AEROSPACE ENGINEERING / ARCHITECTURAL, URBAN AND INTERIOR DESIGN / ARCHITECTURE, BUILT ENVIRONMENT AND CONSTRUCTION ENGINEERING / 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 / MECHANICAL ENGINEERING / PHYSICS / PRESERVATION OF THE ARCHITECTURAL HERITAGE / STRUCTURAL, SEISMIC AND GEOTECHNICAL ENGINEERING / URBAN PLANNING, DESIGN AND POLICY

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

• Mandatory courses in Literature Review and Academic Publishing.
• 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 instil in candidates a researchoriented mind-set, along with expertise and skills relating to a specific research topic. To develop a research-oriented 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)

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, Fondazione Brescia Musei,

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 centres 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.

DATA AND INFORMATION VALORISATION FOR CIRCULAR MANUFACTURING

Federica Acerbi – PhD Supervisor: Prof. Marco Taisch

The technological advancements and the diffused need to move towards green and circular behaviours, is highly affecting the entire society. Among the *sustainable development goals* promoted by the United Nations, the 12th goal suggests embracing more sustainable production and consumption patterns. This goal stimulates the request for a Circular Economy (CE), aiming at narrowing, slowing, and closing the resources' loops, especially by manufacturing companies due to their resource greedy characteristics. Although there are many benefits that CE brings, like resource consumption reduction and waste minimisation, its full potentiality is not reached due to some shortfalls on both the managerial and technological sides. In this regard, properly using and sharing data is fundamental to make new business models run correctly and in a synchronized fashion with the contextual situation. Among all, the discrete manufacturing is experiencing this shortfall since it is asked to manage complex data coming from several data sources. Correctly using and sharing data could enable discrete manufacturing companies to optimize their operations while embracing CE. Therefore, to undertake this transition, manufacturers need to first become aware about their current usage of data for circular purposes. This issue emerged during the definition of the theoretical foundation of this research, in which the concept of Circular Manufacturing (CM) was defined as: *"the concurrent adoption of different CM strategies (e.g., circular design, recycling, remanufacturing, cleaner production etc.), which enable to reduce resources consumption, to extend resources lifecycles and to close the resources loops, by relying on manufacturers' internal and external activities that are shaped in order to meet stakeholders' needs".*
This preliminary review enabled also to highlight the two main research streams employed by scholars in studying CM (i.e., technology-based studies and assessment models-based studies), and the main open gaps. In both research streams, the prominent position of data emerged, especially as supporting tool for the decision-making process in CM adoption, and at the same time, data and information usage and sharing was considered the main gap to be furtherly investigated. For this reason, the research objective (RO) of this PhD Thesis is to *"Analyse the role of data and information to foster CM adoption in discrete manufacturing companies and define how to assess their use to enhance the decision-making process in CM".*
To address this RO, the relevant aspects characterising the decision-making process of manufacturers and the related information flows were first investigated based on the extant literature and practitioners' interviews. The major influencing external stakeholders, i.e., customers and suppliers, were detected, and the need to make internal functions be aligned in this transition, both horizontally, across functions, and vertically, at the hierarchical levels (i.e., strategic, tactical, and operational) was emphasized.
Then, the data required for each CM strategy was investigated, defining a theoretical framework including the categories of data in common to the different CM strategies (i.e., product, process, management) and the tools (e.g., technologies) to be used to gather and use data. Based on that, it was developed a conceptual data model clarifying the main classes of data, characterising CM, and their relationships. This model is a complete graphical representation of the necessary data to embrace CM creating the basement for an assessment model development. Thus, a maturity model (MM) allowing an introspective analysis, named CircularMan, was developed to assess the current use of data for CM in manufacturing companies to support manufacturers' decision-making process.
