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# Performance and efficiency of national innovation systems: lessons from the wine industry

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**Abstract.** The multiplicity of factors involved in the innovation process makes its measurement and evaluation a complex endeavor. In this study we propose a new approach to measure and decompose the efficiency of national innovation systems in the wine industry considering the relationship between the innovation environment and economic performance. The analysis applies the data envelopment analysis approach to quantify the relative efficiency of each national system using a set of four indicators to describe the innovative environment in the wine industry as model inputs, and an index of international market performance as output. The results demonstrate a clear perspective of the innovation process within the wine industry, identifying the systems that efficiently use the available resources and those that encounter difficulties in translating innovation into economic performance. The proposed approach also captures the dynamics of the international innovation landscape in the wine industry, providing potential country-level strategies and opportunities to increase innovation systems' efficiency.

**Keywords:** efficiency, DEA, wine industry, innovative performance.

## 1. INTRODUCTION

Innovation is a multifaceted concept that encompasses numerous spheres of technological, economic, and social activity, from research and development (R&D) to public and private investments, from production to application and commercialization of new goods or services, representing a crucial driver of economic change [1,2]. A key approach for understanding the innovation process is to chart the progression of perceptions of innovation over the past two decades. In the past, understanding the innovation process was centered on R&D-based product technology innovation for economists and policymakers. Such innovation was conducted by a highly educated workforce in R&D-intensive firms, and the processes leading to such innovation was conceptually perceived as being closed, internal, and localized. Technological breakthroughs were deemed to be radical and disruptive and at the global frontier of knowledge [3]. Today, the ability to innovate is increasingly considered to be related to the capability to leverage new technological combinations, encompassing the concept of incremental innovation [4]. Therefore, comprehending how innovation evolves and the impact that incremental forms of innovation can have on economic development are key aspects for understanding and guiding innovation processes [5].

The wine industry can serve as an example of how the agri-food sector's innovation landscape has shifted in recent decades, with the growth of the international wine trade due to market liberalization, the emergence of new players, and changes in consumer behavior [6], [7]. Armed with new technological capabilities, emerging producers have challenged the innovative frontier by creating new technologies, organizational structures, and markets [8]. The success of new entrants in eroding the market share of traditional producers is primarily attributable to ongoing experimentation, development, and innovation [9]. In response, traditional producers have increased R&D efforts, resulting in improved product quality, branding, diversification, and conferring higher unit values to innovative production systems with barriers to entry and high local value added [10]. Consequently, wine has been transformed from a processed agricultural product into a highly diversified and innovative product undergoing a decommodification process [11].

Compared with other sectors, measuring innovation in the wine industry poses a greater challenge due to its distinctive characteristics, such as a high concentration of small and medium-sized enterprises [12], family ownership [13], dependence on a specific local terroir for wine production [14,15], tradition-oriented operations [16], fragmented business and knowledge networks [17], and reliance on tacit information [18,19]. A significant challenge for measuring innovation in the wine industry is identifying metrics to accurately reflect its complexity and multidimensionality. This requires a comprehensive analytical approach that encompasses entire national innovation systems [20].

This study addresses the conceptual and practical challenges to understanding and directing the fundamentals of innovation in the wine sector at the national level. We propose a novel approach for quantifying efficiency and decomposing the inefficiency of national innovative systems in the wine industry considering the relationship between the innovation process, intellectual property rights ownership, and economic performance. The assessment is designed to provide a comprehensive overview of national wine industry innovation systems by examining five indices, based on the data envelopment analysis (DEA) approach to calculate the relative efficiency of each national system as decision making unit (DMU). The indices include four input indices to capture elements of the economy that enable and facilitate innovation activities, and one output index to examine international market performance. Investigating performance in foreign markets reveals systems' adoption of the contemporary concept of innovation, promoting organizational development, implementation of technological change, and investment in training and education to maintain an approach of continuous learning and adaptation [21].

## 2. LITERATURE REVIEW

Numerous studies on innovation in the wine industry have relied heavily on the resource-based view (RBV) theory introduced by Barney in 1991 [22]. This theory argues that competitive advantage can be achieved by strategically managing human resources, technological capabilities, financial resources, and R&D activities [23,24]. The dynamic capabilities and knowledge-based vision extensions respectively proposed by Easterby-Smith and Prieto in 2008 and Grant in 2015 [25,26] have also been relevant to this approach. In the RBV theory, internal resources must be heterogeneous and immobile to be considered as resources for sustained competitive advantage. However, in the competitive global environment of the wine industry, firms' key factors for success include timely response, flexibility, speed of product innovation, and effective managerial capabilities to redistribute internal or external competencies [27,28]. Therefore, the dynamic capabilities perspective emphasizes a system's ability to build, integrate, and reconfigure capabilities in response to rapid changes [29].

Another approach is diffusion theory, which was proposed by Rogers in 1962 [30] to analyze how innovations are communicated and adopted over time within a social system. The evolutionary theories advanced by Nelson and Winter and Dosi in 1982 [31,32] view innovation as a path-dependent process that emerges from interactions between multiple actors that is then tested in the market. Other innovation theories such as Kline and Rosenberg's (1986) chain model [33] and innovation systems theory [34-36] emphasize innovation as a complex process that involves interactions and feedback loops between public and private actors.

The complex activities and relationships related to innovation represent significant challenges for measurement. Innovation measurement methods start by covering a defined scope such as a sector of interest, a jurisdiction, or a geographic area where data are collected [37]. The practical aspect of quantifying innovation begins with an analysis of existing potential to effectively use it [38]. Innovation potential refers to the ability of a system to use internal resources efficiently under current circumstances to improve, manage, or optimize a product or process [39]. Many authors have considered innovative potential to be a composite of several factors and resulting metrics have generally included composite synthetic indicators. The solution adopted by the drafters of the Frascati Manual, which is the Organization for Economic Co-operation and Development's (OECD) operational statistical manual for R&D data collection [40], was to draw up definitions of research activities and introduce data on expenditure and/or human resources devoted to these activities. Thus, the concept of measuring R&D is economic in nature, and the resulting datasets are collections of economic indicators that are compatible with industrial datasets and national accounts [41]. The Global Innovation Index [5] is presented as a series of rankings that are structured with metrics at the index, subindex, or indicator levels and used to monitor performance over time and compare developments with economies in different regions or income group classifications.

Innovation capacity has predominantly been understood in terms of innovative performance [42]; however, its measurement has not been thoroughly developed in previous research at the same level as innovation potential, and authors' approaches to measuring have primarily been based on frontier techniques. Murillo-Zamorano (2004) [43] offered a thorough overview of the predominant methods of frontier analysis, identifying two analytical methodologies that are used in the economic and statistical literature, including econometric estimation of cost or production functions and mathematical programming techniques. The two strands of analysis are referred to as parametric such as deterministic frontier analysis and stochastic frontier analysis and nonparametric, including DEA and free disposal hull methods. Parametric analyses require the a priori explication of a production function, while nonparametric approaches are characterized by the possibility of determining the relative efficiency of similar DMUs through linear programming techniques without the need to specify the relative significance of different factors of production and prices or the distribution of efficiency. A comprehensive review of the application of parametric and nonparametric frontier techniques to analyze R&D system efficiency was provided by Bonaccorsi and Daraio (2005) [44]. The nonparametric method of frontier analysis chosen for this study is the DEA approach, developed by Charnes, Cooper, and Rhodes (1978) (CCR). We use DEA to empirically measure the relative efficiency of the sample of national innovation systems.

## 3. METHODOLOGY AND DATA

### *3.1. Data collection*

This section outlines the data used to profile the sample nations' wine economies, including the title, description, definition, and source for each of the 29 indicators included in the analysis. The analysis encompasses data for the top 35 wine-producing nations from 2016 to 2019, to exclude the effects of the COVID-19 pandemic. Four years are considered to ensure the accuracy of measuring the delay in the administrative processes for obtaining intellectual property rights for an invention (18–24 months), and the time it takes to commercialize an innovation. Some indicators are scaled during the calculation to make them comparable across economies, in relation to other comparable indicators or through division by gross domestic product (GDP) in current US dollars, GDP at purchasing power parity in international dollars (GDP PPP$) and gross national income (GNI). The selection of the subindices that contribute to the construction of individual indices is based on their relevance to the specific innovation domain, scientific literature review, data availability, and the value of correlation measured post hoc to verify statistical consistency. In summary, the model is constructed using four input indices, including a production structure, institutional and business environment, human capital and research, and knowledge and technology indices and one output index covering international market performance. Descriptions of the variables and data sources are detailed below.

