max-1}}}$ and $\boldsymbol{I_{t_{max}}}$.

According to the recollected data, we consider four of study (2019-2022), three stages (early, middle and advanced), distributed in six periods:

(i) Early stage:

$\boldsymbol{II_{t_{max-3}}}$: second semester 2019 (M07-M12), $\boldsymbol{I_{t_{max-2}}}$: first semester 2020 (M01-M06);

(ii) Middle phase:

$\boldsymbol{II_{t_{max-2}}}$: second semester 2020 (M07-M12), $\boldsymbol{I_{t_{max-1}}}$: first semester 2021 (M01-M06);

(iii) Advanced phase:

$\boldsymbol{II_{t_{max-1}}}$: second semester 2021 (M07-M12), $\boldsymbol{I_{t_{max}}}$: first semester 2022 (M01-M06).

2.1 Some growth rates

In this study, the following indices are defined to establish growth rates for the different industries.

Definition 1 (Growth rate): Let $V_{t_{max}}$ be the Volume index of production where t_{max} represents the last year of study.

Define the rate $R_{t_{max}}(t_{max-k})$ by

$$R_{t_{max}}(t_{max-k}) = \left(\frac{V_{t_{max}}\,M0X}{V_{t_{max-k}}\,M0X} - 1\right) * 100 \qquad (1)$$

for k=1,2,3.

The rate $R_{t_{max}}(t_{max-k})$ represents the percentage change compared with the same month of the previous year.

Definition 2 (Recovery rate): Let $V_{t_{max}}$ be the Volume index of production where t_{max} represents the last year of study.

Define the recovery rate $RC_{t_{max}}(t_{max-j})$ by

$$RC_{t_{max}}(t_{max-k}) = \frac{V_{t_{max}}\,M0X}{V_{t_{max-k}}\,M0(X+1)} * 100 \qquad (2)$$

for k=1,2,3.

The rate $\boldsymbol{RC_{t_{max}}(t_{max-j})}$ represents the percentage change compared with the next month and previous year.

Additional to indices above, the efficiency model is introduced.

2.2 Efficiency score calculation

The Data Envelopment Analysis (DEA) and the Multidirectional Efficiency Analysis (MEA) are two non-parametric techniques that allow to calculate the efficiency and that is sustained in a linear programming between all DMU (decision-making units), introduced in [3] and [4], respectively.

In what follows, we give a general description of the efficiency models used and fix notation.

Let $k = (c, s, t) \in$ N be a tuple identifying the country $c \in C$, sector $s \in S$ and year $t \in T$, which we call a country/sector/year tuple. Consider that any given tuple $n \in$ N produces $J \in$ N outputs $y_j(n)$, $j \in [J]$, using $I \in$ N inputs $x_i(n)$, $i \in [I]$.

Definition 3 (Efficiency score): For a given dataset Z={z(k)} $_N$ with z(k)=(x(k), y(k)), the DEA efficiency score of each DMU k∈ N, is then defined as the value h_k, $0 \leq h_k \leq 1$, such that h_k satisfies (3) for MEA/VRS, (respectively satisfies (4)-(6), for DEA/CRS).

Definition 3.1 (MEA/VRS): Consider the Variable Returns to Scale (VRS) model for the efficiency measurement of decision-making units: $\Lambda^n = \{\lambda \in R^N : \sum_{n=1}^{N} \lambda_n = 1 \wedge \lambda n \geq 0\}$. The efficiency relative of a DMU k can be obtained by solving the following three linear programs:

P_m^α (z, n̄):

min $\alpha_m(\bar{n})$ subject to

$\sum_n \lambda_n x_m(n) \leq \alpha_m(\bar{n})$

$\sum_n \lambda_n x_i(n) \leq x_i(\bar{n})$, $i \in [I]$, $i \neq m$

$\sum_n \lambda_n y_l(n) \leq y_l(\bar{n})$, $l \in [J]$

P_j^β (z, n̄):

max $\beta_j(\bar{n})$ subject to

$\sum_n \lambda_n x_i(n) \leq x_i(\bar{n})$, $i \in [I]$

$\sum_n \lambda_n y_j(n) \leq \beta_j(\bar{n})$

$\sum_n \lambda_n y_l(n) \leq y_l(\bar{n})$, $l \in [J]$, $l \neq j$

(3)

P^γ (α, β, z, n̄):

max $\gamma(\bar{n})$ subject to

$\sum_n \lambda_n x_i(n) \leq x_i(\bar{n}) - \gamma(\bar{n})(x_i(\bar{n}) - \alpha_i^*(\bar{n}))$, $i \in [M]$

$\sum_n \lambda_n x_i(n) \leq x_i(\bar{n})$, $i \in [I] \backslash \{m\}$

$\sum_n \lambda_n y_l(n) \geq y_l(\bar{n}) + \gamma(\bar{n})(\beta_l^*(\bar{n}) - y_l(\bar{n}))$, $l \in [J]$

where $\lambda \in \Lambda^N$, $\alpha_m^*(\bar{n})$ y $\beta_j^*(\bar{n})$ are the optimal solutions to the problems P_m^α (z, n̄) and P_j^β (z, n̄) respectively.

