An analysis of technical efficiency and the effect of CAP subsidies on Italian chestnut farming

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Abstract

For many rural areas of Italy, particularly hilly and mountain landscapes such as the Apennines and the Alps, the chestnut represents a typical tree crop. However, whilst various studies have analysed technical efficiency in relation to olive, wine, and citrus production, finding that land capital endowment is one of the most important inputs able to impact productivity and technical efficiency in those sectors, technical efficiency in Italian chestnut farming has not previously been investigated. The purpose of this study, then, was to assess through a quantitative approach the level of technical efficiency in chestnut farming in various Italian provinces following the NUTS 3 classification standard, and using a dataset of farms specialised in chestnut cultivation that are included in the Italian Farm Accountancy Data Network (FADN) and that received some form of CAP subsidy during the period 2008–2020. Moreover, using the results of this analysis, the study aims to evaluate the specific role that subsides allocated through the first and second pillars of the CAP have had on technical efficiency in this sector.

The findings reveal that financial subsides allocated under the first pillar of the Common Agricultural Policy have impacted technical efficiency in a positive way. The novelty of this research lies in its assessment of technical efficiency in relation to chestnut farming. Moreover, through the use of Multi-directional Efficiency Analysis, it has been possible to assess patterns of technical inefficiency in farming in some Italian provinces where chestnuts are cultivated.

Key words: DEA; MEA; FADN; first pillar of CAP

Introduction

The chestnut has always been a widely grown crop in many Italian regions, even if its cultivation underwent a steep decline in the second half of the last century (Beccaro et al., 2009). According to these authors, one of the main reasons for this abandonment was the spread of pests and diseases, such as the chestnut gall wasp and Ink disease, even if various measures, funded partially through the Common Agricultural Policy and local Italian public administrations, have been implemented with the aim of restoring plantations and preserving old chestnut groves. Despite this decline, however, the chestnut still represents a typical tree crop in many Italian rural areas, particularly in hilly and mountain landscapes such as the Apennines and Alps. In these mountainous rural areas, the chestnut is an important crop able to provide economic support for local communities (Castellini et al., 2010). In the past, Italy was one of the most important chestnut producers in the world with a peak total cultivated area of around 800,000 hectares, of which a little less than 150,000 hectares were orchard (Castellini et al., 2010). As these authors have pointed out, with the decrease in the cultivated area to about 54,000 hectares spread across some 30,000 farms, the average size of enterprises special-

ised in chestnut production is now actually very small, at slightly less than 2 hectares.

In addition to the biological factors previously mentioned, this drastic decline in chestnut cultivation in Italy has largely been due to various anthropological factors, primarily population ageing, the fragmentation of land holdings, and permanent emigration from rural areas. To contrast this, specific local forestry policies directed towards supporting the income of chestnut growers and hence, satisfy local social and economic needs, can act as driving variables to positively impact rural areas (Gullino et al., 2009; 2020). A recent study in Greece, for instance, highlighted certain policy measures that have been introduced in less agriculturally productive land that have the aim of encouraging farmers to substitute common field crops with forest cultivations such as chestnut (Zafeiriou et al., 2022). According to these authors, farmers with a strong link to their land and who use it purely for cultivation and other agricultural purposes have been encouraged to adopt ecologically sustainable agroforestry practices through public subsidies and financial incentives.

New internationally recognised marks of certified production such as Protected Geographical Indication (PGI) and Protected Designation of Origin (PDO) have presented marketing opportunities that some *Italian regions* have successfully *managed to leverage for the purpose of protecting the rural landscape as well as* improving the income of local farmers. Indeed, products marked with PDO, PGI, or other local Italian brandings such as De. C. O. recognition (Designation of Origin from a Municipality) are well appreciated by consumers, and securing such recognition has become a key to success for small local producers. Moreover, certified chestnut producers have been able to take advantage of social networks to enhance the exchange and dissemination of ideas, skills and knowhow, and innovative approaches to generate a value chain in which the network among farms and local private and public stakeholders is fundamental in bringing the product to the market (Focacci et al., 2018).

