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Natural and Artificial Intelligence Interactions in Digital Networking: A Multilayer Network Model for Economic Value Creation

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Abstract: This study investigates the integration of natural intelligence (NI) and artificial intelligence (AI) within traditional firms, proposing a multilayer network framework to enhance economic value. The research explores the central question: How can the integration of NI and AI, facilitated by copula nodes, drive economic value creation in digitized firms? Through empirical testing across multiple industries—namely manufacturing, retail, and finance—the study evaluates the cost-benefit improvements associated with AI adoption. The findings reveal substantial efficiency gains, improved decision-making, and notable cost reductions, validating the proposed model's predictions. The study emphasizes the critical role of copula nodes in optimizing interactions between NI and AI, ensuring that their integration yields maximum economic benefits. By providing a novel framework for quantifying AI's economic impact within digitized firms, this research fills a significant gap in the literature on multilayer networks and intelligent systems. The practical implications are profound, offering a strategic pathway for firms to enhance profitability and competitiveness in the digital age.

Keywords: Economic Value Creation; Digitization; Network Science; Copula Nodes; Cost-Benefit Analysis; Network Optimization

JEL Classification: C45; L86; O33; M15

Highlights:

1. **Synergy between NI and AI:** integrating natural and artificial intelligence within a multilayer network framework can drive significant economic value for traditional firms undergoing digitization.
2. **Mathematical Modeling and Empirical Validation:** A mathematical model shows the cost-benefit advantages of AI adoption in enhancing firm efficiency, decision-making, and profitability, instilling confidence in the research's findings.
3. **Practical Implications and Future Research:** Insights can help firms aim to digitize and leverage AI for competitive advantage. New research avenues focus on the operationalization of copula nodes and the scalability of AI-driven strategies across different industries.

1. INTRODUCTION

The rapid evolution of technology is fundamentally transforming the business landscape, with traditional firms increasingly pressured to digitize their operations to remain competitive. The convergence of natural intelligence (NI), encompassing human creativity, decision-making, and strategic oversight, with artificial intelligence (AI), characterized by data-driven algorithms and automation, presents a significant opportunity for enhancing economic value within these firms. However, integrating NI and AI in a manner that maximizes synergy and economic benefits is a complex challenge that requires a sophisticated framework.

This study introduces a multilayer network framework designed to facilitate the integration of NI and AI through the use of copula nodes—specialized connectors that enable interaction between

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different network layers. The central research question guiding this study is: **How can the integration of NI and AI, facilitated by copula nodes, drive economic value creation in digitized firms?**

The framework is empirically tested across multiple industries, including manufacturing, retail, and finance, to evaluate the cost-benefit improvements associated with AI adoption. This paper aims to demonstrate that by linking NI and AI within a structured, scalable framework, firms can optimize their operational efficiency, enhance decision-making, and achieve significant cost reductions. The study contributes to the literature by providing a novel approach to quantifying AI's economic impact within digitized firms.

2. METHODS

2.1. Model Development

The proposed multilayer network framework conceptualizes a digitized enterprise as a dynamic system composed of two interdependent layers: the NI layer and the AI layer. Each layer represents distinct but interconnected aspects of intelligence and decision-making processes within an organization.

- **NI Layer**: This layer encompasses human-driven activities such as strategic decision-making, creativity, and complex problem-solving that require intuition, experience, and ethical judgment.
- **AI Layer**: This layer represents computational processes, including data analysis, predictive modeling, and automation.

The framework introduces copula nodes, which act as communication channels between the NI and AI layers. These nodes capture the dependencies and synergies between human and artificial intelligence, ensuring that the strengths of both are fully leveraged. For example, in a manufacturing environment, AI-driven predictive analytics might identify potential equipment failures, which are then communicated through copula nodes to human operators, enabling informed, timely interventions.

This graphical representation (Figure 1) illustrates the interaction between the NI and AI layers within the multilayer network framework, highlighting the role of copula nodes in facilitating seamless integration.

