The impact of digital transformation on innovation in European companies: a new generation of AI predictive model test against predictive machine learning algos

Victor Santos[1,2], [0000-0003-3399-5414] vsantos@iscac.pt,
Pedro Malta[3*] [0000-0002-4908-4458] pmalta@novaims.unl.pt

[1] Coimbra Business School, Polytechnic Institute of Coimbra, ISCAC, Quinta Agrícola, Bencanta, 3045-231, Coimbra, Portugal

[2] REMIT—Research on Economics, Management and Information Technologies, Portucalense University, Porto, Portugal

[3] NOVA Information Management School (NOVA IMS), Campus de Campolide, Universidade Nova de Lisboa, 1070-312 Lisboa, Portugal

[*]Corresponding author

This is the Author Peer Reviewed version of the following article published by Springer:

Santos, V., & Malta, P. (2024). The Impact of Digital Transformation on Innovation in European Companies: A New Generation of AI Predictive Model Test Against Predictive Machine Learning Algos. In J. L. Reis, J. Zelený, B. Gavurová, & J. P. M. D. Santos (Eds.), Marketing and Smart Technologies: Proceedings of ICMarkTech 2023, Volume 1 (Vol. 1, pp. 447-458). (Smart Innovation, Systems and Technologies; Vol. 386). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-97-1552-7_30

The impact of digital transformation on innovation in European companies: a new generation of AI predictive model test against predictive machine learning algos

Victor Santos [0000-0003-3399-5414]

Coimbra Business School | ISCAC, Polytechnic of Coimbra, Coimbra-Research Centre, PT
e-mail: vsantos@iscac.pt
REMIT - Research on Economics, Management and Information Technologies, Portucalense University, Portugal

Pedro Malta [0000-0002-4908-4458]

Universidade Nova de Lisboa | Nova IMS – Information Management School
e-mail: pmalta@novaims.unl.pt

Abstract. In recent years, the global business landscape has witnessed a profound shift driven by the relentless march of digital transformation. This research provides an overview of the impact of digital transformation on innovation within European companies, shedding light on the key drivers, challenges, and outcomes of this transformative process. Digital transformation is characterized by the integration of digital technologies into all aspects of business operations. It has fostered a culture of continuous adaptation and creativity, driving firms to explore novel solutions, products, and services. From finance to healthcare, manufacturing to retail, companies are leveraging technologies like artificial intelligence, the Internet of Things, and cloud computing to streamline processes, enhance customer experiences, and create new business models. Using a machine learning approach to analyse the impact of digital transformation (DT) on innovation in European companies. Based on Eurostat data sets of different technologies were identified to consider which one do have more impact on digital transformation strategies by country and which one are evidence of asymmetries. This way it is possible to advise the better strategy per country and what model should be used to predict the future impact on different countries simulating different values of DT appliance adjusted to each country needs. The outcomes of European companies are witnessing improved efficiency and productivity through automation and data analytics. Customer-centric approaches driven by digital technologies are enhancing customer satisfaction and loyalty. Moreover, several aspects of what digital human skills should be improved and be acquired to reach the European Union goals.

Keywords: Digital transformation, Machine Learning, DT Technologies, SME Small and Medium Enterprises, Generative AI.

Introduction

In recent past, digital transformation has been a major driver of innovation and competitiveness in many organizations. Small and medium-sized enterprises (SMEs) are particularly susceptible to the impact of digital transformation, as they often face the challenge of limited resources and the need to quickly adapt to changing market conditions (Skare et al., 2023)Some authors refer to three major factors as relevant elements of digital transformation, digital technologies, employees' digital skills and digital transformation strategy (Teng et al., 2022).As digital technologies provide more information, computing, communication, and connectivity, they enable new forms of collaboration across distributed networks of diverse actors. In doing so, they also create dependencies between actors whose interests may not be fully aligned. This new reality offers great potential for innovation and performance in organizations and extends beyond the boundaries of the company to affect individuals, organizations, and society (Vial, 2019) This study aims to examine the impact of digital transformation on the innovation of European companies using quantitative data analysis and trying to answer several questions that emerge. What is the current level of digital transformation among companies in Europe? What is the relationship between digital transformation and innovation in European companies? How do the different dimensions of digital transformation (e.g. digital infrastructure, digital skills and digital culture) impact innovation in companies in European countries?
This paper is structured has follows. Sections 2 delivers the literature review on the subject. Section 3 goes through the main underpinning assumptions on the methodology employed. Section 4 provides the description of the implementation of the models. The discussion of results is given in Section 5. Finally, conclusions are drawn, highlighting the main limitations found and future work developments.