CircularMan is based on four analysis dimensions composed by other sub-dimensions, reflecting the classes of data of the conceptual data model. More specifically, the analysis dimensions are:
• Tools: representing the backbone of CM transition since it enables to collect, analyse, use, and share data to fully benefit from the CM adoption. Four main sub-dimensions characterize this dimension (i.e., authoring tools, information systems, industry 4.0, sustainable sensorized technologies).
• External Stakeholders Management: representing the management of external specific external stakeholders seen as the opportunity to establish with them external relationships by sharing data to fully benefit from CM adoption. Three main sub-dimensions characterise this dimension (i.e., customers' management, suppliers' management, industrial symbiosis management).
• Process: representing all the types of processes, both traditional (i.e., design, production, and logistics/delivery) and circular (i.e., reverse logistics, reuse, recycle, remanufacture, disassembling, maintenance, and repair) enabling to treat resources in a sustainable and circular way, necessary to fully benefit from CM adoption. These processes need to be established either internally or externally to the company by properly using and sharing the data to ensure the correct treatment of resources.
• Product: representing the core element of CM. It covers the usage and sharing of data on the product produced, its packaging, the waste generated, the product turned back to be treated and the by-products. These are the five sub-dimensions of this dimension (i.e., industrial waste, new product, packaging, turned-back product, by-product).
These dimensions are evaluated across five levels of maturity:
1) DATA FOR LINEARITY: Data collection and usage do not allow the introduction of circular manufacturing strategies in the traditional company's practices and values. The company respects only mandatory sustainable and social regulations or laws,
2) DATA FOR EXPLORING CIRCULAITY: Data collection and usage allow the exploration of economic, environmental, social returns from the introduction of some circular or sustainable strategies,
3) DATA FOR PILOTING CIRCULARITY: Data collection and usage allow the introduction of some circular piloting initiatives in the design and production of a specific product family to explore the different circular benefits,
4) DATA FOR DREAMING FULL CIRCULARITY: Data collection and usage allow the systematic internal introduction of circular manufacturing strategies, backed by spotted sharing of data to exchange resources with external actors,
5) DATA FOR EMBRACING FULL CIRCULARITY: Data collection, usage and sharing with external stakeholders allow the systematic introduction of all the possible CM strategies to ensure the circular management of the resources used by the company.
The assessment is performed through a questionnaire based on normative answers ensuring the objectivity of the evaluation. Relying on these answers, a qualitative output is given, backed also by a quantitative one computed thanks to the indexes referring to each dimension (i.e., respectively: tools = TMI, management = ESMI, process = PCMI, and product= PDMI).
CircularMan has been verified through practitioners and academic expert's interviews and focus groups. Moreover, it has been validated through pilot applications in two different manufacturing companies, and finally it has been applied to other two manufacturing companies fostering its generalizability. CircularMan stimulates manufacturing companies in using and sharing data to support manufacturers' decision-making process in CM adoption. Thus, being CircularMan a prescriptive MM, it enables to define customized improvement paths starting from the company's current maturity state. To report an example from the model application, a company, operating in the whitegoods production, was suggested to develop smart products to gather data from consumers, improving the reverse flows once the products are used, and tailoring the maintenance activities to extend the product lifecycle.

