MECHANICAL ENGINEERING | PHYSICS | PRESERVATION OF THE ARCHITECTURAL HERITAGE | STRUCTURAL, SEISMIC AND GEOTECHNICAL ENGINEERING | URBAN PLANNING, DESIGN ΔΝΠ POLICY | AEROSPACE ENGINEERING | ARCHITECTURE, BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING | ARCHITECTURAL, URBAN AND INTERIOR DESIGN | BIOENGINEERING | DATA ANALYTICS AND DECISION SCIENCES | DESIGN | ELECTRICAL ENGINEERING | ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY | ENVIRONMENTAL AND INFRASTRUCTURE ENGINEERING INDUSTRIAL CHEMISTRY AND CHEMICAL ENGINEERING | INFORMATION **TECHNOLOGY** | MANAGEMENT ENGINEERING | MATERIALS ENGINEERING | MATHEMATICAL MODELS AND METHODS IN ENGINEERING

PhD Yearbook | 2024



Dean: Prof. Michela Arnaboldi

DOCTORAL PROGRAM IN MANAGEMENT ENGINEERING

INTRODUCTION

The Doctoral Program in Management Engineering (DRIG) offers students advanced training and preparation to conduct research in the field of management, economics and industrial engineering. It aims at training professionals who are able to carry out high-quality research in the fields of management, economics and industrial engineering at universities or other research institutions. Ph.D. graduates from DRIG are also well equipped with distinctive skills and advanced knowledge to pursue a professional career in manufacturing and service companies, regulatory authorities and other public bodies. The program allows the student to develop a sound methodological background and multidisciplinary knowledge by attending courses designed to provide a multiplicity of visions, theories and approaches, a broad cultural panorama. The program emphasizes the benefit of studying problems in an innovative manner, combining various analytical approaches and research methodologies.

The commitment of the Department of Management, Economics and Industrial Engineering (DIG) to research and scientific cooperation with other academic institutions, major industrial companies and other organisations results into an ideal environment in which for students to acquire leading-edge knowledge and cultivate their own research interests in a broad range of research subjects.

PH.D. PROGRAM STRUCTURE AND CONTENTS

The Full Time doctoral program covers three years, whereas the Executive Program lasts four years. They are entirely taught in English.

The Faculty of DRIG includes, in addition to professors of the Department of Management, Economics and Industrial Engineering, several international scholars: Rodney Turner, Editor of the International Journal of Project Management; Mike Wright, Imperial College London, UK; Irvine Lapsley, University of Edinburgh, UK; Hans De Bruijn, Delft University of Technology, The Netherlands; Abraham B. Rami Shani, California Polytechnic University, USA; Christopher Worley, University of Southern California, USA; David Coghlan, Trinity College Dublin, Ireland; Donald Huisingh, University of Tennessee, USA; Tobias Kretschmer, Ludwig-Maximilians-Universität München, Germany.

The program covers three main types of training activities.

Main courses

- Literature Review.
- Methodological courses, addressing specific research methodologies and related skills relevant to research in management, economics and industrial engineering;
- Thematic courses, aiming at introducing students to the reference theoretical background and the cutting-edge research in specific disciplines, such as Entrepreneurship and Entrepreneurial Finance, Innovation Economics and Management, Supply Chain Management, Organisational Theory and Design, Service Operations Management, Enterprise and Operations Risk Management, Sustainability and Social Challenges in Industrial Systems.

Elective courses and training on specific themes Elective training activities are customised according to the specific needs and research interests of students. The aim is to strengthen the scientific knowledge of students in very specific topics and to introduce them to the international research community through their active participation to international scientific conferences and PhD schools.

Thesis

The aim of the Ph.D. programs at Politecnico di Milano is to instill in candidates a research oriented mind-set, along with expertise and skills relating to a specific research topic. To develop a researchoriented mentality, candidates must acquire the ability to solve complex problems, including a thorough analysis of the problem, identification of an original solution and the ability to evaluate the solution and its applicability in given contexts. Ph.D. s who possess these abilities will have greater opportunities for advancement in research positions, both in the academic environment as well as in public and private organisations. The main goal is the development of an original research contribution. The Ph.D. thesis should help increase knowledge in the applicant's research field. It also needs to be consistent with the research topics studied at the Department. The final thesis can be submitted in the form of either a monograph or an edited compilation of papers. The research projects presented in the following section are typical examples of the research work carried out by DRIG students.

SCIENTIFIC AND INDUSTRIAL COLLABORATIONS

Students are required to spend at least one semester in a foreign research institution. In addition, students are encouraged to attend doctoral schools and workshops organized by other institutions and to participate in international scientific conferences. The presentation of an original research work in an international conference is mandatory for admission to the final exam. To his end, students are granted of a personal research budget, covering a three years research period, and have access to mobility support measures aimed at promoting international collaborations between the doctoral programs in Europe and overseas.

In addition, Double Degree agreements are in place at the Ph.D. level:

- Double Degree Programme with the Pontificia Universidad Católica de Valparaíso (Chile), Escuela de Ingeniería Industrial, Doctorado en Ingeniería Industrial.
- Double Degree Programme with the Copenhagen Business School (CBS, Denmark), PhD School in Economics and Management.
- Double Degree Programme with the University of Reading, Henley Business School
- (United Kingdom), PhD in Management.
- Double Degree Programme with the National Research University Higher School of Economics in Moscow (Russia).
- Double Degree Programme with TuDelft (The Netherlands).
- Double Degree Programme with Universidad Politécnica de Madrid – UPM (Spain).
- Double Degree Programme with Gent Universiteit (Belgium).

- Double Degree Programme with Skema Business School (France).
- Double Degree Programme with UNIANDES (Colombia).
- Double Degree Programme with Tampere University (Finland).
- Double Degree Programme with LUT University (Finland).
- Double Degree Programme with Qatar University (Qatar).
- Double Degree Programme with USP Universidade de São Paulo (Brazil).
- Memorandum of understanding with TUM (Technical University of Munich).

DRIG has also developed several research collaborations with private manufacturing and service firms, regulatory bodies, and other public research institutions to fund PhD oriented research. In recent years, the following organisations supported DRIG Scholarships: Value Partners, TXT e-solutions, IBM, Siemens, Telecom Italia, Windesheim University of Applied Scencies, INAIL, INPS, Regione Lomabrdia.

PROFESSIONAL OPPORTUNITIES AND THE JOB MARKET

Typical career opportunities opened up by the doctoral program include:

- Post Docs, research fellows and young lecturers at Italian and foreign universities;
- Researchers and scholars in Management Engineering at public and private organisations;
- Highly qualified personnel at research and training institutions, or at technology transfer centers in Italy and abroad;
- Professionals at leading management and strategic consulting firms who can provide deep and advanced insights into companies' business areas;
- High-level professional roles at national and international public institutions;
- Managerial roles at multinational companies with a strong focus on innovation;
- Entrepreneurs in contexts characterised by a high level of innovation.

Support actions for placement are provided with the purpose of sharing experiences, services and information through a number of initiatives fitting the different types of career opportunities. Particular emphasis is given to career development in the Management Engineering area.

VALORIZATION OF DATA FOR SUSTAINABLE FIRM PERFORMANCE IN THE EVOLVING FINANCE SECTOR

Claudio Bonvino - Supervisor: Prof. Marco Giorgino

Co-Supervisor: Prof. Laura Grassi

The valorization of data remains a challenge for many firms, despite substantial investments. As data volume is projected to escalate from zettabytes to brontobytes, and storage capacity is expected to increase at a 19.2% CAGR from 2020 to 2025, firms' challenge is to develop concrete data use cases to enable competitive advantages and sustainable firm performance. Data has emerged as a fundamental input in addition to land, capital, labor, and oil. Most organizations have invested in technologies and personnel overlooking business inquiries, thus struggling to implement successful data practices. When contextualized, data can sustain financial and non-financial performance in the short and long term, namely sustainable firm performance. Existing literature provides scattered studies covering data characteristics and processes, with less emphasis on the managerial and economic aspects of data valorization. Among sectors, the finance sector is recognized for its ability to manage large volumes of data and offers an innovative context, driven by fintech, open banking, and open finance, for investigating data valorization.

Several gaps are evident: (i) understanding what makes data

valuable resources, how data can be strategically used, and how firms can competitively use data; (ii) exploring how data stakeholders use data in the evolving finance context; (iii) exploring how data can be successfully used to achieve sustainable firm performance; and (iv) explaining key determinants in using data to achieve sustainable firm performance. Thus, the theoretical lens of this thesis is data valorization, specifically the strategic use of data resources for competitive and sustainable performance purposes. The context covers financial incumbents and emerging financial and non-financial players (e.g., insurtech companies, bigtechs) within the financial ecosystem. The identified overarching research question is: how does successfully valorizing data enhance sustainable firm performance within the evolving finance sector? Reviewing literature and consulting practitioners confirmed the significance of the investigated subjects, aligning them with prior research. To address these gaps, the

overarching research objective was divided into sub-objectives and sub-research questions investigated in four papers. The thesis adopts an abductive approach and scientific realism paradigm. Initially, it aims to qualitatively understand data valorization and analyze finance firms' key concepts through literature reviews and a multiple case study (Papers 1-3). Subsequently, it employs empirical observations of firms' behaviors to discover and validate relationships for generalizing data valorization via a quantitative survey (Paper 4). This structured approach enables thorough examination and comprehensive findings. By investigating how data can be managed strategically to create competitive value in the insurtech context, Paper 1 identifies the need to orchestrate data assets, data infrastructure, and data activities. Firstly, senior managers must structure data assets composed of data sources, types, and characteristics. Then, they need to bundle these assets with data infrastructures, complementing data technologies and practices to develop data competencies. Finally, they need to strategically leverage these data competencies with competitive primary and support activities of the value chain. Paper 2 explores the emerging

paradigm of data democratization in open finance, focusing on key stakeholders and their challenges in transitioning from data sharing

to democratization. It delineates seven stakeholders (regulators, financial incumbents, fintech startups, techfin companies or bigtechs, customers, developers, and non-financial third parties), and the principles of data democratization (findability, accessibility, interoperability, and reusability) within legal, confidentiality, and security boundaries. The paper discusses the democratization processes, culture, and competencies required for each stakeholder to coevolve and develop an innovative digital financial ecosystem. By exploring how firms successfully use data assets to capitalize on sustainable firm performance, Paper 3 identifies that senior managers need to develop a data management strategy that connects the right data assets to the business goals, ultimately developing data outcomes. These data outcomes can be categorized into three strategies: boosting efficient profitability, effective growth, and data democratization. The success of these strategies lies in the level of innovation, economic return, and stakeholder benefit produced. Paper 4 explains the determinants of using data innovatively to increase sustainable firm performance and finds that data valorization requires capabilities based on business-data alignment, data savviness, and definition of data-related primary and support activities. Leveraging these capabilities, using data sustains the firm performance based on the positive mediation of processes and copetition within the ecosystem, while

there is not significant evidence of success in increasing and retaining customers. Further, the moderating effect of ambidexterity, depending on the level of ambidexterity of the firm, contributes to leveraging data resources within the ecosystem, ultimately leading to improved firm results. Sustainable firm performance significantly and positively depends on the level of experience in using data of the firm, whereas neither the size of the firm nor the phase of the firm significantly impacts sustainable results.