Definition 3.2 (DEA/CRS): Consider the Constant Returns to Scale (CRS) model for the efficiency measurement of decision-making units: $\Lambda^n = \{\lambda \in R^N : \lambda n \geq 0\}$. The efficiency relative of a DMU k can be obtained by solving the following program:

$$\min h_k \sum_{i=1}^{n} v_i x_{ik} \qquad \text{subject to} \tag{4}$$

$$\sum_{r=1}^{m} \lambda u_r y_{rj} - \sum_{i=1}^{n} \lambda v_i x_{ij} \leq 0 \tag{5}$$

$$\sum_{r=1}^{m} \lambda u_r y_{rk} = 1 \tag{6}$$

$$u_r, v_i \geq 0$$

where u represent the weights of the outputs; v the weights of inputs; r ∈ [M], i ∈ [N]. and j ∈ [J].

A very interesting feature of the MEA model is that the inefficiency of each input, it can be analyzed individually. Indeed, based on the input excess and using the ideas in Bogetoft et al [11] we define the following index.

Definition 4 (MEA inefficiency index):

$$\mathrm{Inf}_i(\mathrm{n}) = \frac{\sum_{n=1}^{N} \gamma(\mathrm{n})\left(x_i(\mathrm{n}) - \alpha_i{}^*(\mathrm{n})\right)}{\sum_{n=1}^{N} x_i(\mathrm{n})}, \tag{7}$$

for all i ϵ [I] and n ϵ N. We refer to the inefficiency index to know the number of times each input was used inefficiently.

Analyzing the behavior of groups with different levels of efficiency is an aspect of relevant importance in data analysis. The statistics of the efficient group with those of the non-efficient group in this article are compared using a technique developed by Inman et al [12], which is based on a distribution intersection coefficient.

The general idea of the **coefficient NC-value** (Crossed Normal distribution) is the following. We consider two groups according to the efficiency score:

$$E_1 = \{k(c,t) \in C \; x \; T\colon 0{,}6 \leq h_k \leq 1{,}0\}, \qquad E_0 = \{k(c,t) \in C \; x \; T\colon 0{,}0 \leq h_k \leq 0{,}4\}. \tag{8}$$

The NC-value is calculated as the intersection of the Gaussian functions associated with the efficiencies shown in E_1 and E_0. The higher the value-NC, the less common the behavior of the two groups with respect to the selected variables. In this way, it is possible to compare the behavior of the input and output variables between groups with different levels of efficiency and determine their influence on the MEA model from the point of view. See more details in [10].

3. Characterization of the data

The analysis in this work, is made on different approaches and the data set is recollected from the two databases: Eurostat and Amadeus (Bureau van Dijk) database.

From the Eurostat database, was extracted financial information on the production industry of 32 European countries, during the period 2019-2022. From the Amadeus (Bureau van Dijk) database, was extracted financial information of Portuguese manufacturing sector, during period 2006-2013.

The analysis involves three approaches under the characteristics exposed in Table 1: (A1) Portuguese manufacturing sector; (A2) General analysis for 32 European countries and (A3) Particular analysis for 5 European countries.

Table 1: Description of approaches (A1) -(A3)

	Approach (A1)	Approach (A2)			Approach (A3)
Inputs	I1, I2, I3, I4, I5	General analysis			I1, I2, I3
Outputs	O1, O2, O3, 04, O5				O1
Years	2006-2013	2019-2022			2021(M10-M12) 2022(M01-M06)
Countries	Portugal	Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Greece, Spain, France, Croatia, Italy,	Cyprus, Latvia, Lithuania, Luxembourg Hungary, Malta, Netherlands Austria, Poland, Portugal, Romania,	Slovenia, Slovakia, Finland, Sweden, Norway, Montenegro, North Macedonia, Serbia, Turkey, Bosnia and Herzegovina	Germany, Luxembourg, Malta, Austria Portugal

The data set from Amadeus involves information of Portugal about ten variables (five inputs and five outputs) in Table 2 (approach A1). The data set from Eurostat involves information of European countries about four variables (three inputs and one output) in Table 2 (approach A3).

Table 2: Description of variables, approaches (A1) and (A3)

	Inputs		Outputs	
Approach (A1)	(I1)	Number of employees	(O1)	profit margin
	(I2)	Total assets	(O2)	liquidity ratio
	(I3)	Long term debt	(O3)	solvency ratio
	(I4)	Current liabilities	(O4)	EBIT margin
			(O5)	EBITDA margin
Approach (A3)	(I1)	Employment (number of persons employed)	(O1)	Volume of production
	(I2)	Volume of work done (hours worked)		
	(I3)	Gross wages and salaries		

4. Analysis of the results

Due to different factors, the evolution of the pandemic was not generated uniformly, neither internationally nor nationally, even at the intrafamily level. Therefore, it is not possible to draw a single line of analysis. However, keeping in mind the different phases of the pandemic and the strategies considered in each country, in order to unify the analysis, three approaches will be considered in this study:

(A1)-Analysis for Portuguese manufacturing sector. A review for Portuguese manufacturing sector, before COVID-19 and during financial crisis, (2006-2013);

(A2)-Economic analysis for European countries. A general analysis on industrial production for 32 European countries, during COVID-19, (2019-2022);

(A3)-Particular efficiency analysis. A particular analysis for 5 European countries, during the last phase of COVID-19, (2021-2022).