"FINTECH": THE IMPACT OF REGULATORY POLICY AND REGULATORY TECHNOLOGY ("REGTECH") ON FINANCIAL INSTITUTIONS

Luca Battanta - Supervisor Prof. Marco Giorgino - Co-supervisor Prof. Laura Grassi

The 2008 crisis highlighted the difficulty, particularly for incumbents, in promptly analyzing and managing the data needed to comply with compliance, reporting and anti-money laundering requirements. This opened up unexpected financial scenarios that required an appropriate regulatory response to prevent new crises. On the part of the Authorities, an increasingly voluminous and rigid regulation has been drawn up which has caused problems for the banks, forced not only to keep up with the pressing regulations but above all to contain the explosion of the relative costs. On the other hand, even the authorities have not had an easy time in verifying the conformity of regulated subjects and have had to innovate their methods and technologies of verification. The knowledge and use of RegTech have become year by year more important both for regulated entities and regulators.
This is the context in which I develop my research project.
I started with an analysis of RegTech from a definitional, policy and business application perspective.
The thesis intends to offer a contribution both from a theoretical definitional point of view and from a more practical one, focusing on regulation, policies and applications in one of the most known and appreciated markets by investors and start-ups, the Swiss one.
The first chapter of this thisis specifically aims to study the definition of RegTech starting from those proposed by the main actors in the academic world, consultancy firms and Authorities, and this in order to discover what is behind the word "RegTech" through a work of "codification" of definitions.
The usefulness of reaching a definition as complete as possible is to monitor and map technologies and applications so as to determine a perimeter of RegTech and, indirectly, of its mirror counterpart for the Authorities, known as SupTech. Current contributions are primarily focused on the legal aspect or are biased by the interest of the consultancy firm. The exanimated definitions have not the intention to create an industry perimeter for RegTech. I will examine, gap in the literature, the technologies employed by RegTech and its applications inside and outside the financial system with an examination of whether RegTech is only part of fintech or is cross-sectoral.
At the end of the analysis emerges a definition of RegTech that encompasses both Academics', Industry's and Regulators' perspectives: "RegTech is the use of technology in the context of regulatory compliance requirements, in fraud detection, aimed at lowering the cost of complying with regulations but also for insight into customer characteristics and needs, risk monitoring and management and anomaly reporting that is more advanced than existing capabilities.
RegTech started as an offshoot of FinTech, it is used by regulators for oversight in the field of financial firms but is now peacefully used in many industries".
Outside the financial context, one of the most interesting area where RegTech can be used is the pharmacovigilance. Telemedicine, similarly, promises to be a very interesting area for RegTech; in fact, the protection of highly sensitive patient data is certainly the area of most immediate attention.
But even the use of wearable monitors for patient safety brings with it greater obligations in terms of data protection and privacy. The pervasiveness of the proposed methodologies and IT tools mapped by the RegTech which 'contaminates' different managerial disciplines, is also very different but united by the need to define standard procedures and fulfilments. Among the standard procedures we can certainly remember those relating to compliance on the loading of new customer cards following the conquest of new users. The solutions based on artificial intelligence and machine learning,
technologies that we found in our mapping of RegTech can be reported in different sectors. A concrete example will be described in the third chapter where we will report an interview with a Swiss startup that deals, among other businesses, with images acquisition and compliance on customer cards.
This company offers the same RegTech solution to the postal and telecommunications sector as well as to the banking sector.
The second chapter examines one of the most active markets from the point of view of RegTech development, that is, Switzerland, given the important innovations present there in terms of regulation and the development of startups specialized in technology linked to financial markets. After a necessary introduction that illustrates the peculiarities of this market and the reasons for its interest, we examine the measures and rules implemented by the Swiss political and regulatory authorities regarding the development of technology applied to finance and regulation.
The Swiss authority has proven to be one of the most innovative in the world and through favourable regulations and practices, has generated an attractive force for investment in the financial sector, allowing Switzerland to remain competitive.
To conclude this chapter reflects future policy developments and lessons learned by the Swiss regulator.
In the third chapter we delve into the Swiss ecosystem of RegTech startups, centered around the Swiss incumbent Swisscom, associations and incubators in the RegTech sphere, grasping their characteristics and the strongest business opportunities in this sector.
Through an in-depth study of the single realities, by means of direct on-site contact and a series of interviews, we collected, compared and studied ideas, experiences and projects and expectations in progress.
The areas are varied and range over solutions that can also be extremely useful in other market contexts and 'exportable' to other countries, such as AML and KYC for onboarding, data cleansing for compliance and compliance reporting and of course digital categorization of regulations.
The Swiss market, familiar with internal innovation from banks and financial institutions, has surprised us by introducing for the first time an ecosystem powered by an incumbent that belongs by birth to the telecommunications sector, namely Swisscom.
We learned how the creation of a RegTech aggregation system like this one can modernize many activities and applications related to financial regulation. Swisscom has tied to itself through its "bridge" function with banks and other companies that are its clients, RegTech startups that are very diversified in terms of the solutions developed and in terms of the sector of implementation.
Associations are also important, for exchanges of expertise and to be represented as a RegTech sector before government and regulatory authorities. In addition, by joining forces, members of RegTech associations could increase the power of political pressure on the government and media in the visibility of the industry as well as the possibility of growth for member companies especially if the partecipants will be big players for dimensions.
The Swiss system can therefore be an interesting model for systems in less mature countries in the development of start-ups and collaboration between RegTech start-ups and incumbents.
Finally, in the fourth and final chapter, after the necessary reflections and considerations induced by the interviews conducted and the overall documentation collected, we set out our conclusions, focusing on what we learned about the Swiss RegTech market, reporting and comparing examples of best practices that could be implemented and even imported into Switzerland from the rest of the world.

