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Measuring Total Factor Productivity Change in Medium-Sized Portuguese Wine Producing Farms

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Abstract: *This article presents a study on the productivity variation of medium-sized Portuguese farms that produce wine. Quantifying these variations, commonly referred to as Total Factor Productivity (TFP), lies at the core of the economic notion of productivity. The study applies the Malmquist Data Envelopment Analysis approach, which calculates distance functions to generate indices of total productivity change. The data consists of 2 outputs and two inputs for 19 analyzed farms from 2019 to 2022. The main objective of the study was to understand if the productivity of wineries changed during the period of the COVID-19 pandemic, with a focus on the year 2020. The results show, on average, a decline in productivity during the COVID period, but with different outcomes for the set of farms, indicating that some farms were better prepared to face the COVID crisis.*

1. INTRODUCTION

The study of efficiency is an important topic for farms and has attracted many researchers, and many studies have analyzed this subject (Sequeira & Teixeira, 2024, p. 2). Efficiency is interconnected with productivity and in many situations, they tend to be confused (Teixeira & Sequeira, 2024, p. 11), but they are different concepts. Productivity is a ratio between the output generated per unit of input employed (Lovell et al., 1994, p. 177). Efficiency can be defined as the maximum output produced with a certain amount of inputs or the minimum inputs required to produce a certain amount of output (Barros et al., 2013, p. 514). Efficiency is one of the variables that contributes to productivity, but variations in productivity can also be due to technological progress and variations in scale. Another concept associated with productivity is the total productivity factor (TFP), because it allows relating more than one output and more than one input (Färe & Grosskopf, 1992, p. 158). This concept is often used in a dynamic framework where change in TFP, that is to say productivity improvement, is investigated (Malmquist, 1953, p. 211). This study aims to measure productivity variations in 19 wine producing farms in Portugal from 2019 to 2022. For this purpose, the Data Envelopment Analysis (DEA) method is applied. This method has the advantage of not requiring any requirements for a cost or profit function (Sequeira et al., 2023, p. 228). To use the DEA method, it is necessary to construct a frontier function and for calculate the TFP it is necessary to construct distance functions. Frontier functions and distance functions are closely linked and from the latter it is possible to measure productivity variations (Barros & Antunes, 2014, p. 214). Multi-input, multi-output production technology can be represented using distance functions.

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In this study, the DEA method is applied to calculate a productivity indicator. This indicator is the Malmquist index through which productivity variations are measured.

The motivation for this study is based on the importance of productivity for farms and also because to our knowledge this analysis has never been applied to wine-producing farms in Portugal. The main objective of this study is to find out whether Covid 19 had an impact on the productivity of the farms analyzed in this study.

The remainder of this paper is organised as follows. Section 2 presents the contextual setting. Section 3 details the methodology. Section 4 presents the future research directions. Section 5 concludes.