Literature review

For this section the scientific database Web of Science was used to address the topics

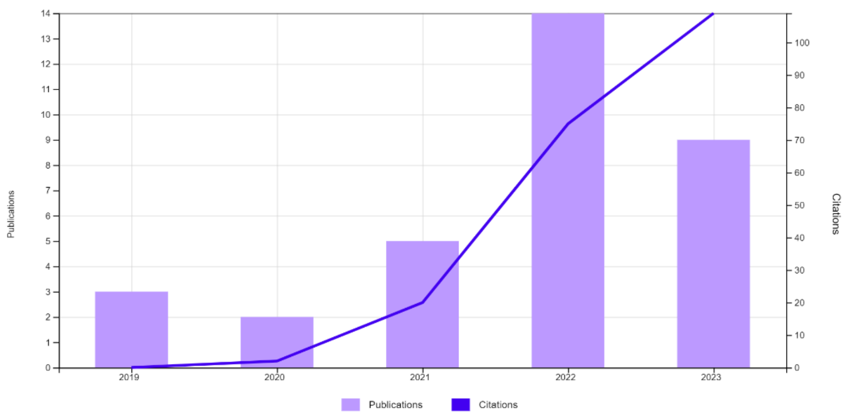


Fig. 1. : Number of publications and citations of the research topics

of digital transformation, for small and medium enterprises facing innovation. The time bound was according to figure 1, 5 years from 2019 to present year, where a considerable and increasing interest to these topics is proved by the number of publications and citations.

It was obtained a total of 33 documents between articles, early access, proceeding papers and review articles. The outstanding authors are presented in figure 2 followed by the main keywords in figure 3.