Given the conditions of this study, the model selected for the analysis under the approach (A1) is MEA/VRS and under the approach (A3) is the DEA/CRS, in combination with other mathematical techniques, see section 2. The data processing in this work, is done supported by a software package developed in [13].

To continue, each approach is presented.

4.1 (A1) Analysis for Portuguese manufacturing sector

It is important to point out that the performance of the production industry today is not only a consequence of COVID-19. Ten years before the first manifestations of the pandemic appeared, a financial crisis (2008-2009) hit the world in such a drastic way that it led most countries to apply strong measures to overcome the different effects. This crisis led many companies of industrial production to go into debt and many others to date for not being able to assume the different commitments adopted before the crisis. To get an idea of how European countries faced the European crisis at that time, this study is addressed as part of the analysis of the Portuguese manufacturing sector, during 2006-2013.

The Portuguese manufacturing sector ((NACE Rev.2-Statistical classification of economic activities in the European Community) is divided in seven subgroups as follows:

(S1)-Manufacture of food products, beverages and tobacco products;

(S2)-Manufacture of textiles, apparel, leather and related products;

(S3)-Manufacture of wood, paper and printing; rubber plastics products, and other non metallic mineral products; basic metals and metal products, except machinery and equipment;

(S4)-Manufacture of coke, refined petroleum products and chemical products;

(S5)-Manufacture of pharmaceuticals, medicinal chemical and botanical products;

(S6)-Manufacture of computer, electronic and optical products; Manufacture of electrical equipment; Manufacture of machinery and equipment n.e.c; Other manufacturing, and repair and installation of machinery and equipment;

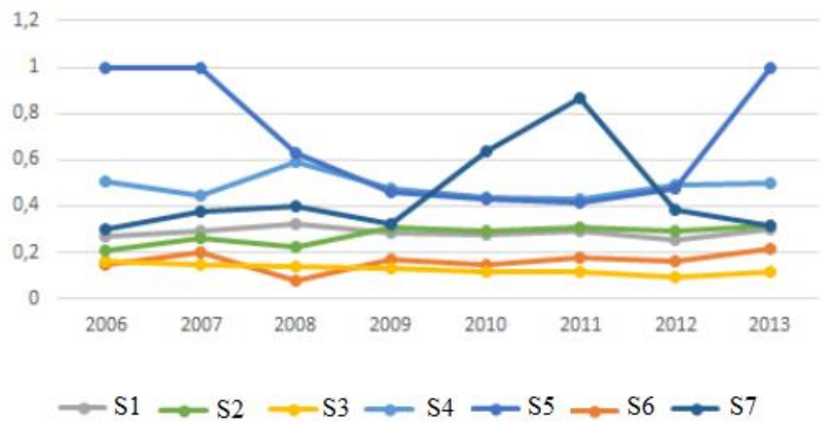
(S7)-Manufacture of transport equipment.

The technical efficiency of 23.862 units (3.977 Portuguese firms) was analyzed, during the period 2006-2013. The industry (S1) has 553 firms; (S2) 727; (S3) 1787; (S4) 103; (S5) 21; (S6) 692 and (S7) 94 firms.

We apply efficiency model with the inputs (I1) - (I4) and the outputs (O1) - (O5) and we calculated the Efficiency score (Equation for MEA/VRS) in the seven subsectors.

Define EFF as the subset of tuples $\boldsymbol{n}$ such that $\mathbf{0.6} \leq \boldsymbol{EffZ}(\boldsymbol{n}) \leq \mathbf{1}.0$ for a fixed sector $\boldsymbol{S}i, \boldsymbol{i} \in [\mathbf{1}, \mathbf{7}]$.

Figure 1: EFF mean, sectors S1-S7



Source: Author calculations from Amadeus.

The Figure 1, show the mean EFF for each year. We can see S4, S5 and S7 subsectors are consistently more efficient than the others subsectors and the S3 always remains as one of the least efficient subsectors along the years.

Consider the two groups E_1 and E_0 according to the efficiency score

$$E_1 = \{k(c,t) \, \epsilon \, C \; x \; T: 0{,}6 \leq h_k \leq 1{,}0\}, \qquad E_0 = \{k(c,t) \, \epsilon \, C \; x \; T: 0{,}0 \leq h_k \leq 0{,}4\}. \qquad (8)$$

The NC-value is calculated for each variable and the results for each sector are presented in Table 3.

Table 3: NC-value, S1-S7

	S1	S2	S3	S4	S5	S6	S7
(O1)	37,6	63,	1,2	46,1	213,6	67,4	130,5
(I4)	67,4	155,3	100,1	14,5	231,6	415,1	357,4
(I3)	71,2	221,9	117,8	44,1	30,27	211,2	314,7
(I2)	97,8	257,1	235,3	20,2	483,8	192,0	548,7
(O4)	125,4	267,0	10,2	43,2	242,9	71,6	171,9
(I1)	136,1	305,0	197,8	67,2	210,7	268,2	472,3
(O3)	266,6	359,6	70,5	27,7	103,0	176,5	155,9
(O2)	330,8	426,5	190,6	46,1	161,2	250,2	298,7
(O5)	379,5	152,0	93,7	39,8	297,5	222,3	271,3

The variables that show the greatest difference between the two efficiency groups are (O5) in S1, (O2) in S2, (I2) in S3, (I1) in S4, (I2) in S5, (I4) in S6 and (I2) in S7.

