Volume 14 No 2 2022

Regional and Business Studies

ISSN 2732-2726 (Online)

Hungarian University of Agriculture and Life Sciences, Institute of Rural Development and Sustainable Economy, Kaposvár Campus

Regional and Business Studies

Regional and Business Studies is a scientific journal published several times a year, and contains original scientific reports, research results, critical résumés, conference reviews and letters to the editor. The topics of journal include the important fields of rural development, regional, economic- and social science.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM
Fenntartható Fejlesztés és Gazdálkodás Intézet

Hungarian University of Agriculture and Life Sciences, Institute of Rural Development and Sustainable Economy, Kaposvár Campus

Editorial office

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ISSN 2732-2726 (Online)
ISSN 2061-2311 (Print until 2020)

Published and distributed by
Hungarian University of Agriculture and Life Sciences,
Institute of Rural Development and Sustainable Economy,
Kaposvár Campus
H-7400 Kaposvár, Guba Sándor u. 40.

Responsible for publication

Dr. Zoltán BUJDOSÓ, PhD
Head of the Institute

Kaposvár, January 2023

CONTENTS

Regional and Business Studies (2022) Vol 14 No 2, 5-20
Hungarian University of Agriculture and Life Sciences Kaposvár Campus
Kaposvár
doi: 10.33568/rbs.4434

AN OVERVIEW OF PERFORMANCE MEASUREMENT FOR DEMAND FORECASTING BASED ON ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Demand forecasting is an essential task to match supply and demand. From a supplier's view, demand forecasting is important to optimize supply chains and thus maximize profits. The ever-increasing availability of data that can be used as input factors for predictive models allows more and more sophistication for diverse forecasting tasks in the context of demand forecasting. On the one hand, increasingly complex models have been used for demand forecasting over the last years, from simple exponential smoothing methods and ARIMA models up to complex, hybrid (deep) artificial neural networks. On the other hand, little attention is paid to the methods that evaluate the forecasting performance of these models, which are essential for the selection from among potential forecasting models. In this article, we aim to answer the question of what are the most favourable measurements in recent literature on applied neural network demand forecasting for supply chain management. To this end, we analyzed 193 relevant publications in which demand forecasting was applied using artificial neural networks. We found that in artificial neural network demand forecasting used to evaluate forecasting performance, Mean Absolute Percentage Error, Root Mean Squared Error, Mean Squared Error and Mean Absolute Error are by far the most popular methods. Furthermore, we found that when forecasting performance measurements are combined, the most common combination is the combination of Mean Absolute Error, the Root Mean Squared Error and the Mean Absolute Error.
Keywords: artificial neural networks, decision support systems, performance measurements, supply chain management

INTRODUCTION

From a higher level, demand forecasting is an essential task to match supply and demand. From a supplier's view, demand forecasting is key to optimising supply chains and thus maximising profits. The planning of the expected demand is the first step in putting together a business model and consequently, the basis of all planning activities (*Haberleitner et al.*, 2010). The increase in the global competition meant that, on the one hand, storage costs were cut while the availability of products improved. This requires a high level of forecasting of the expected demand (*Lewis*, 1997;

Carbonneau et al., 2008). In the retail sector, demand forecasting is used to estimate which products the seller will provide and in what quantity (e.g. *Fildes et al.*, 2022). If the forecast is too low, the customers who cannot be served will change vendors and possibly the image will be damaged. If the forecast exceeds demand, the products will remain in stock and spoil, or their storage will incur storage costs. In both cases, there is financial damage. After all, in the retail sector, a time gap between supply and demand can be compensated for by proper warehousing. This is not the case in other sectors. In the case of electricity, an existing demand must be covered by an offer from the energy supplier. It goes without saying that the potential damage from large-scale power blackouts is significant (*Suganthi & Samuel*, 2012; *Ghalehkhondabi et al.*, 2017). In the tourism sector, a good demand forecast is also essential. Based on the expectations in the sector of tourism, logistics capacities in the form of flights, hotel capacities, but also capacities for staff and food are provided in advance. If the forecast is above the demand, inefficiencies arise because these capacities are not called up and cause financial damage on the one hand, and on the other are not available elsewhere. If the forecast is too low and the capacities provided based on it is also too low, customers will be dissatisfied because the quantity or quality of service is insufficient. This causes substantial damage to the respective holiday region (*Burger et al.*, 2001; *Andrawis et al.*, 2011). These three examples show that an accurate forecast of the demand is very important. The ever-increasing availability of data that can be used as input factors for prediction allows more sophisticated models to be constructed and operated in practice. This means that increasingly complex models have been used for demand forecasting over the past ten years, from simple exponential smoothing methods, and ARIMA models to complex hybrid (deep) artificial neural networks (*Schmidhuber*, 2015). Forecasters must always ask themselves which forecasting model is the best for their respective area of application. This raises the question of how the accuracy of a forecasting model is measurement and how different forecasting models can be compared. Forecasting performance measurements or forecasting accuracy measurements quantify the accuracy of forecasts. Dealing with these methods and selecting the appropriate forecasting performance measurement for the respective application is very important, as it has a direct influence on the choice of the forecasting model and consequently, on the result that is to be achieved with forecasting (*Makridakis*, 1993). Given the importance of forecasting performance measurements, this article aims to answer the question of which are the most favored forecasting performance measurements are in the recent literature on artificial neural network demand forecasting. For this purpose, we conducted an analysis of relevant research in which demand forecasting was carried out using artificial neural network methods. In this article, we want to answer the following research questions.

Research question 1: What are the most frequent forecasting performance measurements used for applied artificial neural network demand forecasting?

Research question 2: What are the most frequent combinations of forecasting performance measurements?

We performed a Google Scholar search and analyzed 193 papers in the context of applied artificial neural network demand forecasting in detail for their used methods,

their area of application and their forecasting performance criteria. With this dedicated study, we can provide a complete overview of the forecasting performance measurements used in demand forecasting over the last ten years. As far as we know, there is no systematic treatment of the forecasting performance measurements used in the field of demand forecasting using methods of artificial intelligence. We want to help the users of forecasting methods to critically deal with the properties of the forecasting performance measurements and use them consciously and specifically in the context of a given forecasting framework. We explain the advantages and disadvantages of the most frequently used forecasting performance measurements and which alternative methods are the more suitable. Our article is organized as follows. We provide an overview of the most important research on demand forecasting using artificial neural networks and forecasting performance measuring. Then we describe the methodology we used to conduct our systematic literature review. We then discuss the results in detail. Finally, we summarize the most important findings and give an outlook on possible further research.

THEORETICAL BACKGROUND

The literature, including *Armstrong* (2001) and *Thonemann* (2010), distinguishes between three basic approaches to predicting customer demand: qualitative forecasts, causal forecasts, and time series forecasts. In this paper, we focus on research using time series demand forecasting. Time Series Forecasting is based on historical data using time series analysis methods. A connection between the past and the future of a variable is assumed. Applied to the prediction of customer demand, this approach draws a conclusion on future demand based on historical demand. The methods for forecasting time series and their fields of application are quite numerous. A good overview can be found in *De Gooijer & Hyndman* (2006). We first provide a brief overview of forecasting time series using artificial neural networks and then briefly review the literature related to forecasting performance measurements.

Artificial Neural Networks for Demand Forecasting

Artificial Neural Networks (ANNs) have become a very popular approach for modelling and predicting time series. ANNs are based on the idea that by networking many individual calculations, the functioning of the human brain can be simulated and thus the ability to solve a variety of (non-linear) problems is created. The versatile applicability is exactly the reason why ANNs became so popular. *McCulloch & Pitts* (1943) were the first to model the artificial neuron. Combinations of these neurons then form an artificial neural network. With the perceptron, which consists of a single artificial neuron with adjustable weights and a threshold value, *Rosenblatt* (1958) published the simplest form of an artificial neural network. The building blocks of an ANN are the artificial neurons, which are arranged in different layers. From the input layer, information enters the network in the hidden layers, which process the information, and finally in the output layer, which gives the information out. Since the first neural networks, research on artificial neural networks has progressed steadily and has been applied to a wide range of problems. A good overview of the

development of ANNs can be found in *Schmidhuber* (2015) and *Goodfellow et al.* (2018). The neural networks can be roughly divided into the following categories: shallow neural networks (e.g. *Aggarwal*, 2018), multilayer perceptrons, also called deep neural networks (e.g. *Schmidhuber*, 2015), convolutional neural networks (e.g. *Gu et al.*, 2018), recurrent neural networks (e.g. *Salehinejad*, 2017), long-short term memory neural networks (e.g. *Yu et al.,* 2020), attention based neural networks (e.g. *Wang et al.*, 2016) and generative adversarial network (e.g. *Creswell et al.*, 2018). Numerous applications of artificial neural network demand forecasting can be found in the literature. *Ryu et al.* (2016) used deep learning to forecast the short term electricity demand. *Constantino et al.* (2016) forecast tourism demand by ANNs. *Wanchoo* (2019) proposed a deep learning model to forecast retail demand. Babai (2014) used an ANN to forecast intermittent demand. *Panapakidis & Dagoumas* (2017) forecast natural gas demand one day in advance using a hybrid artificial neural network. *Ke et al.* (2017) have examined the demand for on-demand ride services, and *Kilimci et al.* (2019) used a deep learning model to forecast demand in a supply chain framework.

Forecasting Performance Measuring

As there are a lot of different approaches to forecast demand, from the point of view of a decision-maker, the question now arises as to which of the different forecasting models is to be preferred. To assess this, *Granger & Pesaran* (2000a) remarked that a decision-maker needs one or more criteria to compare the performance of given forecast models. *Granger & Pesaran* (2000a) and *Granger & Pesaran* (2000b) noted that it is crucial for decision-making based on forecasts, that the forecasts are linked to a cost- or loss function, which quantifies the forecasting error in terms of the specific forecasting problem. Therefore, a fundamental problem for the decision-maker is the selection of a suitable forecasting criterion, to measurement the accuracy of forecasting or a loss function which quantifies the forecasting error. *Makridakis* (1993) wrote that from an ex-ante perspective, the decision-maker cannot judge which forecasting model is the best model, since a sample of forecasts must be made to assess the forecasting performance using a forecasting performance measurement. This means that the forecasting performance measurement that best provides information about future forecasting performance should be used. From an ex-post situation, an evaluation of different forecasting models is possible by forecasting performance measurements. It is important to realize that future forecasting performance would be influenced by the choice of a forecasting performance measurement. This happens insofar as the forecasting performance measurement is used to decide regarding the forecasting method used in the future, based on the perceived performance today. This means, that when deciding between two forecasting models, one forecasting measurement can prefer one model and another measurement can prefer another one, *Makridakis* (1993) remarked. Another dependency is the scope of the forecasting horizon. So, the outcome of a forecasting performance measurement can change with different forecasting horizons. This shows that a consistent selection of forecasting model is not easily possible, as *Clements & Hendry* (1993) showed this in the example of the mean square forecast error (MSE). To overcome this problem, *Diebold & López* (1996) formulated properties that optimal forecasts should possess. The following properties