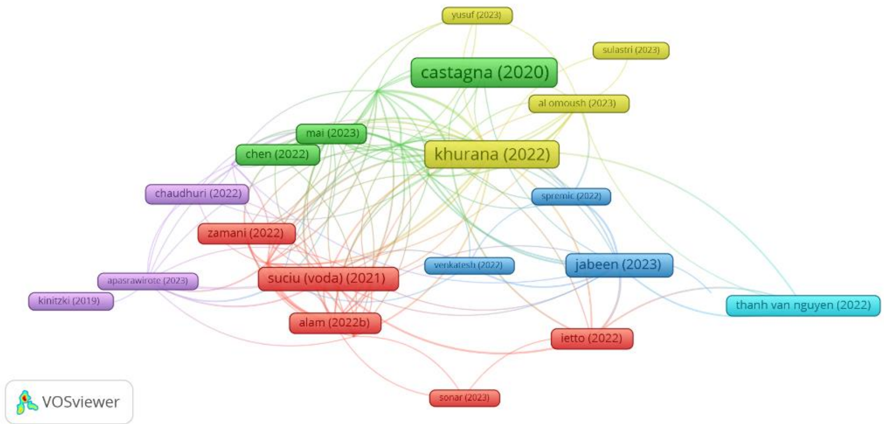


Fig. 2. : Outstanding authors of the research topics

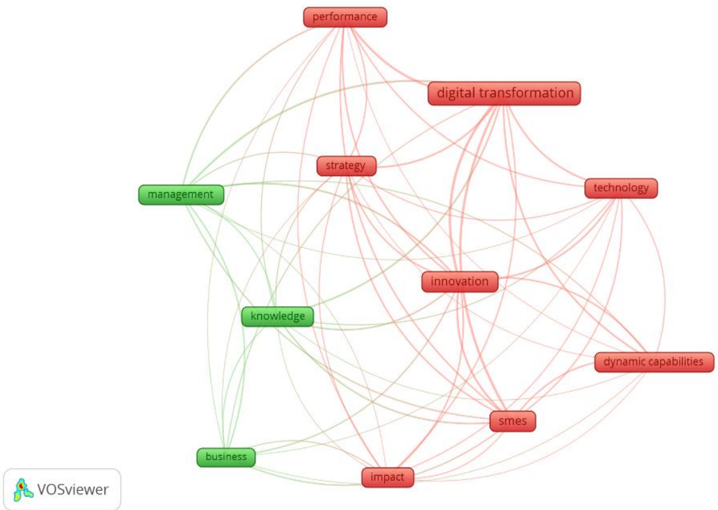


Fig. 3. Keywords of the research topics

The Web of Science categories were restricted to Management, Business, Economics, Green and Sustainable Science Technology.

The COVID-19 crisis has underscored the imperative for small and medium-sized enterprises (SMEs) to embark on digitalization efforts and embrace emerging technologies (Zamani, 2022). This shift is essential for their survival and competitiveness within the continuously evolving contemporary business landscape, as emphasized by (Chen et al., 2016).

Based on the European business statistics and Eurostat's website at https://ec.europa.eu/eurostat together with a range of online articles from this literature review (Zamani, 2022) it was possible to collect the values achieve to be analyzed and model with different artificial intelligence algorithms(Chaudhuri et al., 2022) to better evidence the different country strategies.

The review was not restricted to European companies to better understand and compare with all over the world small and medium enterprises. This way (Khurana et al., 2022)addresses DT in India how small and medium-sized enterprises (SMEs) engage in the adoption of digital technologies during crisis situations to cultivate resilience capability, which can be considered a second-level dynamic capability. Additionally, the dynamic interplay among sensing, seizing, and transforming capabilities is a crucial part of the orchestration process within the entrepreneurial ecosystem. Another concept is SME resilience, was found in Indonesia (Sulastri Sulastri, 2023) calling attention to the Entrepreneurial ecosystems and its significant effect on SMEs digital transformation. Entrepreneurial Ecosystem and Digital Transformation have a significant impact on Collaboration Capability. DT and Collaboration Capability, and Innovation Value have a significant effect on SME Resilience.

Methods/Methodology

A sample from the Eurostat was analyzed in relation to a survey, where data was collected meaning the number of SMEs of each of the 27 countries using that technologies. The data was prepared using descriptive statistics and regression analysis to determine the relationship between digital transformation and innovation, using a RapidMiner data mining tool. The approach use RapidMiner data preparation tool to identify where "Machine Learning" algorithms are used to identify the best model to apply. According to (van Zeebroeck et al., 2021) it is possible to define an estimation model in order to aggregate and evaluate web and cloud computing technologies.

Based on the technologies presented on the following table 1 it is important to explicit that each technology has a different impact on innovation and consequently on DT. Depending on the industry, organization, and specific use case. For example, Cloud Computing can enable scalable and cost-effective infrastructure for digital transformation initiatives. AI can enhance decision-making and automate processes. IoT can enable data collection from physical objects for analysis and automation. Big Data can provide insights from large datasets. 3D Print & Robotics can transform manufacturing and prototyping. CRM Auto can streamline the customer relationship management. Process Integration can enhance workflow efficiency. So, DT represents the broader initiative of transforming an organization digitally using these technologies, although in the realm of marketing, several technologies have a significant impact on companies, and their effectiveness can vary depending on the industry, target audience, and marketing goals. Here are a few key technologies that often have a substantial impact on marketing efforts:

1. Data Analytics and Big Data: Analysing large volumes of data allows marketers to gain insights into customer behaviour, preferences, and trends. It enables data-driven decision-making, personalized marketing campaigns, and better ROI tracking.

2. Artificial Intelligence (AI) and Machine Learning: AI-powered tools can automate tasks such as lead scoring, chatbots, and content recommendations. Machine learning algorithms can optimize ad targeting and predict customer behaviour.

3. Customer Relationship Management (CRM):** CRM software enables companies to manage customer interactions, track customer journeys, and provide personalized experiences.