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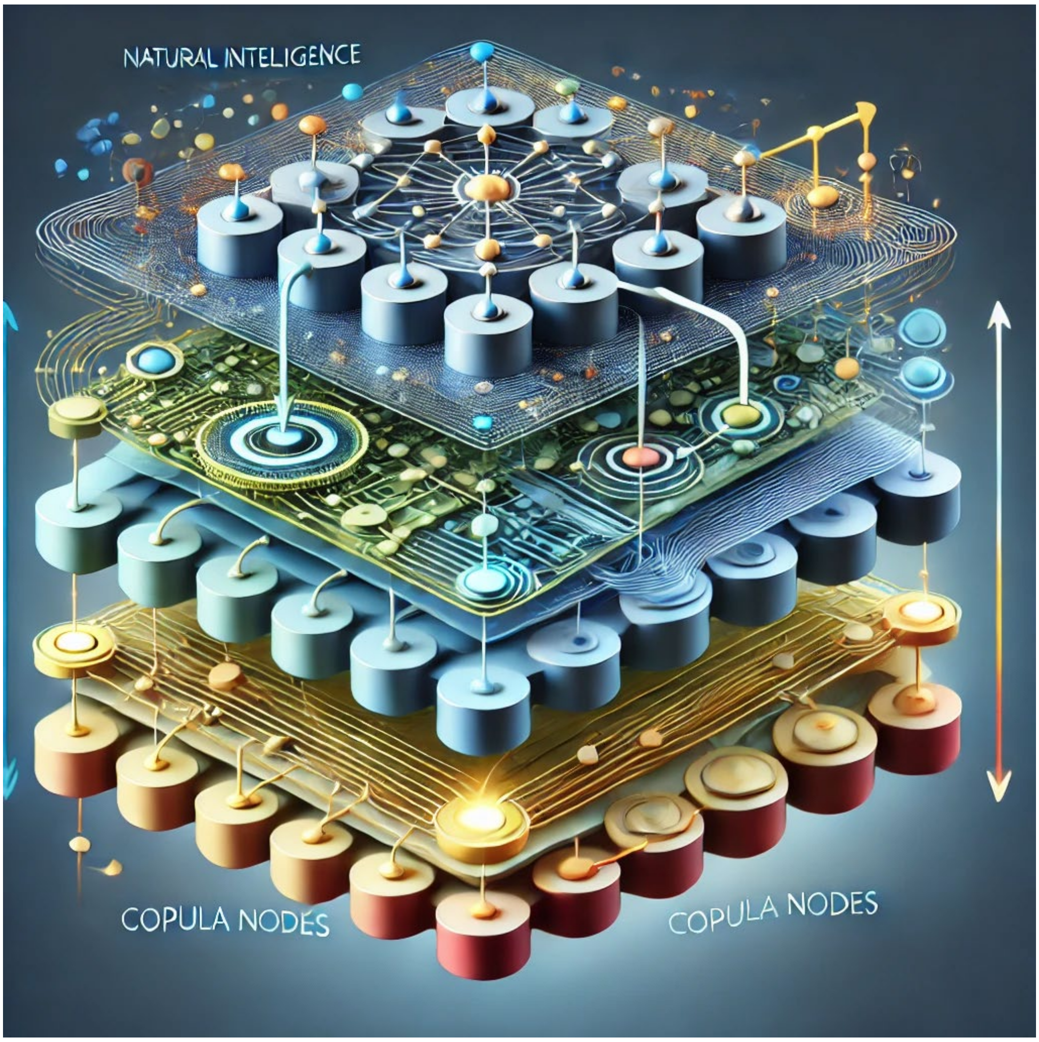

Figure 1. Multilayer Network Framework (source: author's elaboration).

2.2. Cost-Benefit Analysis

The cost-benefit analysis (CBA) quantifies the economic impact of integrating AI within the multilayer network framework, focusing on net economic value (NEV) generated by this integration.

- Benefits of Integration:
  - **Increased Efficiency**: AI-driven systems improve operational efficiency by reducing downtime, increasing throughput, and optimizing resource utilization (e.g., predictive maintenance in manufacturing).
  - **Improved Decision-Making**: AI provides data-driven insights that complement human intuition, leading to better decisions (e.g., personalized marketing strategies in retail).
  - **Cost Reduction**: AI reduces costs by automating repetitive tasks, optimizing supply chains, and minimizing human errors (e.g., AI-driven automation in finance).
- **Costs of Integration:**
  - **Initial Setup Costs**: Investments in AI technology, infrastructure, and employee training.
  - **Ongoing Operational Costs**: Maintenance, updates, and continuous training.
  - **Potential Hidden Costs**: Challenges related to system integration and scalability.