Overall, the thesis validates data resources as valuable strategic business assets, introduces the resource orchestration theory to strategically structure data assets, bundle them with competencies, and leverage them for achieving competitive advantages, and proposes the concept of data democratization in the managerial literature referring to the information systems literature and practitioner evidence. It identifies data valorization strategies for achieving sustainable firm performance and validates the importance of data resource management and ambidexterity competency, expanding the resourcebased view and ambidexterity theories. These elements are essential for sustainable firm performance, mediated by operations and ecosystem values. Additionally, it extends the study of data valorization to seven data stakeholders in the finance ecosystem and proposes generalizations to other datadriven sectors.

Moreover, the thesis offers financial senior managers an explanation of how to create data outcomes and a data toolkit for specific competitive advantages (enhanced risk assessment, optimized operations, customer engagement, and openness). It outlines organizational challenges and opportunities for the seven data stakeholders in the finance ecosystem, proposes the three data strategies for developing sustainable data outcomes, and the determinants of using data for sustainable firm performance. Policymakers are provided with a data valorization framework to incentivize innovation, and growth guidelines, along with state-of-the-art data concerns (opaque market, systematic risks, harmonization, sustainability) in the evolving finance sector, revealing the need for major coordination among regulators or the creation of an international institution. Individuals benefit from the increased competition and innovation in the finance sector with an increase in welfare, a wider access to products and services, although greater transparency and data, and financial literacy are required. In conclusion, the thesis lays the groundwork for advancing management and economic research across fields, including data valorization, data democratization, data strategies, data regulation, sustainable firm

performance, and open finance, yielding to a democratic ecosystem where data stakeholders are

offered to valorize their data

resources sustainably.

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Alessandro Carrera - Supervisor: Prof. Emanuele Lettieri

Life sciences and healthcare sectors are undergoing a profound transformation because of the pervasive diffusion of digital solutions that are reshaping the whole value chain from upstream to downstream. Among these drivers of change, Digital Therapeutics (DTx) deserve particular attention as they represent a profound and powerful paradigm shift from traditional approaches and pathways of care. Digital Therapeutics stand as a particularly radical digital health technology due to their profound impact on clinical practice and healthcare systems, and it is worthwhile to explore the topic further. These innovative interventions represent a shift in the traditional approach to medical treatment by delivering evidence-based therapies through digital platforms (i.e., digital excipients), often in the form of mobile apps or webbased tools. What characterizes DTx is the rigorous scientific evidence required to ensure their effectiveness, safety, and patient outcomes. Indeed, unlike many health-related apps, DTx offerings undergo stringent clinical trials and regulatory processes to demonstrate their therapeutic value. This level of evidence is critical for gaining approval

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from healthcare authorities and garnering trust among healthcare providers and insurers, leading to integration into clinical workflows and reimbursement schemes. To benefit from the advantages that DTx can bring to society, it is first necessary for these solutions to be adopted. DTx, as well as their adoption by users and their development, has received growing attention from scholars and practitioners in the last few years. Still, its concept is far from mature, especially in some countries like Italy. The present thesis aims at advancing knowledge around digital innovation and transformation in the healthcare sector. The main objective is to analyze the factors affecting and explaining the users' acceptance and adoption of rising and radical

digital health technologies like DTx. Therefore, the overarching research objective of the thesis is to explore the main factors that may explain the adoption of DTx in the profoundly evolving field of life sciences. Figure 1 summarizes the thesis's conceptual framework driven by the investigational domain (namely, the adoption of Digital Therapeutics). This thesis consists of a collection of four papers, each addressing a specific aspect of the adoption of DTx. The thesis encompasses several methodologies depending on the research questions. Both quantitative (e.g., surveys in Paper 1 and Paper 2) and gualitative (e.g., interviews in Paper 4) approaches have been followed, as well as a systematic literature review



Fig. 1 - Thesis conceptual framework

(Paper 3) and analytical models (Paper 4). Among the strengths of this research is that it is one of the first papers to address the topic of DTx in a circumscribed and in-depth manner. Considering the Italian context, this thesis turns out to be the first extensive and rigorous work on the issue from a managerial perspective. This thesis mainly contributes to theory by advancing the debate on the factors explaining the adoption of a new digital health technology, particularly considering radical innovations such as DTx. Moreover, the thesis contributes to the scientific discussion on the appraisal and evaluation of new radical technologies, focusing on the Health Technology Assessment framework. At the very core of this work lie the practical implications related to DTx development and adoption to provide valuable insights to various audiences, such as healthcare professionals, companies interested in investing in DTx, policymakers, and other actors involved in these solutions' approval and validation processes. One of the main constraints is the everchanging DTx landscape, which future research is encouraged to monitor over time.

CORPORATE ENTREPRENEURSHIP IN THE DIGITAL AGE

Stefano D'Angelo - Supervisors: Prof. Angelo Cavallo, Prof. Antonio Ghezzi

In a digital world increasingly characterized by new business opportunities and challenges driven by the proliferation of pervasive digital technologies, companies are more than ever called to act entrepreneurially as an antidote to inertia and business stagnation. This has raised important questions at the intersection of corporate entrepreneurship and digital technologies. A large body of research has documented the antecedents and the positive outcomes that companies can achieve by engaging in corporate entrepreneurship (CE), i.e., entrepreneurship in incumbent organizations. However, the rapid adoption and use of digital technologies urge scholars to question whether we need to reconsider, extend, or reframe extant body of knowledge of CE field in the digital age and the related antecedents, processes, and outcomes associated with the traditional CE. Several companies have implemented or are implementing digital infrastructures and platforms to manage their CE and innovation activities supported also by increasing investments in digital technologies by corporations. This new reality characterized by the pervasiveness of powerful digital technologies, the so-called "digital age", offers tremendous

potential for entrepreneurship and innovation in corporations. For example, digital technologies, digital platforms and digital infrastructures have made the ability to source and synthesize dispersed and scattered knowledge a key asset for entrepreneurship in incumbent organizations. Emerging general purpose technologies such as AI may also enable faster and more distributed CE decisionmaking processes. However, despite the contemporary significance of digital technologies and their increasing proliferation, use and implementation in organizations, we find that the debate on CE in the digital age is still in its infancy and deserves more scholarly attention. The increasing importance of the role of digital technologies in CE is also confirmed by recent special issues and call for papers. As highlighted by recent works, several questions have being raised concerning whether and how digital technologies are changing the nature of CE and whether we are witnessing the birth of a potential distinct research field at the crossroads between digital technologies and corporate entrepreneurship. Starting from this premise and in

response to the highly theoretical and practical relevance of the topic, this research focuses on

the foundations of a modern CE influenced/shaped through the pervasive role played by digital technologies. We discuss the impact of digital technologies on CE at firm-level and individuallevel according to the established and comprehensive picture of CE that refers to all entrepreneurial activities of incumbent firms at the individual-team or organizationalunit level aimed at creating and adding new business, or at developing and fostering innovation in order to create competitive advantage. Moreover, to understand the overarching impact of digital technologies on CE, given the sociotechnical nature of digitalization we examine both digital technologies characteristics (i.e., digital affordances) and human/social agency in CE in the digital age and the associated issues. Digitalization, being a sociotechnical phenomenon, defined as "the sociotechnical process of applying digitizing techniques to broader social and institutional contexts that render digital technologies infrastructural", does not only relate to digital technologies characteristics but also imply the human/social aspect involving individuals who use and adopt digital technologies and firms that mobilize and reconfigure their human resources in response to digitalization.

In articulating the value of a digital technology perspective in corporate entrepreneurship field, this thesis focuses on how digital technologies may advance, expand, till renewing what we know about corporate entrepreneurship at multiple and cross-level of analysis. To shed light on corporate entrepreneurship in the digital age, this thesis is articulated in three main investigations, one for each chapter. The first chapter provides a literature review at the crossroads of corporate entrepreneurship and digital technologies to advance our current understanding regarding corporate entrepreneurship in the digital age. The second chapter explores the implications of digital technologies in corporate entrepreneurship at firm-level, by investigating the enabling role of digital affordances in facilitating firms to embrace experimentation through corporate venturing. The third chapter explores the implications of digital technologies in corporate entrepreneurship at individual-level, by investigating how incumbents can prepare their workforce to embrace digitalization to foster entrepreneurial and organizational rejuvenation processes. In particular, in **Chapter 1**, we perform a literature review at the intersection of corporate entrepreneurship and digital technologies. Through this review, we build an integrative framework of corporate entrepreneurship in the digital age articulated across six building blocks. Our framework presents corporate entrepreneurship in the digital age as a phenomenon where digital technologies trigger

corporate entrepreneurial responses from the part of incumbent organizations that use digital technologies to leverage on and exploit the affordances offered by digital technologies to remain competitive. To that end, organizations must implement structural enablers and overcome barriers that hinder the potentialities of digital technologies for corporate entrepreneurship. Building on this framework, we elaborate a research agenda for future exploration on corporate entrepreneurship in the digital age. In Chapter 2, we examine how incumbents can organize to embrace experimentation and innovate. Through an in-depth case study, we provide detailed empirical evidence on how incumbents can embrace experimentation approaches through structural (i.e., corporate venturing) and technological enablers (i.e., digital technologies and related features) together with a set of specific managerial practices. Our case shows that by enacting cognitive, organizational and behavioral tactics incumbent organizations can use corporate venturing as a structural enabler to embrace experimentation. We also document and discuss how digital technologies permit the corporate venture to enable the adoption of experimentation. Our findings show that the generativity of the digital platform upon which the business model of the corporate venture is based facilitates vertical experimentation, by rapidly adapting different applications for a single customer, and horizontal experimentation, by generating solutions for different types of

clients. Based on these insights, we develop implications for research and practice.

In **Chapter 3**, we explore how incumbents mobilize digital skills through an in-depth case study. We provide detailed empirical evidence on how incumbents can mobilize digital skills of their individuals to embrace digital transformation and initiate organizational rejuvenation processes. Based on the process perspective of resource mobilization, we shed light on the mechanisms to search, access and transfer digital skills. In the investigation of these mechanisms, we uncover the agentic role of digital champions, who become an organizational capability to mobilize digital skills in incumbents. We also document how digital technologies, as operant resources, can support the mobilization of digital skills aimed to develop and leverage digital skills in incumbents. Based on the findings of this study, we contribute to knowledge at the interface between digitalization and resource mobilization in the broader context of digital transformation in incumbent organizations. In doing so, we offer practical implications for incumbents to prepare their workforce to embrace the possibilities of digital technologies and lead to intrapreneurial behavior in the digital age.