It's important to note that the impact of these technologies can vary based on the specific industry and marketing strategy. Successful marketing often involves a combination of these technologies to create a cohesive and effective marketing ecosystem. Additionally, staying up-to-date with emerging technologies and trends is crucial for maintaining a competitive edge in the marketing landscape.

To determine which technologies from the "Digital Transformation vs Technologies in Europe 2023" dataset could have a significant impact on digital transformation and innovation, it's essential to consider the potential implications of each technology. Here's an analysis of some of the technologies that could have a substantial impact:

Cloud Computing: Cloud computing provides scalable and cost-effective infrastructure, enabling organizations to adopt digital transformation initiatives more efficiently. It allows for flexible data storage, processing, and application deployment, which can lead to innovation in various industries.

Artificial Intelligence (AI): AI, including machine learning and deep learning, has a transformative effect on digital transformation. It enables automation, predictive analytics, and personalized customer experiences. AI-powered insights and automation can drive innovation in business processes and decision-making.

Internet of Things (IoT): IoT connects physical objects and devices to the internet, facilitating data collection and automation. It can drive innovation in product development, supply chain optimization, and smart city initiatives, contributing to digital transformation efforts.

Big Data: Big Data analytics provides valuable insights from large datasets. It can inform strategic decisions, improve customer understanding, and enhance operational efficiency, supporting innovation and transformation efforts.

3D Printing & Robotics: These technologies can revolutionize manufacturing and prototyping processes. They enable rapid prototyping, customization, and automation, leading to innovation in product design and production.

Supply Chain Management Automation (SCM Auto): Automation in supply chain management streamlines operations, reduces costs, and improves visibility. It can drive innovation in logistics, inventory management, and demand forecasting.

Customer Relationship Management Automation (CRM Auto): Automated CRM systems enhance customer interactions, personalize marketing, and improve customer satisfaction. Innovations in customer engagement and loyalty can result from CRM automation.

Process Integration: Integration technologies allow for the seamless flow of data and processes across an organization. They can lead to process optimization, innovation in workflows, and improved collaboration.

Digital Transformation (DT): Digital transformation itself represents a holistic approach to innovation. It encompasses the integration of various technologies and the transformation of business models and operations to stay competitive in the digital age.

The impact of these technologies on digital transformation and innovation will depend on how effectively they are integrated into an organization's strategy and how well they align with its specific goals and challenges. Often, a combination of these technologies is necessary to drive significant transformation and innovation in various industries. These will have a huge impact on the result for each country. As an example, let’s consider Cloud Computing evolution from 2014 through out 2021 on the 27 countries as presented directly from the Eurostat.

Dataset:	Cloud computing services by NACE Rev.2 activity [ISOC_CICCE_USEN2$DEFAULTVIEW]
Last updated:	29/08/2023 11:00
Time frequency	Annual
Size classes in number of persons em	10 persons employed or more
Statistical classification of econom	Manufacturing, electricity, gas, steam and air conditioning; water supply, sewerage, waste management and reme-
Information society indicator	Buy cloud computing services used over the internet
Unit of measure	Percentage of enterprises