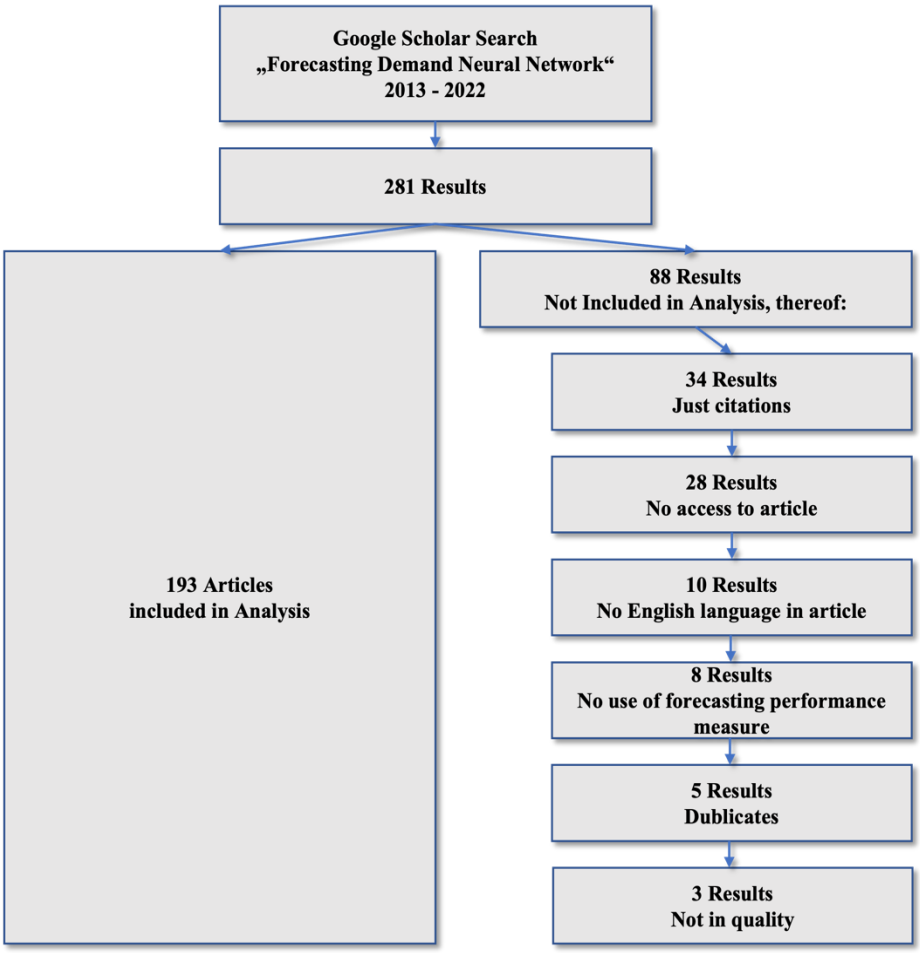
should therefore apply to the forecast errors of an optimal k-step ahead point forecast of a linear forecast model: the forecast errors have a zero mean, the 1-step ahead forecast errors following a white-noise process, the k-step ahead forecast errors following a MA(k-1) moving average process and the k-step ahead forecast error variance is not decreasing in k. So, these properties can be tested statistically. Moreover, for the ex-post comparison of two forecasts, *Diebold & Mariano* (2002) showed other approaches which test statistical significance whether one forecast has the same forecasting accuracy as the other one. However, these methods are not found in many application-related articles. Instead, and we will go into this in detail later in the Results, methods section, the Mean Average Percentage Error (MAPE), the Mean Square Error (MSE) or the Root Mean Square Error (RMSE) are used. *Hyndman & Koehler* (2006) note that the MAPE is often recommended for example by *Hanke and Reitsch* (1995); *Bowerman et al.* (2003) and *Makridakis et al.* (1982). There is a wide variety of practical applications. *Petrucci et al.* (2022); *Porteiro et al.* (2020) and *Jnr et al.* (2021) used the MAPE to benchmark models for the forecasting of electricity demand. The RMSE was used by e.g. *Zhang et al.* (2020); *Anisa et al.* (2021) and *Liang* (2022) to compare forecasts of tourism demand. *Slimani et al.* (2015); *Chawla et al.* (2019); *Herrera-Granda et al.* (2019) and *Maragkos* (2020) made their retail forecasting model selection by the MSE.

METHODOLOGY

Our research was conducted as a systematic literature review, which entails a thorough, transparent, and replicable process for literature search and analysis. This choice of method is suitable as the research questions require a quantitative overview of existing usage of methods and areas of application for demand forecasting. We made our search in Google Scholar (http://scholar.google.com). We decided to use We chose Google Scholar for the literature research because it provides a simple search, finds many sources, lists documents soon after they are published and has a good relevance ranking. The search for 'Forecasting' and 'Demand' and 'Neural Network' which are in the title of the paper was conducted from the 28th of January 2023 to the 14th of February 2023. To examine the current literature, we restricted the search to research between 2013 and 2022. With these search strings, the total number of hits was 281 publications. All hits were collated in an Excel spreadsheet as a record of the search. We then carried out a filter with regard to the type of publication, language, quality and accessibility of the publications we found. Furthermore, we only used publications that shed light on a practical forecasting problem in the supply chain context. This procedure is presented in *Figure 1*. In total, from 281 hits, we excluded 88 hits because they were just citations (34 hits), we had no access to the publication (28 hits), the publication was not written in the English language (10 hits), there was no explanation about the usage of a forecasting performance measurement (8 hits), the publication was listed twice (5 hits) or the publication was bad quality (3 hits). To be able to make our evaluations, we recorded the following details of the publication: reference, date, number of citations, the field of application of demand forecasting, forecasting method, back propagation algorithm and forecasting accuracy measurement. For the evaluation of the used

forecasting performance measurements, we analyzed the publications in our database and collected the forecasting performance measurements that were used in the research in a database. We recorded all the procedures mentioned in the publication, and we also allowed multiple entries. Then we calculated the absolute and relative frequencies across all recorded performance measurements. An overview of the various forecasting performance measurements can be found in articles by *Chen & Yang* (2004) and *Koutsandreas et al.* (2022).

Figure 1: Methodology of literature collection



RESULTS

Using a systematic literature review, we investigated the forecasting performance measurements for demand forecasting based on neural network in supply chain frameworks. We found that by far the most frequently used measurements are

MAPE, RMSE, MSE and MAE. Although these metrics have well-known weaknesses, they are widely used in relevant research. Different measurements are often used in combination with research. We have analyzed which combinations of forecasting performance measurements are used and found that the combination of MAPE, RMSE and MAE are used most frequently. In the following, we discuss these two results in detail.

Most favourite forecasting performance measurements for neural network demand forecasting

We analyzed a total of 193 publications and collected 343 database entries of forecasting performance measurements. We collected all measurements which were used. Overall, we collected 29 different forecasting performance measurements (*Table 1*). However, as we will discuss it later, only a small number of these measurements have been widely used.

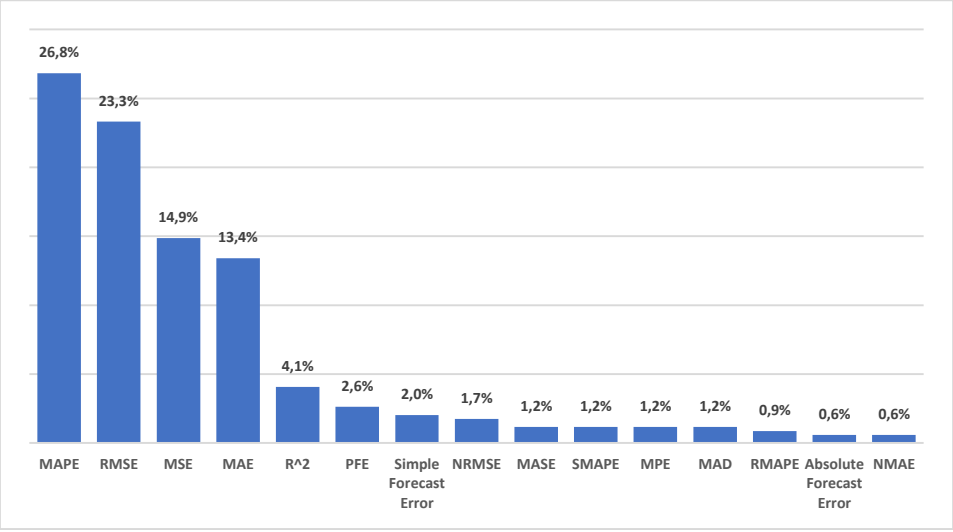
Table 1: Overview of all collected different forecasting performance measurements

Absolute Forecast Error (AFE)	Average Relative Mean Absolute Error	Coefficient of Determination (R^2)
Correlation Coefficient	Diebold-Mariano Test (DM-Test)	Mean Absolute Deviation (MAD)
Mean Absolute Error (MAE)	Mean Absolute Percentage Error (MAPE)	Mean Absolute Relative Error
Mean Absolute Relative Normalized Error (MARNE)	Mean Absolute Scaled Error (MASE)	Mean Negative Error (MNE)
Mean Percentage Error (MPE)	Mean Positive Error (MPE)	Mean Squared Error (MSE)
Nash-Sutcliff-Index	Normalized Mean Absolute Error (NMAE)	Normalized Mean Squared Error (NMSE)
Normalized Root Mean Squared Error (NRMSE)	Pearson Product-Moment Correlation Coefficient (PPMCC)	Percentage Forecast Error (PFE)
Relative Mean Absolute Percentage Error (RMAPE)	Relative Root Mean Squared Error (RRMSE)	Root Mean Squared Error (RMSE)
Root Mean Squared Scaled Error (RMSSE)	Simple Forecast Error	Sum of Squared Errors (SSE)
Symmetric Mean Absolute Percentage Error (SMAPE)	Wilcoxon-Signed-Ranks Test	

On average, every research paper used 1.78 different forecasting performance measurements. This is particularly useful when measurements with different properties are combined and thus allowing the evaluation of a forecasting model under various aspects. *Figure 2* presents the most popular forecasting performance measurements in the collected sample, which were found more than once. It can be seen that four measurements are particularly common. With a total count of 92 (26.8% of overall 343 recorded forecasting performance measurements), we can observe that the Mean Average Percentage Error (MAPE) is the most preferred

measurement. This is probably the case because the MAPE is scale independent and it is easy to interpret and compute, which makes it very popular among practitioners (e.g. *Byrne*, 2012). A significant disadvantage is that only data without zero and extreme values are necessary for the MAPE. If the true value is extremely small or large, MAPE value takes on an extreme value (*Kim & Kim*, 2016). In practice, many datasets contain zeros in the realized values, e.g., in retail, when no transaction takes place. To obtain a usable MAPE value, these observations would have to be removed as outliers from the sample used to calculate the MAPE. A specific suggestion was made by *Makridakis* (1993) who proposed to exclude values with actual values less than one or with an average percentage error values greater than the MAPE plus three standard deviations. However, since these are normal observations, the sample is distorted, and comparison is made more difficult. Another method *Makridakis* (1993) suggests is the replacement if the MAPE by the Symmetric Mean Absolute Percentage Error (SMAPE). In our analysis, however, the SMAPE was only used 4 times (1.2%). *Hyndman & Koehler* (2006) also recommended dispensing with the MAPE and using the Mean Absolute Scaled Error (MASE) instead.

Figure 2: Favourite performance measurements of demand forecasting



Sample size = 343 collected forecast performance measurements

However, the MASE was only used 4 times (1.2%) in the research papers we analyzed. In general, *Swanson et al.* (1999) have noted that measurements based on percentage errors, like the MAPE, are often highly skewed, and therefore transformations such as logarithms can make them more stable. *Clements et al.* (2004) discusses this in more detail. We did not find a measurement based on log transformation in our analysis. The second most common measurement is the Root Mean Square Error (RMSE) with a total count of 80 (23.3%). As mentioned above, the RMSE is defined as the root of the Mean Square Error (MSE), which is also a very

common measurement. Due to the square root function, the RMSE is in the same unit as the forecast and true values and is, therefore, easier to interpret than the MSE. Its popularity in our research is also consistent with former research, such as *Carbone and Armstrong* (1982) who found that RMSE is preferred by practitioners. On the other hand, *Armstrong and Collopy* (1992) found that the RMSE is not reliable in terms of the repeated application of a method that produces the same results. By using the Spearman rank-order correlation, they showed that the RMSE is not consistent in producing accurate rankings of out-of-sample forecasts of different time series extrapolation methods and performed worse than for example the MAPE. *Willmott & Matsuura* (2005) found that the RMSE approaches the mean average error for a small number of observations and increases as the number of observations increases. They, therefore, recommend that the measurement is not adequate for average model performance and do not suggest the use of it. In opposition to this, *Chai & Draxler* (2014) mentioned that RMSE is appropriate for Gaussian distributed errors resulting from the forecast models. Another measurement that is also used very frequently is the Mean Squared Error (MSE). We found that it was used 51 times in total and a share of 14.9%. The MSE is for a long time the dominant performance metric in the field of signal processing (*Wang & Bovik*, 2009). A major reason for this is probably the simple calculation, but also its properties of a valid distance metric, its physical interpretability and its excellent properties in optimization contexts. Besides, the MSE is widely used and it is therefore an established practice to compare forecasting model performance (e.g. *Wang & Bovik*, 2009). Because of the quadratic term, large errors are weighted more than small ones. The MSE is more difficult to interpret in different contexts because it is no longer in the original units of measurementment of the observed values due to the quadratic expression. The Mean Absolute Error (MAE) is the fourth most common forecasting performance measurement because the error value units match the predicted target value units. In the research articles we reviewed, the MAE was used a total of 46 times, with a share of 13.4%. The changes of the MAE are linear and therefore intuitive, unlike RMSE or MAPE. Since the error values are measurementd in the original units, the MAE is not suitable for evaluating forecasts from different units. Moreover, the errors are not weighted differently, but are treated equally. For example, MSE and RMSE penalize larger errors more. (*Schneider & Xhafa*, 2022). When measuring an average model accuracy *Chai & Draxler* (2014); *Willmott et al*., (2009) and *Willmott & Matsuura* (2005) showed that MAE outperforms RMSE in most situations, especially at Laplace distributed forecast errors, but worse in Gaussian noisy scenarios (e.g. *Qi et al*., 2020). As we observed, these four performance measurements account for more than 78% of the total measurements collected. According to the research articles we analyzed, this is mainly due to the following. First, these measurements have been in use for a long time and have therefore been widely used in the relevant research. This is likely to improve the comparability of research on forecasting. Second, they're easy to interpret as they use the same scaling as the analyzed time series, except for the mean square error. However, we have also seen that there is widespread criticism for the usage of scale-dependent measurements (e.g.: MAE, RMSE), measurements based on percentage errors (e.g.: MAPE) and measurements based on relative errors (MRAE). A good overview of this criticism is provided by *Hyndman and Koehler* (2006).