ENGAGING THE CROWD IN DECISION-MAKING OF COMPLEX SOCIETAL ISSUES

Diletta Di Marco - Supervisor: Prof. Raffaella Cagliano

In the complex milieu of today's society, a particular category of challenges, often termed "wicked issues," defies straightforward solutions and spans multiple dimensions, such as environmental sustainability, public health, and social justice. These issues are complex, resistant to singular solutions, and have broad societal implications. Traditional approaches to stakeholder engagement, frequently confined to the realms of industry experts and policymakers, fall short of addressing these multidimensional challenges This dissertation introduces a novel framework, termed "strategic crowd engagement," that aims to integrate the "crowd"-or the citizenry-as a crucial stakeholder in problemsolving. The importance of this new approach emanates from two central ideas. The first is the idea of participatory dynamics, where traditional stakeholder engagement methods are expanded beyond mere consensus-building. Strategic crowd engagement aims to include a broader dialogue by incorporating perspectives from the crowd, thereby challenging the conventional wisdom that only "expert stakeholders" can provide meaningful input. The second is

the notion of dynamic problemsolving. Unlike traditional topdown methods, which often neglect the multifaceted nature of modern challenges, strategic crowd engagement promotes a shift from 'solution creation' to 'collaborative problem-setting.' This research conceptualizes and enhances our understanding of crowd engagement within public administration and policymaking contexts through four interrelated studies, examining its motivational drivers, challenges, benefits, and technological considerations. - The first study offers a foundational bibliometric exploration into the concept of crowd engagement, highlighting its application in various decisionmaking realms such as public service design, urban planning, and crisis management. It lays the groundwork for understanding the participatory dynamics and motivations behind crowd engagement, especially in addressing wicked problems that traditional governance models struggle with. - Building on this, the second study delves into the practicality of crowd engagement, weighing its challenges and benefits. Utilizing case studies, this research identifies and systematically categorizes challenges such as incentive alignment and citizen

aggregation and benefits like innovative solution generation and stakeholder relationship enhancement. This study extends the theoretical boundaries of crowd engagement by revealing its potential to democratize the innovation process in public administration. - The third study specifically focuses on understanding the intrinsic motivational drivers of citizen participants or 'solvers' in crowd engagement initiatives It investigates how enjoyment and competence are pivotal in fostering engagement during the problem and solution-framing phases. Field studies reveal that intrinsic motivations, including enjoyment and task-related competence, positively influence solver engagement, even when the tasks are inherently complex and daunting. - Lastly, the fourth study intersects technology and crowd engagement by examining the role of privacy concerns in adopting digital platforms, taking the example of a COVID-19 tracing app in Italy. This study employs the Unified Theory of Acceptance and Use of Technology (UTAUT) to understand the factors affecting citizens' willingness to engage via digital platforms. It highlights the critical role of trust, transparency, and communication in the adoption process. Collectively,

these studies conceptualise crowd engagement and dissect its complexities, offering academic and practical insights. They underscore the need for a more dynamic, inclusive, and technologically supported approach to address societal challenges. This research contributes to the discourse on innovation and leadership by offering an in-depth understanding of crowd engagement as a multifaceted, transformative phenomenon for public decision-making. The dissertation's theoretical contributions are manifold. First and foremost, it advances a refined understanding of what constitutes crowd engagement. The bibliometric analysis in the first study clarifies the concept and pinpoints motivational assets and technology's role as pivotal elements in crowd engagement. This conceptual clarity is vital for consistent operationalization in future research. The second study goes beyond simple analyses and offers a nuanced framework that elaborates on the challenges and benefits of crowd engagement in the public sector. This framework, identifying challenges like technological limitations and privacy concerns, provides researchers with a detailed landscape

for studying engagement in complex organizational settings. Furthermore, the third study brings a psychological dimension into the theoretical discourse by highlighting intrinsic motivational factors influencing crowd participation. By focusing on enjoyment as a significant determinant, the research enriches knowledge of human-centric factors in crowd engagement. Lastly, adopting the UTAUT model in the fourth study introduces a fresh perspective on technology adoption within the crowd engagement literature. By shedding light on performance expectancy, effort expectancy, and facilitating conditions as central influencers, the study adds depth to our theoretical understanding of how technology intersects with human behavior in crowd engagement contexts. In terms of practical implications, this dissertation acts as a toolkit for practitioners, particularly those involved in designing and implementing crowd engagement initiatives. The first study serves as a foundational resource, offering decisionmakers a clarified concept of crowd engagement that they can reliably implement in various settings. The findings from the second study provide actionable insights for public sector

organizations by elaborating on the risks and rewards of crowd engagement. This information enables policymakers to weigh their options more carefully and make informed decisions, considering the benefits and the potential pitfalls. The third study offers valuable information for those creating or maintaining engagement platforms. By emphasizing the role of enjoyment and structural elements in boosting intrinsic motivation, the study offers a roadmap for designing systems that encourage sustained, meaningful engagement. The insights from the fourth study can guide practitioners in the technology domain. Understanding the key factors affecting the adoption of crowd engagement platforms, such as the Immuni Covid-19 tracing app, can help in the design phase, targeting specific features that enhance user adoption rates. The dissertation offers a balanced perspective, making it a cornerstone for theoretical and practical advancements in crowd engagement. It enhances academic discourse and serves as a comprehensive guide for practitioners in the field.

UNRAVELING THE RELATIONSHIP BETWEEN CORPORATE BEHAVIOR AND FINANCIAL PERFORMANCE IN EMERGING VS. DEVELOPED COUNTRIES: INSIGHTS FROM CSR, CSI, SUPPLY CHAIN IRRESPONSIBILITY, AND TAX HAVENS

Gezim Hoxha - Supervisor: Prof. Stefano Elia

Co-Supervisor: Prof. Lucia Piscitello

The general objective of this dissertation is to disentangle the relationship between corporate behavior and financial performance in emerging vs. developed countries, motivated by the increasingly growing role of CSR, CSI, Supply Chain Irresponsibility, and Tax Havens locations. This dissertation includes three main chapters which investigates i) the relationship of CSR/CSI and financial performance of companies located in developed vs. emerging countries, ii) the effect of corporate supply chain irresponsibility on corporate financial performance, and iii) the relationship between CSR and Tax Haven locations. The first chapter presents an empirical study aims at investigating the effect of corporate social responsibility and irresponsibility on corporate financial performance in firms headquartered in developed vs. emerging countries. Building upon stakeholder and legitimacy perspective, we argue that the CSR/CSI - CFP relationship differs depending on the home countries' level of economic development as this reflects their different sensitivity towards sustainability. Thus, we expect the effect of CSR

on CFP to be more positive for firms headquartered in developed than in emerging countries. At the same time, we propose a more negative relationship between CSI and CFP for firms headquartered in developed countries. The second chapter, building on the stakeholder and the expectancy theory investigate the effect of corporate supply chain irresponsibility on corporate financial performance; and the moderation effect arising from the violation of prescriptive expectations - which are based on the country of origin of the firm; and the violation of predictive expectations - which are based on the adoption of SSCM practices and on the past reputation of the firm. We claim that the negative effect of supply chain irresponsibility is more severe for firms in developed countries than for those in emerging countries, and that the previous adoption of sustainable supply chain practices as well as a good reputation strengthen these relationships. The third chapter aims at investigating the relationship between corporate social responsibility (CSR) and Tax Haven location, for firms originating from developed and emerging countries. On

average, I find that companies headquartered in Tax Havens have lower levels of CSR practices. These findings align with the corporate culture theory, which contend that socially responsible firms do not establish operations in Tax Haven locations. However, this relationship takes a different turn when considering countrylevel factors, particularly the country-of-origin variable. I posit a more positive relationship between Tax Haven locations and CSR practices for firms originating from developed countries compared to firms originating from emerging countries. This proposition is rooted in the risk management theory, which suggests that firms from developed countries may use CSR activities to overcome and mitigate risks that emerge from the tax avoidance behavior. Firms in developed countries face those risks due to stricter legal and regulatory environments, and higher stakeholder demands and expectations.

UNIVERSITY BUSINESS INCUBATOR MODEL: THE SYNERGY OF THEORY AND PRACTICE

Saken Kazhenov - Supervisor: Prof. Cristina Rossi Lamastra

Business incubators, particularly University Business Incubators (UBIs), play a pivotal role in fostering entrepreneurial ecosystems by nurturing new ideas into sustainable businesses. Despite their significance, the historiography of UBIs lacks exploration from a business model perspective, hindering insights for both theory and practice. This research aims to fill this gap by analyzing UBI literature trends, developing a model using Business Model Canvas (BMC) and Input-Process-Output (IPO) perspectives, and conducting case studies. A systematic literature review from credible sources forms the basis, while interviews with UBI representatives provide additional insights. Findings indicate a growing research interest in UBIs and identify key thematic areas, leading to the proposal of a conceptual framework. Moreover, the study presents UBI models and offers recommendations for researchers and practitioners, contributing to incubation theory and enhancing understanding of UBIs' operational dynamics.

Introduction:

University Business Incubators (UBIs) are integral components of innovation ecosystems, providing crucial support services to university-related startups, especially in their early stages. However, evolving mission objectives and changing industry expectations necessitate a reevaluation of sustainable incubation models. UBIs play a vital role in fostering entrepreneurship, mitigating risks associated with new ventures, and cultivating an entrepreneurial culture by imparting necessary skills and knowledge. Despite the significance of UBIs, there remains a lack of consensus on their structure and business models, highlighting the need for further research in this area.

UBIs & Entrepreneurship:

Entrepreneurs play a crucial role in societal advancement, yet their journey is fraught with challenges such as market fit and competition. UBIs serve as a vital tool in mitigating these risks, offering a range of services aimed at developing entrepreneurial skills and fostering an innovative mindset. While entrepreneurial skills are essential, the organizational structure of UBIs and the services they provide are evolving, with a shift towards intangible assets and networking. However, there remains ambiguity regarding UBI business models, necessitating research for clarity.

Research Objective:

This study seeks to analyze trends in UBI literature, develop a model using BMC and IPO perspectives, and conduct case studies to gain insights into UBI operational dynamics. By synthesizing existing literature and gathering empirical data from UBI representatives, the research aims to contribute to incubation theory and provide practical insights for practitioners.

Research Methods:

A systematic literature review is conducted using papers from credible sources such as Scopus and Web of Science databases. Additionally, case studies involve interviews with representatives from leading UBIs to gather qualitative data on incubation processes and business models. The integration of BMC and IPO frameworks guides the analysis, allowing for a comprehensive understanding of UBI dynamics.