TIME / GEO (Labels)	2014	2015	2016	2017	2018	2020	2021
Bulgaria	6,2	4,4	4,3	5,1	7,0	8,7	9,7
Czechia	13,2	:	14,7	19,4	23,4	26,8	38,9
Denmark	34,3	34,5	40,9	48,4	55,7	66,6	62,8
Germany	10,1	:	13,8	:	19,3	30,8	38,8
Estonia	12,7	:	19,5	:	32,4	54,9	58,2
Ireland	30,3	35,9	40,5	:	47,6	60,5	67,4
Greece	: u	6,7	8,6	: u	: u	: u	18,7
Spain	12,8	12,7	16,5	18,9	18,3	24,6	27,9
France	9,7	:	16,7	:	18,4	25,1	27,7
Croatia	19,4	19,4	18,5	26,7	23,2	40,0	34,8
Italy	38,6	:	20,3 b	:	21,3	59,4	61,9
Cyprus	7,2	6,0	6,3	14,6	18,8	27,1	43,9
Latvia	5,2	7,7	6,8	8,6	12,2	19,1	26,7
Lithuania	11,6	14,5	14,7	19,2	22,4	30,6	35,3
Luxembourg	13,6	:	19,5	:	24,3	26,4	36,2
Hungary	5,8	9,4	10,0	13,7	17,4	23,3	24,8
Malta	16,0	19,9	: u	:	: u	: u	53,4
Netherlands	22,8	:	26,2	:	41,7	48,7	62,0
Austria	10,8	:	14,6	19,4	21,9	38,4	37,1
Poland	4,9	6,3	7,2	8,3	10,7	23,3	28,2
Portugal	8,7	:	12,7	17,1	20,5	24,2	29,4
Romania	4,5	6,0	5,8	10,2	7,5	15,7	11,2
Slovenia	11,6	16,2	18,4	25,5	25,6	38,9	42,9
Slovakia	14,0	19,4	14,5	22,3	21,1	24,5	33,8
Finland	48,2	52,3	59,0	70,0	71,2	83,0	85,2
Sweden	36,9	:	46,4	:	58,1	75,4	76,9
Iceland	42,0	:	:	:	:	:	:
Norway	28,2	37,5	36,1	46,1	51,5	70,7	72,1
United Kingdom	19,0	:	31,6	:	: u	: u	:
Bosnia and Herzegovina	:	:	:	:	: u	5,0	4,1
Montenegro	:	:	6,5	:	17,3	22,7	: u
North Macedonia	: u	:	6,3	:	:	: c	: u
Albania	:	:	:	:	:	:	: c
Serbia	3,4	:	:	10,9	14,6	16,1	23,7
Türkiye	:	:	10,3	:	10,5	13,7	10,6

Fig. 4. 27 European Countries Cloud Computing evolution from 2014 to 2021

At the source there is a missing year for all countries, and that is 2019. As it can be seen on the table above there are some missing values but hopefully the majority could be used to achieve an average value because there is an increasing trend on the use of Cloud Computing for each country by interpolation. Unless like Belgium where data is missing for all over the years, and we must adopt another data preparation strategy. For the other technologies it was used the same approach by interpolation on missing data. As a result for Cloud Computing to each country could be:

	Country\Year	2014	2015	2016	2017	2018	2020	2021	Average
1	Belgium	28	29	30	34	40	53	53	38,0
2	Bulgaria	6,2	4,4	4,3	5,1	7,0	8,7	9,7	6,5
3	Czechia	13,2	14	14,7	19,4	23,4	26,8	38,9	21,5
4	Denmark	34,3	34,5	40,9	48,4	55,7	66,6	62,8	49,0
5	Germany (until	10,1	12	13,8	17	19,3	30,8	38,8	20,2
6	Estonia	12,7	16	19,5	26	32,4	54,9	58,2	31,4
7	Ireland	30,3	35,9	40,5	44	47,6	60,5	67,4	46,6
8	Greece	6	6,7	8,6	10	15	17	18,7	11,6
9	Spain	12,8	12,7	16,5	18,9	18,3	24,6	27,9	18,8
10	France	9,7	13	16,7	18	18,4	25,1	27,7	18,3
11	Croatia	19,4	19,4	18,5	26,7	23,2	40,0	34,8	26,0
12	Italy	38,6	29	20,3	21	21,3	59,4	61,9	36,0
13	Cyprus	7,2	6,0	6,3	14,6	18,8	27,1	43,9	17,7
14	Latvia	5,2	7,7	6,8	8,6	12,2	19,1	26,7	12,3
15	Lithuania	11,6	14,5	14,7	19,2	22,4	30,6	35,3	21,2
16	Luxembourg	13,6	17	19,5	22	24,3	26,4	36,2	22,6
17	Hungary	5,8	9,4	10,0	13,7	17,4	23,3	24,8	14,9
18	Malta	16,0	19,9	22	23	24	38	53,4	28,0
19	Netherlands	22,8	25	26,2	34	41,7	48,7	62,0	37,1
20	Austria	10,8	13	14,6	19,4	21,9	38,4	37,1	22,1
21	Poland	4,9	6,3	7,2	8,3	10,7	23,3	28,2	12,7
22	Portugal	8,7	11	12,7	17,1	20,5	24,2	29,4	17,6
23	Romania	4,5	6,0	5,8	10,2	7,5	15,7	11,2	8,7
24	Slovenia	11,6	16,2	18,4	25,5	25,6	38,9	42,9	25,6
25	Slovakia	14,0	19,4	14,5	22,3	21,1	24,5	33,8	21,4
26	Finland	48,2	52,3	59,0	70,0	71,2	83,0	85,2	67,0
27	Sweden	36,9	41,7	46,4	52,25	58,1	75,4	76,9	55,4