The literature on chestnut farming is predominantly focused on production in different countries, the developments and opportunities in chestnut markets, and particular aspects and problems of chestnut crops, while very little attention has been given to production costs and profitability (Bozoglu et al., 2018; Jin, 2014). Specifically, there is a complete absence of research into the effect of financial subsidies allocated through the CAP on technical efficiency in Italian chestnut farms. Furthermore, no studies have been made into technical efficiency in chestnut farming that investigate patterns of technical inefficiency in farms specialised in chestnut production in different Italian provinces, focusing on which inputs and outputs are more or less technically efficient in the production process.

Review of the relevant literature

A recent literature review has identified a number of studies regarding financial subsidies allocated through the CAP and their effect on technical efficiency in certain EU member states, but only a few of these have been focussed on Central and Eastern European countries such as Italy (Mikus et al., 2021; Minviel and Latruffe, 2017; Galluzzo, 2021). Furthermore, the analyses of technical efficiency have been centred on olive, wine, and citrus farming (Raimondo et al., 2021; Cisilino et al., 2021; Urso et al., 2018; Galluzzo, 2022; Madau, 2011; 2015), while no investigations have previously been made into chestnut cultivation.

In general, previous research findings have underlined that technical efficiency is influenced by a number of different variables in terms of input used in production, even if certain exogenous variables such as crop specialisation, type of financial subsidy allocated through the CAP, and the level of land capital endowment can themselves have a statistically significant effect on the technical efficiency of farms (Cisilino et al., 2021; Galluzzo, 2016; 2013; Latruffe et al., 2017; Gorton and Davidova, 2004; Latruffe and Nauges, 2014; Bojnec and Latruffe, 2013; Garrone et al., 2019).

Since the first reforms to the CAP implemented by European Commissioner Ray MacSharry in 1992, the productivity in farms has changed

and consequently the type of subsidies allocated to productivity have changed, having either a positive or negative effect on technical efficiency depending on the production orientation and on the type of coupled or decoupled financial support itself (Latruffe and Desjeux, 2016; Zhu and Lansink, 2010; Zhu and Milán Demeter, 2012; Minviel and Latruffe, 2017; Latruffe et al., 2017; Boussemart et al., 2019; Garrone et al., 2019). The financial subsidies allocated through the CAP have had notably mixed effects on the productivity of farms in the EU, being generally positive in the case of decoupled subsidies allocated through Pillar I as well as decoupled payments made under Pillar II, but largely negative in the case of coupled subsidies allocated under Pillar I (Garrone et al., 2019). Regardless of the relative effect on productivity of either coupled or decoupled subsidies, moreover, some studies undertaken in France have revealed that decoupled payments seem to slow down the pace of technical advancement in farms (Boussemart et al., 2019).

Broadly speaking, land capital endowment is one of the most important inputs in farming, able at the same time to impact the productivity and technical efficiency of the farm, and to influence the farmers' decision-making process of whether or not to adhere to specific CAP measures (Defrancesco et al., 2018). Focusing in depth on the role of CAP subsidies and, consequently, the decision-making process of farmers to participate in CAP policies, some studies investigating certain specialised European farms have found that coupled payments have a positive impact on farm efficiency in that they reduce the level of risk aversion in the farmer (Martinez Cillero et al., 2018; Latruffe et al., 2017; Zhu and Lansink, 2010). In fact, in other European countries, less favoured area payments and input subsidies have been found to have a fundamental and direct impact on technical efficiency in specialised farms, while the effect of investments or other types of subsidies was insignificant (Todorović et al., 2020). Zhu and Lansink argued (2010) that there is a relationship between the total amount of subsidies a farm receives as a proportion of its total revenue which impacts the farm's technical efficiency in a negative way. In contrast, some subsidies allocated as agri-environmental payments have had the effect of reducing the allocation of some inputs, the total productivity in terms of yields, and have had a negative impact on technical efficiency (Minviel and Latruffe, 2017; Galluzzo, 2021). Moreover, in regards to this aspect, as both Pagliacci et al. (2020) and Bogetoft and Hougaard (2003) argued, the participation of farmers in certain CAP measures that negatively impact technical efficiency may be the consequence of a rational decision taken by the farmer in favour of other, possibly intangible objectives that can be explained under the theoretical framework of rational inefficiency.