Production structure index:

- *Share of world grapevine area*: This index reflects the viticultural area in each country, which is obtained by averaging individual annual percentage values from 2016 to 2019 (International Organization of Vine and Wine (OIV), Annual Database of global wine markets).
- *Share of total agricultural crop area under vines*: This index provides an assessment of the national weight of viticulture in terms of occupied land and is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets; OECD data; the United Nations Food and Agricultural Organization's FAOSTAT database).

- *Vineyard area per million US$ of real GDP*: This index determines the average vineyard area scaled by real GDP for individual years from 2016 to 2019. The index quantifies the planted vineyard area for comparison across different economies (OIV, Annual Database of global wine markets; OECD).
- *Share of world wine production volume*: This index reflects the amount of wine produced by each nation in relation to global production and is obtained by averaging individual percentage values for each year from 2016 to 2019 (OIV, Annual Database of global wine markets).
- *Volume of wine production (1,000 liters) per US$ millions of real GDP*: This index quantifies national wine production volume, which is measured in thousands of liters and scaled by millions of US dollars of real GDP and obtained by averaging the individual values for each year from 2016 to 2019 (OECD data; OIV, Annual Database of global wine markets).
- *Wine self-sufficiency in terms of volume*: This national supply balance index quantifies each country's degree of specialization in wine production and is obtained by averaging data for 2016 to 2018; however, there are missing values in 2019 (OIV, Annual Database of global wine markets).
- *Share of world wine consumption volume*: This index is obtained by averaging individual values from 2016 to 2019 and is a proxy for the historicity of the wine sector in the country (OIV, Annual Database of global wine markets).
- *Wine consumption as a proportion of total alcohol consumption*: This index quantifies wine consumption as a proxy for its historicity, stripped of cultural habits related to alcohol in general, which is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets).

Institutional and business environment index:

- *Cost of business startup procedures (% of GNI per capita)*: The cost of registering a new enterprise is normalized as a percentage of GNI per capita. This index is obtained by averaging individual values from 2016 to 2019 to quantify the impact of institutional and bureaucratic structure on the commercialization (thus, new business development) of innovations (World Bank).
- *Ease of doing business score (0 = lowest performance to 100 = best performance)*: These scores identify benchmark economies to compare the best regulatory practices. Economies are scored on a scale of 0 to 100, where 0 represents the worst regulatory performance and 100 represents the best regulatory performance. The index is obtained by averaging the individual values from 2016 to 2019 (World Bank).
- *Startup procedures to register a business (number)*: Startup procedures refer to the requirements for starting a business, including interactions to obtain necessary permits and licenses and complete all inscriptions, verifications, and notifications to begin operations. The index is obtained by averaging individual annual values from 2016 to 2019 and is a proxy for the impact of bureaucracy on the innovation system (World Bank).
- *Time required to start a business (days)*: This index measures the number of calendar days required to complete the procedures for legal business operation. If a procedure can be expedited at an additional cost, the fastest procedure is chosen, regardless of the cost. The index is obtained by averaging individual annual values from 2016 to 2019 (World Bank).
- *Charges for the use of intellectual property, payments (balance of Payment in current US$)*: This index quantifies the charges for the use of intellectual property, referring to payments and collections between residents and nonresidents for authorized use of proprietary rights (such as patents, trademarks, copyrights, industrial processes, and designs, including trade secrets) and for the use of original or prototype products (such as computer software) and related rights through licensing agreements. These data are expressed in current US dollars, and the index is obtained by averaging annual values from 2016 to 2019 (International Monetary Fund, Balance of Payments Statistics Yearbook).
- *Agriculture, forestry, and fishing, value added (% of GDP)*: Value added refers to the net output of the indicated agribusiness sectors after summing all outputs and subtracting intermediate inputs. This is calculated without deducting depreciation of manufactured goods or depletion and degradation of natural resources. The index is then normalized as a proportion nations' real GDP and obtained by averaging annual values from 2016 to 2019 (OECD; World Bank).

Human capital and research index:

- *Employment in agriculture (% of total employment)*: The agriculture sector includes activities in agriculture, hunting, forestry, and fishing, in accordance with division 1 (ISIC 2), categories A–B (ISIC 3), or category A (ISIC 4). This index is obtained by averaging estimated values for each year from 2016 to 2019 (the United Nations International Labor Organization's ILOSTAT database).

- *Share of tertiary education graduates from agriculture programs*: This index quantifies the proportion of total tertiary education graduates, regardless of age, to the share of the group that officially corresponds to agricultural education programs. The index is obtained by averaging values for each year from 2016 to 2019 (the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics database).
- *Gross Expenditure on R&D (% of GDP)*: This index quantifies total domestic expenditure on R&D in each period as a proportion of GDP. Intramural R&D expenditure is all R&D expenditure made within a statistical unit or economic sector in each period, regardless of the source of funding. The index is obtained by averaging annual values from 2016 to 2019 (UNESCO Institute for Statistics online database; Eurostat; OECD, Database of Principal Science and Technology Indicators; Ibero-American and Inter-American Network of Science and Technology Indicators).
- *Researchers, full-time equivalent (per million population)*: R&D researchers are professionals engaged in the conception or creation of new knowledge. Full-time equivalent quantifies the average annual time devoted to the activity (if an individual worked for 6 months it is counted as 0.5 for the reference year). The index is normalized per million inhabitants and obtained by averaging individual annual values from 2016 to 2019 (UNESCO Institute for Statistics online database; Eurostat; OECD, Main Science and Technology Indicators database; Ibero-American and Inter-American Network of Science and Technology Indicators).

Knowledge and technology index:

- *Wine PCT Patent Families/billions GDP PPP$*: The number of wine-related Patent Co-operation Treaty (PCT) patent families filed in at least two patent systems, scaled per billion GDP PPP$. A PCT application is defined as an international patent application administered by the World Intellectual Property Organization (WIPO). The PCT system makes it possible to simultaneously obtain patent protection for an invention in several countries by filing a single international patent application. The origin of PCT applications is defined by the residence of the first applicant. Data are available only for economies that are PCT contracting states (156 to date). Data are scaled by GDP in PPP$ (billion). A patent family is a set of interrelated patent applications filed in one or more countries or jurisdictions to protect the same invention. A patent is a set of exclusive rights granted by law to applicants for new, nonobvious, and industrially applicable inventions, and is valid for a limited period (usually 20 years) and in a defined territory. The patent system is designed to encourage innovation by providing innovators with exclusive, time-limited legal rights, which allows them to reap the benefits of the initial innovative activity. The index is obtained by using a time filter from January 1, 2016 to December 31, 2019 for the date of application (WIPO; International Monetary Fund; Questel Orbit Intelligence).
- *National wine tech share*: This index quantifies the proportion of the number of wine-related PCT patents to the total number of PCT patents from the individual country from 2016 to 2019. The index provides the relative weight of innovative production in the wine industry compared with the entire national innovation system (WIPO; Questel Orbit Intelligence).
- *Patent intensity*: This index examines the number of PCT patents with the word wine in the title or abstract in relation to the value of wine exports as a proportion of real GDP. The index is obtained using the average annual values from 2016 to 2019 to analyze patent intensity in relation to the significance of the wine industry at the national level. Countries with a high patent propensity but a small international wine market in the national economy will receive a higher value. (OIV, Annual Database of global wine market; OECD; World Bank; Questel Orbit Intelligence).
- *Share of international scientific articles published (wine)*: This index quantifies the proportion of international articles published in the wine field from 2016 to 2019 (Web of Science; Scopus).
- *Number of science and technology journal articles (per billion GDP PPP$):* This index measures the number of wine-related articles published in the fields of science and technology from 2016 to 2019. Articles are quantified and assigned to each economy based on the institutional addresses provided in each article. Data are reported per billion GDP PPP$ (Web of Science; OECD).

International market performance index:

- *Share of world wine export value*: This index measures the proportion of the value of wine exports in the world share. The index is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets).