CLIMATE CHANGE AND FINANCIAL MARKETS

Roberto Bianchini – Supervisor: Prof. Annalisa Croce

Over the years, public opinion and policymakers across the world have become increasingly concerned about the impact of climate change on economic activities. In August 2021 the Sixth IPCC assessment report defines the relationship between observed warming and human activity virtually certain. The scientists argue that the increase of global surface temperature, caused by human, falls between +0.8°C and +1.3°C, with a best estimate of +1.07°C. Human influence is very likely the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic-sea ice area in the last 40 years. Moreover, human-induced climate change is the main driver of single and compound extreme events: since the 1950s we observe more frequent and more intense heatwaves and heavy precipitation across most land regions and increase in concurrent heatwaves and droughts on the global scale.
In last years, also financial industry perceived the potential negative consequences of climate risk in terms of asset allocation, risk management and investment perspectives. In early 2020, Larry Fink, the founder and chief executive of BlackRock, the world's largest asset manager with nearly $7 trillion in investments, wrote in the annual letter to chief executives that "the evidence on climate risk is compelling investors to reassess core assumptions about modern finance [...]". In a recent publication, the Bank for International Settlement overwhelming this concern defining climaterelated risk as a new type of systemic risk "that involves interacting, nonlinear, fundamentally unpredictable, environmental, social, economic, and geopolitical dynamics" (Bolton et al., 2020).
This PhD thesis aim at studying the interaction between climate change risks and companies' behaviours with a microeconomic prospective. A crucial point for analysis of climate change risks and implementation of effective adaptation and mitigation strategies is the estimation of the causal impact of temperature exposure and extreme weather events on economic activity. While there is virtually no disagreement that climate-related risks may represent a threat to economic activities, the relationship between climate change risks and financial market is not fully uncovered
In the first paper, I investigate the impact of exposure to extreme temperature on the performance of European companies. Based on a dataset of 5.6 millions of firms across 10 years and granular daily weather data from 1980 to 2018, our analysis shows a statistical significant impact of exposure to extreme temperatures on firms' performances. More in details, I find a nonlinear relationship with initial positive impact and subsequent negative effect of exposure to extreme temperatures on companies' performances. Our analysis shows the relationship varies among European areas with a linear negative effect in North and East regions for almost all range of exposure to extreme temperature. In West and South regions I find an inverted U-shaped relationship and negative impact of extreme temperature only in years with large numbers of days with temperature above the historical pattern.
In the second paper, I investigate the market reaction to extreme weather events, which have become more prevalent over time, due to climate change. My focus is on the European electricity companies. These companies have a diversified and geographically distributed portfolio of power plants, which are virtually exposed to a multitude of extreme weather events. I show that when an extreme weather event occurs in proximity of a power plant, investors respond negatively, a response that is stronger when the event occurs in an area where a nuclear or a CCGT power plant is located or when the extreme wheatear event is either a drought or a heatwave. Overall, the findings consistently support the idea that the market incorporates information on extreme weather events in asset pricing.
Finally, the third paper provides insights on the role of environmental policies in promoting venture capital investments in companies involved in the development of clean technologies. Based on a supervised machine learning algorithm, I develop a fully replicable methodology to identify cleantech firms among a comprehensive database of invested companies by venture capital funds. I then analyse the relationship between the stringency level of environmental policies and venture capital investments in cleantech companies operating in 21 OECD countries. I explore whether policies have a differential effect in fostering institutional venture capital (IVC) and governmental venture capital (GVC) investments. Our findings indicate that IVC investments in cleantech are mainly driven by the level of environmental taxes and market pull mechanisms as feed-in tariffs and R&D subsidies, whereas GVC investment decisions are driven by a country's commitment to reach environmental targets. Moreover, our results suggest that GVC funds are developed as an alternative incentive mechanism: when direct incentives applied by governments are less developed, the relevance of GVC investments increases, which suggests a substitution effect between the two forms of intervention.
The research I developed in the three papers contributes to better understand the impact of climate change on financial markets. Firstly, I contribute to fill the knowledge gap in the relationship between temperature exposure and firms' performances. Contrary to previous study, I find a statistically significant impact of exposure to extreme temperature on sales and Ebitda. We find a nonlinear inverted U-shaped relationship. In the overall sample Sales and ebitda exhibit reduction onl in year with large number of days with temperature above the historical level. The result is non homogenous at regional and sectorial level.
Secondly, I estimate the effect of extreme weather events on stock market, analyzing behaviour of listed electricity companies over European countries. I find a significant immediate negative market reaction when power plants are affected by an extreme event. Market reaction appears larger when heat weaves and droughts hit plants due their severe and prolonged consequences on plants' functioning.
Thirdly I study the role of environmental policies in promoting investments in technologies able to mitigate the effect of climate change. I find that the interaction between environmental policies and institutional investor behaviour is complex and influenced by several factors. Not only incentives but also taxes and limits can promote sustainable investments, as long as the environmental costs do not reach too high level for private institutional investors.
The results of the thesis show that physical climate risks are heavily affecting both performances of companies around European countries both in terms of sales and ebitda but also in terms of financial market returns. Private and public sectors may urgently act to try to minimize the impact of physical risks though the development of adaptation strategy able to improve firms' response to climate change. At the same time, they should promote the development of effective adaptation strategies able to reduces the potential negative consequences of acute and chronic climate risks. Governments should also properly design mitigation strategies with the aim of maximize the development of sustainable technologies knowing that institutional investor's reaction to policy stringency is complex and driven, not only by the type, but also by the level of policy stringency.