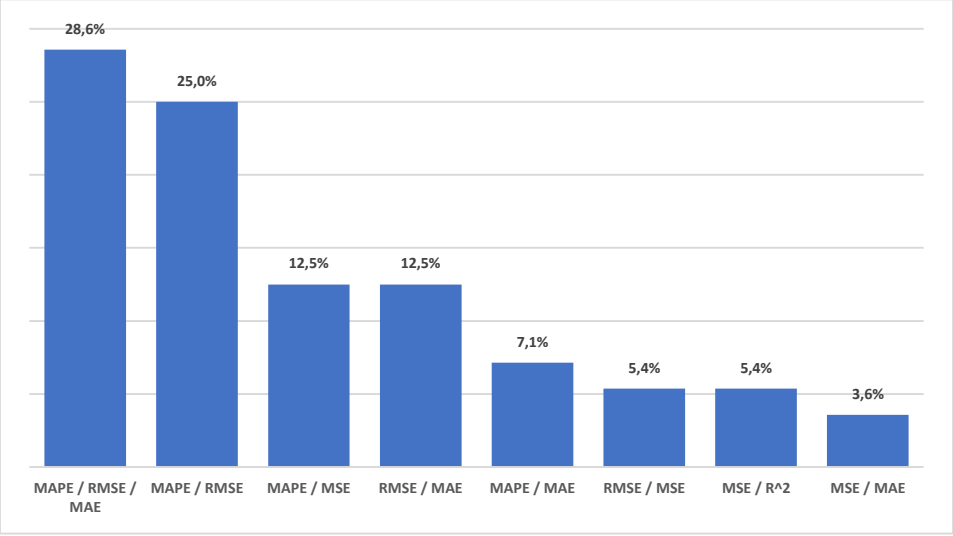
In addition, according to *Hodson* (2022) the use of RMSE and MAE can be appropriate when the measurements are chosen as a function of forecast errors – RMSE is appropriate for Gaussian errors and MAE for Laplace errors. Although less frequently, the coefficient of determination (R^2) with a total count of 14 (4.1%), the Percentage Forecast Error (PFE) with a total count of 9 (2.6%), the Simple Forecast Error with a total count of 7 (2.0%), the Normalized Root Mean Squared Error (NRMSE) with a total count of 6 (1.7%), the Mean Absolute Scaled Error (MASE) with a total count of 4 (1.2%), the Symmetric Mean Absolute Percentage Error (SMAPE) with a total count of 4 (1.2%), the Mean Percentage Error (MPE) with a total count of 4 (1.2%), the Mean Absolute Deviation (MAD) with a total count of 4 (1.2%), the Relative Mean Absolute Percentage Error (RMAPE) with a total count of 3 (0.9%), the Absolute Forecast Error with a total count of 2 (0.6%) were also used. Of the 29 discussed measurements, 15 account for a total of 95.6% of all observations.

Favorite combinations of forecasting performance measurements

In our research, we found that often more than one forecasting performance measurement was used. To examine which combinations of forecasting performance measurements were most frequently used, we analyzed 102 publications (52.8% of the complete sample of 193 publications) that used more than one single forecast measurement. Of these, a total of 54 publications (28.0%) used two forecasting measurements and 48 (24.9%) publications used three or more forecasting measurements. Each combination of forecast performance measurements (e.g. MAPE & MSE) comes from a specific publication of our database. For the analysis of clusters, we recorded all combinations (i.e. MAPE & MSE) that occurred more than once. Overall, we found 56 (54.9% of the total 102) combinations of forecasting performance measurements that occurred more than once. 46 (45.1% of overall 102) combinations were unique and were not shown separately. The results are shown in *Figure 3*. In 16 cases (28.6% of the total 56 recorded combinations), the most popular combination of forecasting performance measurements is the combination of the three measurements of MAPE & RMSE & MAE. measurement. The second most common combination with a frequency of 14 (25.0% of the total 56 recorded combinations) was the combination of MAPE & RMSE. This is followed by the combination of MAPE & MSE, with a frequency of 7 (12.5% of the total 56 recorded combinations), and the combination of RMSE & MAE with a frequency of 7 (12.5% of the total 56 recorded combinations), next, the combination of MAPE & MAE with a frequency of 4 (7.1% of the total 56 recorded combinations), then, the combination of RMSE & MSE with a frequency of 3 (5.4% of the total 56 recorded combinations), finally, the combination of MSE and R^2 with a frequency of 3 (5.4% of the total 56 recorded combinations) and the combination of MAE & MSE with one Frequency of 2 (3.6% of the total 56 recorded combinations). This result shows that the most popular combinations include the most popular measurements of MAPE, RMSE, and MAE. In general, when choosing the best forecasting model, the use of multiple forecasting performance measurements should be challenged from a decision-theoretical point of view. If a single measurement is used, the forecasting model that generates the smaller forecasting loss should be selected. When two

measurements are combined, they should prefer the same forecasting model in order to choose a clear forecasting model. In this case, one of the forecasting performance measurements is redundant. If different forecasting model is preferred, it is difficult to choose. A first limitation of combinations with MAPE is the fact that MAPE produces extreme values with small input values (differences between forecast and true value). As explained above, this means that the choice regarding the best forecasting model cannot be made or that MAPE is no longer used as a criterion. An adjustment of small differences between forecast and true value must then also be made for the comparison models – but these can take completely different values, which means that the sample is distorted. The combination of MAPE and RMSE is complementary in that the MAPE quantifies the forecasting performance as a percentage and the RMSE quantifies it in the unit of the original time series. As we pointed out above, MAE is better for Laplace distributed errors, and RMSE is better for Gaussian distributed errors. Therefore, the combination of these two measurements makes little sense. Instead, one of the two measurements should be chosen based on the existing errors, again in the interests of better choice.

Figure 3: Favorite combinations of forecasting performance measurements



Sample size = 56.

DISCUSSION AND FURTHER RESEARCH

In our evaluation, we found that the Mean Absolute Percentage Error (MAPE), the Relative Mean Squared Error (RMSE), the Mean Squared Error (MSE) and the Mean Absolute Error (MAE) are the most frequently used performance criteria. These measurements dominate the literature for applied artificial neural network demand forecasting in supply chain contexts. This is because they are easy to compute and most of them are easy to interpret. They were also widely used in the past, therefore,

more recent research uses them as a guide. Because of their widespread use, it seems to be easy for researchers to compare their results with other research, other models and applications. However, there have been several criticisms of the measurements in the literature concerning measurement their consistency, their behaviour with outliers and their comparability. As the decision between different forecasting models, based on these forecasting measurements, depends on sample size of the dataset and the forecasting horizon, decision-making is not consistent. Although alternatives (e.g. SMAPE and MASE) with better characteristics are proposed in the literature to choose between different forecasting methods and overcome the weaknesses of the commonly used measurements, we found only a few examples of this Likewise, in our analysis, we found hardly any individual loss functions specific to an application that quantifies the economic effects of incorrect forecasts. That means that over-forecasting is just as problematic as under-forecasting. The use of symmetric performance criteria (like MAPE or RMSE) makes sense in a theoretical context and in the comparison of forecasting models. However, as explained above, this is not appropriate for the forecast of electricity demand. In principle, the choice of the forecast performance measurement should also consider the forecasting framework measurement. It follows that the choice of the forecasting model can still be optimized and so can the forecasting results, since the loss function has not been adapted to the forecasting problem. The most common combinations of forecasting performance measurements are MAPE & RMSE & MAE. This is the combination of the most widely used forecasting performance measurements. A combination of forecasting performance measurements only makes sense if the two measurements complement each other in terms of their properties. Finally, from the perspective of the decision maker, the question is which forecasting model should be preferred if the combined use of performance measurements results in different recommendations. So, the recommendation is that we should use only one "efficient" measurement. Our results detail variability in the use of forecasting performance measurements in the research of applied demand forecasting with artificial neural networks, and thus generate new insights. In our analysis of demand forecasting applications, we did not find any application for the forecast of the demand of financial services, although this is a huge industry. The application to generate optimization potential in this area seems worthwhile and would fill a research gap.

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Regional and Business Studies (2022) Vol 14 No 2, 21-29
Hungarian University of Agriculture and Life Sciences Kaposvár Campus
Kaposvár
doi: 10.33568/rbs.3278

ASSESSING AGROECOLOGICAL VOCATIONAL TRAINING APPROACH THROUGH THE EYES OF FARMERS

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ABSTRACT

Agroecology (AE) as a broad collection of good farming management practices, recognizes the impacts of agriculture on ecosystems and society. Even though AE does not have a specific certification method, its basic components can be identified at the farm level too. In the context of the trAEce project, research was conducted in order to investigate the concept of AE at the farm level. Furthermore, the topics that can be taught in the form of vocational training designed for farmers in connection with AE have also been identified. Accordingly, a 6-module training with 7 events was organized with the aim of testing the developed AE vocational training curriculum. The main target group of the training was conventional farmers who are committed to changing their farming methods and are open to agroecological solutions. The participants had opportunities to express their opinion about the training after each module day, and after completing the whole course. The analysis of the feedback questionnaires seeks the answer of whether the practice-oriented vocational training course that promotes well-established good practices combined with basic theoretical knowledge is considered an effective method to increase farmers' knowledge about AE. The results confirmed that the training helps conventional farmers in the transition towards AE which also contribute to the even more efficient use of EU subsidies.

Keywords: agroecology, vocational training, farmers, practical feedback
JEL codes: Q01, Q13, Q18

INTRODUCTION

Agroecology as a holistic approach

Many studies and research discuss the topic of sustainability and try to find the best alternatives for sustainable development (*Lozano*, 2022). By recognizing the limits of endless growth, the ideas of harmonic development have become in the limelight. The human society closely fits into the natural environment and if the environmental boundary conditions are damaged, the human society also is endangered (*World Commission on Environment and Development*; 1987). According to *Altieri & Nicholls* (2012) an agricultural strategy that fits within the sustainability criteria, must contain the basic requirements of a viable and durable agricultural system while facing the challenges of the twenty-first century (such as land degradation, excessive input- and

energy consumption, large emissions of greenhouse gases). The question is often raised of what sustainability means meanwhile we are looking for a general approach that can be applied in order to reach sustainable agriculture and food sovereignty.

Agroecology (AE) may provide the answer as it can be defined as an interdisciplinary field and characterized as a science, a set of practices, and a social movement based on ecological and social justice principles (*Gliessman,* 2013; *Altieri,* 2018, *Wezel et al.* 2009; *Wezel et al.* 2018). *FAO* (2018) describes agroecology as follows: 'Agroecology is an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimise the interactions between plants, animals, humans, and the environment while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system.' As a science, AE applies a holistic approach and participatory research, as well as transdisciplinarity that includes different knowledge systems. As a practice, it is based on the sustainable employment of local renewable resources, local farmers' knowledge and priorities, the cautious use of biodiversity to provide ecosystem services and resilience, and solutions that provide multiple benefits (environmental, economic, social) from the local to the global level. As a movement, it defends smallholder and family farming, farmers and rural communities, food sovereignty, local and short food supply chains, diversity of indigenous seeds and breeds, and healthy quality food. (*The European Association of Agroecology*, 2016).

trAEce project – Agroecological Vocational Training for farmers

Experts from 6 institutions in 5 European countries (Austria, Czech Republic, Hungary, Portugal and Romania) worked together to describe a clear, practical approach to agroecology (AE) and to provide training tools for farmers and instructors that aim to assist in integrating agroecological principles into their practices. The first step in the project was for each partner team to develop a country-specific agroecology situation analysis, which identified relevant political discourses, regulations, actors, practices, networks, etc. while documenting a comprehensive view of the level of knowledge of farmers regarding agroecology-based activities. The report also documented current AE-related training courses and learning opportunities that are available at different levels (*Bálint et al.*, 2020). Based on these situation analyses, the AE vocational training program designed for farmers was elaborated and refined by the project team, which incorporated the results of pilot training sessions (see the Materials and Methods). In order not to limit knowledge transfer to one-off training sessions and to more effectively spread knowledge of AE practices, the project team also developed a methodological guide designed for trainers and educators for introducing agroecology to farmers (*Hudcová,* 2022).

One of the ideas behind the agroecological vocational training designed for farmers is the more efficient use of EU subsidies, as the training would help practitioners in the agroecological transition. Provided incentives and subsidies cannot have the necessary impact required for wide-scale adoption of agroecological practices if they are not accompanied by awareness-shaping training created for farmers. Consequently, practice-oriented vocational training courses that promote

well-established good practices should be considered an effective method to increase farmers' knowledge of AE.

MATERIALS AND METHODS

In the framework of the project a pilot training course was organized. The aim of this pilot training was to test the vocational training program and curriculum developed with international project partners. The main target group of the training was conventional farmers who are committed to changing their farming methods and are open to agroecological solutions.

The training (7 events) took place from 21 March to 25 April 2022 within the framework of six modules:

1. Agroecology – shaping attitudes;
2. Permaculture farm design and planning;
3. Economic strategy and business model;
4. Agroecology in practice (three optional topics: arable crop production, small-scale fruit and vegetable production and grassland management and animal husbandry);
5. Added value and marketing;
6. Social benefits of agroecology.