- *Share of world wine export volume*: The proportion of the volume of wine exports in the world share. The index is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets).
- *Export as % of wine production volume*: Proportion of wine exported by volume in relation to production. The index is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets).
- *Volume of wine exports per million dollars of real GDP*: This index quantifies the volume (1,000 liters) of wine exports per million US dollars as a proportion of real GDP. The index is obtained by averaging annual values from 2016 to 2019 and allows for a comparison between different economies in relation to the significance of the wine industry within the country (OIV, Annual Database of global wine markets).
- *Share of wine exports in the value of all merchandize exports*: This index measures the relative weight of

**Table 1.** Descriptive statistics of the subindices used to construct the indices.

| | Indices | Sub-indices | Mean | Median | St. dev. | Kurtosis | Skewness | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| Input | Production structure | Share of world vine area | 2.42% | 0.90% | 0.03 | 3.03 | 2.02 | 0.02% | 12.57% |
| | | Vine area as share of total crop | 2.51% | 0.86% | 0.03 | 1.19 | 1.45 | 0.02% | 11.02% |
| | | Vine area (ha) per million real GDP | 0.608 | 0.282 | 1.18 | 24.386 | 4.635 | 0.001 | 6.856 |
| | | Share of world wine production (volume) | 2.71% | 0.88% | 0.04 | 4.42 | 2.29 | 0.02% | 16.50% |
| | | Wine prod (.000 litres) per million real GDP | 1.716 | 0.975 | 1.91 | 1.515 | 1.261 | 0.002 | 7.833 |
| | | Wine self-sufficiency | 126.87% | 103.84% | 1.23 | 5.64 | 2.18 | 0.56% | 552.86% |
| | | Share of world wine consumption (volume) | 2.50% | 1.14% | 0.03 | 3.25 | 1.96 | 0.08% | 13.22% |
| | | Wine consumption as share of total alcohol consumption | 31.48% | 30.73% | 0.19 | -1.05 | 0.05 | 0.11% | 67.52% |
| | Institutional and business environment | Cost of business start-up procedures (% of GNI per capita) | 5.19% | 4.13% | 0.05 | 2.35 | 1.54 | 0.03% | 22.93% |
| | | Ease of doing business score | 72.606 | 72.935 | 8.23 | 1.54 | -0.96 | 47.358 | 86.989 |
| | | Start-up procedures to register a business (number) | 6.436 | 6.000 | 2.79 | 0.15 | 0.29 | 1.000 | 12.750 |
| | | Time required to start a business (days) | 12.209 | 9.250 | 10.74 | 4.90 | 2.02 | 0.500 | 50.425 |
| | | Charges for the use of intellectual property, payments (BOP, current mln US$) | 6.509 | 1.838 | 10.02 | 4.75 | 2.18 | 0.018 | 42.847 |
| | | Agriculture, forestry, and fishing, value added (% of GDP) | 4.62% | 3.62% | 0.04 | 1.42 | 1.30 | 0.58% | 16.42% |
| | HC and R&D | Employment in agriculture (% of total employment) | 10.81% | 6.21% | 0.11 | 1.94 | 1.62 | 0.09% | 43.61% |
| | | Share of graduates teriary education from Agriculture programmes | 1.95% | 1.83% | 0.01 | 0.50 | 0.97 | 0.47% | 4.23% |
| | | GERD as % ofGDP | 1.36% | 1.18% | 0.01 | -0.53 | 0.82 | 0.26% | 3.20% |
| | | FTER per million inhabitants | 2660.292 | 2250.786 | 1836.720 | -1.56 | 0.27 | 234.352 | 5510.906 |
| | Knowledge and technology | Wine Patent families per billion ofPPP$ GDP | 0.098 | 0.078 | 0.09 | 4.00 | 1.81 | 0.005 | 0.400 |
| | | National Wine Tech Share | 12.28% | 6.36% | 0.14 | 8.10 | 2.57 | 0.63% | 72.00% |
| | | Patent Intensity | 5.08E+07 | 8.33E+04 | 2.80E+08 | 34.93 | 5.91 | 174.220 | 1.66E+09 |
| | | Share of international scientific wine related topic articles published | 3.08% | 1.61% | 0.04 | 2.31 | 1.84 | 0.09% | 13.69% |
| | | Scientif and technical articles wine topic per billion PPP$ GDP | 0.668 | 0.427 | 0.68 | 2.55 | 1.67 | 0.047 | 2.734 |
| Otput | International market performance | Share of world wine export (value) | 2.73% | 0.35% | 0.06 | 13.49 | 3.55 | 0.00% | 29.96% |
| | | Share of world wine export (volume) | 2.74% | 0.43% | 0.05 | 6.18 | 2.58 | 0.00% | 20.93% |
| | | Share of wine production exported | 100.91% | 21.91% | 3.81 | 33.74 | 5.77 | 0.47% | 2272.47% |
| | | Wine export (.000 litres) per million of real GDP | 0.747 | 0.132 | 1.27 | 8.28 | 2.65 | 0.000 | 6.044 |
| | | Wine export value as share of value of all exports | 0.79% | 0.11% | 0.01 | 5.02 | 2.32 | 0.0002% | 5.33% |
| | | Unit value of wine export (current US$/litre) | 7.207 | 3.020 | 17.05 | 21.69 | 4.55 | 0.791 | 94.271 |

wine exports by value in relation to countries' total exports. The index is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets; OECD; World Bank).
– *Unit value of wine exports (current US cents/liter)*: This index quantifies the unit value of exports expressed in US cents/liter. The index is obtained by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets; World Bank; the European Commission's Agriculture and rural development Wine Market Observatory).

### *3.2. Data processing*

The sample includes 35 economies, which account for 95.1% of world wine production and 84.6% of the world's vineyard area. Indices were constructed from quantitative data and composite indicators (subindices). All 35 economies are chosen based on sufficient data to be included in the study. Only annual data from 2016 to 2019 are considered for each economy. The robustness of the modeling choices such as those of normalization and arithmetic averages follow the approach provide by the Joint Research Center (JRC) for the validation of the GII 2022 construction [45].

Potentially problematic subindices with outliers that could distort results and unduly distort performance rankings are treated according to the rules described below, as recommended by the JRC-Competence Center on Composite Indicators and Scoreboards (COIN). First rule: selection. Indicators were classified as problematic if they presented an absolute skewness value greater than 2.25 and kurtosis greater than 3.5 [46]. Second rule: treatment. Indicators with between one and three outliers were subjected to winsorization (values with skewness in the indicator distribution were assigned the next higher value, up to the level at which skewness and/or kurtosis had the values specified above). Indicators with three or more outliers and for which skewness or kurtosis did not fall within the ranges specified above were transformed using natural logarithms using following formula:

$$\ln [((\max - 1)\ (value - \min))/(\max - \min)) + 1]$$

The indicators were then normalized using the min–max method to the range [0, 100], with higher scores representing better results.

The indices were obtained from the weighted arithmetic mean of the value of the normalized subindices that compose the index itself. With the goal of obtaining index scores that were balanced in their underlying components (i.e., that the subindices could explain a similar amount of variance), we constructed them using a weighted arithmetic mean with predefined weights for the subindices. Becker et al. (2017) and Paruolo et al. (2013) [47,48] demonstrated that the ratio of two nominal weights in weighted arithmetic averages provides the rate of substitutability between two indicators and can be used to reveal the relative significance of individual indicators. This significance can then be compared with ex-post measures of variables' importance such as the nonlinear Pearson correlation ratio [5]. As a result of this analysis, all indicators were assigned a weight of 1 and only two indicators (agriculture, forestry, and fishing, value added as % of GDP and patent intensity) were assigned a weight of 0.5.

Finally, the analysis includes a measure of the distance to the efficiency frontier of innovation using DEA. We chose the output-oriented CCR model, which imposes three restrictions on frontier technology, including constant returns to scale, convexity of the set of feasible input–output combinations, and strong availability of inputs and outputs [43]. The CCR model reformulates the calculation of individual input efficiency measures by solving a linear programming problem for each national innovation system. This efficient frontier is computed as a convex shell in the input space that is represented by a convex set of facets.