Research Results and Contributions:

The findings reveal a growing research interest in UBIs, with identified thematic areas forming the basis for a proposed conceptual framework. Through the integration of BMC and IPO perspectives, UBI models are developed, offering novel insights into their operational dynamics. Recommendations for researchers and practitioners are provided, aiming to enhance understanding of UBIs and contribute to incubation theory.

Conclusion:

In conclusion, this study underscores the importance of exploring UBIs from a business model perspective, offering valuable insights for theory and practice. By synthesizing existing literature, conducting case studies, and proposing UBI models, this research contributes to the ongoing discourse on incubation theory and provides practical guidance for stakeholders in the entrepreneurial ecosystem.

UNFOLDING THE SYSTEMIC ROLE OF EMERGING END-OF-LIFE TECHNOLOGIES TOWARDS A CIRCULAR ECONOMY OF PLASTICS

Carol Maione - Supervisor: Prof. Paolo Trucco

Transitioning to a circular economy (CE) of plastics has been advanced as a possible solution to face the ongoing plastic waste crisis and find alternative ways to handle plastic materials. A CE of plastics envisages a sustainable management of plastic materials and waste through a combination of practices that can be applied at multiple stages of the plastic value chain, with an increased focus on recycling and monitoring plastic material and pollution flows throughout the plastic's life cycle.

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However, despite the remarkable efforts to accelerate the CE transition, there is a paucity of empirical evidence of the alignment between policy frameworks and industrial actions, making it more difficult to track progress towards circularity. For these reasons, there is a need to address the underlying conditions which pose significant challenges towards achieving a CE of plastics. To this end, this research takes a stance on the body of literature investigating CE as a system, and in particular a complex system perspective, to investigate the systemic and evolutionary dynamics that characterize the transition to a CE of plastics. This research aims to advance

knowledge of emerging technologies with a potentially disruptive role in the transition to a CE of plastics via conceptual and empirical investigation of their contribution to a better management of the life cycle of plastic. Specifically, it firstly aims to provide a detailed mapping of the material flows and stocks. the value chain actors, and related barriers and drivers that characterize the CE transition. Hence, the following research question is put forth: (RO1) What are the system's elements and influential dynamics in the transition to a CE of plastics? Secondly, with the aim of addressing current knowledge gaps on the role and influence of emerging end-of-life management technologies in fostering the CE of plastics, the study also intends to assess the role and impact of recycling and monitoring technologies in the CE transition, and highlight how contextual factors may influence the implementation and effects of these technologies. Accordingly, the following additional research questions are introduced: (RO2) How do emerging technologies for plastic's end-of-life management contribute to fostering the CE of plastics?(RQ2a) What are the potential role and influence

of recycling technologies in fostering the CE of plastics? (RQ2b) What are the potential role and influence of monitoring technologies in fostering the CE of plastics? To answer the research questions, we employed a mixed methods approach: an exploratory study was conducted to answer RQ1; RQ2a was addressed using an explanatory approach; finally, a methodological and exploratory

RQ2b. The results of the study are then presented in five appended papers.

Paper 1 investigates R01 and demonstrates that the CE of plastics is a complex system that evolves over time (ideally tending to higher degrees of circularity) due to dynamic complexities and deep uncertainty, that are typical of the CE transition. The findings indicate that each value chain player perceives influential factors in the CE transition differently, resulting in major differences in the implementation of CE practices for upstream and downstream actors respectively. Paper 2 and Paper 3 address R02a within the context of the Lombardy region (Italy), as this industrial setting offers a leading example for plastic

waste sorting and recycling. The papers' results point out that a balanced mix of mechanical and chemical recycling technologies in the plastic recycling chain is necessary to accelerate the CE transition in Lombardy, as it could increase recycling efficiency, expand recycling capacity overall, obtain highquality recyclates from both processes, and finally create new end-market opportunities where recycled plastics are economically competitive and viable substitutes for traditional virgin materials.

Paper 4 and Paper 5 address R02b within the context of the U.S.-Mexico international border, as this area uniquely presents issues related to monitoring material flows. The papers' results suggest that an integrated monitoring methodology that combines remote sensing technologies (e.g., satellites, drones) with in-situ techniques (e.g., observations, field sampling) can provide decisionsupport value for policy makers and industrial practitioners on how to map and manage mismanaged waste flows. Our analysis offers findings that contribute to theory-building in two different ways: first, we discuss the key elements and dynamics that characterize

the CE of plastics as a complex system, and, second, we examine the systemic effects of the introduction of emerging technologies to appreciate how such elements and dynamics change under specific conditions. Based on the theoretical contributions of this thesis, we

propose a number of areas of intervention that could set the successful path towards the transition to a CE of plastics based on the introduction of emerging recycling and monitoring technologies in existing value chains. On one hand, these interventions are aimed at removing existing challenges associated with traditional recycling technologies, including barriers of economic, technical, and environmental nature, to increase efficiency and capacity of the recycling infrastructure. On the other hand, they aim to overcome the obstacles of insufficient data on the fate and composition of mismanaged plastic waste flows, to support the implementation of pollution management and material retention strategies. Pragmatically, implications for industrial actors include the interdependence between actors of the forward and reverse supply chain in the development of

plastic's closed loops, pointing out the urgent need for crossvalue chain collaboration to accelerate the CE transition. Finally, implications for policymakers are relative to the development of policy instruments that consider the structural complexity of CE and the heterogeneity and dynamics between all stakeholders across the plastic value chain.

STRATEGIZING IN NASCENT INDUSTRIES: BUSINESS MODEL DYNAMICS IN THE EUROPEAN NEW SPACE ECONOMY

Jacopo Manotti - Supervisor: Prof. Antonio Ghezzi

In recent years, both scholars and practitioners have been devoting increasingly attention to industries in the early stage of their formation, namely nascent industries. For scholars, the interest is mainly triggered by understanding why industry dynamics got stabilized in a certain way, how the contrast between different stages and potential standards are resolved, and who will be the actors shaping the form and taking part in such process. For practice, sources of innovation and uncertainty have always attracted attention from the possibility to "take the wave" and enjoying possible first-mover advantages in the competition with substitutes. Nascent industries research is still in infancy, with some structural open debates concerning how is it possible to distinguish between new industry emergence and other industry dynamics (like niche creation or industry adaptations), or when a nascent industry stage concludes and the other begins, to mention some. Often referred also as nascent markets, these are "intriguing settings" to advance management research from an organizational perspective, given the idiosyncrasies of uncertainty and ambiguity characterizing the environment,

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in terms of technology, demand, ecosystem, and institutions. In this regard, from a firmlevel perspective, management research on nascent industries has been mainly devoted to macro-level investigations, such as the entry-exit dynamics and the definition of proxies to determine the different stages of the market emergence process. These studies largely adopted guantitative methodologies in their analysis, thus leaving mostly uninvestigated the finer-grained mechanisms characterizing the firm level in such contexts. such as the identification of entrepreneurial opportunities, the triggers of strategic decisions, etc.

Conceptualized in the early stage of the Internet revolution to explain how firms adopted new value creation mechanisms, the lens of the business model gained popularity also in the practitioner community and is today increasingly accepted as grounded theoretical construct. Defined as the system of interdependent activities performed by a focal firm and its key stakeholders, as well as the linking mechanisms between these activities, the business model has been recently used in some firm-level studies of nascent markets, providing novel insights and a fresh perspective to strategy research, given its holistic, boundary-spanning, and decision-making oriented nature.

Building on these premises, this doctoral thesis aims at advancing the body of knowledge at the firm's level in the context of nascent markets from a strategic entrepreneurship perspective, using the business model as main theoretical lens of investigation, and specifically investigating how business model dynamics take place in such settings. The empirical setting of the overall research is the European New Space Economy (thereinafter "New Space"), a nascent industry made up of different sub-markets and sub-segments exhibiting different levels of dependence and independence from the traditional space industry, which have characterized spacerelated activities in the last 60 years. Estimated to worth over 1 trillion dollars globally by 2040, New Space has been defined as the humans' final economic frontier, with a huge number of new ventures founded and been able to scale in the last years, as well as visible reconfigurations of space industry incumbents and increasing budgets allocated by governmental agencies worldwide. In New Space, a real

commercialization seems vet far to be reached, and the nonindependence from the prior industry configuration (i.e., space industry), as well as the active presence of governments and policymakers, makes this setting exhibit interesting idiosyncrasies to investigate how firms strategize in a nascent industry which is at the crossroad between a new emergence and an evolution, providing fresh and novel insights to such debate. Organized as a collection of three academic papers (a bibliometric review of the nascent market literature and two inductive multiple case studies in the New Space), this doctoral thesis contributes to strategy and entrepreneurship literature in several ways, and specifically, to nascent industries and business model research. First, it sheds light on the importance of the temporal nature of nascent industries, providing an integrative definition and making a distinction from other contexts, such as highvelocity environments and highuncertainty environments. Second, it advances the proposal to employ the theoretical construct of the business model as "navigator" or "time marker" of the progressive stabilization of nascent industries, given its

holistic and boundary spanning nature which may capture dynamics from both supply and demand perspectives. Third, this thesis set up a future agenda for research in nascent industries, leveraging the inherent idiosyncrasies of these settings as boundary conditions for other management theories, such as the signaling theory and experimentation approaches in entrepreneurship. Fourth, it advances how the perception of uncertainty in nascent industries might be relative not only to the prior knowledge possessed by the firm, but also to the industry subsegment the firm is part of. Fifth, the thesis shows how established firms may decide to implement open innovation initiaties with the aim to adapt their business model during the new industry emergence. Sixth, the thesis sheds light on the role of prior industry knowledge possessed by new ventures' founders as creator of "knowledge corridors" in the opportunity identification phase leading to the new venture's inception in nascent industries, as well as how institutions may work as knowledge builders and

knowledge aggregators in such

Seventh, it highlights how prior

activity.

industry knowledge possessed by new ventures' founders may influence the prioritization of some business model design activities over other, showing how the previously accumulated knowledge may mitigate uncertainty experienced. Moreover, it shows how institutions (governmental agencies, universities, incubators, and accelerators) may work as knowledge builders and knowledge aggregators also in the phase of business model design of new ventures, through monetary and non-monetary mechanisms aimed at fostering entrepreneurship in the nascent industry.