2. CONTEXTUAL SETTING

Fragoso and Vieira (2022, p. 1) state that viticulture holds a prominent position in Portugal, being a fundamental pillar due to both its cultural heritage and its economic structure. On the global stage, Portugal establishes itself as one of the leading wine producers, playing a significant role in the international wine market (Salvado & Monteiro, 2024, p. 1). This position reflects not only the country's long wine-making tradition but also the quality and diversity of its products, which contribute to its relevance in the sector worldwide (Costa et al., 2021, p. 1). Rebelo and Baptista (2024, p. 1) mention in their study that Portugal is predominantly a low-cost wine market, both in terms of domestic consumption and exports. The lack of recognition of most wines limits their potential to generate and transfer value to wine producers. Rebelo and Baptista (2024, p. 11) concluded that failures in the wine market are the result of information asymmetries and high transaction costs. In contrast, Guo and Zhong (2024, p. 80) state that the portuguese wine business model places particular emphasis on market expansion, brand development, technological advancement, and environmental sustainability. Rebelo et al. (2017, p. 320) state that the wine sector exhibits a monopolistic competition market structure. According to this model, it is relatively easy for new producers to enter the market because there are no barriers to entry. Thus, farms of various sizes compete against each other. Varas et al. (2021, p. 1105) remind us that larger farms benefit from the effect of economies of scale, which allows easier access to technical and commercial opportunities. "In this complex and competitive context, where farms need to produce and market in different segments, wine farms must meet their customers' needs at an affordable cost. Thus, to keep the wine industry competitive in an increasingly global market, efficiency is a critical factor" (Fragoso & Vieira, 2022, p. 1). Barros and Santos (2007, p. 119) state that the factors influencing efficiency are the type of organisation, resources, and location. Specifically, i) Portuguese wine cooperatives are more efficient than private wine farms; ii) wine quality, managerial competence, and distribution networks; and iii) wine regions with better reputations are more likely to be more efficient. Varas et al. (2021, p. 1104) highlight the importance of monitoring the performance of wine farms to ensure that the level of efficiency is maintained or increased in the context of competition in a global market. Jradi et al. (2019, p. 13) studied revenue efficiency, distinguishing between productivity and allocative changes. They found that the behaviour of the regions analysed is different. Alsace, Beaujolais, Loire, and Provence showed the greatest decreases in revenue due to productivity changes, while in Burgundy, Languedoc-Roussillon, and Rhône, the negative impact was due to allocative changes. In the regions of Champagne and Bordeaux, no significant differences were found between the two types of change. Jradi et al. (2019, p. 12) noted that the various regional adaptation strategies to new market conditions were influenced by the Common Market Organisation for agricultural products. Santos et al. (2020, p. 573) argue that some wine farms have a low level of efficiency, justified by the poor use of available resources. The adoption of recent technologies could lead to substantial increases in the productivity of these vineyards. Research conducted by Santos et al. (2021, p. 11) on the productive efficiency of wine farms in Northern Portugal revealed that production efficiency is intrinsically linked to the ability to adapt to regional specificities and the unique characteristics of each farm. The study highlights that, despite the importance of operational efficiency, profitability remains a critical factor, particularly for larger farms and producers specialising in Port wine. Bragagnolo et al. (2024, p. 167) assessed the productive efficiency in wine production in the southern region of Brazil and found that there were no significant differences between the actual calculated efficiency and the maximum potential efficiency in these three states. Bragagnolo et al. (2024, p. 168) concluded that the variables statistically significant in productive efficiency are the farmer's age, farming style, price, gender, and the proportion of vineyard area. The same authors noted that the size of the farm does not have a significant impact on productive efficiency. In contrast, Varas et al. (2021, p. 1105) found that smaller wine farms tend to be less efficient. Sellers-Rubio et al. (2016) found that efficiency levels are very low in the wine farms analysed in Italy and Spain. Even more concerning is the fact that average annual productivity has decreased. During this period, from 2005 to 2013, a negative trend in total productivity was observed, resulting from the interaction of two opposing dynamics. On one hand, there was technological progress that positively boosted productivity. On the other hand, this effect was offset by a reduction in the operational efficiency of the wineries. The balance between these opposing forces culminated in an overall decline in productivity in the wine sector.

3. METHODOLOGY

DEA models are widely used to measure the efficiency and productivity of Decision Making Units (DMUs). A DMU is regarded as the entity responsible for converting inputs into outputs and whose performances are to be evaluated (Coelli, 1995, p. 220). These DMUs must be homogeneous. DEA models can be applied to any sector of activity, providing a means for assessing the relative efficiencies of a set of Decision Making Units. One of the DEA models that can be applied to measure variations in productivity is the Malmquist index (Barros & Antunes, 2014, p. 214). The introduction of distance functions in the calculation of the Malmquist Index (Caves et al., 1982, p. 1395) allows the calculate of a total factor productivity index. The main objective of Malmquist TFP is to quantify variations in productivity.

When the orientation for calculating productivity takes the input perspective, it means that the analysis focuses on the level of production factors necessary to produce the observed level of output subject to a given production technology. Assuming that period t is taken as a reference, the Malmquist productivity index will be defined for periods t and t+1 as:

$$m_i^t\,(y_t, y_{t+1}, x_t, x_{t+1}) = \frac{d_i^t\,(y_{t+1}, x_{t+1})}{d_i^t(y_t, x_t)} \tag{1}$$

If we take the technology of period t+1 as a reference, then:

$$m_i^{t+1}\,(y_t, y_{t+1}, x_t, x_{t+1}) = \frac{d_i^{t+1}\,(y_{t+1}, x_{t+1})}{d_i^{t+1}(y_t, x_t)} \tag{2}$$

Since the Malmquist index from the factors perspective can be defined using either the technology of period t or of period t+1 as a reference, the Malmquist TFP index is given by the following expression:

$$m_i\,(y_t, y_{t+1}, x_t, x_{t+1}) = \left[\frac{d_i^t\,(y_{t+1}, x_{t+1})}{d_i^t(y_t, x_t)}\,\frac{d_i^{t+1}\,(y_{t+1}, x_{t+1})}{d_i^{t+1}(y_t, x_t)}\right]^{0,5} \tag{3}$$