Comparing multidimensional innovation performance by subjecting all economies to a fixed, common set of weights may prevent acceptance of an innovation score on the grounds that a particular weighting scheme may not be fair to a particular economy. An interesting feature of the DEA literature applied to real-world decision making contexts is the determination of endogenous weights that maximize the overall score of each DMU given a set of other observations [45]. In this segment, we again relax the assumption of fixed index weights that are common to all economies, and determine the economy-specific weights that maximize an economy's overall innovation score endogenously using DEA. In theory, each economy is free to decide the relative contribution of each area of innovation to its score to obtain the best possible score in a calculation that reflects its innovation strategy. In practice, the DEA method assigns a higher (lower) contribution to areas in which an economy is relatively strong (weak). Reasonable constraints are applied to the weights to prevent an economy from achieving a perfect score. The study then measures DEA efficiency score as the weighted average of all five indices, where the weights are the economy-specific DEA weights, compared with the best performance among all other economies with the same weights. The DEA efficiency score (1 = efficient) represents the study's measure of the distance from the efficiency frontier.

Finally, we construct an index of revealed comparative advantage in the wine industry (RCAW) that quantifies the proportion of wine exports to the value of exports of other commodities as a benchmark for the sample countries' performance. We then calculate the index by averaging individual annual values from 2016 to 2019 (OIV, Annual Database of global wine markets; World Bank; Wine Market Observatory) using the following formula:

$$RCAW = (X_{ij}/X_{it})/(X_{nj}/X_{nt})$$

where X represents exports, $i$ is a country, $j$ is wine export value, $t$ is a set of value export commodities, and $n$ is a set of countries that are used as reference export markets for comparison. We then analyze the relationship between the efficiency score and the RCAW index on a logarithmic scale.

## 4. RESULTS AND DISCUSSION

### *4.1. Performance scores*

The index scores allow for an initial classification of countries in relation to the scope described by the index in question [5]. Table 2 presents the top four nations for each of the study's five indices.

The production structure reveals that old world countries lead, with France, Italy, Spain, and Portugal in the top four positions. France, Italy, and Spain also hold top export positions, where Chile emerges in fourth place. New market countries appear to have an advantage over historical producers in relation to the institutional and business environment, human capital, and R&D investments. In contrast, patent production and scientific knowledge again reveals historical countries leading, with Portugal as the top performer.

Table 3 presents the values and corresponding rankings of countries for the production structure index and the values of the subindices used.

As historic producers, Italy, France, and Spain achieve the highest scores and occupy the top three positions [49]. Performance scores in the production structure are high for Eastern European countries such as Moldova, Georgia, and Romania thanks to subindices corrected for the country's economic strength (vine area per million real GDP; wine production (1,000 liters) per million real GDP), in line with the investments made in these countries to develop wine production potential [50].

**Table 2.** Top four performers for each index.

| | Index | Nation rank | | Index score |
|---|---|---|---|---|
| Input | Production structure | 1 | Italy | 73.53 |
| | | 2 | France | 67.27 |
| | | 3 | Spain | 64.96 |
| | | 4 | Portugal | 53.39 |
| | Institutional and business environment | 1 | New Zealand | 78.19 |
| | | 2 | Canada | 69.98 |
| | | 3 | United States | 64.82 |
| | | 4 | Australia | 64.45 |
| | HC and R&D | 1 | Austria | 58.77 |
| | | 2 | Germany | 56.76 |
| | | 3 | Switzerland | 56.40 |
| | | 4 | Bel-Lux | 55.49 |
| | Knowledge and technology | 1 | Portugal | 72.43 |
| | | 2 | Spain | 57.42 |
| | | 3 | Georgia | 53.20 |
| | | 4 | Italy | 50.42 |
| Output | International market performance | 1 | France | 57.76 |
| | | 2 | Italy | 57.33 |
| | | 3 | Spain | 51.50 |
| | | 4 | Chile | 48.43 |

Table 4 presents the performance values and resulting ranking of countries for the institutional and business environment index and the subindices used in its construction.

New Zealand emerges as the country with the best institutional and economic conditions for making innovations marketable. In general, the United Kingdom and former British colonies achieve the best performance, with Canada, the United States, and Australia occupying the second through fourth positions, respectively. Among old world producers, only France performs close to the best (seventh), while Spain and Portugal are further behind, respectively ranking fourteenth and sixteenth. Italy is only ranked twenty-ninth, with one of the highest values in the cost of innovative startups relative to GNI per capita (14.08%) and the number of procedures required to register a new business (seventh), highlighting a bureaucratic machine that, as widely acknowledged, is a hindrance to innovative activities [51]. The institutional and business environment has an important influence on increasing wineries' economic performance, and these aspects should not be neglected in pursuit of balancing national innovation strategies [52].

Table 5 presents the values and corresponding rankings of countries for the human capital and research index.

**Table 3.** Production structure index scores and ranking.

| | Nations rank | Share of world vine area | Vine area as share of total crop | Vine area (ha) per million real GDP | Share of world wine production (volume) | Wine prod (.000 litres) per million real GDP | Wine self-sufficiency | Share of world wine consumption (volume) | Wine consumption as share of total alcohol consumption | Production structure index |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Italy | 9.22% | 7.44% | 0.61 | 16.50% | 4.32 | 216.57% | 9.16% | 67.52% | 73.53 |
| 2 | France | 10.54% | 4.05% | 0.53 | 16.20% | 3.09 | 159.20% | 10.99% | 56.44% | 67.27 |
| 3 | Spain | 12.57% | 5.53% | 1.25 | 14.17% | 5.16 | 552.86% | 2.85% | 22.28% | 64.96 |
| 4 | Portugal | 2.38% | 10.25% | 1.26 | 2.39% | 4.64 | 125.04% | 2.12% | 65.51% | 53.39 |
| 5 | Moldova | 1.95% | 7.37% | 6.86 | 0.67% | 7.83 | 154.17% | 0.49% | 55.09% | 52.14 |
| 6 | Georgia | 0.69% | 11.02% | 1.55 | 0.51% | 3.41 | 164.75% | 0.34% | 47.32% | 45.18 |
| 7 | Chile | 1.91% | 8.27% | 0.47 | 4.16% | 3.74 | 513.66% | 0.92% | 29.91% | 44.71 |
| 8 | Argentina | 2.96% | 0.55% | 0.47 | 4.57% | 2.41 | 137.06% | 4.00% | 54.15% | 38.69 |
| 9 | United States | 5.68% | 0.26% | 0.04 | 9.77% | 0.29 | 73.31% | 13.22% | 16.95% | 37.57 |
| 10 | Romania | 2.34% | 1.95% | 1.74 | 1.55% | 3.36 | 110.97% | 1.68% | 31.02% | 34.85 |
| 11 | New Zealand | 0.50% | 5.67% | 0.37 | 1.13% | 2.80 | 268.18% | 0.45% | 36.05% | 34.26 |
| 12 | South Africa | 1.66% | 2.34% | 0.39 | 3.80% | 3.51 | 227.13% | 1.79% | 23.90% | 33.87 |
| 13 | Greece | 1.41% | 3.26% | 0.82 | 0.88% | 1.90 | 101.28% | 1.01% | 49.59% | 32.93 |
| 14 | Australia | 1.78% | 0.55% | 0.19 | 4.92 % | 1.80 | 234.82% | 2.31% | 33.82% | 31.01 |
| 15 | Hungary | 0.89% | 1.51% | 0.79 | 1.10% | 3.15 | 141.66% | 0.92% | 30.01% | 29.79 |
| 16 | China | 11.58% | 0.64% | 0.05 | 2.97% | 0.07 | 49.23% | 6.72% | 3.94% | 28.79 |
| 17 | Germany | 1.38% | 0.86% | 0.06 | 3.27% | 0.49 | 44.86% | 8.07% | 29.27% | 25.59 |
| 18 | Austria | 0.63% | 3.33% | 0.21 | 0.91% | 0.97 | 105.42% | 1.01% | 35.51% | 25.07 |
| 19 | Bulgaria | 0.87% | 1.77% | 0.94 | 0.41% | 1.91 | 174.58% | 0.31% | 13.96% | 24.96 |
| 20 | Croatia | 0.32% | 2.59% | 0.61 | 0.16% | 1.11 | 22.97% | 0.75% | 51.12% | 24.58 |
| 21 | Uruguay | 0.09% | 0.28% | 0.15 | 0.27% | 1.54 | 115.09% | 0.27% | 54.22% | 23.73 |
| 22 | Algeria | 0.90% | 0.83% | 0.42 | 0.20% | 0.32 | 84.31% | 0.25% | 43.84% | 22.49 |
| 23 | Turkey | 5.93% | 1.88% | 0.50 | 0.17% | 0.05 | 103.84% | 0.17% | 7.01% | 22.38 |
| 24 | Morocco | 0.62% | 0.50% | 0.27 | 0.14% | 0.22 | 87.81% | 0.16% | 49.74% | 21.78 |
| 25 | Switzerland | 0.20% | 3.52% | 0.07 | 0.37% | 0.45 | 34.28% | 1.14% | 50.14% | 21.51 |
| 26 | Tunisia | 0.29% | 0.44% | 0.28 | 0.08% | 0.28 | 106.95% | 0.08% | 19.87% | 16.44 |
| 27 | Russia | 0.87% | 0.05% | 0.05 | 1.75% | 0.40 | 46.17% | 3.84% | 11.74% | 15.31 |
| 28 | Ukraine | 0.57% | 0.13% | 0.23 | 0.40% | 0.57 | 43.48% | 0.94% | 11.95% | 13.58 |
| 29 | Brazil | 1.04% | 0.12% | 0.05 | 1.03% | 0.13 | 96.44% | 1.37% | 4.20% | 12.77 |
| 30 | UK | 0.03% | 0.04% | 0.00 | 0.02% | 0.00 | 0.56% | 5.30% | 32.39% | 10.99 |
| 31 | Canada | 0.19% | 0.02% | 0.01 | 0.21% | 0.06 | 11.11% | 2.02% | 25.97% | 9.62 |
| 32 | India | 1.91% | 0.08% | 0.02 | 0.08% | 0.00 | 86.89% | 0.10% | 0.11% | 9.59 |
| 33 | Bel-Lux | 0.02% | 0.16% | 0.00 | 0.06% | 0.05 | 5.39% | 1.18% | 30.73% | 8.32 |
| 34 | Mexico | 0.45% | 0.12% | 0.03 | 0.15% | 0.04 | 34.52% | 0.45% | 2.77% | 6.79 |
| 35 | Japan | 0.23% | 0.38% | 0.01 | 0.06% | 0.01 | 5.80% | 1.18% | 3.88% | 3.84 |