The purpose of this study was to assess through a quantitative approach the level of technical efficiency in chestnut farming in various Italian provinces following the NUTS 3 (Nomenclature des Unités Territoriales Statistiques) EU classification standard (Fig. 1), and using a dataset of farms specialised in chestnut cultivation that are included in the Italian Farm Accountancy Data Network (FADN) and that received some form of CAP subsidy during the period 2008–2020. Moreover, using the results of this analysis, the study aims to evaluate the specific role that subsides allocated through the first and second pillars of the CAP have had on technical efficiency in this sector.

The estimation of technical efficiency has been performed through Data Envelopment Analysis (DEA), which is able to give a value of technical efficiency in each farm but is unable to assess the pattern of inefficiency for each input used in farms to produce each type of output. Hence, in order to overcome this main bottleneck of estimating technical efficiency through DEA, the patterns of inefficiency have been assessed using a new quantitative approach. The novelty of this research lies in the investigation of technical efficiency in relation to chestnut cultivation, filling the gap in the literature that previously existed. Moreover, this research has investigated the technical efficiency in relation to each input used in farms in order to identify which are more or less efficient, also with particular attention to the effect of financial subsidies allocated through the

Fig. 1. Italian provinces with farms specialised in chestnut production that are part of the FADN dataset

first and second pillars of CAP. The policy implications of this latter aspect are very important in that such an analysis is fundamental in evaluating the impact and, indeed efficiency, of decoupled payments on technical efficiency in Italian chestnut farming.

Methodology

Generally speaking, two different methodologies can be used to assess technical efficiency in farms or other enterprises: a parametric and a non-parametric method. Through non-parametric modelling or Data Envelopment Analysis (DEA), as used in this study, it is possible to estimate technical efficiency in farms through a linear programming methodology (Coelli et al., 2005; Kumbhakar et al., 2015; Galluzzo, 2021). The DEA approach has two major advantages: firstly, the possibility to assess multiple inputs and multiple outputs in the same time, and secondly the ability to estimate a frontier of technical efficiency without the requirement to use a priori defined functions of production and other specifications in the model (Coelli et al., 2005; Galluzzo, 2021). According to Coelli et al. (2005), it is not essential to know the relationship between inputs and outputs in order to estimate a frontier of production function with linear or other function of inputs.

In this research, carried out on a sample of Italian farms included in the FADN dataset, the estimation of technical efficiency through the DEA approach has used an input-oriented variable returns to scale (VRS) model with the aim of minimising inputs. In the second stage of this research, an output-oriented model has been used since the output incorporates the financial subsidies allocated through both the first and second pillars of CAP.

Despite its advantages, however, one of the main points of weakness of the DEA is its inability to identify inefficiency or efficiency patterns in each of the input and output variables.

Table 1. Input and output variables used in the estimation of technical efficiency in Italian farms

Variable	Unit	Description
Labour	hours	Total labour input in hours worked
Land capital	ha	Usable agricultural area in farms
Fixed cost	Euros	Cost not correlated to the level of production in farms
Variable cost	Euros	Cost correlated to the level of production in farms
Assets	Euros	Fixed assets in current ownership (only). Capital indicators are based on the value of the various assets at closing valuation
Total output	Euros	Total produce of farms specialised in chestnut cultivation
I Pillar CAP subsidies	Euros	Financial payment allocated through CAP related to production
II Pillar CAP subsidies	Euros	Subsidies for Rural Development

Source: Author's own elaboration on Italian data available from FADN.

This bottleneck of the DEA can be overcome in the follow-on stage of the study by using a new approach called Multi-directional Efficiency Analysis, or MEA (Bogetoft and Hougaard; 2003; Asmild et al., 2003; Hansson et al., 2020). According to these authors, MEA has the advantage of simultaneously estimating efficiency in multi-input and multi-output models and also assessing inefficiency in each of the inputs used and outputs produced in the production process (Manevska-Tasevska et al., 2021). Using Multi-directional Efficiency Analysis, it is possible to estimate the patterns of inefficiency in inputs and outputs in terms of an excess of input used to achieve a given output.

Fig. 2. Italian provinces with chestnut productions certified as PDO or PDI

The most positive aspect of the MEA is its ability to identify deviations from the production frontier, expressed in terms of productivity change, resulting from variables not incorporated in the analysis of technical efficiency (Bogetoft and Hougaard; 2003, Hansson et al., 2020). Consequently, the MEA scores are in a range between zero, in the case of totally inefficient farms, and 1, in the case of totally efficient farms where there is no excess in inputs or outputs. A score of 1 for an investigated Italian province would indicate that there was no potential for improvement in the input/output variables, while an input efficiency score of less than one would indicate that the DMU should reduce the given input to be efficient.