IDENTITY AND AMBIGUITY OF IMPACT INVESTING

Alice Borrello – Supervisor: Prof. Mario Calderini

The thesis is a collection of four papers that aims to make a unique addition to the theory and practice of the impact investing ecosystem. Impact investing refers to all of the investments made in organizations, funds, and/or projects which have the scope of generating measurable social impact in addition to traditional financial returns. Impact investing and other forms of sustainable finance have grown in popularity in recent years, with the goal being to bring societal and environmental benefits.
Consequently, several financial investors have increased their interest in these approaches. Impact investing differs from the sustainable approaches, because it includes the concept of systemic transformation, and it incorporates proactivity to build additional social value while the other investment strategies do not.
Furthermore, there is evidence that some financial institutions adopt the impact investing rationale merely for marketing or reputational reasons in order to make profits from its success. This behavior is known as impact washing, which is defined as an organization's deceptive conveyance of a social or environmental issue-related image in order to promote its reputation while having no demonstrated positive social impact and causing a dilution of the term impact investment. Impact integrity is at the heart of impact investing, and newcomers must uphold it. The impact investing literature is still young and expanding. In the most recent literature reviews, numerous research streams and related gaps in the field were discovered. Impact investing emerged as a practice primarily as a result of a series of significant pioneering initiatives by professionals and innovators. It is a field of co-creation between policymakers and practitioners, in which the latter define "game rules while playing". The development of an impact investing theory was largely preceded by its practice. This resulted in a lack of understanding of the nature itself, a significant conceptualization, and a robust theory. Considering its popularity and these gaps, the objective of this Ph.D. research is to gain a better understanding of the core characteristics of impact investing in order to ensure impact integrity and to avoid impact washing behaviors.
The research problem is examined in the context of the impact investing ecosystems in Europe, Italy, and Australia. Due to the exploratory nature of the topic, a combined qualitative and quantitative methodology is used to analyze the data.
The purpose of Paper 1 is to show how modern impact investing lacks in a specific implementation strategy capable of translating the key concepts of this approach into the capital allocation process.
Paper 1 tries to understand how this problem can be solved. We created a framework that includes the elements that academics identify as concerns in the impact investment industry. We identified three actions that characterize an impact investing practice: (i) fostering a culture shift among intermediaries, (ii) incorporating social impact into financial transaction terms, and (iii) adopting a coopetition approach. The study shows how industry actors can put the impact investing concept into practice without losing the traits that set it apart from other financial approaches.
Furthermore, the paper contributes results that aim to help future scholars in their studies. These results include a better understanding of impact investors' utility functions, a deeper investigation of the investor–investee relationship in light of the coopetition approach, and a deeper exploration of the topic of social impact measurement.
Paper 2 focuses on the assessment of impact investing qualifying elements, which differentiate it from other sustainable finance initiatives, to address its lack of conceptual and practical clarity. The findings reveal that intentionality is the most important aspect of impact investing, and it includes behaviors such as having a clear hybrid investment mission and defining the social objectives for each investment. Measurability is fundamental in demonstrating the impact obtained by identifying specific targets and measurements and by regularly monitoring them and integrating them into a financial mechanism. Additionality is essential for ensuring impact integrity, and it is shown by the willingness to take on a higher level of risk, which constitutes a both financial risk and a social risk.
By demonstrating how industry actors can put the impact investing criteria in place, the research helps to avoid the risks of impact washing and mission drift.
The goal of Paper 3 is to investigate the interdependencies between impact risks, financial risks, impact returns, and financial returns as well as to comprehend the new shape of the portfolio efficiency change frontier when we take into account the impact return and impact risk dimensions.
I developed assumptions about the interdependencies of social and financial factors based on the literature. We built a four-dimensional model based on the seminal work of Markowitz' (1952) and Gasser et al. (2016), and we assumed that investors have different preferences in the economic and social impact sectors. Then, we tested our model and hypothesis in a real-world context. By expanding the current academic literature on impact investing and adding to the previous discussion on the trade-offs and relationships between various dimensions, this study raises awareness of the financial and social dimensions that investors should consider when investing.
Finally, Paper 4 analyses and compares the investment approaches of two countries, Italy and Australia, in terms of impact investing funds (IIFs). It contributes to the debate over the proper returnto-impact ratio; the findings show that IIFs should avoid sectors with large and predictable financial returns as well as those with government incentives, since in this sector, the impact of an investor's risk-adjusted return and risk-taking propensity are ignored. IIFs should focus instead on high-need sectors and social development concerns as well as on areas where the government is less involved or successful. The research finds that Australia has a less developed impact measurement industry and that Australian IIFs are guided by fiduciary obligations to achieve larger returns. As a result, Italian IIFs are more impact-oriented, while Australian IIFs are more finance-oriented, although both have a clear purpose of supporting Social Purpose Organizations (SPOs). Finally, the study defines the "ideal" impact investment practices that preserve impact integrity.
Despite the best attempts to develop this study with the utmost precision and rigor, there are objective limitations that may reduce the dependability and generalizability of the results. These restrictions, on the other hand, may become important objects of study in the future. First, the empirical setting may be the first source of criticism, as two of the studies concentrate on only one country (Italy). We devised and documented a straightforward methodology for testing and validating the findings.
Second, replication studies in several places, as well as associated comparative analyses, are promising future study topics. The findings of Paper 1 suggest that regulators and policymakers may play an important role in developing a distinctive impact investing implementation strategy and legitimizing impact investing. Studies on the public sector's role and on public-private partnerships were encouraged.
Third, examining techniques for incorporating mainstream financial investors in this industry is an intriguing topic for future research. Their participation could have a significant impact on the dominant future design of impact investing. Finally, further investigation into how to measure impact return and impact risk and how to better understand social data, focusing on access, standardization, and collection, are suggested.