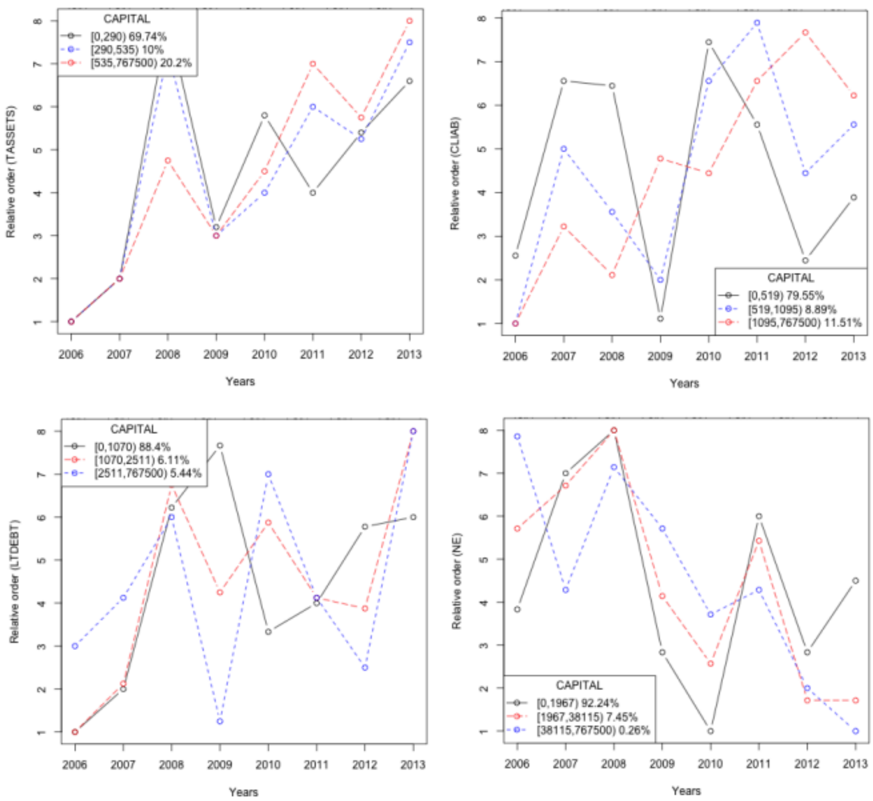
The values in Table 4 represent the percentages of inefficiency (Equation 7) of each input, for sectors S2, S4, S5 and S7. Thus, the inefficiency index of I1 for sector S5 is 70.8% (2009), 71.7% (2010) and 66.2% (2011). This means the number of times the variable has been used inefficiently and the percentage by which the level of efficiency can be improved. These values can be compared with the inefficiency indices for the other inputs (I2-I4) in the same sector. Or compare this indicator with those of other sectors (S1-S4, S6-S7 with the same variable I1.

Table 4: Inefficiency index, sectors S2, S4, S5 and S7

YEAR	Sector	I1	I2	I3	I4	Sector	I1	I2	I3	I4
2009	S2	66,1	69,0	73,8	75,2	S4	76,7	95,0	98,5	94,3
2010		71,0	78,5	87,6	79,3		72,0	95,2	95,5	94,7
2011		67,2	75,5	85,2	77,8		66,7	93,3	91,8	93,8
2009	S5	70,8	42,6	67,9	57,5	S7	57,1	67,9	74,4	81,7
2010		71,7	62,3	95,8	68,0		80,2	63,8	84,9	67,6
2011		66,2	54,9	53,8	72,6		83,0	84,9	95,1	92,8

In a more specific way and being S3 one of the most influential industries in Portugal, due to the large number of existing companies in the country (1787 companies), it is important to study the differences between the performance of large, medium and small companies. In this sense, the relative order can be established, the inputs (I1) -(I4) versus the capital, as can be seen in Figure 2.