The estimation of technical efficiency using both the DEA and the MEA approaches has been made using the RStudio software packages deaR, rDEA, and Benchmarking.

Results

In large part, the cultivation of chestnut crops occurs in small holdings scattered through the Italian provinces, while the vast majority of the produce is sold in local markets. The certification of chestnut productions with the PDO and PGI marks is not yet so common in Italy. In fact, of 107 provinces in Italy, only 7 are characterised by the presence of certified chestnut productions. In particular, the greatest diffusion of provinces which are part of consortia for the valorisation of chestnuts production through PDO and PGI marks is found in southern and central Italy.

Table 2. Main descriptive statistics for all chestnut farms included in the Italian FADN dataset

Variable	Observation	Mean	St. dev	Max value
Land capital	129	0.841	1.180	5.50
Labour	129	321.16	309.12	1,359.98
Fixed costs	129	1,324.82	1,885.04	12,711.91
Variable costs	129	3,326.57	5,619.66	39,682.40
Assets	129	70,483.61	132,407.20	796,776.50
Total output	129	7,739.38	9,885.91	55,244.55
I Pillar CAP	129	3,310.68	4,381.57	36,283.00
II Pillar CAP	129	3,910.90	5,292.61	24,080.00

Source: Author's own elaboration on Italian data available from FADN.

The descriptive statistics for all investigated Italian chestnut farms reveals a very narrow range of values for land capital endowment, which on average is less than 1 hectare (Table 2). In terms of labour input, the average value was around 321 hours per year. Fixed costs were lower than variable costs, while the value of assets was very high, with an average of around 70,500 Euros. Focusing on output variables, the total chestnut output averaged 7,739 Euros per year per farm. A very small difference was found between the value of financial subsidies allocated through the first and second pillars of CAP.

The findings reveal that the presence of certified chestnut productions in the provinces in which farms are located was a fundamental factor, with consequently higher values being recorded for all investigated input and output variables in all cases (Table 3). In particular, a higher land capital endowment emerges when comparing the two clusters. In fact, with the exception of the variable assets, farms located in areas that are part of certified product consortia had average values of input and output variables that were double or triple those of farms located in provinces without verified chestnut productions.

Table 4 reveals that the lowest value of land capital cultivated with chestnut was recorded in the provinces Forli-Cesena and Rieti, whilst the highest average values were found in Avellino and Firenze. In general, provinces with very small areas of chestnut cultivation had the lowest levels of inputs and output. Meanwhile, significant fluctuations emerged in the level of financial subsidies allocated through the first and second pillars of the CAP when comparing all investigated Italian provinces. The highest levels of financial subsidies allocated under the first pillar of CAP were identified in the provinces of Firenze and Viterbo, while the highest levels of financial subsidies allocated under the second pillar of CAP were found in the provinces of Salerno and Avellino.

The highest value of technical efficiency using the input-oriented DEA model was assessed in the province of Forli-Cesena, while the lowest value was recorded in the province of Arezzo (Table 5). Using the output-oriented model in order to be able to consider the output including total financial subsidies allocated through the CAP, the highest values of subsidies were recorded in the provinces of Forli-Cesena and Reggio Calabria. In general, the total amount of CAP subsidies had a positive effect in increasing the technical efficiency in chestnut Italian farms, even if a more in-depth investigation comparing the two types of pillar I and II subsidies show that subsidies allocated under the first pillar of Common Agricultural Policy have had the greatest effect in increasing the level of technical efficiency in chestnut farms.