DOES EVERYONE WIN IN SUPPLY CHAIN FINANCE? A MULTI-STAKEHOLDER ANALYSIS

Christiaan de Goeij - Supervisor: Prof. Federico Caniato - Co-supervisors: Prof. Antonella Moretto, Prof. Luca Gelsomino

Introduction and Research Question

Supply Chain Finance (SCF) is about the financial flows and allocation of financial resources in a supply chain through the collaboration of at least two primary supply chain members. This is possibly facilitated by external service providers, such as financial service providers (FSPs) or logistics service providers (LSPs). There is one overarching central question defined in this PhD-research: *"How can buyers, suppliers and financial and logistics service providers, throughout different stages of adoption, contribute to creating long-term benefits from Supply Chain Finance (SCF)?".*

This research question contains two important elements: actors involved and a time element referring to different phases of adoption. While most research in SCF takes the perspective of the buyer, and to a lesser extent of the Financial Service Provider (FSP), in my PhD-research I also focus on the supplier and Logistics Service Provider (LSP) perspective, and show what is needed in collaboration between these actors to make SCF successful. Next to the adoption phase of SCF, I look at how SCF instruments are developed before they are adopted, and I compare benefits perceived before and after adoption in a longitudinal study. The research consists of four papers with large amounts of empirical data, responding to a need for more empirical research in the field of SCF. Due to many areas in SCF having limited previous research mostly case study methodology is used.

Core results

The results show that not only financial attractiveness determines the adoption decision of suppliers. Mainly uncertainty, in the form of bounded rationality and opportunism, influences the relationship between the supplier's assessment of financial costs and benefits of SCF and the supplier's decision to accept or reject an offer. The post-adoption results show that perceived benefits for suppliers can differ substantially before and after adoption, caused by both financial factors and non-tangible factors such as perceived complexity. Furthermore, the research shows the role for LSPs in offering SCF solutions is not always as straightforward as presented in literature, since LSPs can face difficulties in forming the necessary alliances with FSPs and customers, and have challenges in turning such SCF services into price premiums to really capture value from it.