Fig. 5. Cloud computing linear interpolation

Table 1 allows the analysis by country of each technology and for each technology the countries with more SME using them. For example, it is easy to identify the significant lack of application of these technologies in Romania. On the opposite way Finland leads the head of the countries with most use and with digital transition being well applied. The resulting column of DT by country uses different weights resulting on a pondered final sum with different contribution for each technology.

Based on Table 2 DT for each country results from the average contribution and participation of SMEs on their country for each technology and the weight it represents for DT. This way it results the following formula to be applied for each country and to be tested on the predictive Machine Learning models as well as the predictive generative AI models:

DT = 0,8* CC + 0,7 * AI + 0,6 * IoT + 0,6 * BD + 0,5 * 3D P&R + 0,3 * CRM + 0,1 * PI

Meaning that if take a regression analysis approach the weight of each independent variable will vary.

Table 1. – Digital Transformation by country and technologies

Countries	CC	IA	IoT	Big Data	3DP&R	CRM Auto	PI	DT
Belgium	38,0	10,6	28,2	22,9	25,6	25,1	22,5	91,1
Bulgaria	6,5	2,8	15,0	6,3	8,1	7,7	8,0	54
Czechia	21,5	4,2	31,4	9,1	19,0	17,0	16,2	118
Denmark	49,0	27,3	20,0	27,0	32,1	31,1	27,5	214
Germany (un	20,2	9,4	35,6	17,8	21,7	20,9	21,1	147
Estonia	31,4	2,8	17,4	9,9	17,2	15,7	12,6	107
Ireland	46,6	8,5	34,0	22,7	29,7	28,3	24,6	194
Greece	11,6	5,6	22,8	12,9	13,3	13,2	13,6	93
Spain	18,8	7,5	27,5	9,0	17,9	16,2	15,6	113
France	18,3	5,5	22,0	21,7	15,3	16,6	16,2	116
Croatia	26,0	8,4	23,2	13,6	19,2	18,1	16,5	125
Italy	36,0	6,7	32,3	8,6	25,0	21,7	18,9	149
Cyprus	17,7	1,9	33,3	6,2	17,6	15,3	14,9	107
Latvia	12,3	2,6	28,4	8,5	14,4	13,3	13,4	93
Lithuania	21,2	5,1	28,4	10,5	18,2	16,7	15,8	116
Luxembourg	22,6	12,6	22,2	18,7	19,1	19,1	18,3	133
Hungary	14,9	4,0	22,3	7,0	13,7	12,4	11,9	86
Malta	28,0	7,3	28,0	30,0	21,1	22,9	21,9	159
Netherlands	37,1	12,5	20,7	27,2	23,4	24,2	21,6	167
Austria	22,1	9,8	50,8	8,7	27,6	23,8	24,1	167
Poland	12,7	2,3	18,6	8,5	11,2	10,7	10,3	74
Portugal	17,6	19,1	23,4	10,6	20,0	18,2	18,3	127
Romania	8,7	1,2	10,5	5,1	6,8	6,5	6,0	45
Slovenia	25,6	12,4	49,5	6,6	29,2	24,6	24,5	172
Slovakia	21,4	5,3	27,4	5,6	18,0	15,5	14,4	108
Finland	67,0	17,2	40,5	21,6	41,6	37,6	31,7	257
Sweden	55,4	9,5	40,3	19,2	35,1	31,9	27,2	219

From [0, 1] as a percentage we have the following weight technologies table:

Table 2. Weight Technologies

Acronym	Technology	Weight
CC	Cloud Coumputing	0,8
AI	Artificial Intelligence	0,7
IoT	IoT	0,6
BD	Big Data	0,6
3DP&R	3D Print & Robotics	0,5
CRM	Customer Relationship Management - CRM Auto	0,3
PI	Process Integration	0,1

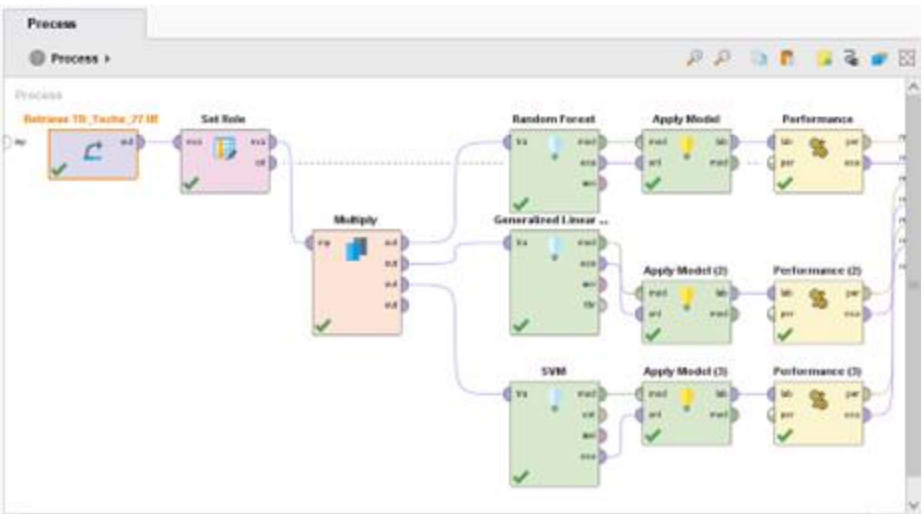
Predicition analysis with Rapidminer

To test the most used and recommended predictive methods when data are scarce it was used Rapidminer as a data science platform that allows data engineering, model building, machine learning operation, among others. It has a two-phase automation tool, TurboPrep for data preparation and Auto Model to test a simulate the different prediction models both in an automatic way. However, it was not possible to use these two tools since the source data table result in less then one hundred total data. This challenge forced both stages of the CRISP-DM, data preparation and model building to be done manually.

Authors like (Kumar et al., 2011) and (Diao et al., 2015) utilize hierarchical generalized linear models (GLM) or enhanced principal component analysis (PCA) in combination with adapted support vector machines (SVM) for the purpose of discerning the primary factors associated with both quantity and quality prediction. Reinforcing this algo utilization SVM for better predictions (F.Y et al., 2017) has compared several supervised ML algos to achieve this conclusion.

As shown in the figure below, table 2 was retrieved and added to the process area as the data source. After the identification of the main attribute, in this case was naturally DT – Digital Transformation, the data source was injected into the different three models to be tested for performance and accuracy, as shown in the figure 4.

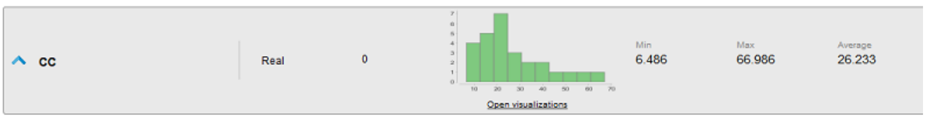
Fig. 6. – RapidMiner Process area with predictive models' performance analysis



Results analysis and model's comparison

For each technology it's possible to evaluate measures of central tendency and range factors that represent the discrepancy for each technology in use by SME of each country. Figure 5 represents these conclusions for CC – Cloud Computing.

Fig. 7. – Statistics for Cloud Computing in the 27 EU countries



The PerformanceVector for the first model Random Forrest present a root_mean_squared_error of 10.712 +/- 0.000 and for DT the lowest is Romania with 44,7 and the highest is Finland with 257,1.