Farms located in provinces in which the chestnut is part of a certified production have been found to have a lower technical efficiency than farms located in provinces without certified quality products. In specific terms, the research findings reveal that in the former cluster of provinces, the average technical efficiency score estimated using the DEA input-oriented model was 0.88 compared to around 0.82 for the latter. This result was verified with a t-test that showed a p-value < 0.01, corroborating the significant difference between these two clusters of farms. The results of the technical efficiency analysis using the output-oriented approach further corroborated the statistical difference between these two groups of farms. It can, therefore, be asserted that farms not located in provinces characterised by certified

Table 3. Average value of the main descriptive statistics for all chestnut farms included in the Italian FADN dataset in function of their location in provinces whish are part of certified productions

Variable	Farms located in areas with certified chestnut production	Farms not located in areas with certified chestnut production
Land capital	1.15	0.39
Labour	411.04	195.97
Fixed costs	1,811.67	638.74
Variable costs	4,339.30	1,910.41
Assets	100,163.70	28,460.48
Total output	10,060.49	4,495.82
I Pillar CAP	4,080.46	2,249.28
II Pillar CAP	5,326.35	1,917.39

Source: Author's own elaboration on Italian data available from FADN.

Table 4. Main descriptive statistics for all Italian provinces with chestnut farms included in the FADN dataset

Province	Land capital	Labour	Fixed costs	Variable costs	Assets	Total output	I Pillar CAP	II Pillar CAP
Arezzo	0.81	654.66	3,066.00	4,094.00	70,405.00	16,129.00	2,296.00	2,695.00
Avellino	2.19	178.38	653.00	1,515.00	53,765.00	5,135.00	1,821.00	7,124.00
Bologna	0.55	176.66	805.00	3,891.00	71,606.00	5,445.00	3,401.00	2,028.00
Caserta	1.61	410.77	721.00	2,818.00	27,160.00	6,094.00	0.00	0.00
Catanzaro	0.27	143.97	451.00	888.00	10,462.00	2,120.00	256.00	0.00
Crotone	1.35	452.58	962.00	2,867.00	28,376.00	9,439.00	2,002.00	2,873.00
Cuneo	0.10	257.31	590.00	2,222.00	21,422.00	3,825.00	2,671.00	2,471.00
Firenze	1.67	720.24	4,394.00	11,561.00	116,777.00	23,567.00	8,782.00	5,899.00
Forli-Cesena		22.17	40.00	390.00	2,045.00	179.00	4,259.00	1,823.00
Genova	0.04	100.97	636.00	340.00	13,819.00	1,715.00	84.00	0.00
La Spezia	0.09	294.18	1,601.00	1,805.00	82,181.00	11,434.00	1,300.00	4,073.00
Massa-Carrara	0.13	153.59	155.00	144.00	7,592.00	864.00	405.00	0.00
Ravenna	0.68	236.64	1,154.00	9,385.00	93,833.00	8,754.00	1,533.00	574.00
Reggio di Calabria	0.23	161.53	344.00	1,072.00	4,278.00	2,062.00	3,665.00	3,889.00
Rieti	0.02	19.41	228.00	179.00	355.00	458.00	1,787.00	3,899.00
Salerno	1.24	469.92	697.00	2,844.00	303,861.00	6,758.00	2,565.00	8,537.00
Viterbo	0.98	259.11	1,807.00	3,642.00	43,755.00	6,079.00	6,483.00	5,927.00
Average	***0.84***	***321.15***	***1,324.00***	***3.327.00***	***70,484.00***	***7,739.00***	***3,311.00***	***3,911.00***

Source: Author's own elaboration on Italian data available from FADN.

Table 5. Technical efficiency estimated for all chestnut farms included in the Italian FADN dataset

Province	DEA input oriented	DEA output oriented I and II pillar subsidies	DEA output oriented II pillar CAP	DEA output oriented I pillar CAP
Arezzo	.5879274	.6228445	.5540064	.5853966
Avellino	.8279506	.9175598	.8954498	.8015783
Bologna	.8173561	.848993	.801208	.848993
Caserta	.793325	.7632818	.7632818	.7632818
Catanzaro	.9079632	.8825649	.8805778	.8825649
Crotone	.6597472	.7064071	.6303593	.6998846
Cuneo	.8208439	.8874405	.7914659	.8749595
Firenze	.6313709	.7536509	.6539284	.7328624
Forlì-Cesena	.9872332	.9857633	.9819886	.9857633
Genova	.9377823	.9036126	.9036126	.9036126
La Spezia	.7861419	.8373429	.8016026	.7045747
Massa-Carrara	.96556	.9403459	.933638	.9403459
Ravenna	.8697983	.8703835	.8610894	.8703835
Reggio Calabria	.7972653	.9724343	.8487553	.9512805
Rieti	.8600464	1.000	.864265	.9874917
Salerno	.7419159	.8598158	.7504799	.777466
Viterbo	.8213624	.9161406	.8499117	.8945753
Average	***.792781***	***.8548237***	***.7957815***	***.8184716***

Source: Author's own elaboration on Italian data available from FADN.

chestnut productions achieve a statistically higher level of technical efficiency than farms not located in provinces with certified productions.