Central Europe emerges as a cluster of excellence, with Austria, Germany, Switzerland, and Bel-Lux occupying the top four positions. Among the *old world* countries, France and Portugal, ranked tenth and eleventh, respectively as the highest scores, while Italy ranked twentieth, with the subindex of full-time equivalent researchers per million inhabitants weighing more negatively compared to the reference countries. These human capital indicators, which have a crucial role in the wine industry's competitiveness, are often absent or poorly expressed [53]. National employment, funding for research, and training in agriculture appear to be the best proxies in a cross-country comparison [5].

Table 6 presents the scores and ranking of countries for the knowledge and technology index.

The highest performance is achieved by Portugal, followed by Spain in second place. These two countries lead in different ways. Portugal, Georgia, Croatia, Roma-

**Table 4.** Institutional and business environment index scores and ranking.

| | Nations rank | Cost of business startup procedures (% of GNI per capİta) | Ease of doing business score | Start-up procedures to register a busİness (number) | Time required to start a busİness (days) | Charges for the use of intellectual property, payments (BOP, current mln US$) | Agriculture value added (% of GDP) | Institutional and business environment index |
|---|---|---|---|---|---|---|---|---|
| 1 | New Zealand | 0.25% | 86.99 | 1.00 | 0.50 | 0.91 | 5.70% | 78.19 |
| 2 | Canada | 0.35% | 79.54 | 2.00 | 1.50 | 12.30 | 1.82% | 69.98 |
| 3 | United States | 0.03% | 83.41 | 4.00 | 4.50 | 13.69 | 0.91% | 64.82 |
| 4 | Australia | 0.70% | 80.73 | 3.00 | 2.38 | 3.48 | 2.42% | 64.45 |
| 5 | United Kingdom | 1.05% | 83.69 | 6.00 | 5.25 | 42.85 | 0.58% | 63.69 |
| 6 | Georgia | 2.35% | 82.76 | 1.50 | 1.75 | 0.03 | 6.70% | 62.19 |
| 7 | France | 0.70% | 76.46 | 5.00 | 3.63 | 14.34 | 1.54% | 61.42 |
| 8 | Russia | 1.10% | 76.84 | 4.00 | 10.10 | 6.03 | 3.58% | 59.55 |
| 9 | China | 1.35% | 69.65 | 7.00 | 17.75 | 30.72 | 7.43% | 59.02 |
| 10 | Switzerland | 2.30% | 76.57 | 6.00 | 10.00 | 25.09 | 0.65% | 56.55 |
| 11 | Ukraine | 0.70% | 68.20 | 6.00 | 6.50 | 0.50 | 10.25% | 55.15 |
| 12 | Moldova | 5.20% | 73.19 | 3.75 | 4.75 | 0.03 | 10.83% | 54.08 |
| 13 | Morocco | 5.80% | 70.88 | 4.25 | 9.25 | 0.14 | 10.91% | 52.08 |
| 14 | Spaİn | 4.08% | 77.72 | 7.00 | 12.75 | 5.88 | 2.71% | 51.87 |
| 15 | Bel-Lux | 5.33% | 73.58 | 5.00 | 4.63 | 3.35 | 0.64% | 51.23 |
| 16 | Portugal | 2.03% | 76.52 | 6.00 | 6.38 | 0.87 | 2.07% | 50.50 |
| 17 | Japan | 7.50% | 78.00 | 8.00 | 11.20 | 22.60 | 1.08% | 50.39 |
| 18 | Germany | 6.63% | 79.49 | 9.00 | 8.00 | 14.67 | 0.75% | 49.65 |
| 19 | Romania | 0.78% | 72.93 | 6.00 | 19.75 | 0.91 | 4.43% | 49.35 |
| 20 | Hungary | 5.48% | 72.68 | 6.00 | 7.00 | 1.59 | 3.62% | 49.29 |
| 21 | Chile | 5.05% | 72.11 | 7.25 | 6.25 | 1.84 | 4.10% | 48.79 |
| 22 | Greece | 1.75% | 67.51 | 4.00 | 10.50 | 0.32 | 3.70% | 47.72 |
| 23 | India | 12.65% | 63.85 | 11.50 | 23.08 | 6.94 | 16.42% | 46.66 |
| 24 | Austria | 4.95% | 78.76 | 8.00 | 21.00 | 1.77 | 1.13% | 44.00 |
| 25 | South Africa | 0.20% | 66.11 | 7.00 | 42.50 | 1.65 | 2.28% | 42.68 |
| 26 | Turkey | 13.58% | 73.08 | 8.50 | 8.50 | 1.99 | 6.09% | 42.65 |
| 27 | Bulgaria | 1.15% | 71.77 | 7.00 | 23.00 | 0.21 | 3.68% | 42.57 |
| 28 | Tunisia | 4.13% | 66.68 | 8.00 | 11.00 | 0.02 | 9.29% | 41.87 |
| 29 | İtaly | 14.08% | 72.73 | 7.00 | 11.00 | 4.89 | 1.94% | 41.58 |
| 30 | Croatia | 6.85% | 72.83 | 7.75 | 21.75 | 0.30 | 2.94% | 37.98 |
| 31 | Brazil | 4.73% | 57.13 | 11.00 | 50.43 | 5.23 | 4.53% | 34.91 |
| 32 | Mexİco | 16.55% | 72.39 | 8.00 | 8.40 | 0.32 | 3.38% | 33.57 |
| 33 | Argentina | 7.88% | 57.92 | 12.75 | 17.88 | 2.05 | 5.34% | 31.63 |
| 34 | Uruguay | 22.93% | 61.16 | 5.00 | 6.50 | 0.13 | 6.08% | 30.28 |
| 35 | Algerİa | 11.68% | 47.36 | 12.00 | 18.00 | 0.14 | 12.05% | 26.30 |

nia, and Moldova obtain highest score in subindices that measure the importance of patent activity and academic research in relation to GDP weight (patent families per billion PPP$ GDP, national wine tech share, and scientific and technical articles on a wine topic per billion PPP$ GDP). In contrast, Spain, Italy, the United States, China, and France excel in international scientific production (percentage of international scientific wine topic articles published) and in the patent intensity subindex, which describes the propensity to patent regardless of the value of the wine market.