The theoretical modules were hosted by the Hungarian University of Agriculture and Life Sciences Szent István Campus, Gödöllő, while the practical modules were held at partner farms in Csoroszlya Farm (Szár), Zsámboki Biokert (Zsámbok), Pallagvölgyi Bikokert (Kóspallag) and Táncoskert (Polgár).

The application to the training was open for farmers who engage in full-time or part-time agricultural activities, has some level of agricultural experience. More than 70 applications were received and based on their short motivations 15 farmers were selected. It was important to select female participants as well and a big emphasis was also placed on choosing conventional farmers who are ready to change. The participants had several opportunities to express their opinion about the training. On the one hand at the end of each module the participants received a paper-based questionnaire about the module content, the methodology of teaching and the preparedness of the trainer, and on the other hand at the end of the entire training they had the opportunity to express their opinion through a Google Form where they could evaluate the whole training course in general. We received 11 responses to the general questionnaire, which means 73% willingness to respond. In the case of written module questionnaires this ratio was almost 100% as we could control whether the participants completed the forms or not. However, it should be noted that for some modules, the number of responses received is lower than the number of respondents to the general questionnaire due to the lower number of participants (e.g. optional module 4 days).

The questions of the two questionnaires were partly open questions that required short answers or closed questions where Likert Scale from 1 to 6 was used. During the analysis of the responses, an average was calculated from the indicated scores. For the sake of possible comparison, the first seven questions of the module questionnaires were the same. These were followed by specific module-related questions.

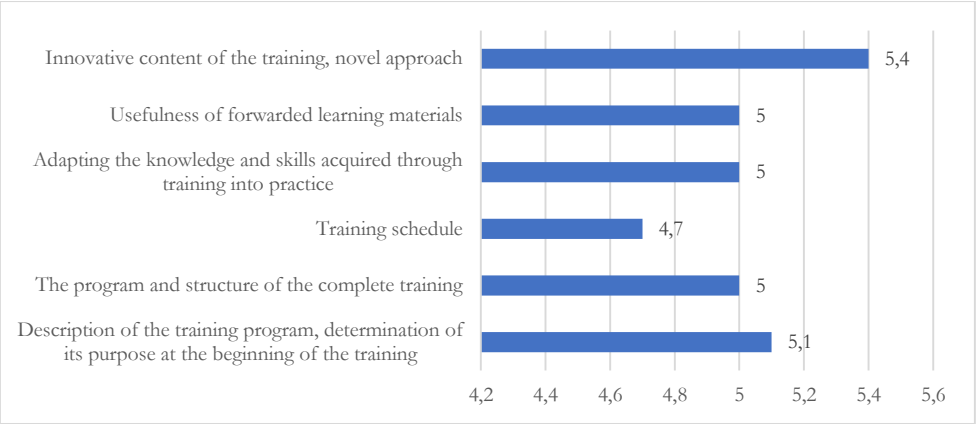
RESULTS AND DISCUSSION

General evaluation

As a first part of the general evaluation sheet, participants were asked to evaluate the description, the structure of the training program, the determination of its purpose at the beginning of the training, the training schedule, the usefulness of the forwarded learning materials, the innovative content of the training and its novel approach and the adaptation of the knowledge and skills acquired through training into practice.

For the evaluation the average scores calculated from the 1 to 6 Likert Scale was used. The results can be seen in *Figure 1*.

Figure 1: The evaluation of the comprehensive viewpoints (measured with a 1-6 Likert scale)



Based on the results it can be stated that the training and its approach was successful as there are not any evaluation under 4.7. The lowest average belongs to the training schedule. It is important to mention that in the module questionnaires one of the most frequent remarks was the lack of time and that the participants wanted to learn more and in more detail about the topics.

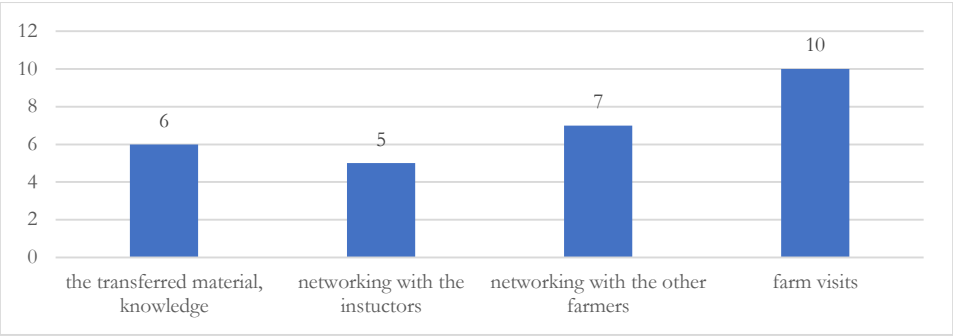
Participants were asked about the topic they would have liked to hear about agroecology during the training. The most relevant answers were:

- regenerative agriculture,
- biodynamic agriculture,
- weed treatment in permaculture,
- fruit production,
- profitability aspects.

This shows us that the participants are open to all alternative agricultural solutions and they think all of them can be part of the agroecological approach.

The next question was related to the most useful thing in the training (multiple answers were possible). *Figure 2* shows the results.

Figure 2. The most useful things of the training (how many times an element was mentioned)



It should be highlighted that almost all of the 11 respondents considered the farm visits useful. An important result of the training is that the practical approach and sharing the personal farm experiences with each other are very important to the farmers.

In the next part of the questionnaire, participants were asked to formulate some criticism about the parts of the training that should be developed or to suggest some changes. The results can be summed up as the following:

- more time for each module to get a deeper insight into the topics,
- more practical experiences and knowledge,
- fruit growing, regenerative and a more holistic approach are missing,
- more focus on the importance of the soil,
- more homogenous training groups with similar farm size or knowledge.

Module questionnaires

As it has already been introduced in the Materials and Method chapter all participants got a paper-based questionnaire at the end of all module days. The first seven questions were identical for all modules.

In the first five questions, respondents had to evaluate some aspects of the training days (the usefulness of the module's content, the time management and preparedness of the lecturer, the method of teaching, and the practical task) on a Likert scale 1 to 6. An average was calculated from the answers. To sum it up in the vast majority of the cases the ranking was between 5 and 6. The few exceptions were: How satisfied were you with the practical part? 4.9 in Module 1. but this was the introductory module with less practical elements, the How well did the lecturer manage to keep to the planned timeframe? 4.9 in Module 4. – crop production and 4.2 in Module 5. – Added Value and Marketing. We have to admit that in these two cases there were unexpected technical problems that caused delays in the program. Module 6 – Part 1 has the lowest ranking with its numbers between 4.8 and 5 for each question. This module day was only an afternoon organized after the half-day long Module 3 and this probably caused the participants to be more tired.

The last two common questions were about what the best part of module day was and what else they would have heard. It is true for all module days that participants liked the practical parts, teamwork and farm visits the best. Most of them would have to hear more about the topics. The other suggestions are summed up in *Table 1.*

Table 1. The suggested topics for the module days

Module 1	Module 2	Module 3	Module 4 crop production	Module 4 market gardening	Module 4 Animal husbandry
agricultural research	market gardening	how to get / raise capital	tools for agroecology	composting	Community Supported Agriculture
comparison of yield averages in organic and conventional farming	economical questions	economic and social effects	manure treatment	plant association	
regenerative agriculture, holistic approach	planning	examples more fitting to small farms	regenerative agriculture	deep mulch	
more practical, measurement data	specific garden practices	economic efficiency	weed control		
		market access, sales, cost efficiency	the conditions for bio / organic production in the crop rotation		
			conclusions of a wheat cultivar experiment		
Module 5	**Module 6 Part 1**	**Module 6 Part 2**			
pricing	good practices already operate	tillage			
	practical examples	deep mulch technology			
		economic data, cost/ benefits			

In the next part of the module questionnaires participants had to answer module-related questions about what would they had skipped out from the material and how practical did they find certain methods. In most of the cases we asked them whether they learned anything new during the module day, would they plan to introduce the learned methods and approaches into the practice of their own farm, or have the ecological aspects had been strengthened in them as a result of what you heard during the day.

During the module days, almost everything was new for the participants, they mentioned frequently methodological and technical novelties like permaculture planning considerations, crop rotation, plant association, weed control without pesticides, grow tent, permanent bed system, composting bio power plant, mulching, soil surface covering methods and minimum tillage. They found the economic, marketing, sales, and social aspects important as well, the entire Business Model Canvas method or the approach of the Community Supported Agriculture were considered useful parts of the training.

Finally, participants were asked about their future plans. Based on the knowledge gained during the training they are planning the following:

- buying new lands,
- planning and starting a new farm,
- keep on farming in a regenerative way and trying to build in the permaculture elements,
- composting and the introduction of bio-intensive vegetable production,
- increasing the cultivated area on an "eco-way",
- starting cultivating on further territories 50 ha already based on the principles of organic farming,
- try to produce crop with strip cultivation,
- mulching,
- pasture design as learned in the training,
- creating a business model.

CONCLUSIONS

Based on the collected feedbacks, agroecological vocational training with a holistic approach is important and necessary for Hungarian farmers. Even if the participants practice conventional farming, all of them are open to new approaches and technologies, if they are also economically convincing for them.

According to our results, the so-called perfect training fits the schedule of seasonal agricultural work during the year, focuses on practical examples, and encourages the exchange of personal farm experiences. Furthermore, the training should provide networking opportunities for both the farmers and the experienced trainers.

The trainers have to find the right balance between theory and practice. Farmers tend to underestimate the significance of theoretical considerations, however, the large number of topic proposals made by the farmers during the feedback session proves that farmers classify all alternative farming methods under the concept of agroecology while they have difficulties identifying its theoretical framework. In the case of permaculture, it became obvious that understanding such a complex approach without a theoretical background is very challenging.

The fact that all of the participants would recommend this practice-oriented training to other farmers and are even willing to pay for the course shows that such training can be a gap-filling initiative in Hungary and sustainable in the long run.

ACKNOWLEDGEMENT

The training materials were developed and the pilot training was organized in the framework of the trAEce - Agroecological Vocational Training for Farmers nº2019-1-HU01-KA202-060895 Erasmus + project.

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Regional and Business Studies (2022) Vol 14 No 2, 31-45
Hungarian University of Agriculture and Life Sciences Kaposvár Campus
Kaposvár
doi: 10.33568/rbs.4121

A SURVEY ABOUT PATENTS, INVENTION AND COMMERCIALIZATION PROCESSES IN KAZAKHSTAN

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ABSTRACT

This article is about the importance of intellectual property in the innovation process. It focuses on the results obtained in the survey with owners of patents in Kazakhstan. The questions were related to the processes of invention and commercialization. From the mainstream of responses, we identified those that are crucial in the process of invention and those that can affect the process of commercialization in the future. Namely, we were interested in the variables which are significant in the process of invention and how they affect commercialization. The result of the post-hoc test identified the data which differ within groups. It was found that eight variables were different in the combination of groups: the number of authors, the type of resource R&D, the number of patents, and the evaluation of the invention, expressed in terms of money. This test revealed that these variables change from group to group. Moreover, it allowed us to look deeper into the inventive process and identify the direction of these changes.
Keywords: intellectual property, patent, Kruskal-Wallis test, innovation
JEL codes: O310, K110,

INTRODUCTION

Intellectual property (IP) plays a critical role in the innovation process to secure the rights of those who create new concepts, goods, and technology (*Brandl & Glenna*, 2016). IP rights, such as patents, trademarks, copyrights, and trade secrets, provide a legal framework for innovators to secure the innovation benefits and control the use of their IP assets (*Hall et al.*, 2014; *Fang et al.*, 2017).

One of the significant IP rights that contribute to innovation is patent. Patents give inventors temporary exclusive rights to their ideas, enabling them to stop others from making, utilizing, or commercializing the same product. As a result, innovators are encouraged to devote time, money, and resources to creating new technologies and goods because they know that their work will be protected and that they will profit from their ideas. Copyrights safeguard creative works like music, movies, and novels, whereas trademarks protect the branding and reputation of products. These intellectual property rights guarantee that creators have control over how their work is used and that they are fairly compensated for their work. At the same time, there is another tool for technology protection – trade secrets. Trade secrets are confidential business information that companies keep confidential to maintain a

competitive advantage. This information can include anything from client lists and the company plans to manufacture procedures and calculations. By protecting trade secrets, businesses may keep their innovations a secret and prevent competitors from stealing or copying them.