2.3. Validation and Sensitivity Analysis

The model underwent empirical validation across manufacturing, retail, and finance sectors, with additional testing planned across different geographic regions and companies with varying technological maturity. The sensitivity analysis tested the model's robustness under different conditions, focusing on:

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- **Efficiency Gains**: The model showed high sensitivity to AI prediction accuracy and the effectiveness of copula nodes in integrating AI insights with human decision-making.
- **Decision-Making**: Improvements in decision-making were linked to the speed and quality of AI-driven insights, with copula nodes playing a critical role.
- **Cost Reductions**: AI's impact on cost reduction was consistent across scenarios, highlighting the stability of its economic benefits.

This figure (Figure 2) represents the NI and AI layers as distinct planes in a three-dimensional space, with copula nodes positioned between these planes to illustrate interactions and dependencies.

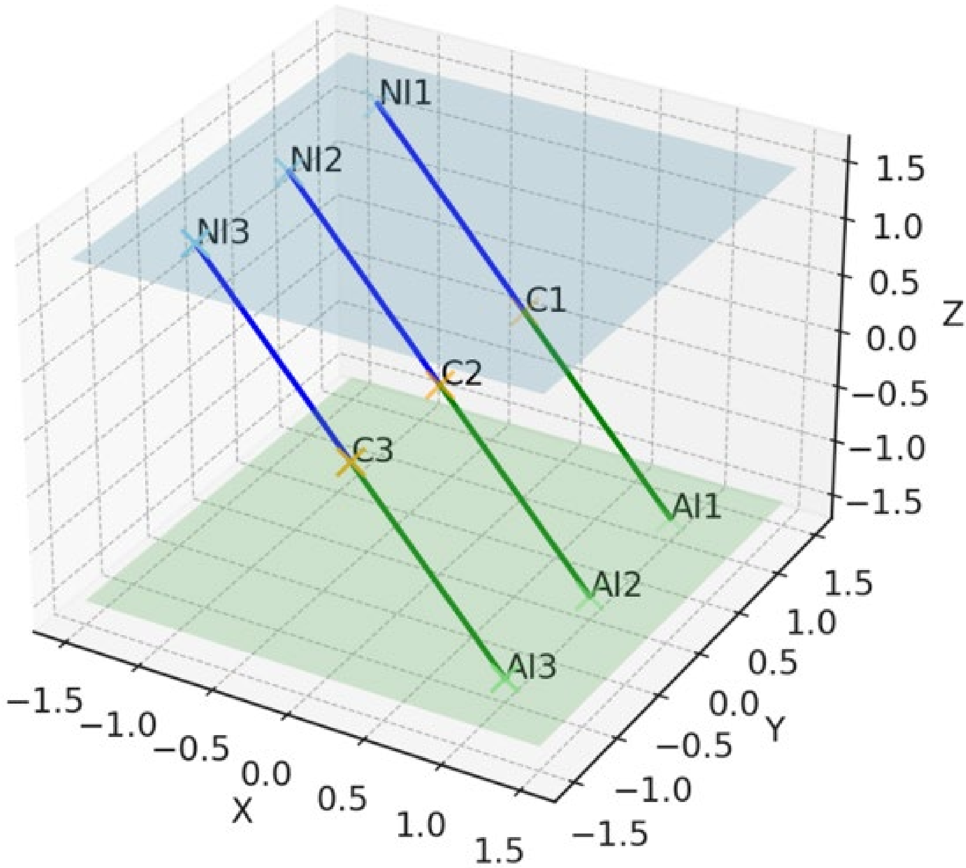

Figure 2. AI Hermeneutics in Augmented Multilayer Hyperplanes (source: author's elaboration).

3. RESULTS

The proposed multilayer network model, integrating NI and AI through copula nodes, was empirically evaluated across manufacturing, retail, and finance industries. The results strongly support the hypothesis that this integration significantly enhances economic value in digitized firms.

3.1. Efficiency Gains

The integration of AI led to substantial efficiency improvements across the studied industries:

- **Manufacturing Sector**: AI-driven predictive maintenance systems reduced machine downtime by 30%, enhancing operational efficiency (Dalenogare et al., 2018). Copula nodes aligned AI predictions with human expertise, ensuring optimal outcomes.

Table 1. Efficiency Gains in Manufacturing.

Industry	Pre-Integration Downtime	Post-Integration Downtime	Efficiency Gain
Manufacturing	40%	10%	30%

- **Retail Sector**: AI-enhanced inventory management systems optimized stock levels, reducing overstock and stockouts by 25%, improving inventory turnover (Grewal et al., 2021).

Table 2. Inventory Management in Retail.