Table 7 presents the scores and rankings for the International market performance index and the values of subindices used.

**Table 5.** Human capital and research index scores and ranking.

| | Nations rank | Employment in agriculture (% of total employment) | Share of graduates tertiary education from Agriculture programmes | GERD as % of GDP | FTER per million inhabitants | HC and R&D index |
|---|---|---|---|---|---|---|
| 1 | Austria | 3.91% | 1.57% | 3.11% | 5510,91 | 58.77 |
| 2 | Germany | 1.26% | 1.85% | 3.06% | 5114.83 | 56.76 |
| 3 | Switzerland | 3.02% | 1.45% | 3.07% | 5353.24 | 56.40 |
| 4 | Bel-Lux | 1.08% | 1.99% | 2.85% | 5038.07 | 55.49 |
| 5 | Japan | 3.45% | 1.00% | 3.20% | 5307.83 | 54.51 |
| 6 | New Zealand | 6.18% | 2.28% | 1.33% | 5458.61 | 49.37 |
| 7 | Hungary | 4.91% | 3.52% | 1.40% | 3407.61 | 47.86 |
| 8 | United States | 1.10% | 0.94% | 3.02% | 4500.56 | 47.43 |
| 9 | China | 26.52% | 2.00% | 2.18% | 1322.59 | 46.83 |
| 10 | France | 2.62% | 1.57% | 2.23% | 4626.35 | 46.36 |
| 11 | Portugal | 6.21% | 2.10% | 1.37% | 4478.12 | 43.92 |
| 12 | Greece | 12.08% | 2.54% | 1.18% | 3427.57 | 43.68 |
| 13 | Romania | 22.36% | 4.06% | 0.49% | 901.74 | 41.78 |
| 14 | Croatia | 6.75% | 3.86% | 0.97% | 1916.57 | 40.39 |
| 15 | Canada | 1.53% | 1.47% | 1.68% | 4457.95 | 39.61 |
| 16 | Ukraine | 14.81% | 4.23% | 0.48% | 958.70 | 38.74 |
| 17 | Morocco | 34.60% | 1.99% | 0.71% | 1073.54 | 37.75 |
| 18 | Australia | 2.60% | 0.71% | 1.88% | 4550.00 | 37.28 |
| 19 | United Kingdom | 1.40% | 0.95% | 1.67% | 4470.13 | 36.03 |
| 20 | İtaly | 3.83% | 2.41% | 1.42% | 2405.95 | 35.15 |
| 21 | Georgia | 41.00% | 1.21% | 0.29% | 1461.59 | 34.46 |
| 22 | Turkey | 18.86% | 2.20% | 0.99% | 1463.13 | 34.33 |
| 23 | Brazil | 9.49% | 2.72% | 1.23% | 887.70 | 31.71 |
| 24 | India | 43.61% | 0.87% | 0.67% | 234.35 | 31.16 |
| 25 | Russia | 6.08% | 1.53% | 1.07% | 2854.09 | 29.85 |
| 26 | Uruguay | 8.43% | 3.60% | 0.41% | 703.90 | 29.11 |
| 27 | Spain | 4.20% | 1.16% | 1.25% | 2897.54 | 28.04 |
| 28 | Bulgaria | 6.74% | 1.83% | 0.82% | 2250.79 | 27.20 |
| 29 | Tunisia | 14.42% | 1.40% | 0.67% | 1826.69 | 25.44 |
| 30 | Moldova | 27.86% | 0.47% | 0,.6% | 894.05 | 19.08 |
| 31 | Algeria | 9.98% | 1.69% | 0.53% | 819.34 | 18.93 |
| 32 | Mexico | 12.88% | 1.96% | 0.34% | 316.11 | 18.31 |
| 33 | South Africa | 5.32% | 1.96% | 0.71% | 494.01 | 17.99 |
| 34 | Chile | 9.23% | 1.76% | 0.36% | 494.96 | 15.96 |
| 35 | Argentina | 0.09% | 1.49% | 0.54% | 1231.11 | 13.86 |

The results show the leadership position of historic producers such as France and Italy, which respectively fall into first and second place. Chile appears to be extremely competitive, with a strong export propensity (85.70% of production destined for export) and a structure that is capable of achieving value (5.63% of the world share of value in wine exports) [49]. The United States, ranked fifteenth, has the worst performance in international markets among countries that hold at least 2% of the world's wine export value share.

### *4.2. Measure of efficiency*

We next conduct an assessment of the distance to the global efficiency frontier by comparing countries on an intercontinental basis. Despite countries operating with different processes, this intercontinental comparison allows a sharper discrimination between intracontinental groups (Table 8) [54].

According to the results, Italy, Chile, and New Zealand are at the frontier of efficiency, defining this frontier as the

**Table 6.** Knowledge and technology index scores and ranking.

| | Nations rank | Wine Patent families/ billion PPP$ GDP | National Wine Tech Share (PCT wine/PCT total) | Patent Intensity (PCT wine/wine exp value as % of real GDP) | Share of international scientific wine topic articles published | Scientif and technical articles Wine topic/billion PPP$ GDP | Knowledge and technology index |
|---|---|---|---|---|---|---|---|
| 1 | Portugal | 0.40 | 42.57% | 2.34E+04 | 4.42% | 2.73 | 72.43 |
| 2 | Spain | 0.14 | 13.20% | 7.62E+04 | 12.88% | 1.35 | 57.42 |
| 3 | Georgia | 0.36 | 72.00% | 5.47E+02 | 0.12% | 1.02 | 53.20 |
| 4 | İtaly | 0.15 | 9.01% | 8.44E+04 | 11.58% | 0.82 | 50.42 |
| 5 | United States | 0.13 | 4.8% | 3.58E+07 | 13.69% | 0.10 | 50.05 |
| 6 | Croatia | 0.10 | 19.57% | 2.32E+04 | 0.97% | 2.35 | 46.80 |
| 7 | China | 0.07 | 1.86% | 2.52E+07 | 13.13% | 0.14 | 43.28 |
| 8 | Romania | 0.05 | 37.11% | 9.26E+04 | 2.08% | 1.32 | 43.09 |
| 9 | France | 0.18 | 6.36% | 1.23E+05 | 8.03% | 0.43 | 42.86 |
| 10 | Moldova | 0.19 | 29.81% | 1.74E+02 | 0.17% | 2.33 | 42.78 |
| 11 | Australia | 0.17 | 12.99% | 1.54E+05 | 5.25% | 0.55 | 42.58 |
| 12 | Greece | 0.09 | 19.10% | 4.58E+04 | 1.41% | 0.98 | 37.08 |
| 13 | Japan | 0.19 | 1.90% | 1.66E+09 | 1.67% | 0.05 | 35.88 |
| 14 | Bulgaria | 0.13 | 16.86% | 1.38E+04 | 0.41% | 0.93 | 35.60 |
| 15 | Hungary | 0.13 | 13.59% | 2.77E+04 | 0.68% | 0.64 | 33.03 |
| 16 | Chile | 0.09 | 13.23% | 3.36E+03 | 1.77% | 0.91 | 32.17 |
| 17 | Uruguay | 0.03 | 19.67% | 8.23E+03 | 0.48% | 1.08 | 30.5 |
| 18 | Germany | 0.10 | 2.08% | 1.30E+06 | 3.95% | 0.15 | 29.62 |
| 19 | New Zealand | 0.08 | 6.00% | 2.72E+03 | 1.55% | 1.06 | 28.57 |
| 20 | United Kingdom | 0.08 | 4.05% | 8.53E+05 | 3.14% | 0.16 | 28.12 |
| 21 | Brazil | 0.01 | 4.11% | 6.51E+06 | 4.71% | 0.35 | 27.85 |
| 22 | India | 0.04 | 5.53% | 3.01E+07 | 2.46% | 0.13 | 27.41 |
| 23 | Switzerland | 0.14 | 2.10% | 5.59E+05 | 0.92% | 0.18 | 26.6 |
| 24 | South Africa | 0.06 | 8.14% | 1.10E+04 | 1.72% | 0.65 | 26.53 |
| 25 | Turkey | 0.05 | 2.75% | 3.02E+06 | 1.63% | 0.28 | 24.20 |
| 26 | Argentina | 0.01 | 18.31% | 3.98E+03 | 1.61% | 0.42 | 24.04 |
| 27 | Russia | 0.03 | 5.07% | 8.94E+06 | 1.29% | 0.12 | 23.82 |
| 28 | Ukraine | 0.07 | 5.71% | 2.93E+04 | 0.38% | 0.43 | 23.13 |
| 29 | Tunisia | 0.02 | 11.43% | 1.10E+04 | 0.19% | 0.63 | 22.94 |
| 30 | Canada | 0.03 | 1.69% | 1.03E+06 | 2.56% | 0.22 | 21.57 |
| 31 | Bel-Lux | 0.06 | 2.30% | 8.33E+04 | 0.8% | 0.22 | 20.17 |
| 32 | Algeria | 0.01 | 10.96% | 2.78E+05 | 0.10% | 0.08 | 19.48 |
| 33 | Mexico | 0.01 | 2.55% | 1.13E+06 | 1.06% | 0.13 | 17.39 |
| 34 | Austria | 0.02 | 0.63% | 2.02E+04 | 1.05% | 0.35 | 15.67 |
| 35 | Morocco | 0.01 | 2.61% | 1.17E+04 | 0.09% | 0.10 | 12.24 |