If we compare with the second model, Generalized Linear Model the performance vector presented a root_mean_squared_error: 28.825 +/- 0.000 and for DT with Romania 44,7 but with a prediction value of 92,1. On the opposite way Finland achieved 257,1 and a prediction value of 181,6.

For the third model, SVM – Support Vector Machine presented a root_mean_squared_error: 34.828 +/- 0.000 with DT for Romania with 44,7 and a prediction of 97,2. As expected Finland presented 257,1 with a prediction of 158,5.

As can be stated Random Forrest achieve a better performance with the lowest root mean squared error.

The question that naturally arises is about the behaviour of the generative AI predictive models to DT compared to the machine learning models presented before.

Using the OpenAI GPT for every country with the same equation to calculate DT prediction it was obtained for Romania 17,7 the lowest value and 314,7 for Finland the highest one from all the 27 countries. The Root Mean Squared Error (RMSE) for Romania is approximately 12.97, and for Finland, it's approximately 53.98.

Conclusion

Comparing the results and the performance of all the models presented before even with few data the Machine Learning models do have a better performance and a lower error rate. Generative AI models need to be more tested, and sources controlled for final results.

References

Chaudhuri, R., Chatterjee, S., Vrontis, D., & Chaudhuri, S. (2022). Innovation in SMEs, AI Dynamism, and Sustainability: The Current Situation and Way Forward. *Sustainability (Switzerland)*, *14*(19). https://doi.org/10.3390/su141912760

Chen, Y. Y. K., Jaw, Y. L., & Wu, B. L. (2016). Effect of digital transformation on organisational performance of SMEs: Evidence from the Taiwanese textile industry’s web portal. *Internet Research*, *26*(1), 186–212. https://doi.org/10.1108/IntR-12-2013-0265

Diao, G., Zhao, L., & Yao, Y. (2015). A dynamic quality control approach by improving dominant factors based on improved principal component analysis. *International Journal of Production Research*, *53*(14), 4287–4303. https://doi.org/10.1080/00207543.2014.997400

F.Y, O., J.E.T, A., O, A., J. O, H., O, O., & J, A. (2017). Supervised Machine Learning Algorithms: Classification and Comparison. *International Journal of Computer Trends and Technology*, *48*(3), 128–138. https://doi.org/10.14445/22312803/IJCTT-V48P126

Khurana, I., Dutta, D. K., & Singh Ghura, A. (2022). SMEs and digital transformation during a crisis: The emergence of resilience as a second-order dynamic capability in an entrepreneurial ecosystem. *Journal of Business Research*, *150*, 623–641. https://doi.org/10.1016/j.jbusres.2022.06.048

Kumar, N., Mastrangelo, C., & Montgomery, D. (2011). Hierarchical modeling using generalized linear models. *Quality and Reliability Engineering International*, *27*(6), 835–842. https://doi.org/10.1002/qre.1176

Skare, M., de las Mercedes de Obesso, M., & Ribeiro-Navarrete, S. (2023). Digital transformation and European small and medium enterprises (SMEs): A comparative study using digital economy and society index data. *International Journal of Information Management*, *68*. https://doi.org/10.1016/j.ijinfomgt.2022.102594

Sulastri Sulastri. (2023). *RESILIENCE ACCELERATION MODEL OF SMALL AND MEDIUM ENTERPRISES THROUGH DIGITAL TRANSFORMATION*. https://doi.org/http://dx.doi.org/1015549/jeecar.v.10i4.1355

Teng, X., Wu, Z., & Yang, F. (2022). Impact of the Digital Transformation of Small- and Medium-Sized Listed Companies on Performance: Based on a Cost-Benefit Analysis Framework. *Journal of Mathematics*, *2022*. https://doi.org/10.1155/2022/1504499

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. In *Journal of Strategic Information Systems* (Vol. 28, Issue 2, pp. 118–144). Elsevier B.V. https://doi.org/10.1016/j.jsis.2019.01.003

Zamani, S. Z. (2022). Small and Medium Enterprises (SMEs) facing an evolving technological era: a systematic literature review on the adoption of technologies in SMEs. *European Journal of Innovation Management*, *25*(6), 735–757. https://doi.org/10.1108/EJIM-07-2021-0360