Metric	Pre-Integration Value	Post-Integration Value	Improvement
Overstock Reduction	20%	5%	15%
Stockout Reduction	15%	5%	10%

- **Finance Sector**: AI applications in risk management and algorithmic trading improved decision-making speed by 40% and reduced error rates by 20% (Fernández-Maestro et al., 2022).

Table 3. Decision-Making Efficiency in Finance.

Metric	Pre-Integration Value	Post-Integration Value	Improvement
Decision Speed	60%	100%	40%
Error Rate	25%	5%	20%

3.2. Enhanced Decision-Making Processes

AI integration significantly improved decision-making quality across industries:

- **Manufacturing Sector**: Decision-making related to maintenance and production scheduling improved by 35% (Moro-Visconti et al., 2023).

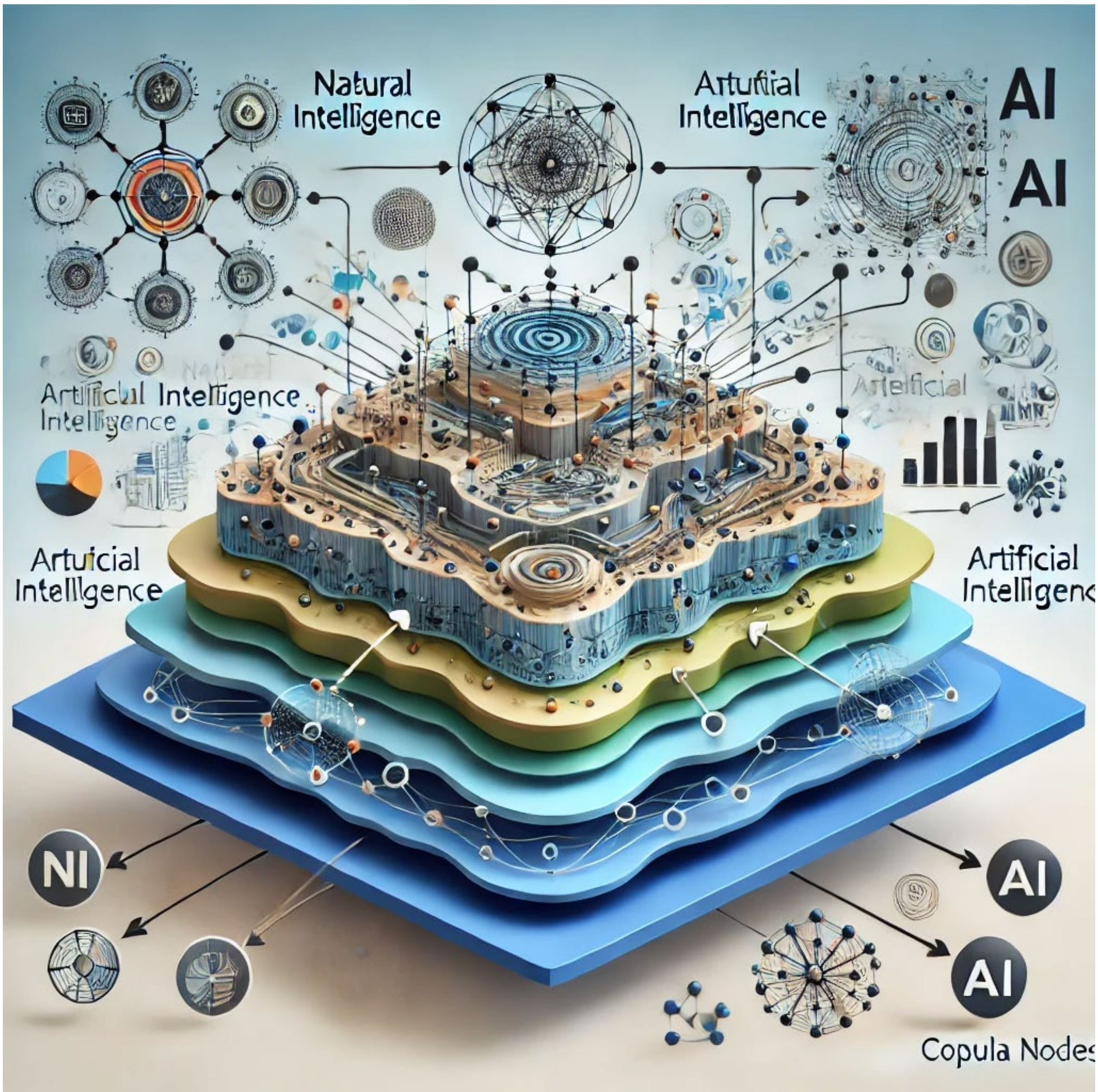

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Figure 3. Improved Decision-Making in Manufacturing.