Most of the studies related to patents are interrelated with the innovation activity of Kazakhstan (*Yessengeldin et al.*, 2016; *Nurpeisova et al.*, 2021; *Raihan & Tuspekova*, 2022). The other part of the studies directly related to patents is often based on secondary data in Kazakhstan (*Sagiyeva et al.*, 2018; *Nurgalieva et al.*, 2022). The main problem of patent research in Kazakhstan is that nobody is allowed to understand the dynamics of patent development and commercialization. It is very important to understand the owners of patents and their problems in order to efficiently solve them at government level. A common problem in patenting is what to do after obtaining a patent. During the survey, we noticed that self-filed authors have more difficulty commercializing an invention than a group of authors. These questions have lead us to following goal: we aimed to identify the factors that play a noticeable role in the invention process in Kazakhstan. These questions are the following: How can the invention process be described in Kazakhstan and who plays the main role in the patent process? What factors influence inventiveness in Kazakhstan and contribute to the commercialization of intellectual property, inventions that of patents?

The structure of this paper includes 4 chapters. The first chapter introduces the key message and the article's research aim and research questions. In the second chapter, the background of intellectual property and patents are discussed. The third part includes data and methodology. The results are discussed in the fourth chapter, and the conclusion of this article is presented in the fifth chapter.

LITERATURE REVIEW

In modern conditions, economic development is increasingly dependent on the creation and effective use of high technology, the introduction of fundamentally new technologies, and the use of information resources. All this can be expressed in one word - "innovation". However, for involving successfully innovative performance, the interests of the government and other participants in this process must be taken into account. Interest means a balance among government, suppliers, executants, and authors to consolidate and implement the rights to the results of scientific, technical, experimental design, and other activities (*Belderbos et al.*, 2014).

To regulate this balance and respect the rights of all participants, it is necessary to combine innovation together with intellectual property. Effective protection and management of intellectual property contribute to the penetration of innovations in all countries with economies in transition (*de Almeida Borges et al.*, 2020).

The principle of IP is used to protect the legal rights of individuals and organizations that create new concepts, goods, and technologies. IP rights are necessary because they provide a legal framework that allows individuals and organizations to secure the benefits of their innovations and control the use of their IP assets (*de Rassenfosse et al.*, 2019; *Wineinger et al.*, 2019). There are some reasons why society needs IP rights. First of all, it encourages innovation (*Yang et al.*, 2014). IP

rights provide an incentive for individuals and organizations to invest time, money, and resources into developing new ideas, products, and technologies. The protection of their innovations through IP rights gives innovators the confidence to take risks, knowing that their efforts will be protected and that they will be able to reap the benefits of their innovations (*Niaounakis,* 2019; *Arya & Shinde*, 2022). The second reason is promoting competition. IP rights ensure that competitors cannot freely copy or use the innovations of others, promoting a competitive and dynamic marketplace (*Maresch et al.,* 2016). This encourages companies to invest in research and development and to create new and innovative products, leading to a thriving economy (*Galasso & Schankerman*, 2015). The protection of creativity is the third reason. IP rights protect the rights of creators, artists, and authors to control the use of their creative works and to receive fair compensation for their efforts. This allows them to continue to create and share new and innovative works, contributing to the cultural and artistic richness of society (*Liu et al.*, 2017; *Raju*, 2017; *Song & Yu*, 2018). It is also important to maintain confidentiality. For instance, IP rights such as trade secrets allow companies to protect confidential information, such as manufacturing processes, formulas, and business plans, which they use to maintain a competitive advantage. This confidentiality is important for businesses to protect their innovations and to keep their operations running smoothly. The last main reason is to support the economy (*Sweet & Maggio*, 2015). IP rights play an important role in the economy by providing the legal framework that allows innovators and businesses to secure the benefits of their innovations and to commercialize their ideas and products (*Fang et al.*, 2017). This contributes to economic growth and job creation, making IP an important component of any thriving economy (*Bielig*, 2012).

In this research, we focus on invention patents that contribute more to innovation performance. Legal protection of the invention is granted if it is new, involves an inventive step, and is industrially applicable. The main normative documents are the Paris Convention for the Protection of Industrial Property, the Patent Cooperation Treaty, the Eurasian Patent Convention, and the National Patent Law. It should be noted that paragraph 3 of Article 6 of the Patent Law of the Republic of Kazakhstan provides for the list of objects that are not recognized as inventions: a) discoveries, scientific theories, and mathematical methods; b) methods of organization and management; c) conventions, mappings, rules; d) rules and methods for performing mental operations, conducting games; e) programs for computers and algorithms, as such; f) projects and layouts for buildings, and territories; g) proposals that are only the appearance of products; h) proposals that are contrary to public order, principles of humanity, and morality.

The patent certifies the priority, authorship and exclusive right to the object of industrial property. A patent document includes the following details: the invention's name, an abstract, and a complete description of it; the inventor's name, address, and country of origin; the owner of the invention's name, address, and country of origin; the technological classes to which the patent relates; and references to earlier patents, among other things (*Archibugi*, 1992; *Joung & Kim*, 2017; *Charreau et al.*, 2020). An invention patent is valid for twenty years from the filing date of the application. By mentioning the invention and its applicability, the society undertakes the benefits of

the intervention through commercialization and access to the invention. An invention usually receives legal protection if it is granted patent protection through publication. The invention can also enter the trade secret phase, where the owner is solely responsible and independently establishes the scope of protection for the invention (*Wyatt et al.*, 1985; *Levin et al.*, 1987; *Wexler*, 2017; *Glaeser*, 2018).

The relationship between patents and innovation has been discussed for many years (*Hall & Ziedonis*, 2001; *Kim & Marschke*, 2004; *Kortum & Lerner*, 1999, *Carrier*, 2002; *Boldrin & Levine*, 2013; *Moser*, 2013; *Sampat & Williams*, 2019). However, in this article, we pay attention to innovation through the value of intellectual property. By their nature, patents are more efficient in terms of innovative products than that of the process. Product innovation can be protected by both the confidentiality of the process and product patents (*Levin et al.*, 1987; *Granstrand*, 1999; *Ceccagnoli*, 2009; *Levitas & McFadyen*, 2009; *Estrada et al.*, 2016), family patenting (*De Massis et al.*, 2013).

The main reasons of low efficiency of patents in transition countries may be due to some patenting shortcomings. The main disadvantage is the ability of competitors to legally invent patents and disclose information related to patenting (*Harabi*, 1995; *Veugelers & Schweiger*, 2016), as well as high economic and non-economic costs of patenting (*Cohen et al.*, 2000; *Dang & Motohashi*, 2015). Moreover, the inventors in Kazakhstan also noted such a factor as the lack of support from the state and enterprises. Despite these shortcomings, and the relatively low efficiency of patents, companies continue to obtain patents. In some industries where patents are not considered as essential, they are nonetheless patented. By virtue of a certain time, patent holders cease to protect patents (unprofitable) for personal or financial reasons. This is sometimes called the paradox of patenting, which leads to the question: why do companies patent (*Granstrand & Holgersson*, 2013; *Leiponen & Delcamp*, 2019)?

Patent is always a component of innovative activity. More scientists confirm this through their theories and writings (*Schmookler*, 1966; *Devinney*, 1994; *Crosby*, 2000; *Papageorgiadis & Sharma*, 2016) about the impact of the patent on innovative processes. Moreover, increasing patenting activity leads to improving labour productivity and economic growth. However, patents are necessary to start to patents (*Crosby*, 2000; *Aghion et al.*, 2015; *Farre-Mensa et al.*, 2020).

Transition countries lack certain factors to move into the innovation phase (*Švarc*, 2006; *Kim et al.*, 2019). Such countries seem to be stuck in the checkpoint to move towards innovative countries and cease to be dependent on natural resources. Moreover, Kazakhstan has the possibility to move forward in innovative performance through good management, and proper distribution of natural resources and capacity building in the innovation sphere. Unfortunately, Kazakhstan has little practical experience in this area and, therefore, this work has potential importance. Certainly, one can name some common factors that hinder the innovation process in Kazakhstan, but this work will show which factors influence innovative activities of inventors in terms of intellectual property.

In addition, attention has been paid to the results of previous studies in which the authors have addressed the economic component of intellectual property. (*Pakes*, 1984; *Schankerman & Pakes*, 1986; *Griliches et al.*, 1986; *Reitzig*, 2003; *Hall et al.*, 2007; *Bessen*, 2008; *Gambardella et al.*, 2008; *Kerber*, 2016). They showed a new vision of the

value of patents for future research. The use of data on renewed patents and renewal fees helped to identify parameters that had a positive and significant impact on European countries (*Pakes*, 1984). Moreover, through the behaviour of patent holders in relation to the payment of fees for the renewal of patents it was found that the distribution of the values of patent rights was considered and investigated the private value of patent protection and its changes over time (*Schankerman & Pakes*, 1986). Valuable contribution was made by a group of authors that collected data at the firm level and described in detail the use of patent data to assess the importance of R & D distribution (*Griliches et al.*, 1986). Further studies were conducted in narrower areas of enterprises to determine the value of patents (*Reitzig*, 2003; *Hall et al.*, 2007). The concept of the economic value of a patent is difficult to calculate unequivocally. With this approach, it is always necessary to take into account such factors as the size of the inventive step, the demand for a patented product, as well as investments in the cost of patenting etc. The European survey, in which countries such as Germany, the Netherlands, France, Italy, Spain participated (*Gambardella et al.*, 2008) helped us in the formation of our questions. Another theory considers the need for new exclusive intellectual property rights for data related to the economic aspects of the patent (*Kerber*, 2016). These studies formed the basis of this questionnaire. In this paper we presented the factors that influence inventiveness and commercialization process.

About Kazakhstan Patent Profile

The first patent of the Republic of Kazakhstan was issued in the name of the Institute of Chemical Sciences A.B. Bekturov on "redoxide" with the date of publication 16.06.1997. During the independence of the Republic of Kazakhstan, more than 37.553 inventions, 4.558 utility models, 3.586 industrial designs, and 917 new varieties successes have been filed until 2019. These are elements of intellectual property that have a direct impact on patent law and patenting.

In 2019, the Kazakhstan Patent Office received 973 innovation applications, including 811 from domestic applicants and 162 from foreign applicants. These numbers are 0.9% lower than in 2018. The proportion of domestic and international applicants was around 83% and 17%, respectively. In addition, 544 national applicants and 186 international applicants received patent protection for the invention in 2019. In the same year, the number of applications submitted patent applications under the Patent Cooperation Agreement (PCT) protocol increased by 38.9% in 2018, while the number of applications filed patent applications under the Eurasian Patent Convention (EAPC) procedure increased by 14.6%.

MATERIALS AND METHODS

The original language of the questionnaire to was English. The paper-based interviews were in Kazakh and Russian languages because both of them were the native languages of Kazakhstan`s inventors. The Patent office in Kazakhstan supported the survey. The development of the questionnaire started at the end of 2018, and it was translated in Kazakh and Russian) at the beginning of 2019.

The study started in 2008. For some patents, for example, in the field of medicine and chemistry, the commercialization process usually takes more than 6 years. Therefore, research started in 2008 to give all patents time to be approved. We also focused on this year, because the global financial crisis started in 2008, which for some countries brought a standstill in the development of innovation and new technologies. The total amount of granted patents was 171 in 2008. 8% of granted patents were foreign patents. We excluded foreign patents because we were interested in how national patents develop in Kazakhstan. 96 patents were filed by organizations, research institutes and universities, while 36 inventions were filed independently by one owner or a group of owners. During filling of the questionnaire by hand we found a lot of difficulties, for example the authors died; some authors had serious problems with their health; some of them changed the patent more than once or they moved out from Kazakhstan.

Despite these problems, we found 47 inventors and they helped us to find other authors and co-authors. We asked them 43 questions about their patent and the inventive process. The questionnaire used Likert-type scales, semantic differentials, yes/no questions, multiple choice questions, rank order questions, dichotomous questions etc. The questionnaires were collected only by one person who visited the most significant patent regions in Kazakhstan. The total amount of respondents was 66 authors of inventions with a priority date in 2008.

Some of the answers of the inventors were greatly expanded and we categorized them by the total number of patents by one inventor, time spent on the invention and the value of the patent. The research includes the dependent variables (*Table 1*) and the groups (*Table 2*).