EMPIRICAL APPLICATIONS OF AI TO THE PROJECT MANAGEMENT DOMAIN

Costanza Mariani - Supervisor: Prof. Mauro Mancini

In the last few years, technological progress has surged at an unprecedented pace, leading to breakthroughs in several areas and application domains. It is in fact common to hear about computerized devices capable of offering answers to numerous human problems in different companies and industries. The application of Artificial Intelligence was limited to academic research only in the past. As the development of innovative AI techniques continues to advance, the development of computer technology has aroused people's interest in applying it in various management fields. Many studies focused on the potential impact of this new technology in different organizations, analysing the possible benefits and limits companies should face, but very few of them concentrated on managerial activities, especially on Project Management. Because many organizations use a project-based structure, effective project management has a significant impact on the economy's growth. The management of Portfolios,

Programs and Projects, intended as temporary organizations with a high-time focus on achieving specific goals, represents a field of great interest for the adoption of innovative Al-based technologies. Although the high relevance and importance of the topic both for academics and practitioners, the literature regarding the applications of Artificial Intelligence in Project Management is rather narrow and disperse, with several subtopics reporting different perspectives of the concept of Artificial Intelligence. More importantly, the literature does not report cases of application of Artificial Intelligence in empirical contexts, proposing studies that suggest Al-based models without then verifying their benefits and limitations in real project management contexts. This research aims to bridge this gap by proposing the use of Artificial Intelligence in empirical real-world application contexts, verifying the implications of employing AI and the results in comparison to a non-Al based context. The thesis is composed of a cover essay and four appended papers, which are four demonstration case studies concerning three specific domains of project management: the project portfolio selection, the risk management phase, and the stakeholder classification. Paper A deals with project portfolio selection and prioritization through supervised

machine learning. A single demonstration case study approach was employed to investigate the use of supervised machine learning in project portfolio selection. Supervised machine learning algorithms were trained and tested to classify the predicted ROI level of forthcoming projects based on supervised machine learning classification. Decision Tree (DT); Gaussian Naïve-Bayes (GNB); K-Nearest Neighbours (KNN); Logistic Regression (LR); Multi-Layer Perceptron (MLP); Random Forest (RF); Support Vector Machine (SVM) were compared in terms of accuracy in classifying future projects in four classes (very low, low, medium, high, very high). The neural network was the only algorithm able to guarantee satisfactory accuracies with all the classes except from "VH". The neural network has more than 60% accuracy with "VL", more than 80% with "M" and more than 90% with "H", while perfectly predicting projects with a "L" ROI level. However, there is no capability of predicting the "VH" success level which in 64% of the cases is predicted as "L" and in 36% as "H". Paper B is about nuclear decommissioning risk

management adopting artificial

intelligence framework.

single case study of nuclear decommissioning by proposing an entirely Al-based method for project risk management. We adopted a Fuzzy Bayesian Belief Network (FBBN) Canonical Model algorithm. The Canonical Model involves a disjunctive interaction between the risks in a risk probability network (the so-called "Noisy-OR gate"): experts provide the probabilistic values for child nodes on a one-to-one basis, instead of determining the joint impact of parent nodes on dependent nodes. It has been proven that this model is able to produce good results even with a small dataset and it is possible to significantly reduce the amount of data required to build the network. For the mitigation action selection, the authors employed an Ant Colony optimization algorithm, which as shown in previous literature, performs better in discrete optimization problems while being the least demanding regarding processing time. The result of the overall project risk assessment was calculated by the FGDMA algorithm that was used to compute the fuzzy prior probabilities of the independent risks, the conditional one-toone relationships between the risks, and the impact of each of them. The model calculated the probability of time overrun of the project to be 42.2%, which represents a medium probability of delay.

The paper examines a

Paper C regards the selection of projects' primary and secondary mitigation actions through optimization methods in nuclear decommissioning projects. The adopted approach involved selecting a specific NDP, collecting primary and secondary data and information about its projects' risks, and proposing an optimization model to select the optimal set of mitigation actions; to validate the results, the same were compared with the real project data. The data refers both to primary and secondary risks. When secondary risks are considered, the link between primary risks, primary mitigation actions, and secondary risks is ultimately non-linear. The Single Objective Optimization problem was then defined as a non-linear optimization model that was designed to address the non-linearity of the problem. The model was finally solved using an Al-based evolutionary algorithm in Microsoft Excel Solver. The model's mathematical solution made it possible to identify an ideal set of mitigation strategies, which included 47 primary and 4 secondary ones. Thus, the algorithm allowed to select 70% of the 68 mitigation actions and 30% of the 12 secondary mitigation actions identified by the management. Paper D employs unsupervised machine learning for Project Stakeholder Classification. The paper is framed as a single case study, that aims to demonstrate the potential benefits and limitations of employing unsupervised machine learning to support project stakeholder classification. The paper proposes unsupervised clustering as a valid alternative for classifying project

stakeholders. Given that stakeholder dataset is usually composed of categorical and numerical variables, the authors applied the Partitional Medoid Clustering (PAM) which identified as an appropriate alternative since it is able to handle datasets consisting of mixed categories of data. The paper results demonstrate that using unsupervised clustering allows to define a more granular and precise stakeholder classification. In the case examined, employing unsupervised machine learning allowed to better differentiate among stakeholders having different characteristics or attributes.

The four cases applied to project portfolio selection, risk management, and stakeholder management show that AI can be considered a valuable and adaptive tool for supporting project managers in carrying out processes and activities, providing better results than the current methods used in companies. Overall, the findings demonstrate that AI has the potential to significantly enhance project efficiency, decisionmaking processes, and risk management capabilities, while also reducing the biases deriving from the subjectivity of experts' judgment and augmenting the dataset for the analysis.

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THE INTERPLAY BETWEEN SERVITIZATION AND SUPPLY CHAIN FEATURES

Antonio Masi - Supervisor: Prof. Margherita Pero

Co-Supervisor: Prof. Nizar Abdelkafi

In response to increased competition, shorter product lifecycles, and pressure for sustainable business models, more and more manufacturers are moving from solely selling products to delivering integrated offerings of products and services. This phenomenon, known as servitization, has attracted increasing interest from both academics and practitioners in the past decades. In this research domain, a higher and higher number of studies suggests that servitization is inter-dependent with a company's supply chain features. On the one hand, a manufacturer's supply chain features may facilitate or hinder servitization. On the other hand, servitization transforms a manufacturer's supply chain features. This "interplay" between servitization and supply chain features has been discussed by previous works, but evidence is still highly fragmented, and the impact of certain supply chain features is much more controversial than other ones. This thesis fills in such gap by disentangling the interplay between servitization and supply chain features, and by further advancing the understanding of both the supply chain

antecedents and the supply chain consequences of servitization. The thesis consists of three papers. Paper 1 is a systematic literature review that reorganizes extant knowledge on the topic, by summarizing how a wide range of supply chain configuration, collaboration and coordination features affect, or are affected by, servitization, and by proposing a future research agenda. Paper 2 focuses on some of the least studied supply chain antecedents of servitization, namely the features of the supply chains of physical products, and analyses them within the context of Engineer-to-Order companies, whose physical supply chains are crucial to deliver the highly customized products that distinguish this sector from other ones. Paper 3 analyses the opposite relationship, by discussing how supply chain

features evolve over time, due to servitization. In particular, Paper 3 analyses how the configuration, collaboration and coordination features of the value networks of servitized manufacturers evolve throughout the servitization transformation process towards advanced services. Together, the three papers explain how supply chain features constrain or facilitate servitization and, vice versa, how servitization transforms such features. This is helpful both for supply chain managers wanting to start a servitization transformation journey, and for those that are in the midst of it.

The key concepts discussed in the thesis can be summarised in a comprehensive framework, shown in the figure attached. The figure synthetizes the interplay between servitization and supply chain features – the title of this



Fig. 1 - The Interplay between Servitization and Supply Chain Features: a Comprehensive Framework

thesis. On the x axis, it shows time. On the y axis, it shows the servitization level, i.e. the extent to which a company moves from competing though products to competing through increasingly advanced services. The diagonal of the picture represents the continuous interaction between servitization and supply chain features. At the beginning of the servitization journey, each company has a servitization level equal to zero. Then, it increases such servitization level during a transformation process, called Servitization Process (1), i.e. at Time = 1. By doing so, it achieves a certain Servitization Level (1), i.e. at Time = 1. Our Papers 1 and 2 show that such servitization level is impacted by the company's supply chain features. When the supply chain features impact on the servitization level, we refer to them as supply chain antecedents. For instance, at Time = 1, the Supply Chain Antecedents (1) will facilitate or constrain the Servitization Level (1).

Remarkably, this can be only the first loop of a long series. In fact, as we show both in Paper 1 and in Paper 3, the servitization process also reshapes supply chains, and even value networks. For instance, after the first loop, the Servitization Process (2) will lead to certain Supply Chain Consequences(1)(1 because they are the consequence of the first loop). Remarkably, these supply chain consequences will be the antecedents of a new loop, as they will facilitate or constrain the achievement of a new servitization level. This

interaction continues until the company achieves the most recent servitization level, at Time = n.

Overall, the comprehensive framework shows the recursive nature of the interactions between servitization and supply chain features (with antecedents turning into consequences). It is also remarkable how this is not the first model dealing with servitization that exhibits this sort of progressive trend. First and foremost, servitization itself is conceptualized as a "staircase" of services, from basic to more and more advanced ones, by Aston's school. Our framework enriches such staircase by showing the continuous interaction between increasing servitization levels and supply chain features. In addition, similar frameworks could be found in the Product-Service Systems literature. In this sense, while our Paper 2 focuses on a "snapshot", i.e., how supply chain features facilitate or constrain a certain servitization level, our Paper 3 brings the perspective of the "derivative with respect to time", allowing for highlighting the evolution of the value network features. This dissertation has both the perspectives: the "static" one, supported by equally static theories, like the Resource Based View and the Transaction Cost Economics, and the "evolutionary" one, for which more dynamic theories, like the Dynamic Capability Theory and the Resource Orchestration Theory are more suitable. Last but not least, it could be interesting to notice how the

comprehensive framework resembles other frameworks connected to organizational transformation, above all Deming's Cycle of Plan, Do, Check and Act. Also this model shows a time evolution, namely how a certain company continuously improves its quality level by means of proper managerial actions. After each Deming's cycle, a new quality standard is achieved, which serves as the basis for further improvement actions. This resembles our model in the sense that each servitization transformation process leads to changes in the supply chain features, which will serve as a baseline for a new servitization level to which the company can aspire to. Overall, both the models represent an effort towards superior performance, but our framework tries to adopt a broader - i.e. supply chain or value network perspective than the inter-firm one.