Figure 2: Relative order sector S3

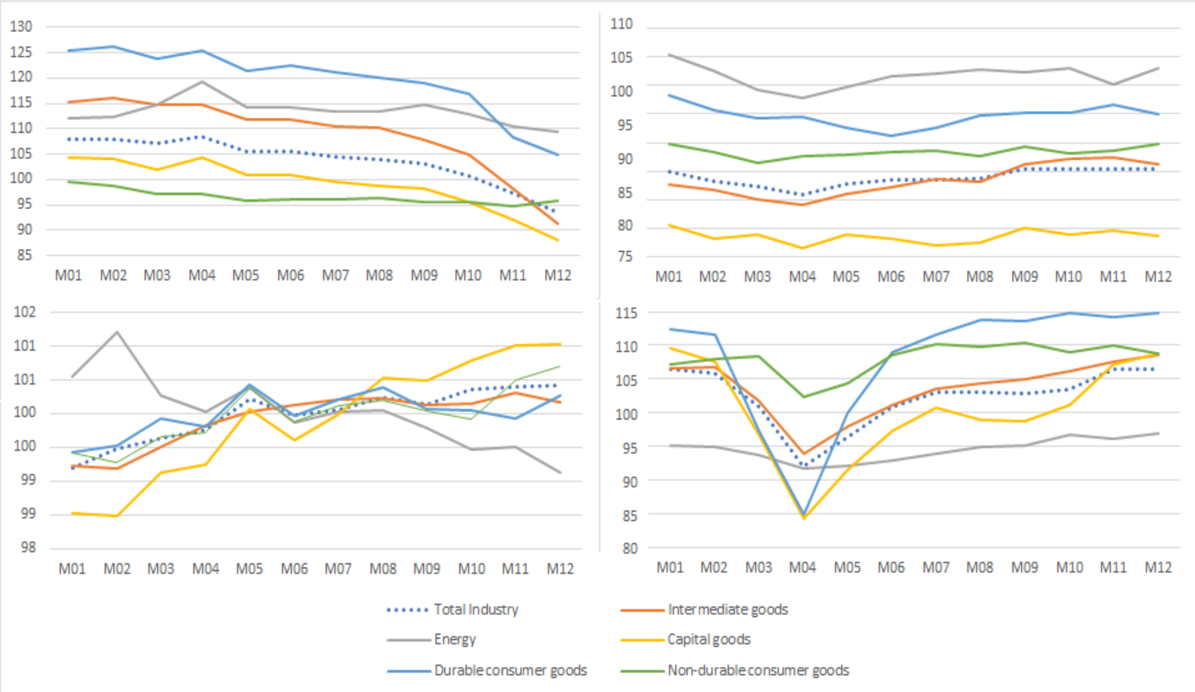


4.2 (A2) Economy analysis for European countries

In this approach, a more general analysis will be considered, which does not include efficiency models, but rather some purely financial factors that will allow us to characterize the performance during the pandemic of the following countries: Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Norway, Montenegro, North Macedonia, Serbia, Turkey, Bosnia and Herzegovina.

It is interesting to compare the development of industrial production with other aspects such as intermediate goods, energy, capital goods, consumer durables, non-durable consumer goods. Figure 3 shows the development of these aspects in three periods, during the global financial crisis 2008 – 2009; after this crisis and before Covid-19 (2010-2019); and during the pandemic.

Figure 3: EU, average monthly development of industrial production: above side left (2008), above side right (2009), down side left (2010 - 2019), down side right (2020-2021)



Source: Author calculations from Eurostat.

Compared to the synchronized nature of the global economic slowdown in the first half of 2020, the global economy has shown signs of a two-way recovery that began in the third quarter of 2020 and has been marked by a nascent recovery in developed economies. where vaccination rates are high, but slower growth rates in developing economies where vaccination rates are low. [1].

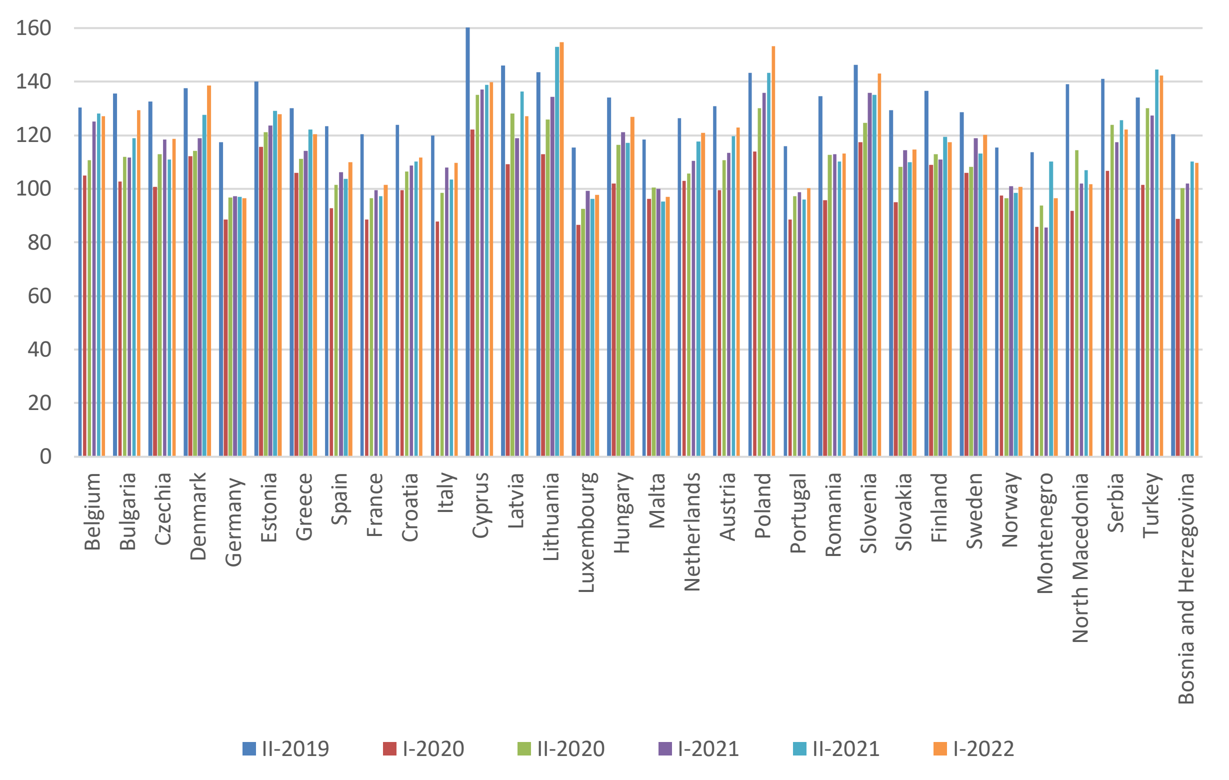
As we can see for each case, there is variability between all aspects, however, industrial production remains in the midst of other productions, even in such different circumstances as the financial crisis and the Covid-19.