- **Retail Sector**: AI-driven customer analytics led to a 20% increase in sales conversion rates (Grewal et al., 2021).

Figure 4. Enhanced Customer Analytics in Retail.

- **Finance Sector**: AI integration improved return on investment (ROI) by 15%, with copula nodes playing a crucial role in merging AI insights with human expertise (Fernández-Maestro et al., 2022).

Figure 5. AI-Driven ROI Improvements in Finance.

3.3. Cost Reductions

AI integration resulted in significant cost savings, particularly in the manufacturing and retail sectors.

Table 4. Cost Reductions Across Industries.

Industry	Pre-Integration Costs	Post-Integration Costs	Cost Reduction
Manufacturing	€1,000,000	€700,000	30%
Retail	€500,000	€375,000	25%
Finance	€750,000	€600,000	20%

4. DISCUSSION

The empirical findings strongly support the hypothesis that integrating NI and AI through copula nodes can significantly enhance economic value in digitized firms. The results underscore several key themes:

4.1. Synergistic Integration of NI and AI

The study demonstrates that the integration of NI and AI can lead to substantial improvements in efficiency, decision-making, and cost reductions. The success of this integration hinges on leveraging the complementary strengths of human intelligence and AI, rather than treating them as substitutes. For example, in manufacturing, AI-driven predictive maintenance systems enhanced operational efficiency when combined with human oversight.

4.2. The Role of Copula Nodes

Copula nodes emerged as critical elements in the multilayer network framework, facilitating seamless interaction between NI and AI layers. The nodes captured the dependencies between human-driven and AI-driven processes, ensuring that both forms of intelligence were fully utilized to optimize decision-making and resource allocation.

4.3. Industry-Specific Insights

While the multilayer network framework is adaptable across industries, the specific applications of NI-AI integration vary depending on industry dynamics. For example, predictive maintenance was a major driver of efficiency gains in manufacturing, while inventory management and customer engagement were more critical in retail. The finance sector benefited most from improvements in decision-making speed and accuracy.

4.4. Practical Implications

For practitioners, the study provides a clear framework for leveraging AI to enhance economic value within traditional firms. The findings suggest that firms should prioritize the development of copula nodes to optimize the integration of AI with existing human-driven processes. Scalable AI integration should be approached gradually to minimize disruption and maximize economic benefits.

5. CONCLUSIONS

This study presents a novel framework for integrating NI and AI within traditional firms through a multilayer network model facilitated by copula nodes. The empirical findings validate the model's predictions, demonstrating that the synergistic integration of human and artificial intelligence can drive significant economic value in digitized firms.

This study's originality lies in its emphasis on the synergy between NI and AI, highlighting the critical role of copula nodes in capturing and optimizing the interactions between these two forms of intelligence. The practical implications are profound, offering a strategic pathway for firms to enhance profitability and competitiveness in the digital age.

Future research should continue to explore the operationalization of copula nodes and the long-term impacts of AI adoption across diverse industries, further refining the insights provided by this study.

Roberto Moro-Visconti is a Corporate Finance professor at the Università Cattolica del Sacro Cuore in Milan, Italy. He earned a Ph.D. in Economics and boasts a substantial academic and research background, with numerous articles published in leading international journals.

His research primarily focuses on the integration of traditional finance with emerging digital technologies, particularly the economic impacts of integrating AI into business frameworks. He has significantly contributed to the understanding of how AI can bolster value creation in digitized companies through innovative network models. Beyond his academic pursuits, Professor Moro-Visconti is a member of the editorial boards of various journals and has actively participated in promoting discussions on the role of AI in transforming businesses. His recent research includes analyses of AI-driven scalability, sustainability, and the valuation of conventional firms, establishing him as a prominent figure in modern economic discourse.

Professor Moro-Visconti's contributions are acknowledged worldwide, and he continues to impact both the academic and business sectors with his perspectives on the future of AI within the field of economics.