INNOVATIVE SUPPLY CHAIN FINANCE SOLUTIONS FOR SUSTAINABLE DEVELOPMENT

Elisa Medina - Supervisor: Prof. Federico Francesco Angelo Caniato

Given the increasing relevance of Supply Chain Finance (SCF) and Sustainable Supply Chain Management (SSCM), academics and practitioners have been devoting more attention to the intersection between the two fields. The literature started to explore SCF as a tool that improves supply chain (SC) sustainability by providing weak suppliers with easier access to finance, ensuring the SC's stability (e.g., Caniato et al., 2016). Firms then started developing Sustainable Supply Chain Finance (SSCF) solutions, which include ESG (Environmental Social, Governance) aspects: the first and most famous case was launched by the sports apparel brand Puma in 2016 and consisted of a SCF solution where suppliers were provided with more convenient financial conditions in the program the more they improved their sustainability (Jia et al., 2020). The literature started to analyze the interconnection between SCF and SSCM, but its focus is still on traditional SCF solutions (i.e., Trade Credit, Advance Payment), while only recently authors have started investigating SSCF as a broader, more innovative concept. SSCF is defined as "SCF solutions that minimize negative impacts on sustainability and

aenerate environmental, social, and economic advantages for the stakeholders involved" (Jia et al., 2020; p.1). Despite this, the SSCF paradigm still needs to be framed in the literature. SSCF solutions might indeed be included in the Sustainable Supplier Management (SSM) process more extensively to support the implementation of various SC sustainability practices (e.g., Akhavan and Beckmann, 2017) and to also reach upstream-tiers suppliers. Indeed, the focus in SCF and SSCF literature is still on single-tier SCF solutions, involving a buyer and the firsttier suppliers, whereas research should concentrate also on multitier SCF solutions that include the buyer, the first supply tiers, and the upstream tiers. When SCF solutions are configured as integrated solutions directly reaching different SC tiers, they are defined as Deep Tier Finance (DTF). These solutions can significantly support SC sustainability at multiple SC tiers, by providing better financial resources for upstream suppliers, which are generally Small and Medium Enterprises (SMEs), also for implementing sustainable practices. However, the research focuses mostly on the technological aspects of these solutions, leaving their integration

with SSCM seldom considered. Given these limits, the main aim of this Ph.D. thesis is to explore how SCF can support sustainable development in SCs, by answering the main research question: How can Supply Chain Finance support sustainable development along Supply Chains? More precisely, the thesis aims at:

- Investigating how single-tier SSCF solutions can support supply chain sustainability, by first exploring how supply chain sustainability practices and SCF solutions be integrated, and second by investigating the expected impacts of SSCF on supply chain sustainability.
 Investigating how DTF
- Investigating now DTP solutions can support supply chain sustainability, by first understanding how SCF can go beyond the first supply tier, and second by exploring how supply chain sustainability practices and DTF solutions can be integrated.
- Investigating why SSCF solutions are adopted, first by considering how positive and negative pressures can influence single-tier SSCF adoption from a multistakeholder perspective, second by investigating why different supply chain stages use different SCF solutions, and third by exploring why DTF

solutions are adopted or not. The Ph.D. thesis is configured as a collection of four papers, which all share a qualitative research approach but that follow different aims and perspectives. From a methodological viewpoint, the thesis starts with a literature review that frames the existing body of knowledge regarding SSCF and identifies the main daps and relevant variables to be analyzed. Then, the first research phase (corresponding to Paper 1) considers singletier SCF solutions with a SC perspective and is based on case studies developed through sixteen interviews. This phase was conducted to pave the groundwork to consider sustainability as a driver for SCF adoption and to consider SCF at multiple SC tiers, adopting the Contingency Theory (Sousa and Voss, 2008) to explore the impact of contingency variables, among which the SC stage, on the adoption of SCF. The second phase (corresponding to Paper 2) considers singletier SSCF solutions with a buyer perspective and is based on eight case studies. The second phase investigates how SC sustainability practices are integrated with single-tier SCF solutions, also exploring the role of stakeholders in facilitating this integration. In doing so, the thesis adopts the concept of brokerage roles, which is part of the Structural Hole theory (Burt, 1992), to explore the role of various stakeholders in integrating single-tier SCF solutions with SC sustainability practices. Similarly, a third phase (corresponding to Paper

3) is conducted, which considers single-tier SSCF solutions with a multi-stakeholder perspective, through four multi-actor case studies. The pressures that foster or hinder SSCF adoption and the expected impacts of SSCF on SC sustainability in terms of sustainability progression are investigated, through the lens of the Stakeholder Theory (Freeman, 1984). Finally, a fourth research phase (corresponding to Paper 4), based on a multitier SC perspective, explores DTF solutions, investigating their integration with SC sustainability practices and their adoption drivers and barriers. The results of this Ph.D. thesis explore the role of single-tier SSCF and DTF solutions in sustainable development along SCs in different ways. First, they explain how SCF can be driven by social and economic sustainability purposes (Paper 1) and how single-tier SSCF solutions can integrate various SC sustainability practices and support focal companies in diffusing SC sustainability practices to their first-tier suppliers (Paper 2). Second, the results show how DTF solutions can potentially integrate SC sustainability practices for buyers to foster multi-tier SC sustainability (Paper 4). Third, they investigate the drivers and barriers of SCF at different SC stages (Paper 1), those that hinder or foster DTF adoption (Paper 4), and the pressures influencing various stakeholders in adopting SSCF (Paper 3). Fourth, the thesis contributes to explaining the potential impacts of SSCF on SC

sustainability progression for different stakeholders (Paper 3). In doing so, these results provide contributions to the literature on SSCF by bridging the literature on SCF and SSCM, framing the concept of SSCF (Papers 1, 2, and **4**), considering the perspective of different stakeholders (Papers 1-4), and considering their roles in SSCF (**Paper 2**). The thesis also contributes to the literature on SCF by adopting different theoretical lenses and enriches the literature based on such theories by introducing SCFspecific elements in them. The thesis' results provide guidelines for managers in buyer, supplier, financial, and technology provider firms on the adoption of SSCF at a single-(Papers 1, 2, and 3) and multi-tier level (Paper 4). The results can indeed increase knowledge on the functioning schemes of the solutions, on the SC sustainability practices that can be integrated with them (Papers 1, 2, and 4), as well as on the drivers and barriers, and positive and negative pressures, that can influence their adoption (Paper 1,3,4). Moreover, the thesis provides managers with a first definition of the potential impacts of SSCF on SC sustainability progression (Paper 3) and on how single-tier SSCF (Paper 2) and DTF (Paper 4) solutions can be included in the strategy of focal companies for diffusing sustainability in their supply base.

PUBLIC POLICIES TO DEVELOP DIGITAL COMPETENCES: INSTRUMENTS, IMPLEMENTATION, AND IMPACTS

Francesco Olivanti - Supervisor: Prof. Luca Gastaldi

Digital competence is vital in modern society, yet it remains a scarce and unevenly distributed resource. While scholars have developed an understanding of the determinants and of the social effects of digital competence development, we know little about effective policies to tackle inequalities in digital skills and usage (secondlevel digital inequalities). This dissertation explores the challenges posed to digital competence policy, their influence on the related policymaking processes, and the success of programs established to equip citizens with competences that are adequate for a digital society. Using diverse empirical methods, we address this goal through a collection of papers, combining a comparative case study and two quantitative impact evaluations. The dissertation thoroughly

discusses the contributions, limitations, and implications of the work, where we also provide valuable insights for policymakers and practitioners, producing the first nationallevel evaluations of programs implemented in the field of digital competence policy. In the cover essay, we lay out the premises of our studies by defining the main constructs and theoretical lenses employed in the rest of the dissertation. Furthermore, we illustrate why and how digital competence policy is characterized by multilayered complexity (*multiplexity*), starting from a literature review of academic and non-academic sources.

Then, in Paper 1, we set out an actionable policymaking approach (knowledge-throughaction) to address multiplexity and overcome the limitations of traditional evidence-based policymaking. We perform a comparative case study that aims at producing a synthesis between three literature streams developed in the last 10 years: policy analytics, pragmatism, and design for policy robustness. The results emphasize the role of agile policy innovation, where design techniques and analytical efforts are combined with the policymaker's orchestration activity and the involvement of stakeholders.

Paper 2 provides an application of the approach theorized in Paper 1, evaluating ex-ante the impact of policies targeting basic digital skills (*outreach initiatives*). Knowledgethrough-action in this case is operationalized mainly by incorporating the role of relevant government stakeholders into static and dynamic panel data models. The findings emphasize how different policy levers should be strategized over time, using short-term interventions to tactically open a window of opportunity and increase the likelihood of success for structural policies. Paper 3 applies knowledgethrough-action by performing an ex-post impact evaluation, analyzing the effects of a specific program on young volunteers who facilitate citizens' engagement with basic digital tools. More specifically, we focus on the shortcomings of policy formulation when dealing with multiple targets and competence dimensions at the same time. Our evidence confirms previous theories stating that a misalignment between macro-level policy aims and governance mode, meso-level policy objectives and policy tools, and microlevel operational plans (mainly in terms of targeting) can be paid in terms of policy effectiveness, resulting in a partial policy failure.

Overall, our research contributes to a new representation of the policy cycle, drawing from agile development to emphasize short iterations and multiple feedback channels. Once data become ubiquitous and multiplexity casts off linearities, in fact, policy cycle phases should be interpreted as process *functions* - i.e., as a set of related activities that are linked to knowledge flows among different actors - rather than as chronological steps.

UNPACKING THE CREATIVITY OF PROBLEM FRAMING: HOW INNOVATORS AND INNOVATION TEAMS FRAME PROBLEMS AS A RESULT OF CREATIVE LOGICS AND INFLUENCING STIMULI.

Cristina Tu Anh Pham - Supervisor: Prof. Claudio Dell'Era

Co-Supervisor: Prof. Stefano Magistretti

While it's acknowledged that the quality of innovation solutions is contingent upon the quality of problem framing, both in practice and theory, emphasis has predominantly been placed on generating and evaluating creative solutions. This narrow focus on solutions seems to assume the problem at hand is understood implicitly. Consequently, innovation teams and individuals may rush into solutions hastily, risking the development of pedestrian and meaningless outcomes.

Without a doubt, comprehending the creative generation and evaluation of novel and meaningful solutions is central to innovation. However, I contend that equal attention should be given to understanding problem framingspecifically, the creativity of problem framing. The creativity of problem framing does not only enable to confidently navigate the ambiguity and uncertainty of innovation contexts but also explore different interpretations of the innovation problem. Indeed, studies have shown that when innovators and innovation teams prioritize the creativity of problem framing - i.e., the creative process by which it is possible to explore the problem space - before problem solving, they "seed the

ground for breakthrough ideas to come". Problem framing is often at the root of successful innovations. With problem framing, innovation teams and innovators recall or create mental representations that help focus their attention on a specific set of elements that they consider relevant to the understanding and the solution of the problem. These mental representations are schemas that help them synthesize the innovation environment in a problem's goal, constraints, core assumptions, and path to solution. The new application of existing mental representation or the creation of new mental representations bring about resulting frames that set the criteria for the generation and evaluation of solutions in innovation. For this reason, there is an increasing interest in understanding how problem framing works, as also shown by Posen et al.'s (2018) call, which invited scholars to investigate the way innovation problems are formed, and not only the way to solve them.