Or simply,

$$m_i\ (y_t, y_{t+1}, x_t, x_{t+1}) = [m_i^t\ (y_t, y_{t+1}, x_t, x_{t+1}). m_i^{t+1}\ (y_t, y_{t+1}, x_t, x_{t+1})]^{0,5} \quad (4)$$

The four distance functions present in equation (3) are respectively:

$$d_i^t(y_t, x_t);\ d_i^{t+1}\ (y_{t+1}, x_{t+1});\ d_i^t\ (y_{t+1}, x_{t+1})\ \ and\ d_i^{t+1}(y_t, x_t) \quad (5)$$

Three outcomes are possible for the Malmquist TFP index:

$m_0\ (y_t,\ y_{t+1},\ x_t,\ x_{t+1}) > 1$, in this case, there is an increase in productivity;

$m_0\ (y_t,\ y_{t+1},\ x_t,\ x_{t+1}) = 1$, in this situation there is a stagnation of productivity; and

$m_0\ (y_t,\ y_{t+1},\ x_t,\ x_{t+1}) < 1$, this result highlights a decline in productivity.

4. RESULTS ANALYSIS AND FUTURE RESEARCH DIRECTIONS

The data were compiled from the Iberian Balance Sheet Analysis System (SABI). Applying the European criterion for classifying the size of farms according to the number of workers they employ, the database was divided by company size. According to this criterion, a large company employs 250 or more workers, a medium-sized company employs less than 250 people, a small company employs less than 50 people and a micro-company employs less than 10 people. The information collected from the SABI database reveals that in Portugal there are 860 wine-producing farms (farms with Code 1102 of the Economic Activity Classification) and that most of them are micro-enterprises and small farms. On the other hand, there are very few farms considered to be large farms. Our analysis focused on the group of medium-sized farms, using as a criterion the selection of farms that during the years under analysis maintained the number of workers above 50 and below 250, as shown in Table 1.

Table 1. Output matrix (Y) and input matrix (X) data

Company	Years	EBITDA	EBIT	Fixed Capital	No of employees
DMU1	2019	11 853	10 505	10 276	162
DMU2	2019	8 920	6 494	26 734	185
DMU3	2019	10 067	8 023	46 164	149
DMU4	2019	6 857	5 183	22 143	145
DMU5	2019	5 068	2 970	49 168	209
DMU6	2019	19 222	18 040	11 569	65
DMU7	2019	3 801	2 646	7 263	89
DMU8	2019	6 988	4 733	21 228	106
DMU9	2019	2 566	1 744	13 370	129
DMU10	2019	661	422	3 094	144
DMU11	2019	1 258	174	8 382	82
DMU12	2019	4 092	3 119	9 578	59
DMU13	2019	1 198	506	12 715	71
DMU14	2019	3 956	3 692	1 438	79
DMU15	2019	2 160	1 197	8 203	97
DMU16	2019	708	381	2 885	86
DMU17	2019	1 765	813	3 025	33
DMU18	2019	398	76	3 025	33
DMU19	2019	42	16	256	156

DMU1	2020	10 548	8 745	11 109	183
DMU2	2020	14 270	11 773	28 270	197
DMU3	2020	12 649	10 052	53 680	148
DMU4	2020	3 750	1 976	23 237	179
DMU5	2020	3 004	874	46 666	202
DMU6	2020	13 213	12 039	11 112	70
DMU7	2020	5 811	4 567	6 675	113
DMU8	2020	5 350	3 220	21 522	102
DMU9	2020	2 545	1 670	12 990	121
DMU10	2020	1 374	1 123	3 389	142
DMU11	2020	2 011	794	10 672	100
DMU12	2020	3 305	2 329	9 796	61
DMU13	2020	783	5	12 613	73
DMU14	2020	4 924	4 618	1 567	84
DMU15	2020	2 087	1 185	7 620	83
DMU16	2020	246	-108	2 750	82
DMU17	2020	1 411	504	4 244	46
DMU18	2020	725	456	4 244	46
DMU19	2020	51	16	233	156
DMU1	2021	10 405	8 574	9 979	174
DMU2	2021	12 805	10 060	31 023	216
DMU3	2021	12 757	10 187	54 242	178
DMU4	2021	7 221	5 445	23 345	160
DMU5	2021	6 412	2 292	80 626	262
DMU6	2021	16 302	15 090	12 251	71
DMU7	2021	4 583	3 442	7 900	95
DMU8	2021	5 777	3 627	21 323	102
DMU9	2021	2 712	1 815	12 427	110
DMU10	2021	1 179	906	3 464	130
DMU11	2021	3 099	1 879	10 520	104
DMU12	2021	4 295	3 227	9 890	68
DMU13	2021	1 001	158	12 112	68
DMU14	2021	4 701	4 294	1 973	85
DMU15	2021	3 590	2 619	8 461	90
DMU16	2021	624	317	2 652	86
DMU17	2021	1 394	592	7 149	58
DMU18	2021	1 392	1 065	7 149	58
DMU19	2021	75	36	229	157
DMU1	2022	8 175	6 386	9 042	176
DMU2	2022	10 130	7 348	34 378	231
DMU3	2022	11 232	8 998	54 132	175
DMU4	2022	10 593	8 847	22 400	154
DMU5	2022	7 970	4 035	80 606	273
DMU6	2022	14 064	12 739	12 224	72
DMU7	2022	3 322	2 225	7 607	100
DMU8	2022	6 341	4 479	20 895	108
DMU9	2022	2 197	1 261	12 194	107
DMU10	2022	1 223	915	3 418	150
DMU11	2022	3 150	1 939	10 552	107
DMU12	2022	3 699	2 639	9 812	72
DMU13	2022	1 981	1 136	12 090	63
DMU14	2022	3 293	2 802	6 777	85
DMU15	2022	3 517	2 500	8 572	98
DMU16	2022	502	185	2 561	90
DMU17	2022	1 813	1 134	7 095	62
DMU18	2022	1 049	719	7 095	62
DMU19	2022	62	27	197	150