Table 1: Dependent variables of the patent survey

Variable name	Description of variables	Types of variables	Type of answer
authors	Number of authors in one granted patent	categorical variables	"1", "2", "3", "4", "5", "6", "7", "8", "9"
pat_rank	Total number of patents by one inventor	categorical variables	"1-3", "4-10", "11-20", "21-50", "< 50"
srs_R&D	Source for R&D "1" - Internal funds "2" - Funds from any other organization "3" - Funds from the financial intermediaries of any kind "4" - Government research programs "5" - Other	categorical variables	"1", "2", "3", "4", "5"
time_rank	Time spent on invention	categorical variables	"3 months – 1 year", "1-2 years", "2-4 years", "4-6 year"
val_pat_rank	The value of patent	categorical variables	"L $ 30 000", "$ 30 000 - $ 100 000", "$ 100 000 - $ 1 000 00", "$ 1 000 000 - $ 3 000 000"

Table 2: Groups used after patent survey

Name in R	Description of variables	Types of variables	Type of answer
city_inv	City of invention	categorical variables	"Almaty", "Astana", "others"
com_use	Commercial use of granted patent	categorical variables	"yes", "no", "I don`t know"
educ	Education of respondents	categorical variables	"PhD", "Bachelors", "others"
pat_fam	Existence of the patent family	categorical variables	"yes", "no", "I don`t know"
work	Workplace during the invention process	categorical variables	"Hospital", "University or research institution", "Private and public research organization", "Private companies and others"
year	The age of the author	categorical variables	"<45", "46-59" and ">60"

The method that was used was related to nonparametric analysis. This research focused on the Kruskal-Wallis test for some variables by R statistical program. The Kruskal-Wallis (*Kruskal & Wallis*, 1952) is a nonparametric statistical test that assesses the differences among three or more independently sampled groups on a single, non-normally distributed variable. Before starting the Kruskal-Wallis test, we had to estimate the probability of getting data from the normal distribution. We chose the Shapiro-Wilk test (*Shapiro & Wilk*, 1965) because it was appropriate for sample sizes we had. For this reason, we used the Shapiro-Wilk test as numerical means to assess normality. Each of the normality tests is essentially a compliance test and compares the observed data with the quantiles of the normal or other specified distribution. For our investigation, we chose p-value = 0.1 (*Neyman & Pearson*, 1933; *Fisher*, 1992). Before starting the main test we needed to analyse the distribution of variables by the Shapiro-Wilk test. The dependent variables are suitable for the the Kruskal-Wallis test. After a Kruskal-Wallis test, post-hoc tests such as the Dunn's test (Dunn's test with Bonferroni correction), were applied and the same rankings were found as in the Kruskal-Wallis test. The null hypothesis was aimed at discovering which sample pairings are significantly different (*Dunn*, 1964).

RESULTS AND DISCUSSION

The normalization data process by Shapiro-Wilks test showed that the data such as he author, pat_rank, srs_R.D, time-rank, val_pat_rank are significantly deviate from the normal distribution (*Table 3*).

If the data are not distributed normally, we need to use a nonparametric test. The results of the Kruskal-Wallis test is shown in the *Table 4*.

Significant values were obtained in the groups of city_inv, com_use, patent family, work, year. The dependent variables showed significant differences in the groups of

the authors, the value of the patent, and the source for R&D and the total number of patents (*Table 4*).

Table 3: The normalization data process of dependent variables by Shapiro-Wilks test

Data	W	P-value
author	0.93854	0.0027
pat_rank	0.95214	0.0125
srs_R&D	0.70669	3.467e-10
time_rank	0.91989	0.0003
val_pat_rank	0.91588	0.0122

Table 4: Results of the Kruskal-Wallis test

Data	Chi-squared	Df	P-value
srs_R.D by city_inv	5.3474	2	0.0690
val_pat_rank by city_inv	5.2935	2	0.0708
srs_R.D by com_use	4.5646	2	0.1020
authors by pat_fam	5.7157	2	0.0573
pat_rank by work	5.8954	3	0.1168
srs_R.D by work	7.2558	3	0.0641
val_pat_rank by work	8.1159	3	0.0436
srs_R.D by year	7.5333	2	0.0231

The important next step after the nonparametric test was the post hoc test – the Dunn test. It clarified and showed the differences inside the groups of the study.

When we interfaced R&D resources with cities, we observed that the main focus was on the national cities of Astana and Almaty. As a result, survey respondents emphasized the necessity of regional R&D development for potential growth in inventiveness (*Ray*, 1998; *Guo & Jiang*, 2022) (*Figure 1*).

Figure 1: The post hoc test variables result «*srs_R.D by city_inv*»

```
> dunn.test(kwt$srs_R.D,kwt$city_inv, alpha=0.1, method="bonferroni")
  Kruskal-Wallis rank sum test

data: x and group
Kruskal-Wallis chi-squared = 5.3474, df = 2, p-value = 0.07


                           Comparison of x by group
                                 (Bonferroni)
Col Mean-|
Row Mean |     Almaty     Astana
---------+----------------------
  Astana |  -2.300514
         |    0.0321*
         |
  others |  -0.712635   1.565961
         |     0.7141     0.1760

alpha = 0.1
Reject Ho if p <= alpha/2
>
```

Simultaneously, significant results were obtained about the value of patents in Almaty and other cities. This confirms that the authors recognise the value of their patentsin the society, which may influence the future of licensing in these cities (*Figure 2*).

Figure 2: The post hoc test of variables result «*val_pat_rank by city_inv*»

```
> dunn.test(kwt$val_pat_rank,kwt$city_inv, alpha=0.1, method="bonferroni")
  Kruskal-Wallis rank sum test

data: x and group
Kruskal-Wallis chi-squared = 5.2935, df = 2, p-value = 0.07


                           Comparison of x by group
                                 (Bonferroni)
Col Mean-|
Row Mean |     Almaty     Astana
---------+----------------------
  Astana |  -0.758491
         |     0.6722
         |
  others |  -2.283019  -0.873235
         |    0.0336*     0.5738

alpha = 0.1
Reject Ho if p <= alpha/2
>
```

When we looked at R&D resources in relation to commercialization, we observed that awareness of the significance of commercialization and concerns about profitability and intellectual property licensing are important variables. It showed the necessity to establish and train patent management, as well as introduce incentives in the public and commercial sectors and support patent implementation (*Etzkowitz*, 2002) (*Figure 3*).

Figure 3 Table 7: The post hoc test of variables result «*srs_R.D by com_use*»

```
> dunn.test(kwt$srs_R.D,kwt$com_use, alpha=0.1, method="bonferroni")
  Kruskal-Wallis rank sum test

data: x and group
Kruskal-Wallis chi-squared = 4.5646, df = 2, p-value = 0.1


                           Comparison of x by group
                                 (Bonferroni)
Col Mean-|
Row Mean |        IDN         No
---------+----------------------
      No |   1.225919
         |     0.3303
         |
     Yes |   1.862232   1.555181
         |     0.0939     0.1799

alpha = 0.1
Reject Ho if p <= alpha/2
>
```

Furthermore, to increase the number of patents and protect them, it is required to educate the relevant stakeholders and expand their capacity to make strong patents (*Harhoff et al.*, 2003). It allows various technologies to protect the interests of the basic patent and to improve manufacturing technology, resulting in a reliable spiral of protection (*Block et al.*, 2013). According to the results of the questionnaire, there is a minimal likelihood of developing a family of patents with one author.

Additionally, the post-test enabled us to see that the two variables R&D and the inventor's place of work were crucial in inventiveness. Private firms, as well as government and private research organizations, produced major results. Obviously,

research institutes and private firms have more access to R&D. For example, research institutes at hospitals provide a budget for R&D too, but they primarily focus on solving problems of a certain diagnosis and are non-commercial. Their contribution to the medical profession's development is considerable. Based on the findings, we may conclude that universities play a minor role in the production of patents. As a result, capacity building in this area is essential. For example, more research, relevant and practical projects should be conducted and developed that solve local social problems and might be significant for universities (*van Zeebroeck et al.*, 2008). We also saw a relationship between the significance of patents and the location of employment. Private enterprises and research institutions value the option of licensing their patents as a consequence of their work. Such organizations frequently have divisions in charge of the technological and legal rights of the authors and patent holders, who have access to more information than other single authors. Nevertheless, during the last three years, Kazakhstan has rapidly begun to build acceleration programmes to assist innovators and intellectual property owners using private and governmental funding via a grant system (*Abeuova*, 2022).

The age range of Kazakhstan inventors is approximately between 45 and 60 years old. According to the survey findings, invention activity is beginning to pick up around the age of 45 but peaks between the ages of 59 and 60 in Kazakhstan. What elements, though, can have an impact on young people's involvement in invention? The experience of developed nations should be researched and resources should be allocated to entice young people to inventiveness.

CONCLUSIONS

In conclusion, intellectual property rights are crucial to the innovation process because they give inventors the tools they need to protect the financial gains from their discoveries and to manage the use of their IP assets. Additionally, these rights promote an environment that stimulates spending on R&D, which results in a thriving and progressive economy.

In this article, the variables that affect the inventive process were analysed, using group data on patents from the year of 2018. According to the nonparametric test, we found that only 3 variables showed differences with the groups: source for R&D, the value of patent and number of authors in one granted patent. We found that the majority of patents were made in the main cities: Astana and Almaty, while, the rest of the patents was distributed in other cities. Despite the openness of many inventors to cooperation and the commercialization, we noticed that many inventions would never be patented. Perhaps, the number of inventive units of one organization (to support reputation) is important for research institutions. However, they should also pay more attention to the commercialization indicators of patents. Moreover, we found that there was no clear idea of who is responsible for the commercialization of a patent: the inventor, the patent owner, the state or SME (*Hanel*, 2006). The process of patent commercialization was discussed superficially, despite the fact that it is an integral part of the innovation process in any country. During the survey and in the meetings with the inventors promising direction for future research in Kazakhstan was seen.

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Regional and Business Studies (2022) Vol 14 No 2, 47-61
Hungarian University of Agriculture and Life Sciences Kaposvár Campus
Kaposvár
doi: 10.33568/rbs.3353

COOPETITION IN THE CONTEXT OF SUSTAINABILITY GOALS – A SYSTEMATIC OVERVIEW

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ABSTRACT

The article explores the literature on coopetition in relation to sustainability goals. The research is based on three parts, which specifically address the terms „coopetition" and „sustainability", respectively, and then examine the literature that specifically focuses on the topic of „coopetition and sustainability". In particular, the research provides the following answers: How is the novel type of mergers between competitors known as „coopetition" interpreted in academia? What is meant by sustainability? What are its origins and the driving forces that can influence cooperation with competitors? It is noted that competitive cooperations between competitors exist in many fields of entrepreneurship and cannot be attributed to one single industry. In the past, the main drivers for entrepreneurs to enter a coopetition were economic aspects. Among others, the reduction of costs, the increase or optimisation of economic performance and thus the strengthening of competitiveness vis-à-vis other competitors, as well as the opening up of new markets and the reduction of business risk. Since the adoption of the Sustainable Development Goals (SDGs) of the 2030 Agenda, however, sustainability considerations have become another driver for entering a coopetition, if not one of the main future drivers. This is because not only political requirements but also the purchasing behaviour of consumers have led to rethinking in the corporate sector.
Keywords: coopetition, competitor, sustainability, environmental protection

INTRODUCTION

The growing importance of cooperative relationships can currently be observed worldwide. The vast majority of these relationships take the form of cooperation. However, cooperation between competitors has also been noted for some time, so-called coopetition, i.e., the simultaneous existence of cooperation and competition between competitors. Previous research on coopetition usually characterises these relationships in the context of the benefits achieved. The question of what impact sustainability has on coopetition and what future directions, as well as new challenges, can be expected has become increasingly important for companies in the current period. For companies, consistent strategic orientation and its implementation is a decisive driver for successful development. The increasingly complicated structures and rules of a largely globalised economy not only confront today's companies with the circumstances of accelerated market dynamics, intensified competition and

constantly growing product demands, but also political requirements in connection with sustainability goals (*Al Danaf & Berke,* 2021). After all, sustainable developments require innovative sustainability technologies in order to counteract societal challenges such as climate change and the use of finite resources. Against the backdrop of these challenges, inter-organisational arrangements in particular are moving into the centre of interest, which can take many forms - especially alliances, networks, clusters or joint ventures. For innovations that contribute to sustainable development, intersectoral cooperation is important. For the economic success of companies, the competition principle (*Porter & Porter*, 1998) is often referred to in the literature. However, inter-company relations as an original strategic challenge have been in the focus of strategic developments for years. Therefore, companies are less and less confronted with the decision between competition and cooperation, but more with the central question of how to effectively shape both components. This phenomenon, which is becoming increasingly common in business practice, has meanwhile given rise to the independent term „coopetition": a paradox that integrates two supposedly fundamentally contradictory and irreconcilable strategic behavioural logics. Although research into this phenomenon has gained much interest since the early 1990s, this research topic is relatively unexplored in relation to sustainability technologies. Previous research on coopetition has generally focused on risks and benefits. There are several studies that have investigated coopetition, but there are still gaps regarding the impact of sustainability on coopetition. Furthermore, there is a lack of comprehensive overview of consumer behaviour on competitor coopetition. The aim is therefore to provide a systematic overview of coopetition and sustainability, with a focus on the influence of sustainability.

MATERIALS AND METHODS

For the literature review, the systematic review of previous research findings is used, which is a popular research tool in science. The basis is the formulation of the research question and the creation of a review overview of the formulated keywords on which the research question is based. As a result, the data selection is analysed and evaluated. The results of the literature then become the basis of the scientific explanations on which the research has already taken a stand.