Consider now, four years of study (2019-2022), three stages (early, middle and advanced), distributed in six periods:

Early stage: II-2019 ($\boldsymbol{II_{t_{max-3}}}$: **2º 2019**) and I-2020: ($\boldsymbol{I_{t_{max-2}}}$: **1º 2020**);
Middle phase: II-2020 ($\boldsymbol{II_{t_{max-2}}}$: 2º 2020) and I-2021 ($\boldsymbol{I_{t_{max-1}}}$: 1º 2021);
Advanced phase: II-2021($\boldsymbol{II_{t_{max-1}}}$:2º 2021) and I-2022 ($\boldsymbol{I_{t_{max}}}$: 1º 2022).

Figure 4 (the values in Table A1, see appendix), represents the average production volume index for each country during the six periods.

Figure 4: Volume index of production during the pandemic



Source: Author calculations from Eurostat.

In general terms, the volume of production manages to show a certain imbalance from period to period among all the countries, some of them manage to be more constant such as Malta and Norway, contrary to countries such as Lithuania, where I will keep it from period to period is very high.

The impact of the COVID-19 viral pandemic on industrial production is evident, being the period I-2020, with a lower volume of production for all countries. In this period, all the countries of the world were already dealing in an exhausted and drastic way with the consequences of a disease, which was slowly killing their population, and would psychologically affect their performance.

To overcome the effects of the viral pandemic, many countries implemented different measures including quarantines, requiring the closure of companies, applying border and travel restrictions, tax exemptions for companies, extensions of certain payments and loan guarantees, and subsidies for workers and companies. Some of these strategies began to give their first results, the last period (I-2022) in Figure 4, presents a higher volume of production in general.

- Growth rates

The growth rate $R_{t_{max}}(t_{max-k})$ of Equation (1) for k=1,2 and the recovery rate $RC_{t_{max}}(t_{max-k})$ of Equation (2) for k=2, both with the moths M01-M02 were calculated for each type of industry. The values in Table 5, allow study the evolution of each type of industry, during the pandemic.

The highest recovery rate occurs in the Computer, electronic & optical products industries; Coal and lignite; and Basic & pharmaceutical preparations. With a much lower recovery rate compared to all types of industry is the industry of Motor vehicles, trailers & semi-trailers.

The highest growth rate compared to the years 2020 and 2021 is the Coal and lignite industry with 22.85 and 33.69 respectively. Contrary to the lower growth rate for 2021 Computer, electronic & optical products and for 2020 Extraction crude petroleum & natural gas.

Table 5: Growth rates for different industries

Industries	Rate	Recovery	Rate
	R_{2022}(2021)	RC_{2022}(2020)	R_{2022}(2020)
Total Industry	0,38	103,03	2,63
Coal and lignite	22,85	133,69	33,69
Extraction crude petroleum & natural gas	-5,05	94,95	-17,40
Mining metal ores	11,84	92,48	-0,64
Other mining & quarrying	11,84	98,16	5,86
Mining support services	10,78	83,46	-12,54
Food products	4,22	106,96	1,53
Beverages	11,27	97,67	-1,90
Tobacco products	-12,26	99,46	-1,29
Textiles	2,04	94,53	-0,11
Wearing apparel	1,29	85,84	-24,81
Leather & related products	3,85	85,96	-15,80
Wood & wood products	3,41	102,91	10,51
Paper & paper products	1,26	107,38	1,06
Printing & reproduction recorded media	4,20	91,25	-5,71
Coke & refined petroleum products	8,26	103,80	-4,59
Chemicals & chemical products	1,68	106,25	5,12
Basic & pharmaceutical preparations	18,57	125,32	31,43
Rubber & plastic products	-0,56	98,06	1,53
Other non-metallic mineral products	4,97	95,67	6,47
Basic metals	0,92	97,81	0,82
Fabricated metal products	0,89	96,05	1,90
Computer, electronic & optical products	-19,95	168,57	14,66
Electrical equipment	-0,19	100,56	5,63
Machinery and equipment n.e.c.	6,38	96,57	5,92
Motor vehicles, trailers & semi-trailers	-9,56	75,34	-16,22
Other transport equipment	0,31	81,09	-13,05
Furniture	1,02	93,43	1,74
Other manufacturing	-4,45	100,90	4,49
Repair & installation of machinery & equipment	3,83	91,86	-2,17
Electricity, gas, steam & air conditioning supply	5,41	117,21	6,36