Although managerial and organizational studies agree that problem framing is a fundamental creative process for innovation, they have addressed the topics

of problem framing and creativity separately. Moreover, existing studies have mostly investigated them at the macro-level of its outputs. More specifically, the creative process of problem framing is often treated as a blackbox process that anticipates the solution generation and evaluation. While it is known that within the black box of problem framing a mix of extraneous elements combine - some external (e.g., cues from the environment), some internal (e.g., individual memories), it is still unclear what exactly is combined, nor how it is combined. In fact, the details of in what way innovators and innovation teams creatively frame problems has merited further investigation. In particular, the existing literature is too fragmented and misses to open the black box of creativity of problem framing, thus missing to explain what specific elements constitute the anatomy of problem framing creativity. As a consequence there is still an unclear understanding of how different constituents of problem framing interact to formulate resulting frames.

In my Ph.D. thesis, I address the calls for detailed research on problem framing. To do so, I build on the insight that problem framing is a creative process and leverage on theories from creative cognition. Hence, I provide an endto-end description of the anatomy of the creative process of problem framing and unpack how its constituents behave and interact.

Across the four studies in my Ph.D. thesis, we made more specific contributions. First, we addressed the fragmentation of knowledge on the creativity of problem framing by systematically reviewing the literature on creativity and problem framing (paper 1). The objective was to understand what constituted the anatomy of the creative process of problem framing. The study's contribution consisted in an integrative framework encompassing five constituents - namely, (i) triggering problem, (ii) activated knowledge, (iii) influencing stimuli, (iv) creative logics, and (v) resulting frames. As an additional contribution, the study identified a set of research directions that were instrumental to the following my empirical studies in the thesis. The empirical studies targeted different gaps that mostly revolved around how specific constituents behaved in problem framing (the first two empirical studies), or how they interacted with other constituents (the third empirical study). In the first empirical study (paper 2), my co-authors and I targeted the need for an improved understanding of the primary process constituent: "creative logics". Creative logics are thinking logics that allow the creative transformation of the ambiguous, complex, and often contradictory inputs into outputs.

Our objective was to build an understanding of how different creative logics worked in practice, since the knowledge was mostly theoretical or focused on a single creative logic. By observing the creative logics in action, my co-authors and lunpacked not only how the different creative logics were applied through different cognitive operations but also how, based on these differences, innovators achieved two forms of resulting frames (output constituent). The second empirical study (paper 3) was carried out with another author. Together, we focused on the constituent of resulting frames. Our specific objective was to extend from the static understanding of them as results of a linear process, by investigating how they changed over time as a result of reframing and iteration By observing how an innovation team changed their initial resulting frames, we found four reframing practices that combined creative logics together to move across a metaphorical space of possibilities - i.e., the problem space. In the last study (paper 4) my co-authors and I focused on the combination of three constituents of the integrative model from paper 1: creative logics, resulting frames, and influencing stimuli. The objectives were multiple. First, the study wished investigating the differences between creative logics, not in terms of how they operated - tackled in the first empirical study - but in terms of how they affected specific attributes of resulting frames. Second, it investigated the interaction between creative

logics and influencing stimuli, and how such interaction impacted on specific attributes of the resulting frames. In line with the second empirical study, this study also suggested combinations. However, in this case it suggested combinations of creative logics and influencing stimuli to achieve resulting frames with specific attributes.

Overall, this Ph.D. thesis addresses the calls for detailed research on problem framing by leveraging on theories from creative cognition. In terms of contributions to the knowledge on problem framing, the thesis wishes to complement the macro-level understanding of problem framing and the output perspective of managerial studies by unpacking the microlevel anatomy of its creative process (paper 1) and the way its constituents behave (paper 2, 3, and 4). The thesis also extends from the idea that the outputs of problem framing are more or less static by elaborating on the concept of reframing and iteration. More specifically, paper 3 and 4 contribute to unpacking such concepts by offering a nuanced description of how it is possible to reframe initial resulting frames through the use of creative logics and the interaction with influencing stimuli. Finally, across the four papers, the thesis also contributes to the understanding of creative cognition: it extends from past perspectives that focused only on a single creative logic and investigates three creative logics together.

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DIGITAL TWINS FOR ADVANCED PRODUCTION SCHEDULING AND CONTROL

Lorenzo Ragazzini - Supervisor: Prof. Elisa Negri

In an era punctuated by rapid technological advancements, the fourth industrial revolution or Industry 4.0, stands out as a transformative force, reshaping the contours of modern manufacturing practices. The area of investigation of this work encompasses Production Planning and Control (PPC) and simulation modeling, especially focusing on how topics in this research domains are being furtherly developed in the light of the deep transformations brought by the Industry 4.0. Within the fourth industrial revolution, simulation is experiencing a renewed interest. Moreover, the Digital Twin (DT) has emerged as the new paradigm for modeling and simulation with the key feature of direct and bilateral communication with their realworld counterparts. This work aims to propose a DT-based decision support framework enabling production scheduling and control at shop-floor level. The way manufacturing operations management decisions are supported by DT has been investigated through the analysis of the literature. The development of a novel decision support framework to address control of manufacturing systems using DT simulations was investigated

with methodologies typical of design science research. The application of a systematic literature review permitted the functional characterization of the DT for manufacturing operations management and the development of a conceptual model. It also permitted to identify the current gaps in the application of DT to PPC and to define a research agenda. This led to the development of a model addressing operational control problems through a simulation-based DT. To achieve this, the functional structure of operational controllers is first revised to allow the design of smart controllers. The integration of the smart controller and the DT is developed through the design of a set of specific interfaces, which permits to enhance control decisions through DT capabilities. The information flow towards the DT was address, focusing on modeling methods for DT and on its synchronization. This permitted to develop a methodology for automated model generation integrating sustainable performance measures into DT. The model is applied to production scheduling and control activities, with the aim to achieve practical and measurable results concerning production system

performances. The effectiveness of the DT is due to how it allows to counteract disturbances and disruptions supporting self-adaptation and selfoptimization capabilities based on simulations. Its strength is in fact tangible in how it provides new means to solve existing problems thanks to diagnostic and predictive capabilities. This work contributes to the scientific knowledge by offering a comprehensive theoretical framework for DT classification and design, by providing enhanced modeling techniques for DT, by developing a model for DT-based decision support, and by validating it through measurements of its impact on production system performances. From a managerial viewpoint, the result of this work allows to identify opportunities for DT adoption and to understand their value, also easing its implementation supporting its integration and providing a reference architecture. Moreover, it provides estimates of DT impact on production system performances, realized by enhancing timeliness and effectiveness of production scheduling and control decisions through increased awareness and insightful predictions.

Elia Rigamonti- Supervisor: Prof. Luca Gastaldi

Introduction

PERSPECTIVE

In the last decade, the increasing globalisation, workforce complexity, and business digitalisation poses unprecedent challenges for Human Resources Management (HRM). On the other side, the spread of digital technologies has facilitated the collection, storage, and analysis of employees' data, providing HR departments with information to better understand their personnel. In this "new world", organisations are progressively leveraging HR Analytics (HRA) practices to support HRM, replacing traditional intuition-based procedures with evidence-based decisional processes. Nowadays, HRA is considered a business toppriority and a "game changer" for HR departments, and the actual market value for HRA solutions (i.e. \$1.81) is expected to triple by 2030 (i.e. \$4.78). Managerial interest and adoption, however, do not go hand in hand. Most firms are indeed struggling in developing and systematically implementing HRA initiatives, revealing a "capability gap" between current and required analytics capabilities. In a similar way, academic interest has dramatically increased over the last 10 years, when researchers published the 98% of the total studies on HRA Recently, scholars defined HRA as an organisational capability that

depends on multiple organisational dimensions and microfoundational levels (i.e. individuals, processes, and organisational structures). In this regard, prior research argued that the successful development of HRA depends on the effective integration of different organisational resources, dimensions, and stakeholders. Furthermore, academics explained that organisational capabilities reside in different microfoundations located at different levels. emphasising the importance to analyse both macro-, micro-, and individual-level variables in order to understand how capabilities emerge and develop over time. **Research objectives**

Despite the interest, empirical and longitudinal research on the development of HRA capabilities is still rare. First, scholars have to define which organisational dimensions should be integrated and reconfigured for HRA development. Second, scientific research did not further investigate the micro-level dynamics underlying HRA emergence and development. Finally, current research provided limited contributions on how employees may perceive and react to HRA processes, leaving a relevant gap for future research. In light of these premises, this research aims at providing managerial and

theoretical contributions on the development of HRA capability in organisational settings and the role of its microfoundations. Method

The dissertation has been designed as a collection of four papers: a literature review and three empirical studies. The first research (Paper 1) maps the extant knowledge on HRA through a scoping review based on natural language processing technique, defining its research boundaries, state-of-the-art, and relevant research gaps. The empirical part of this dissertation, then, has been articulated in three main levels of analysis (i.e. macro-, micro-, and individual-level) and three respective articles (Paper 2, Paper 3, Paper 4), deepening HRA development at different microfoundational levels through both qualitative and quantitative research methods. The selection of multiple methodologies has been guided and unified in the overall research objective of this dissertation. Multiple research methods, indeed, provides a more informed picture of complex organisational problems, deepening specific phenomena residing on different levels or dimensions. More specifically, the first empirical paper (Paper 2) is based on a Maturity Model and interdependency matrix which

operationalise HRA capability and its constituting dimensions. The second empirical paper (*Paper 3*) analyses how microfoundations (i.e. individuals, processes, and structures) and microlevel dynamics determine the emergence and development of HRA capabilities through a single longitudinal case study. Finally, the last paper (Paper 4) descends one microfoundational level by focusing on how employees perceived data collection processes implemented for HRA practices. In this regard, a cross-sectional study has been conducted to understand the relationships between available information, personal beliefs, employee attributions, and their fear of being datafied. **Results and contributions** The first paper (Paper 1) proposes a scoping review based on topic modelling technique that goes beyond traditional search strategies, identifying and organising the existing contributions on HRA. More specifically, the research identified 1.057 documents, six topics, and four main research areas constituting the HRA field. Furthermore, the review organises the existing knowledge in a comprehensive framework (i.e. Conceptualisation, Enabler, Application, Techniques, Outcomes) that describe the actual state-ofthe-art of HRA field. The findings, thus, provide researchers with a map to navigate the HRA field, supporting them in the generation of more interdisciplinary and impactful research. The second study (*Paper 2*) investigated the development of HRA capability from an

organisational perspective, revealing its multi-dimensional nature. The research defines and operationalises for the first time HRA capability through four areas (i.e. Technological; Organisational; Functional; Diffusion) and different organisational dimensions, arguing that its development goes through four stages of organisational maturity (i.e. Initial, Limited, Systematic, Strategic). Furthermore, this paper discusses the role and the interdependencies among it constituting dimensions, providing firms with practical quidance to prioritise their investment and design harmonious development paths. The third research (Paper 3) focuses on the emergence and development of HRA capability over time through a single longitudinal case study, deepening the microlevel dynamics underlying its evolution. Findings show that HRA development goes through six main phases (i.e. Informal development; Persuasion; Legitimisation; Formal development; Integration; Maturity), each characterised by different microfoundational actions and interactions. Additionally, the research identifies and discusses the fundamental factors for each phase and the critical variables for the transition from individual- to organisational-level capabilities. The results provide further empirical evidence on how HRA capabilities are created and developed over time. Finally, the last research (Paper 4) further delves into the microfoundations of HRA capabilities by investigating employees' cognitive-emotional processes towards data collection

initiatives. Prior research explained that data collection processes can be interpreted through both a coercive and care interpretation, according to the purpose attributed to the managerial intentions behind these practices. In this regard, our research demonstrates that employees attribute both benevolent and malevolent managerial motives to data collection processes implemented to develop HRA practices, depending on the presence of information sharing practices and their personal beliefs of legitimacy. Personal legitimacy beliefs and attributions, in turn, influence employees' emotional reaction to data collection processes, determining their fear of being datafied and reduced to a number. Scholars demonstrated that these emotions and attributions are critical predictors of employeeand organisational-level outcomes, including individual support or resistance to organisational practices.