References

1. Arora, M., & Sharma, R. L. (2023). Artificial intelligence and big data: ontological and communicative perspectives in multi-sectoral scenarios of modern businesses. *Foresight*, *25*(1), 126-143.
2. Barabási, A.-L. (2016). Network Science. Cambridge University Press
3. Bianconi, G. (2018). Multilayer Networks: Structure and Function. Oxford University Press
4. Boccaletti, S., Bianconi, G., Criado, R., Del Genio, C. I., Gómez-Gardeñes, J., Romance, M., & Zanin, M. (2014). The structure and dynamics of multilayer networks. Physics Reports, 544(1), 1-122
5. Braun, M., Greve, M., Brendel, A. B., & Kolbe, L. M. (2024). Humans supervising artificial intelligence–investigation of designs to optimize error detection. *Journal of Decision Systems*, 1-26.
6. Brynjolfsson, E., & McAfee, A. (2017). Machine, Platform, Crowd: Harnessing Our Digital Future. W.W. Norton & Company
7. Choudhury, M. D., Lee, M. K., Zhu, H., & Shamma, D. A. (2020). Introduction to this special issue on unifying human-computer interaction and artificial intelligence. *Human–Computer Interaction*, *35*(5-6), 355-361.
8. Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383-394
9. Dhar Dwivedi, A., Singh, R., Kaushik, K., Rao Mukkamala, R., & Alnumay, W. S. (2024). Blockchain and artificial intelligence for 5G-enabled Internet of Things: Challenges, opportunities, and solutions. *Transactions on Emerging Telecommunications Technologies*, *35*(4), e4329.
10. Davenport, T. H., & Ronanki, R. (2018). Artificial Intelligence for the Real World. Harvard Business Review, 96(1), 108-116
11. Durlach, P. J., & Ray, J. M. (2011). Designing Adaptive Instructional Environments: Insights from Empirical Evidence. Advances in Human-Computer Interaction, 2011, Article 7
12. Fernández-Maestro, A. E., Fernández-Vázquez, A., & Pérez-Álvarez, R. (2022). AI and Financial Markets: Challenges, Applications, and Opportunities. Journal of Finance and Data Science, 8, 1-12

 doi:10.20944/preprints202408.2132.v1

13. Górriz, J. M., Ramírez, J., Ortiz, A., Martinez-Murcia, F. J., Segovia, F., Suckling, J., ... & Ferrandez, J. M. (2020). Artificial intelligence within the interplay between natural and artificial computation: Advances in data science, trends, and applications. *Neurocomputing*, *410*, 237-270.
14. Grewal, D., Roggeveen, A. L., & Nordfält, J. (2021). The future of retailing. Journal of Retailing, 97(1), 3-18
15. Joe, H. (2014). Dependence Modeling with Copulas. CRC Press
16. Kivelä, M., Arenas, A., Barthelemy, M., Gleeson, J. P., Moreno, Y., & Porter, M. A. (2014). Multilayer networks. Journal of Complex Networks, 2(3), 203-271
17. Kulik, J. A., & Fletcher, J. D. (2016). Effectiveness of Intelligent Tutoring Systems: A Meta-Analytic Review. Review of Educational Research, 86(1), 42-78
18. McKinsey & Company (2023). The State of AI in 2023: Generative AI's Breakout Year
19. Moro-Visconti, R., (2024) Artificial Intelligence Valuation, Palgrave Macmillan, Cham
20. Moro-Visconti, R., Cruz Rambaud, S., & López Pascual, J. (2023). Artificial intelligence-driven scalability and its impact on the sustainability and valuation of traditional firms. Humanities and Social Sciences Communications, 10(1), 1-14
21. Russell, S., Moskowitz, I. S., & Raglin, A. (2017). Human information interaction, artificial intelligence, and errors. *Autonomy and artificial intelligence: a threat or savior?* 71-101.
22. Seeber, I., Bittner, E., Briggs, R. O., de Vreede, G.-J., de Vreede, T., Elkins, A., & Maier, R. (2020). Machines as teammates: A research agenda on AI in team collaboration. Information & Management, 57(2), 103174
23. Shulner-Tal, A., Kuflik, T., Kliger, D., & Mancini, A. (2024). Who Made That Decision and Why? Users' Perceptions of Human Versus AI Decision-Making and the Power of Explainable-AI. *International Journal of Human-Computer Interaction*, 1-18.
24. Wang, J. X. (2021). Meta-learning in natural and artificial intelligence. *Current Opinion in Behavioral Sciences*, *38*, 90-95.
25. Zhu, Y., Wang, T., Wang, C., Wang, C., Quan, W., & Tang, M. (2023). Complexity-Driven Trust Dynamics in Human-Robot Interactions: Insights from AI-Enhanced Collaborative Engagements. Applied Sciences, 13(24), 12989.