4.3 (A3) Particular efficiency analysis

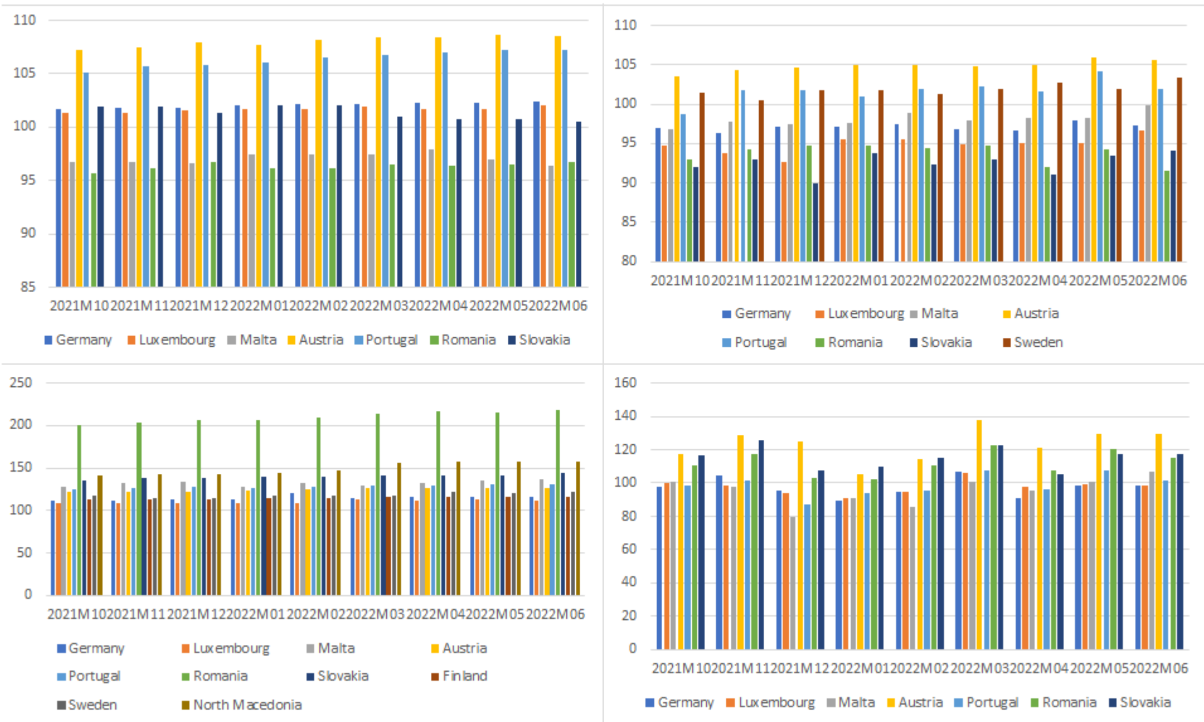
The economic impact on the industry of each country can occur at a differential level depending on the type of industry, since in general terms, efficiency depends on the characteristics of each sector, but above all on the financial capacity of each country.

In this sense we have selected five countries from the initial set (32 countries). All of them with very marked differences between each other. Some considered world powers like Germany and others strongly affected by the financial crisis of 2008-2009 like Portugal. The objective of this selection is to show, according to their financial capacities, each one of the countries, have survived the strong economic impact.

In this approach, are considered the five variables (four inputs and one output). The inputs: (I1) Employment (number of persons employed), (I2) Volume of work done (hours worked) and (I3) Gross wages and salaries. The output: (O1) Volume of production.

To perceive the reason for the selection of the countries, we can visualize the variability of some European countries against each of the inputs mentioned above. Figure 5 represents a different set of countries for each of the entries.

Figure 5: variables



Source: Author calculations from Eurostat.

For the entry (I1) the countries were selected: Germany, Luxembourg, Malta, Austria, Portugal, Romania and Slovakia. For the entry (I2) the countries were selected: Germany, Luxembourg, Malta, Austria, Portugal, Romania, Slovakia and Sweden. For the entry (I3) the countries were selected: Germany, Luxembourg, Malta, Austria, Portugal, Romania, Slovakia, North

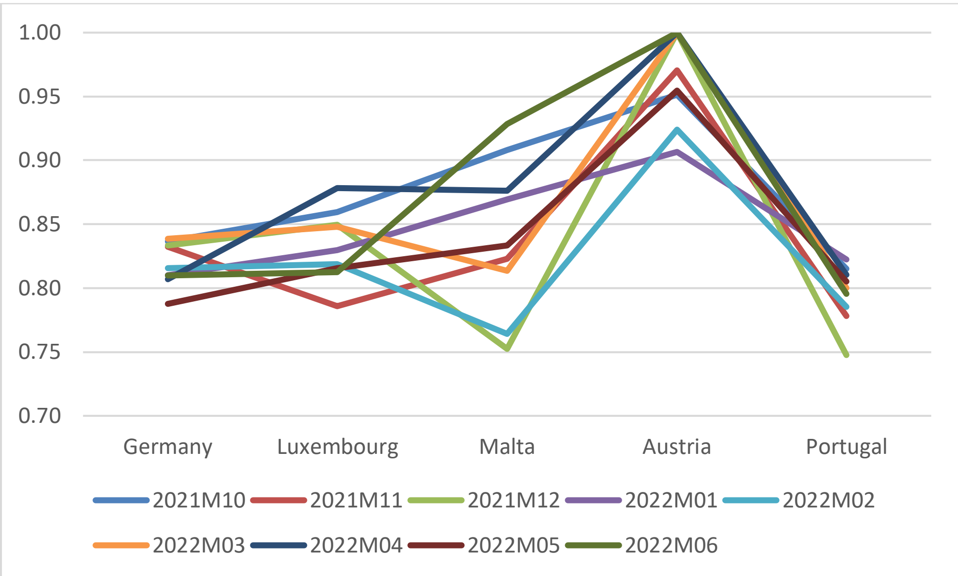
Macedonia, Sweden and Finland. For the entry (I4) the countries were selected: Germany, Luxembourg, Malta, Austria, Portugal, Romania and Slovakia.