Conclusion

Combining these contributions, this research provides an initial description of HRA emergence and development through its multiple dimensions, levels, and underlying microfoundations. This dissertation could be an interesting starting point for further discussion on HRA capabilities but is far from being exhaustive and complete. Thus, research limitations and directions for future research are discussed. *Keywords:* Human Resources Analytics; HR Analytics; Workforce Analytics; People Analytics; Organizational capability; Microfoundation approach; Microfoundations.

DEVELOPMENT OF A TRM METHODOLOGY ENHANCING TWIN TRANSITION IN MANUFACTURING

Marco Spaltini - Supervisor: Prof. Marco Taisch

Introduction

This research presents an in-depth analysis aimed at developing a methodology to facilitate the twin transition (TT) of manufacturers at plant level. The study addresses the pressing need for environmentally and economically sustainable solutions. TT offers opportunities to leverage Industry 4.0 (I4.0) technologies to foster sustainability through Circular Economy principles. However, there is a gap between literature and practical implementation.

To address it, this research focuses on developing a structured and practical model to merge Digital and Sustainability Transition, particularly through Technology Roadmapping (TRM) methodologies. TRM offers a comprehensive approach to planning actions based on desired objectives and readiness levels, making it suitable for guiding manufacturing companies through digital-enabled sustainable transitions. Despite variations in the concept of TRM, its scalability and ability to portray dynamic linkages between various elements make it a valuable tool for facilitating TT.

Overall, this research contributes to bridging the gap between theory and practice in Operations Management by offering practical guidance to manufacturers seeking to navigate the complex landscape of digital-enabled sustainable transitions. By emphasizing the role of TRM in facilitating TT, this study aims to empower manufacturing companies to effectively leverage I4.0 technologies for sustainable development.

Research Project

The study aims to develop a methodology supporting manufacturers to foster TT. This objective is fragmented into subobjectives, including investigating reasons inhibiting digitally-enabled sustainable transition, exploring methods to reduce or eliminate inhibitors, and developing a methodology to transfer knowledge on digitally-enabled sustainable transition to manufacturers. Positioned within Operations Management and Action Research domains, the study employs Design Research Methodology. The Research Classification phase involves a literature review and on-field business cases analysis to understand barriers faced by manufacturers during twin transition processes. Results

Challenges Faced by Manufacturers

The literature analysis identified challenges encountered by manufacturers during the TT process. These challenges encompass multiple dimensions including Process, Technology, Economics, Regulation, and Culture. • Process: Manufacturers struggle with adopting a holistic approach that integrates various functions and organizational levels, resulting in a limited perspective on TT. Additionally, the absence of standard solutions and protocols, along with limited collaboration among supply chain partners, hinders TT initiatives. Lack of structured methodologies and poor awareness of End-of-Life strategies further impede progress.

- Technology: Low digital maturity and inadequate IT infrastructure pose significant barriers to digitalization. Data management issues, including collection, security, and exchange, are also prevalent. Misalignment of technology strategies with overall business goals exacerbates these challenges, along with increased cybersecurity risks associated with sharing product and process data externally.
- Economic: TT is expected to increase operational costs and requires significant upfront investment, leading to financial constraints and uncertainty about returns. Limited market for Circular Business Models and short-term strategies further deter investment.
- Regulation: Limited awareness of sustainability regulations and lack of standardized sustainability standards contribute to regulatory

barriers. Insufficient institutional support and bureaucratic hurdles further complicate regulatory compliance.

 Culture: Resistance to change, inadequate leadership, and skill gaps hinder TT initiatives. Lack of proper methodologies, difficulty in setting priorities, and failure to adopt an integrated vision of digital and sustainable transition add to the cultural challenges. The comprehensive list of challenges identified in this research provides valuable insights for manufacturers aiming to undertake TT.

Requirements

Focusing on the elements, phases, and information characterizing TRM for Digital and/or Sustainable Transition, the state-of-the-art analysis enabled the investigation of existing TRM models, and their classification based on objectives. Literature review revealed a lack of consensus regarding the structure of TRM, suggesting, for instance, that TRM is more akin to a set of practices for managing and planning technology development rather than a rigidly structured method or process.

To address this gap, the study proposed 21 requisites that TRM should fulfil as both a tool and process. These requisites were developed through critical analysis of existing literature, including reviews and developed models. The requisites were clustered into three main areas:

- TRM Development: Requisites that TRM must satisfy throughout the roadmapping process to ensure robust and reliable results.
- 2) TRM Content: Requisites defining the output of the

roadmapping process or what must be considered during TRM development.

 TRM Structural Characteristics: Intrinsic characteristics ensuring the validity and usefulness of TRM in dynamic environments.

Proposed Methodology

The proposed methodology, named DeStRa (Digitally enabled Sustainability Roadmap), aligns with the common objectives of TRM methodologies. The methodology emphasizes constant interaction with managers and operators to tailor TRM to the specific goals of the organization, encompassing economic and sustainability domains.

Drawing from existing literature and empirical evidence, the methodology identifies three central phases characterizing transition processes: Assessment, Roadmapping, and Control. Given the extensive literature on the Assessment phase, the research primarily focuses on the Roadmapping phase. The proposed TRM methodology is designed to complement existing Maturity Models, specifically tailored to operational processes and spanning technology, execution, organizational, and process layers. The methodology unfolds in five main steps, each addressing specific phases and objectives. 1) Goals and Key Performance

- Indicators: it identifies strategic objectives, leading technologies, and KPIs to monitor progress towards achieving targets.
- Identification and Prioritization of Criticalities: Criticalities are identified and categorized based on severity and their impact. Also, root causes are identified as well.
 Solution Development: Solutions

are developed, focusing on process redesign, digital backbone implementation, and I4.0, aligned with identified

criticalities and goals.

- 4) Prioritization and Ordering of Solutions: Solutions are prioritized based on severity, impact on processes, and relevance to achieving strategic goals. Logical priorities are determined to guide implementation.
- Communicating and Ordering Solutions: The resulting graphical outcome of the methodology provides a structured representation of prioritized solutions, facilitating communication and implementation planning.

Validation

Two approaches were employed to evaluate the methodology's effectiveness and applicability. The DeStRa methodology was scrutinized against the requirements identified in the Prescriptive Study and its ability to address the barriers to TT outlined in the literature. This theoretical validation was reinforced through workshops, discussions with academic experts from various esteemed universities and research centres worldwide and conferences. The methodology was implemented and tested in business contexts across four application cases spanning different sectors: Automotive, Food & Beverage, Fashion, and Coffee Machine. Through both theoretical validation and practical implementation, the DeStRa methodology demonstrated its robustness, effectiveness, and real-world applicability in supporting twin transitions across diverse industrial settings.

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FOSTERING DIGITAL PAYMENTS: DRIVERS OF ADOPTION AND IMPLICATIONS ON TAX EVASION

Giulia Spinelli - Supervisor: Prof. Luca Gastaldi

Paying is one of the most important economic activities, which has changed dramatically over time. Now it is changing again thanks to digitalization. Digital payments are transforming not only the payment process but the entire purchasing experience. They provide several benefits and are considered by policymakers as a tool through which curbing tax evasion. Indeed, while cash allows to easily conceal transactions, thereby facilitating tax evasion, digital payments, by being traceable, makes evasion more difficult. Yet, the usage of cash is still widespread. Overall, the objective of the thesis is to investigate the impact of digital payments on tax evasion in Business-to-Consumers (B2C) transactions and the drivers and the barriers to their adoption and usage by consumers. We address this goal through a collection of three papers, which combine qualitative and quantitative methods.

Paper 1 provides a systematic review of the literature on the impact of payment instruments on tax evasion in B2C transactions, highlighting the results achieved and the challenges to be addressed. Paper 2 analyzes the drivers to the adoption of digital payments by consumers in Italy. Paper 3 turns the attention to mobile payment, analyzing the barriers to its usage by Italian consumers.

Overall, the thesis relates to two distinct fields of research: tax evasion in B2C transactions and the adoption of digital payments by consumers. It contributes to a better understanding of the impact of payment methods on tax evasion and of consumers' adoption of a technology. More specifically, cash contributes to tax evasion and the shadow economy, while card payments have a positive impact on tax compliance. However, the literature on the drivers to the adoption of cards by consumers and merchants is rather scarce. Conversely, research on the drivers to the adoption of mobile payment is quite abundant, but its impact on tax evasion is still a rather neglected topic. Similarly, scholars have only started to investigate the impact of Central Bank Digital Currencies (CBDCs) on tax evasion. This is a particularly urgent topic because discussions on the design of CBDCs and their (possible) adoption by central banks are ongoing

Turning to the adoption of digital payments, the drivers, in Italy, are habits, performance expectancy and tax evasion aversion. When it comes to mobile payment, usage, tradition and risk are significant impediments to its usage by Italian consumers. That is, if using mobile payment requires a significant effort, consumers are likely to resist. Similarly, if consumers are traditionally used to pay with cash or perceived mobile payment to be risky, then they might decide not to use it. Finally, we provide valuable insights for scholars on the theories on the adoption of technologies by consumers, by extending the Unified Theory of Acceptance and Use of Technology 2 and integrating the Innovation Resistance Theory with cluster analysis based on the Technology Readiness Index.