The selection process

The focus of the research is on articles and studies on the topics of „coopetition" and „sustainability". The terms sustainability and coopetition were created as follows:

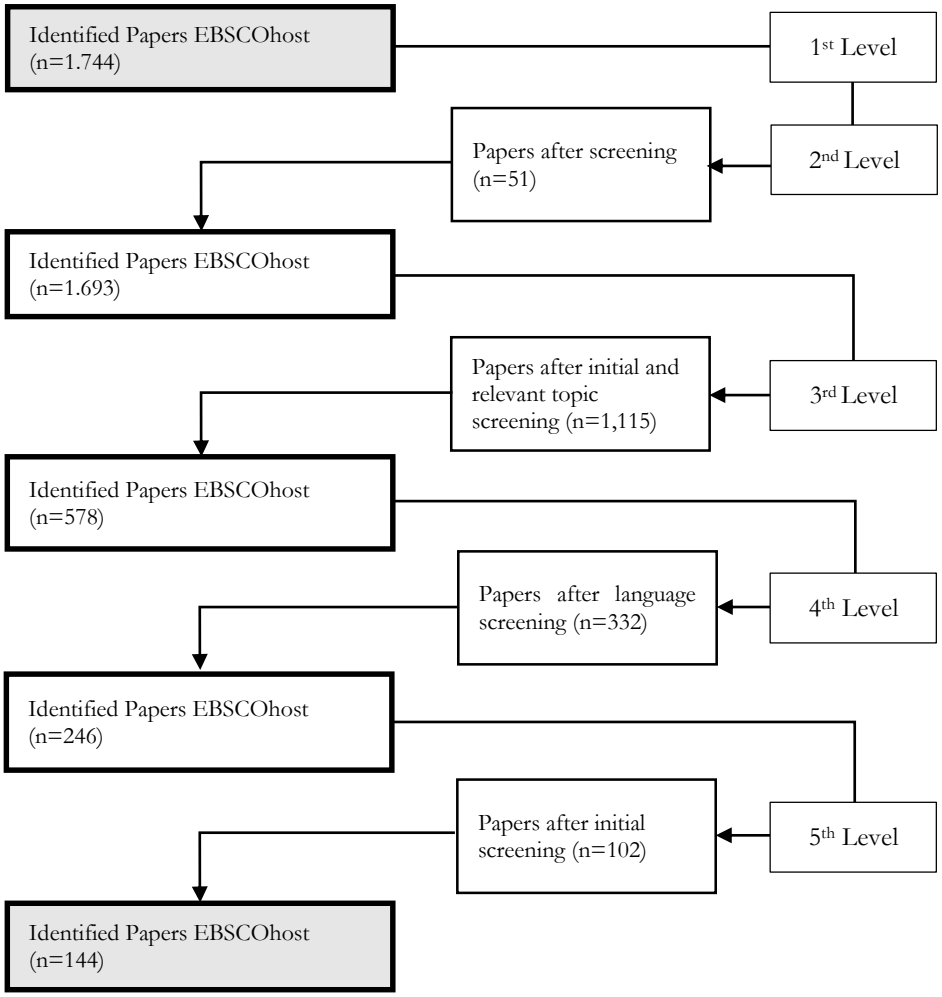
Co-opetition* OR Co-opetition* AND Sustainability* OR Sustainable*

The systematic literature search was conducted in July 2022 in the electronic database EBSCOhost. Due to the broad limits of the keywords, the search in the database resulted in 1,744 titles, which were narrowed down in a multi-stage procedure. In Level 1, all works were excluded whose titles were available in non-topic databases. In Stage 2, the search evaluation was narrowed down into subject fields. Subject areas were excluded that went into the medical or psychological field

and had no connection to the economic field. In Stage 3, all articles and publications were screened according to the topic and, in Stage 4, narrowed down to German- and English-language articles. Furthermore, the research articles were reviewed again, and their content was checked, and only relevant research articles with a reference were included in Stage 5. The full text of the publications was found in various databases such as SCOPUS, Springer-Verlag and ScienceDirect.

The process of screening the literature is shown in *Figure 1*.

Figure 1:PRISMA.flowchart



In recent years, two topics relevant to business have developed, which are to be linked as a result of this work. On the one hand, many articles have been published on coopetition, which is the starting point of the research, and on the other hand, the increasing question of sustainability. Due to the two topics that are included in

the research, the research is divided into three areas. The first subsection analyses the literature on the topic of coopetition and defines this term, which forms the basis for a comprehensive consideration of the topic. The second sub-chapter deals with the topic of sustainability and sustainability goals where a definition is provided, and the existing literature is analysed. In the third chapter, both topics are examined again in summary. The objective is to present and critically examine previous research, show the connection between this research and the existing body of knowledge, as well as identify gaps in the current body of knowledge.

Definition and emergence of coopetition

In order to understand the motivation of cooperation between competitors, the term must first be examined. The term „coopetition" is derived from the terms „cooperation" and „competition" and is thus understood as a relationship built on simultaneous competition and cooperation. This combination is intended to make interdependencies more efficient and effective and thus generate more economic rents than would be possible with the pure competition or pure cooperation. The strategy is based on the idea that through cooperation between competitors, the total value can be created and shared (*Porter & Kramer*, 2010).

A large number of scholars agree that Raymond John Noorda, CEO of the software company Novell, first coined the term in the 1980s/1990s and is thus considered by many to be the creator of coopetition (*Daidj*, 2017). The first authors to shape the paradox as the term „coopetition" and actually address it scientifically were *Brandenburger & Nalebuff*, (1996). Despite the fact that scientists made a significant contribution to early network research, it was not until the beginning of the 1990s that the term „coopetition" gradually gained relevance. This is because in the past, competition and cooperation were fundamentally separated before these components were developed into an important business strategy such as coopetition. But why do competitors join forces? Through strategic alliances, networks and other partnerships, companies seek to improve their performance because resources, capabilities and risks can be shared under these conditions. Various research papers refer to the origin of coopetition on game-theoretic approaches in relation to real mixed-motive games, which can be traced back to Brandenburger and Nalebuff (*Brandenburger & Nalebuff*, 1996). They analysed coopetition using game theory and conceptualised coopetition as a plus-sum game rather than a zero-sum game where players (rivals) can win even if rivals do not lose. The starting point of their chain of arguments is the traditional belief that business life can be compared to war as an extreme form of competition, and that only those who destroy others succeed in the long run. However, the existence of considerably more winners or companies that survive in the market than would be expected under fierce competition shows, in their opinion, that this radical thesis is not tenable. The same applies, in their opinion, to the counter-thesis that business relations can be equated with peace as the extreme form of cooperation, which cannot be affirmed either. As a result, the solution must lie in the synthesis: it cannot simply be about war or peace, but „business is war and peace" at the same time. An important aspect is that this is not an endless cycle of alternating war and peace, but both forms occur simultaneously. A condition they call coopetition. Another research focusing on

this topic was conducted by Bengtsson and Kock in an exploratory study in the 2000s. (*Bengtsson & Kock*, 2000) on the coordination of networks. According to this study, relationships between competitors are not only competitive, but both sides benefit if cooperative aspects are also emphasised and cultivated (*Bengtsson & Kock*, 2000). Porter and Kramer also concluded that the approach is based on the consideration that an overall value of competitions can be created and shared (*Porter & Kramer*, 2010). The basic motivation here is to create a competitive advantage over further counterparts through close cooperation, whether through new access to contacts, improved productivity and/or quality, access to raw materials or through reduced risks. Furthermore, this form offers advantages for companies facing increasing pressure to integrate the global value chain, due to „(a) the increasing importance of economies of scale and the internalisation of global activities, (b) the reduction of profit margins as a result of global competition or declining demand, and (c) the increasing need to improve productivity and efficiency". In each case, cooperation is becoming increasingly compelling" (*Luo*, 2007). Furthermore, Bouncken points out that this cooperation, usually anchored in corporate strategy, is needed to cope with the dynamic business field with fluctuating uncertainties (cf. *Bouncken et al.*, 2015). Although the paradox of coopetition has been interpreted in many ways in different theoretical frameworks in the research world, it has always been based on the same premise that coopetition refers to cooperation with competitors. Since then, a rising trend in research can be observed. With the emergence of competitor mergers and the resulting development of the term „coopetition", it can be summarised that researchers are increasingly addressing this topic.

Functional levels of coopetition

While most research in the field of coopetition relates to the questions of the advantages and disadvantages of such an alliance (*Dagnino & Rocco*, 2011; *Himpel*, 2009; *Garraffo & Siregar*, 2021), nevertheless, further research has broadened the definition of coopetition. For example, *Raza-Ullah et al.* (2014) argue that simultaneous cooperation and competition between firms leads to tensions that arise at the individual, organisational and inter-organisational levels. Furthermore, the research literature differentiates between interorganisational and intra-organisational coopetition. In this context, inter-organisational coopetition examines the possibilities for shaping the network of relationships between several companies. Inter-organisational coopetition is characterised by the fact that a strategic decision is made between organisations that affect the organisation and preserves the independence of the cooperating units. In contrast, intra-organisational coopetition can be characterised by coopetition between individuals, teams (*Baruch and Lin*, 2012), functional units or business units within the same organisation. At the organisational level, the actors must follow the instructions of their organisation and the goals defined by the organisation are to be shared. The cooperation of an organisation with its competitors on an inter-organisational level can have different reasons. The most common ones are access to essential resources and knowledge (*Bengtsson & Kock*, 2000), sharing resources and knowledge to improve efficiency, and developing technical innovations through cooperation in research and development (*Bengtsson & Kock*, 2014; *Walley*, 2007), reducing risks, sharing costs

(*Bouncken et al.*, 2015), achieve economies of scale by combining similar activities(*Gnyawali & Park*, 2011), opening up new markets (*Gnyawali and Park*, 2009) and achieving economies of scope by combining complementary activities (*Luo*, 2005). Furthermore, *Bouncken et al.* (2015) categorised the objectives of coopetition into five further groups: Efficiency, Market Power, Market Exploration and Development, Innovation and Internationalisation. These scientific classifications can be found on the horizontal and vertical levels. The direction indicates at which stage of the value chain the companies are located and in which economic sector they are active. In horizontal coopetition, two companies at the same stage of the value chain work together to develop, produce and launch a new product that will compete with other coopetitors' products. Based on previous research, this type of coopetition can be expected to significantly improve the joining of competitors in terms of sustainability goals and create high synergies. Therefore, it can be assumed that horizontal coopetition has a positive influence on future innovations. Significant research on the horizontal level on creating new markets or improving the company's position in existing markets includes the study by (*Ritala & Hurmelinna-Laukkanen*, 2009), as firms can achieve a better competitive position by improving their capabilities and exploiting unique, inimitable, non-transferable resources (*Quintana-García & Benavides-Velasco*, (2004). If a merger of companies from other industries takes place, you are on a different level of the value chain and cooperate vertically. In vertical cooperation, a distinction is made between customer cooperation and supplier cooperation. The relationship between the supplier and the customer has become increasingly important for several years. The supplier of today is seen and accepted as a „real" value-added partner and forms an interface for the customer himself. Coopetition at the intra-organisational level is an internal tension between cooperation and competition and arises from activities that put the organisational division of labour or cooperation in competition with each other. It can thus occur within a company when, for example, there is competition between two projects.

Definition of sustainability and emergence of the sustainability principle

Whether in business, the media or academia, the term sustainability has become part of our vocabulary in recent years. What is sustainability? The answer to this question is not only complex but also complicated by different terminology that is often associated with the environment, climate change and resource conservation. If this is not broad enough, sustainability is also associated with energy, population development, manufacturing, production, corporate environmental management and climate protection. The term is used by a wide range of actors: from Greenpeace to Friday for Future, banks, mineral water suppliers, the automotive industry and ministries, managers and consumers. However, if one translates the word „sustainability" consistently into German, it is composed of „nach" and „haltig". The logical consequence of this is that the word means „long-lasting effect". And this also corresponds to one of the most commonly used definitions of the term sustainability, which was formulated in the Brundtland Report of the United Nations in 1987. This states: „Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future

generations to meet their own needs." (*Hardtke & Prehn*, 2001). Hauff translates this as follows: „Sustainable development is development that ensures that future generations are no worse off in meeting their needs than those living at present." (*Hauff*, 1987). In summary, it can be said that the term „sustainability" is not comprehensively and accurately explained by a simple definition as others are. Rather, the concept of sustainability is the sum of numerous definitional approaches that take into account the different elements of sustainability. However, it can be concluded from an ecological as well as an economic point of view that:

1. Sustainability is always oriented towards the present and the future and thus a temporal reference is given.
2. Resources, tangible/intangible goods, economic/ecological units, etc., should be protected, especially if they are non-renewable.
3. The continued existence of a reference object is to be ensured in the short and long term.

Sustainability can thus be understood as a form of ecological and economic action that aims to ensure comparable or better living conditions for present and future generations by carefully applying the necessary element and protecting it accordingly.