The relationship of each variable studied with the country and the period allowed the countries to be selected for the study: Germany, Luxembourg, Malta, Austria and Portugal.

Regarding the particular results of these five countries, it is evident how Austria manages to be superior in the variables (I1), (I2) and (I4), followed by Portugal in the entries (I1), (I2). For its part, Romania presents a much higher level in (I3), during the nine months of study.

The efficiency model is applied with the inputs (I1) - (I4) and the output (O1) and the Efficiency score (Equation for DEA/CRS) is calculated in the nine months. The Figure 6, show the score for each country.

Figure 6: Efficiency score



Source: Author calculations from Eurostat.

The result show as Austria manages to be noticeably more efficient than the other countries, throughout the study period, with efficient scores that exceed 0.90. Germany manages to be efficient during the 9 months, without showing great variability. Portugal with less efficiency is the least variable. The same does not happen with Luxembourg and Malta.

5. Conclusions

This work adopted a non-parametric approach that combines mathematics tools and techniques for benchmarking analysis, for examining the economic impact of the industry of European countries, due to the COVID-19 viral pandemic.

The analysis involves three approaches (A1)-Analysis for Portuguese manufacturing sector. A review for Portuguese manufacturing sector, before COVID-19 and during financial crisis, (2006-2013); (A2)-Economic analysis for European countries. A general analysis on industrial production for 32 European countries, during COVID-19, (2019-2022); **(**A3)-Particular efficiency analysis. A particular analysis for 5 European countries, during the last phase of COVID-19, (2021-2022).

As it was possible to evidence through the different approaches of the study, containment measures introduced by the EU Member States had a significant impact on the EU's industrial production, allowing some countries to keep active different sectors of production. However, we are facing one of the biggest challenges of recent times. Some estimates indicate that 65 million to 75 million people may have entered into extreme poverty in 2020 with 80 million more undernourished compared to pre-pandemic levels.

Although with the progress in vaccinating, there were great prospects of a sustained economic recovery into 2022 and, in turn, a recovery in the broader global economy. However new variants of the COVID-19 virus, resistance to vaccinations among some populations, and now the more recent consequences of the war between Russia and Eukrania, increasingly raise questions, about the speed and strength of an economic recovery over the near term.

The results reflected that the European countries in the study are working hard to minimize the impacts of COVID-19, some of them without a clear light on what is the best strategy to follow, in this confusing and highly variable path. It is important to apply strategies that would improve the performance of less efficient countries, and an interesting way is following the plan used by the more efficient countries, to improve the economy not only in Europe; but in all around the world.

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APPENDIX A

Table A1: Volume index of production by country

	II_{2019}	I_{2020}	II_{2020}	I_{2021}	II_{2021}	I_{2022}
Belgium	130,4	105,0	110,7	125,2	128,1	127,2
Bulgaria	135,5	102,8	112,0	111,8	119,0	129,3
Czechia	132,7	100,8	113,0	118,4	111,0	118,6
Denmark	137,6	112,3	114,2	119,0	127,7	138,5
Germany	117,4	88,7	96,7	97,3	97,0	96,5
Estonia	140,0	115,8	121,2	123,8	129,2	127,9
Greece	130,0	106,0	111,3	114,3	122,2	120,4
Spain	123,3	92,7	101,5	106,3	103,7	109,9
France	120,5	88,6	96,6	99,6	97,2	101,5
Croatia	123,9	99,5	106,5	108,7	110,3	111,8
Italy	120,0	87,7	98,5	107,9	103,4	109,8
Cyprus	164,2	122,2	135,1	137,1	138,9	139,9
Latvia	146,0	109,1	128,2	118,9	136,3	127,1
Lithuania	143,6	112,9	125,8	134,3	153,1	154,6
Luxembourg	115,4	86,5	92,5	99,3	96,2	97,8
Hungary	134,2	101,9	116,4	121,2	117,2	126,9
Malta	118,5	96,2	100,5	99,9	95,3	96,9
Netherlands	126,4	102,9	105,6	110,4	117,7	120,8
Austria	130,8	99,6	110,8	113,4	119,7	122,9
Poland	143,4	113,9	130,1	135,8	143,3	153,2
Portugal	116,0	88,7	97,3	98,8	96,1	100,3
Romania	134,6	95,8	112,8	113,0	110,2	113,2
Slovenia	146,3	117,5	124,7	135,8	135,1	143,0
Slovakia	129,3	94,9	108,1	114,5	109,9	114,6
Finland	136,5	109,1	113,1	110,8	119,5	117,5
Sweden	128,6	106,0	108,2	118,9	113,2	120,2
Norway	115,3	97,6	96,4	100,9	98,6	100,7
Montenegro	113,6	85,8	93,7	85,6	110,1	96,6
North Macedonia	139,0	91,9	114,5	101,9	107,1	101,7
Serbia	141,1	106,7	123,8	117,5	125,8	122,2
Turkey	134,2	101,4	130,2	127,4	144,5	142,3
Bosnia and Herzegovina	120,5	88,7	100,3	102,0	110,2	109,6