Source: Authors based on SABI database

Our dataset covers the years from 2019 to 2022, and 19 farms are analyzed, which makes up a balanced panel with 76 observations. To construct a frontier function, it is necessary to identify outputs and inputs and ensure that they are available for all farms analyzed during the selected period. In this analysis, two outputs and two inputs were selected. The outputs are Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) and Earnings Before Interest and Taxes (EBIT) and the inputs are fixed capital and number of employees. The selection of outputs was made considering that, from an economic point of view, they are the two main levels of operating income for farms. Regarding inputs, they are naturally the most important for the activity of this sector. It is possible to detect some heterogeneity, but after applying certain tests, such as the Senguta procedure, we conclude that heterogeneity can be neglected.

Applying the Malmquist DEA method, the results are shown in Table 2.

Table 2. Malmquist index summary of annual means

Period	EFFCH-Technical efficiency change	TECH-Technological change	Malmquist total productivity change
2019/2020	1.000	0.690	0.896
2020/2021	1.000	0.910	0.948
2021/2022	0.901	1.076	0.969
mean	0,967	0.877	0.937

Source: Own research

The main objective was to determine whether COVID-19 had an impact on the productivity of the 19 farms under analysis. There is no doubt that the total productivity factor showed a decrease from 2019 to 2020 (the year with the greatest intensity of the COVID-19 effect). This means, in principle, that COVID-19 had an impact on the productivity of these farms. This result was relatively expected, even though this sector was not as exposed to the effects of COVID-19 as others. In the future, it would be important to monitor the sector about the level of productivity presented and what types of public policies can be implemented to increase the sector's productivity. Another interesting aspect to study it would be the effect of the type of management, although the difficulty to isolate this variable, it would be interesting to carry out this analysis.

In future work, the Malmquist index could be compared with other productivity indices.

5. CONCLUSION

This article analyzed the variation in productivity in 19 Portuguese wine-producing farms. The results show that in the post-Covid 19 period, the average productivity of these farms increased. However, this growth does not occur for all farms. The explanation may be partly associated with the values recorded for technological variation, which in turn is associated with investments in fixed capital. Normally, investment in fixed capital is a source of technological innovation and innovation determines productivity values.

Another conclusion that can be drawn is that although the total Malmquist productivity factor showed growth during the period under analysis, from 2019 to 2022, it recorded values below 1, which means that on average these farms experienced a decrease in terms of productivity.

This decrease in productivity may be related, as the data seem to indicate, to the lack of introduction of technological innovation in the sector. Although the wine-producing sector, like other sectors, has benefited over the last few decades from European subsidies to increase modernisation in the practices used, the reality is that in terms of productivity growth, there is no correspondence. The explanation may lie in the fact that not all farms are able to access European funds and are therefore it is a disadvantage compared to those that are able to obtain these funds to invest in fixed capital that introduces innovation. It would be useful, if information were available, to compare productivity growth between farms that benefited from European subsidies and those that were not covered by this type of support. In terms of public policy, this information is very important, as it could lead to the establishment of different criteria for access to European funds for farms that are in the same sector. And finally, in terms of public policy, it would be advisable to carry out an objective analysis of the impact that these subsidies have in terms of productivity.

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