The origin of the sustainability principle goes back to 1713, Carlowitz's forest management principle. t. As early as 1713, Carl von Carlowitz called for „a steady and persistent use of the forest." It has been used as the most vivid metaphor to explain the sustainability principle: Trees that are cut down must be replanted so as not to deplete the resource base - and thus the economic base. If you cut down all the forest, you have a lot of wood in the short term, but only a little over the next decades (*Pufé*, 2017) It was not until 250 years ago that Dennis Meadows and his team of researchers came to the decisive conclusion. The report „Limits to Growth" in 1972, based on a computer simulation, showed the deterioration of the planet if humanity did not become more resource efficient. The report marked the beginning of the more recent scientific debate on sustainable development and called for a new „world economic policy". In the following period, politics and civil society in particular took up the resource-economy principle again, also under the awareness of the „Limits to Growth" report. In the 20th century, the global community became increasingly aware of problems such as environmental pollution, overpopulation, poverty and resource depletion. At the beginning of the century, the first international conferences on nature conservation were held in this regard. From the mid-1970s onwards, public and political interest in environmental protection issues grew. Binding regulations were adopted between states to protect the environment, such as the Washington Convention on International Trade in Endangered Species. The problems became more specific, the goals more concrete. However, the historical precursors that shaped the image of sustainability include the „Brundtland Report", the „Rio Summit", „Agenda 21" and the „UN Millennium Goals".

As early as 1983, the United Nations founded the so-called World Commission on Environment and Development (WCED), an independent expert commission in Geneva. The reason for writing this Brundtland Report and founding the Commission at that time was the realisation that the quality of the environment worldwide was being significantly affected and rapidly deteriorating due to human

economic activities. It was the time of the greenhouse gas. The change in emission levels led to the accompanying climate change. The world's population was also growing, increasing the pressure on available resources. The aim of the report was to provide a perspective report on „long-term sustainable development on a global scale by 2000 and to make recommendations on how environmental concerns can be translated into greater cooperation among developing countries and among countries at different stages of economic and social development, leading to the achievement of common and mutually supportive goals that take into account the interrelationships between people, resources, environment and development, including to consider ways and means by which the international community can deal more effectively with environmental concerns, and to help establish common understandings of long-term environmental problems and the corresponding efforts required to successfully address the problems of environmental protection and enhancement, as well as a long-term agenda for action in the coming decades and aspirational goals for the global community". to elaborate. The official title of the report was „Our Common Future". (*Brundtland*, 1987) but more commonly known in the local literature as the Brundtland Report. The origin refers to the name of the chairman Gro Harlem Brundtland. The aim of this report was to give recommendations for action for sustainable development. The merit of the Brundtland Report at that time was to have brought the report of sustainable development to the public for the first time as a global uniform guiding principle. The report was the first to state that global environmental problems are mainly caused by human consumer behaviour. The perception of the problem and the resulting approach to solving it led to a strategy that brought together development and the environment and thus coined the term „sustainability". This resulted in the definition: *„sustainability" = „environment" + „development".*

The Brundtland Report was followed by the UN Conference in Rio in 1992. On the basis of the Brundtland Report, which was considered by the UN General Assembly in 1989, it was realised that there was an urgent need for action at the international level. The proposals and demands of the need for action called for at that time were to be translated into binding treaties and conventions. A total of 178 states took part in this process, the aim of which was to deal with development problems in an environmental context and to summarise the course of sustainable development worldwide. A total of six documents were agreed upon, which promoted the formal legal anchoring of sustainability. Not only were the documents signed, but also „Agenda 21" was launched, which was agreed upon as a United Nations action programme. The package of measures primarily served to encourage international organisations and national governments as well as all other political levels to act in the spirit of these goals. The successor agenda is the so-called „Agenda 2030", which came into force on 1 January 2016.

Current development and models

Since the Rio Conference in 1972, the United Nations has been trying to create a framework for climate protection. Since then, a multitude of environmental agreements and measures have emerged. The associated access to nature as well as

social resources, knowledge, trade flows, centres and services decides between rich and poor. This results in a need for further action by the United Nations so that in September 2015 a successor framework was again set for the Millennium Development Goals (MDGs), which expired in 2015. In negotiations with 30 UN member states, a post-2015 agenda with 17 Sustainable Development Goals (SDGs) and 168 sub-goals was agreed upon together with the UN Global Compact, the Global Reporting Initiative (GRI) and the World Business Council for Sustainable Development (WBCSD). The SDGs are thus another outcome of ongoing efforts to create a framework to promote sustainable development at the global level. The aim is to create a new orientation framework for global development and environmental policy to further promote sustainable development over the next 15 years (until 2030). Businesses play a key role in enabling sustainable development, as they are major users of natural and social resources through the production and provision of goods and services. Current environmental problems such as wastewater, air emissions, soil pollution, ozone layer depletion, global warming and deforestation can be seen in large part as the result of the negative impact of business on sustainability (*UNEP*, 2016). Especially the merger of competitors due to this problem, one can see the importance of this issue.

The Paris Agreement thus sends a clear signal. All states are thereby held accountable. Against the background of both tightening environmental laws and ethical social regulations, nations, organisations, companies and households that apply sustainability principles have an advantage. Governments must ensure a sustainable resource base in both ecological and human terms. As far as companies and the economic perspective are concerned, they are subject to globalising and intensifying competitive pressure in terms of raw materials, costs, employees and innovation. In order to operate successfully in the medium and long term, they need to renew their business models and strategies based on sustainable development. From an economic point of view, sustainable development is first and foremost about securing the basis of life and production. This indirectly justifies the claim of sustainable development to preserve the environment globally and permanently and to develop and stabilise the economic and social system on this basis.

The term ecological sustainability has already been mentioned. However, sustainable development requires two further levels, economic and social sustainability. Whereas in the past profit-making alone was the entrepreneurial goal and thus the supporting pillar of any project, this has been supplemented by the ecological pillar due to resource scarcity and environmental pollution. Against the background that not only employees are affected by environmentally damaging business activities of companies, but also numerous internal and external players such as the social environment, communities and developing countries, the social pillar was added. The model emerged as early as the 1990s They were first used as a benchmark for sustainability in international treaties at the Johannesburg World Summit in 2002.

The three-pillar model of sustainable development is based on the idea that sustainable development can only be achieved through the simultaneous and equal implementation of environmental, economic and social goals. Only in this way can the ecological, economic and social performance of society be ensured and improved.

The three-pillar model was „style-forming" for the debate on sustainable development, as it demanded mutual acceptance of the respective interests from the ecological, economic and social actors. Despite its importance, the three-pillar model is sometimes controversial among experts. Critics complain above all that it is difficult to operationalise and that hardly any practical consequences can be derived from it. In its 2002 report, the German Advisory Council on the Environment (Sachverständigenrat für Umweltfragen) denied the three-pillar model an orientation function because it degenerated into a three-column wish list in which every actor could enter his or her concerns. Despite the criticism, this pillar model has contributed significantly to the understanding of sustainability, as it makes clear that all three foundations are needed for sustainability and are interdependent.

Consumer behaviour: Main driver of sustainability concepts for companies and coopetition

Companies are also forced by consumer behaviour to deal with sustainability. Consumers, especially the younger generation, have concrete ideas about sustainability and sustainable products. The consequence can be observed in purchasing behaviour. When buying products, people already pay attention to the fact that the company acts in a socially and ecologically responsible way. This change in attitude in society can be observed most vividly in the purchase of everyday products such as food and can be understood by every person. However, the effects of the change are much more far-reaching and affect not only companies in the food industry, but every company. This is because the entire corporate image is closely linked to the factor of sustainability. The image of a company is essentially determined by a few factors. These include the quality of the service, the economic success and also the issue of sustainability. The consumer certainly sees sustainability as a possible criterion when making a purchase decision. A study by Ernst & Young in 2021(EY Future Consumer Index) (*Bangemann,* 2021) shows that Germans are already well aware that climate change is a fundamental problem. Thus, climate change is seen as the problem by 53 percent of those surveyed. In particular, the production and consumption of goods and services are important to consumers in Germany at 30%. The global average is comparatively 23%. However, plastic waste is of greatest concern, at 65 per cent in Germany and 73 per cent globally, ahead of climate change. German consumers are also particularly concerned about combating the consequences of climate change (38%) (global 28%), promoting sustainable use of ecosystems and biodiversity, and responsible production and consumption of products and services. This sensitivity is also noticeable in purchasing decisions. Thus, a large majority of German consumers pay attention to the sustainability and environmental impact of a product when buying it. When it comes to purchasing decisions, it was determined that fresh fruit and vegetables as well as packaged foods are at the top of the shopping list of sustainability-conscious consumers with 83 and 81 percent, respectively. They are followed by cosmetics and clothing.

According to another study by Stiftung Marktwirtschaft, competition can come from low prices, quality promises, innovative products, good service, long opening hours, attractive locations, convincing advertising and many other things that

customers potentially value. As far as customers value climate-friendly production or good working conditions for workers or „fair" payment of suppliers such as producers, companies can gain competitive advantages by precisely offering this and making it transparent.

The literature review found that sustainability can be an entrepreneurial opportunity for start-ups and established companies. Sustainable business models and innovations are an important way to differentiate oneself from the competition. Similarly, embedding positive contributions to the environment and society makes it easier to build a corporate and employer brand compared to non-sustainable business models. (*Leal Filho*, 2019). In most corporate business models, partnerships with other organisations play an important role. These include strategic alliances between non-competitors, strategic partnerships between competitors (coopetition), joint ventures to develop new business, and partnerships between supplier(s) and customers.

In recent decades, there has been extensive literature on both coopetition and sustainability. However, scholars have mostly studied both coopetition and sustainability in isolation in different contexts. There has been little discussion of coopetition and sustainability when they are brought together. A large body of research aims to examine what benefits these mergers have and what legal frameworks are associated with them (*Bouncken et al.*, 2015) rather than what influences sustainability goals have on coopetition. The literature and the limited discussion on the link to sustainability suggest that there is considerable potential for systematically exploring the use of coopetition strategies by companies in relation to sustainability.

Both the systemic nature and the large scale of sustainability challenges, therefore, require targeted interactions between multiple actors at different levels: within and between industries, sectors and countries. These interactions usually involve cooperation between actors. Various research approaches have been derived from this so far, most of which refer to inter-organisational coopetition and can be divided into three categories according to the literature review:

1. The first category focuses on both coopetition and sustainability. The researchers examined coopetition with the direct intention of supporting sustainability (*Christ et al.*, 2017; *Planko et al.*, 2019; *Sharma et al.* 2021).
2. The second group focuses research on the phenomenon of coopetition under which sustainability is considered as one of the many aspects influenced by coopetition. The studies in this context are based on different aspects of coopetition, but mention sustainability as a means or an indirect result of cooperation with competitors (*Jafarnejad et al.*, 2020; *Munten et al.*, 2021; *Nguyen et al.*, 2022).
3. In the third group of studies refers to the literature on corporate sustainability, where the focus of the research is on sustainability issues and considers competitors as one group of stakeholders among others responsible for sustainability (*Kumar et al.*, 2021; *Shih & Agrafiotis*, 2020).

As a result, there are already research approaches with different orientations, although research in this field still has some gaps. However, it can be assumed that due to the implementation of sustainability goals, this gap can be closed in the future.

CONCLUSIONS

In summary, the paper gives an overview of the state of research on coopetition and sustainability with the result of showing insights into the emergence and the current state of research. The research showed that coopetition is still a young field of research. For example, the term was only formed in the nineties and only gained significant meaning in the 2000's s, which found further presence in today's research literature with the meaning of sustainability. Surprisingly, it was also found that the term sustainability was defined more than two hundred years ago and only gained increasing importance with political decisions in the last forty years. This is also proof that both topics are far from being fully explored. One of the most important findings for future mergers of competitors is that sustainability is the main driver. In particular, political pressure and consumer behaviour is driving companies to coopetition in the future and to think more about and make a significant contribution to sustainability in production and supply chains. One of these pioneers in sustainable sourcing and supply chain management is, for example, a German sports equipment manufacturer that actively monitors its entire supply chain and does so together with its competitors. It also supports material suppliers and works closely with institutions to ensure sustainable practices throughout and to introduce mandatory limits for critical substances. In this way, it indirectly contributes to the reduction of waste and emissions, also for the product user, and the consumer. By doing so, it strengthens its own corporate and brand identity towards its consumers and promotes the resilience of its supply chains. Another example of how to make a difference in sustainability is shown by two large French companies: They signed a polymer recycling partnership to reach their target of 30% recycled content in car interiors. Although cosmetics manufacturers and sporting goods producers, with their correspondingly sensitive target groups, are already on the rise in terms of sustainability, more and more corporate sectors are also addressing the issue, which has been reluctant to do so until now. The literature shows that coopetition is no longer exclusively about economic aspects, but also about the creation of new innovations, and the implementation of the „three-pillar model" in which ecological, economic and social interests are in focus. In this context, the awareness of the manager is crucial to implement sustainable development as a strategy in the company. For the measurement and comparison of the results of sustainable entrepreneurial action, key figures and indicators are already implemented in some corporations. The role of networks, cooperation and coopetition is emphasised in many studies and described as forward-looking, which can be implemented on different levels, for example on the vertical level, i.e., with companies along the

supply chain, or also on the horizontal level in the cooperation of competitors, in which the implementation of ecological goals can be implemented more quickly together due to innovations. Especially on the horizontal level, a merger with competitors can significantly improve the realisation of sustainability goals and thus create high synergies.

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