The comparison of technical efficiency across the two clusters of farms has revealed that those located in provinces that do not have a food quality certification for their chestnut production had generally higher values of technical efficiency (Table 6). Turning our attention to patterns of inefficiency in chestnut farming, the research findings show significant differences in efficiency in regard to all inputs, particularly labour, land, and assets, which have been less technically efficient in chestnut farms located in provinces with certified chestnut productions. In terms of total output, if there is a statistically significant difference between the two clusters, no such differences have been recorded considering the financial subsidies allocated through the first and second pillars of the Common Agricultural Policy.

Discussion and conclusion

This study represents a new strand in the economic literature, assessing the technical efficiency in farming in relation to a permanent crop such as the chestnut. The findings hold some important policy implications in regards to the allocation of financial subsidies disbursed through the CAP. Italian chestnut farming is characterised by the presence of small farms predominately located in mountainous rural areas, and this has a number of negative repercussions on the technical efficiency of farms. Indeed, the results are similar to those of other studies described in the literature review, according to which land capital represents one of the most significant variables that is able to impact the technical efficiency of farms (Cisilino et al., 2021; Galluzzo, 2016; 2013; Latruffe et al., 2017; Gorton and Davidova, 2004; Latruffe and Nauges, 2014; Bojnec and Latruffe, 2013; Garrone et al., 2019). Furthermore, the financial subsidies allocated through the first pillar of the Common Agricultural Policy seem to positively impact the technical efficiency of farms, corroborating the previous research findings of other authors (Latruffe and Desjeux, 2016; Zhu and Lansink, 2010; Zhu and Milán Demeter, 2012; Minviel and Latruffe, 2017; Latruffe et al., 2017; Boussemart et al., 2019; Garrone et al., 2019).

The results show that the financial subsidies allocated through the CAP, and particularly the first pillar of CAP, have a positive effect. Regardless of this, the results of this research show that the Italian chestnut sector has received more financial support through the second pillar than the first. Using Multi-direction Efficiency Anal-

Table 6. Technical efficiency estimated for each input and output using MEA and DEA for all chestnut farms included in the Italian FADN dataset

Cluster	Technical efficiency	Labour	Land	Fixed costs	Variable costs	Assets	Output	I Pillar CAP	II Pillar CAP
Farms not located in provinces with certified chestnut productions	0.867	0.940	0.917	0.927	0.925	0.929	0.925	0.750	0.597
Farms located in provinces with certified chestnut productions	0.783	0.898	0.830	0.881	0.865	0.869	0.882	0.730	0.602
Average	0.817	0.915	0.865	0.900	0.889	0.894	0.899	0.737	0.601
t-value	2.83	3.38	4.10	2.79	3.38	3.50	2.30	0.33	-0.06
significance	***	***	***	***	***	***	***	n.s.	n.s.

**P < 0.001*

Source: Author's own elaboration on Italian data available from FADN.

ysis, it has been possible to describe the pattern of inefficiency in terms of an excess of used input or produced output in all farms and in function of the location of farms in provinces with a certified chestnut production. The findings in relation to the two inputs of labour and land shows that farms adhering to certified production marks registered an excess in terms of labour, largely due to the need to respect the constraints imposed by the consortium regulations. Drawing some conclusions, the research findings have underlined the fundamental role of land capital as the one input able to affect the level of technical efficiency in chestnut farms. Looking to the future, therefore, it is important to increase the amount of financial subsidies allocated through CAP, bearing in mind that the typology of the financial subsidy has an effect on the total technical efficiency of farms. If the financial subsidies allocated through the first pillar of CAP can compensate the income of farmers, the payments allocated through the second pillar are fundamental for encouraging the diversification of farming, and reducing the phenomena of land fragmentation and permanent emigration from the countryside that are typical of the mountainous areas in which the chestnut represents an important crop.

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