best performance achieved. The ratio between the radial distance from the origin and the length of the segment that joins the origin to the efficiency frontier, passing through the coordinates of another country, provides other countries' efficiency [55]. Some economies are highly efficient in converting inputs into output, while others, although not reaching the efficiency frontier, are able to achieve good performance in relation to the RCAW index (Fig. 1).

First, a positive relationship emerges between innovation system efficiency and the opportunity cost in wine production described by the index. Furthermore, it is possible to define those systems above the polynomial trend of the relationship as countries that are capable of performing above their potential, even if they may not have full efficiency in the DEA score. This is the case for France, Spain, Argentina, Australia, and South Africa. United Kingdom and Bel-Lux also exhibit positive efficiency performance, with a negative comparative advantage but excellent innovation performance, which is linked to the phenomena of re-export and innovations

**Table 7.** International market performance index scores and ranking.

| | Nations rank | Share of world wine export (value) | Share of world wine export (volume) | Share of wine production exported | Wine export (.000 litres) per million of real GDP | Wine export value as share of value of all exports | Unit value of wine export (current US$/1itre) | International market performance index |
|---|---|---|---|---|---|---|---|---|
| 1 | France | 29.96% | 13.69% | 34.30% | 0.97 | 1.84% | 7.19 | 57.76 |
| 2 | Italy | 19.79% | 19.55% | 48.94% | 1.85 | 1.33% | 3.32 | 57.33 |
| 3 | Spain | 9.12% | 20.93% | 60.11% | 3.27 | 1.04% | 1.44 | 51.50 |
| 4 | Chile | 5.63% | 8.49% | 85.70% | 2.98 | 2.97% | 2.15 | 48.43 |
| 5 | New Zealand | 3.45% | 2.34% | 83.17% | 2.18 | 3.21% | 4.85 | 43.04 |
| 6 | Moldova | 0.35% | 1.35% | 81.35% | 4.01 | 5.18% | 0.86 | 42.62 |
| 7 | Georgia | 0.52% | 0.54% | 44.13% | 1.05 | 5.33% | 3.14 | 40.61 |
| 8 | Australia | 5.68% | 7.41% | 60.52% | 1.08 | 0.86% | 2.52 | 37.35 |
| 9 | Portugal | 2.54% | 2.75% | 46.44% | 1.99 | 1.46% | 3.02 | 34.27 |
| 10 | United Kingdom | 2.12% | 1.03% | 2272.47% | 0.06 | 0.15% | 6.72 | 32.08 |
| 11 | South Africa | 2.05% | 4.24% | 44.66% | 1.37 | 0.84% | 1.60 | 29.90 |
| 12 | Argentina | 2.35% | 2.43% | 21.70% | 0.56 | 1.41% | 3.19 | 27.35 |
| 13 | Germany | 3.22% | 3.58% | 41.64% | 0.21 | 0.08% | 2.96 | 24.13 |
| 14 | Bel-Lux | 0.53% | 0.38% | 261.94% | 0.13 | 0.04% | 4.54 | 23.46 |
| 15 | United States | 4.29% | 3.63% | 14.98% | 0.04 | 0.10% | 3.87 | 20.50 |
| 16 | Hungary | 0.30% | 0.63% | 21.91% | 0.73 | 0.40% | 1.52 | 19.19 |
| 17 | Austria | 0.55% | 0.50% | 22.10% | 0.22 | 0.11% | 3.63 | 17.86 |
| 18 | Switzerland | 0.35% | 0.01% | 1.33% | 0.01 | 0.04% | 9.42 | 17.58 |
| 19 | China | 1.63% | 0.09% | 1.18% | 0.00 | 0.02% | 4.76 | 16.94 |
| 20 | Greece | 0.25% | 0.27% | 11.96% | 0.22 | 0.27% | 2.98 | 15.87 |
| 21 | Bulgaria | 0.10% | 0.43% | 39.72% | 0.51 | 0.14% | 0.88 | 14.60 |
| 22 | Croatia | 0.04% | 0.04% | 10.22% | 0.11 | 0.37% | 3.41 | 14.00 |
| 23 | Canada | 0.20% | 0.62% | 121.16% | 0.07 | 0.02% | 1.02 | 13.92 |
| 24 | Japan | 0.01% | 0.002% | 1.34% | 0.0001 | 0.0002% | 12.40 | 11.87 |
| 25 | Uruguay | 0.05% | 0.09% | 12.71% | 0.06 | 0.12% | 2.17 | 11.36 |
| 26 | India | 0.02% | 0.01% | 6.12% | 0.0002 | 0.002% | 6.45 | 11.29 |
| 27 | Tunisia | 0.01% | 0.01% | 5.68% | 0.01 | 0.03% | 4.68 | 10.84 |
| 28 | Ukraine | 0.10% | 0.40% | 40.56% | 0.25 | 0.08% | 0.79 | 10.74 |
| 29 | Romania | 0.08% | 0.15% | 3.73% | 0.13 | 0.04% | 1.83 | 10.52 |
| 30 | Mexico | 0.02% | 0.01% | 2.76% | 0.001 | 0.002% | 5.78 | 10.28 |
| 31 | Morocco | 0.03% | 0.05% | 15.28% | 0.05 | 0.05% | 1.50 | 9.63 |
| 32 | Turkey | 0.03% | 0.04% | 9.39% | 0.005 | 0.007% | 2.38 | 9.13 |
| 33 | Brazil | 0.02% | 0.02% | 0.98% | 0.001 | 0.003% | 3.49 | 8.38 |
| 34 | Algeria | 0.00% | 0.002% | 0.47% | 0.001 | 0.002% | 2.51 | 7.13 |
| 35 | Russia | 0.02% | 0.05% | 1.19% | 0.005 | 0.003% | 1.56 | 5.76 |

related to distribution channels. Countries below the trend line, such as Portugal and Georgia, indicate the presence of untapped potential, with high comparative advantage and improvable efficiency scores.

Table 9 presents the efficiency scores for economies that perform under expectations that have a positive RCAW index, along with corresponding input slack. The slack values represent the quantities of input that are not fully used, indicating unused potential. Specifically, input slack values represent the quantities that could be reduced while still achieving the same results.

The results reveal that the human capital and research and knowledge and technology indices are correlated with making such systems inefficient. These findings indicate how these innovation systems generally fall short in making innovations effective and profitable, regardless of individual country cases. Human capital and innovative production are the least fully exploited factors, highlighting the complex issue of the connection between innovative production and profit effects.

**Table 8.** Top five efficient systems by region.

| Region | Nation | Efficiency frontier score (DEA) |
|---|---|---|
| Central Europe | Italy | 1 |
| | United Kingdom | 1.056 |
| | Bel-Lux | 1.078 |
| East Europe | Moldova | 1.143 |
| | Georgia | 1.329 |
| | Hungary | 2.023 |
| North and South America | Chile | 1 |
| | Argentina | 1.243 |
| | Canada | 1.809 |
| Africa | South Africa | 1.301 |
| | Tunisia | 2.468 |
| | Morocco | 2.522 |
| Asia and Oceania | New Zealand | 1 |
| | Japan | 1.014 |
| | Australia | 1.219 |

Recent new world history reveals that production expansion is not the only way to achieve export growth. For example, export growth in Chile and South Africa was possible without large initial production expansion [50]. This is attributable to a shift from low-quality wine intended for domestic consumers to high-quality wine that was primarily intended for export, with innovative approaches and investment in R&D. Such innovative production was one of the pivotal aspects of growth, and slacks in the innovation system regarding the knowledge and technology index should be considered spare capacity that is ready to be used. In this sense, nations such as Portugal (26.485) and Georgia (18.331) can be considered the systems with the highest potential if they are able to exploit and make such innovative productions marketable.

## 5. CONCLUSION

The study investigates the relationship between innovation and export performance to explore the role

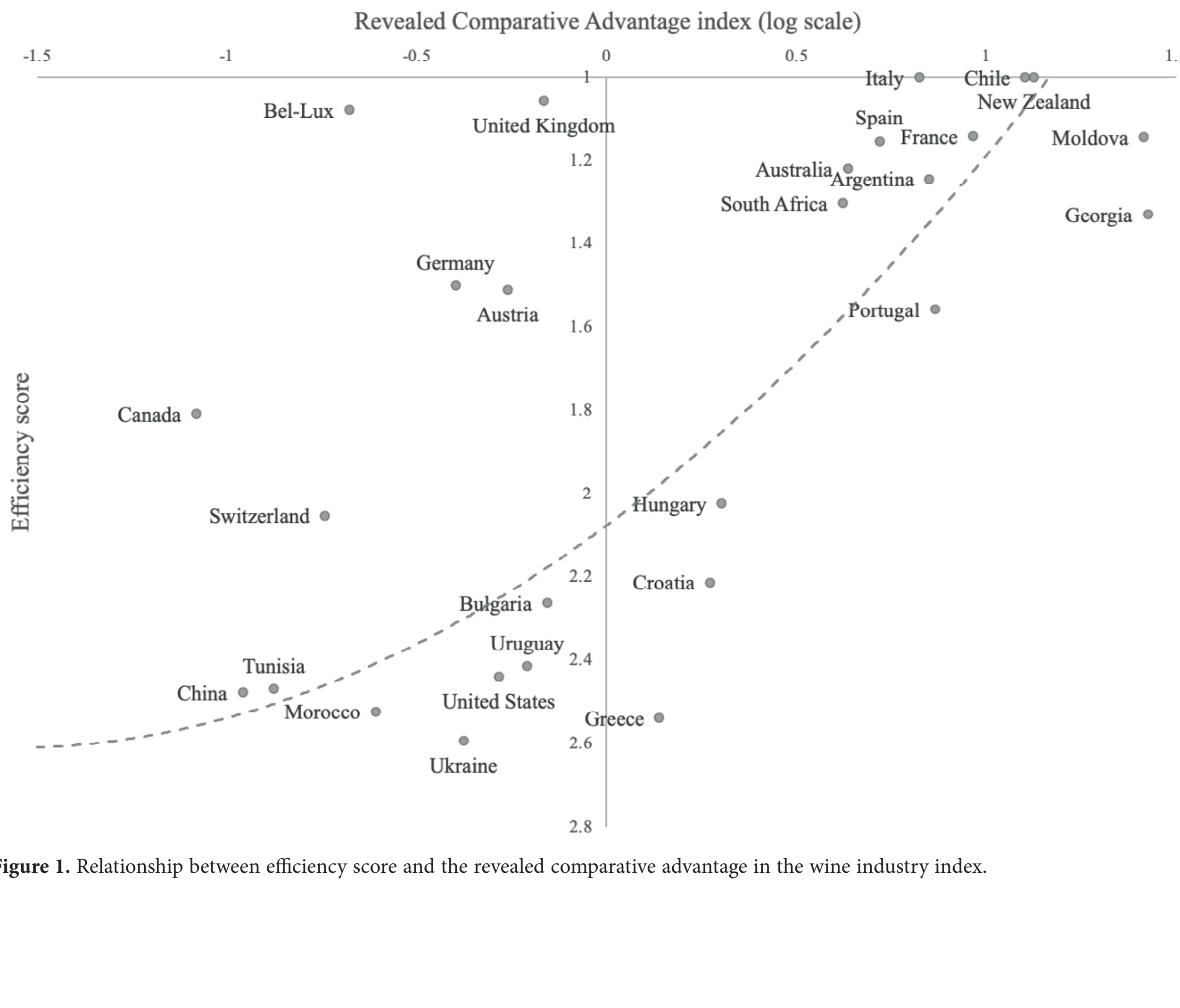


**Figure 1.** Relationship between efficiency score and the revealed comparative advantage in the wine industry index.

**Table 9.** Efficiency score and relative input slack for economies performing below expectations.

| DMU | Efficiency frontier score (DEA) | Efficiency frontier rank (DEA) | slack_input Production structure | slack_input Institutional and business environment | slack_input HC and R&D | slack_input Knowledge and technology |
|---|---|---|---|---|---|---|
| Moldova | 1.143 | 8 | 0.000 | 1.992 | 10.633 | 0.000 |
| Georgia | 1.329 | 13 | 0.000 | 0.000 | 10.323 | 18.331 |
| Portugal | 1.557 | 16 | 0.000 | 0.000 | 23.069 | 26.485 |
| Hungary | 2.023 | 19 | 0.000 | 0.000 | 26.805 | 5.829 |
| Croatia | 2.213 | 22 | 0.000 | 0.000 | 24.687 | 13.717 |
| Greece | 2.538 | 29 | 0.000 | 0.000 | 24.608 | 7.986 |

of national innovation systems in the nexus between innovation and performance. We develop a model that diverges from a sole assessment of R&D impact on performance and encapsulates the multifaceted nature of the innovation process and environment within a national system, categorizing multiple variables into production inputs, regulatory environment, human capital, types of innovation, and market performance. This approach theoretically tracks the process by which innovation outcomes influence firms' performance in international markets. The analysis reveals that historical producers have sustained their leading positions in the market by building efficient, diversified innovative systems that are capable of meeting the challenges of the international market. In contrast, less efficient countries exhibit significant potential that can be realized through targeted investments and policies to connect innovation to export demand and enhancing knowledge transfer practices.

The efficiency analysis could assist countries in improving their policy mix. It might be more effective to focus on policies to augment investments in production, regulatory, and human capital components for nations demonstrating high efficiency that aim to enhance overall performance in the international market. Moreover, given their high efficiency levels, these countries might find it challenging to boost performance without increasing innovation-related input. Examples of such countries include Italy and New Zealand, which had elevated performance in production and administrative system dimensions. Consequently, it is crucial for these nations to ensure that the escalation in innovation-related input does not result in reduced system efficiency, which requires policies tailored to enhancing the capacity to absorb incremental innovative inputs.

For countries exhibiting lower efficiency, it may be more effective to concentrate on implementing policies to enhance efficiency in converting inputs into outputs. Relevant policies can support businesses' innovation processes (such as innovation support services) and stimulate the demand for innovation. By enhancing efficiency, countries' outcomes can improve without necessarily requiring increased input investments. Moreover, if low efficiency countries solely invest in augmenting innovation inputs without adopting policies to enhance efficiency, the impact in terms of increased outcomes are at risk of being limited.

The development of a national innovation system should support the creation and demand for knowledge and expedient dissemination and absorption into entrepreneurial activities, particularly for systems with untapped potential and inefficiency. In contrast, enterprises operating within more efficient national systems will be motivated to innovate when innovation is perceived as a significant business opportunity. Related policies should aid in identifying innovative business opportunities and effectively channel support capital into the innovation process to render the innovation process self-sustaining.

In terms of methodology, our study approach incorporates a new measure of innovation efficiency that is connected to the market. The primary limitations concern the availability and quality of data, although the methodological choices are focused on decreasing any bias caused by missing data. Moreover, the relationship with wine export performance for some of the indicators used must be further investigated in future research to increase the robustness of the proposed approach. Future studies could replicate this research in other areas to validate the model in different contexts to allow cross-sector comparisons.

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