Furthermore, while SCF papers seldomly use theoretical lenses for the framing of results, this research both explores and applies such lenses. It concludes that agency theory, network theory, transaction cost economics and social exchange theory can help to build a stronger theoretical foundation, while the lens of collaborative networks is less suitable. Transaction cost economics is applied in the second paper, while further theoretical lenses are explored in the third and fourth paper (the resource-based view and innovation diffusion theory), altogether contributing to the development a stronger theoretical bases for the academic field of SCF.

Managerial contribution

Suppliers cannot simply assume every SCF offer will lead to a 'win-win situation', in the way it is often presented by buyers and FSPs, since multiple offers in the research were financially unattractive. Therefore, the research provides an easy-to-use tool for suppliers to assess financial costs and benefits, which they can use when evaluating SCF offers. A quantitative model for assessing financial costs and benefits is often not used among suppliers, and therefore the PhD-study helps suppliers to make a better informed decision.

The tool designed can also be used by buyers and FSPs to help suppliers assess the benefits and costs of SCF. In addition, the overall research helps buyers and FSPs understand the qualitative factors that influence the supplier's decision on SCF offers, next to purely quantitative factors. It enables buyers and FSPs to improve the way they present an SCF offer and communicate with suppliers to avoid rejections of financially attractive offers. Especially the longitudinal study shows the importance of good communication. In the cases where the perception of SCF becomes worse after adoption, the supplier describes a lack of communication possibilities with the buyer and the FSP led to distrust, a decrease in perceived observability of effects of SCF and more perceived complexity. In contrast, in cases where the perception of SCF became better after adoption good communication between suppliers and buyers was a key reason for this.

For LSPs the research contributes to understanding the potential value of SCF solutions and gives clear indications of the resources needed to offer SCF solutions, especially inventory financing. In addition, for FSPs the research contributes in exploring the collaboration possibilities with LSPs for jointly developing SCF solutions.

Theoretical contribution

The PhD-research contributes to the developing academic field of SCF. It responds to a need expressed by several recent strategic literature review papers in SCF for more empirical papers, since all four papers have a strong empirical base.

Overall, the PhD trajectory contributes to strengthen the theoretical base for SCF. Few SCF studies have applied theoretical lenses for the grounding of their research. To facilitate this, I both explored and applied theoretical lenses in the research. This not only contributes to the development of a stronger theoretical base for SCF, but also provides effective methods and practices for further studies to apply theoretical lenses.

In response to research gaps described by many authors on the supplier perspective and the LSP perspective in SCF, the multi-actor research in the PhD provides theoretical contributions especially on the roles of these two actors in the supply chain. A substantial contribution is made by showing qualitative, relational factors are also important for suppliers assessing SCF offers, and not only objective, quantitative costs and benefits.

The understanding of the relational dynamics in SCF is enhanced by analysing which factors play the most important role and how. The research demonstrates uncertainty factors bounded rationality and opportunism have a mediating role in the relationship between the financial attractiveness and acceptance of SCF offers by suppliers A puzzle piece is added to SCF literature, by analysing the role of LSPs as potential contributors to SCF by developing SCF instruments themselves or as suppliers responding to SCF offers of buyers and FSPs. Many conceptual or modelling based papers in SCF seem to assume an LSP can logically play an important role in SCF by using their control over the physical and information supply chain flows to lower risks in financing inventories. The PhD-results have a clear contribution by showing this role for the LSP is not as logical and straightforward as sometimes presented in literature. It shows the main challenges for LSPs are forming the necessary alliances with FSPs and customers to successfully venture into SCF.

Finally, an important contribution is made on the post-adoption perspective of SCF, in response to a need expressed by many authors. The last PhD-paper is the first longitudinal study in SCF, and compares perceived innovation characteristics before and after adoption for involved suppliers.

The longitudinal method not only contributes to an explanation on factors relevant for the adoption decision, but also helps in explaining the process through which such factors are formed, can evolve over time and influence the satisfaction of suppliers after SCF adoption.

ABSTRACT OF THESIS: INDUSTRY 4.0, SUSTAINABILITY AND GLOBAL VALUE CHAIN GOVERNANCE IN THE ATHLETIC FOOTWEAR INDUSTRY

Andrew Forterre

The starting point of our PhD research is the recent adoption of Advanced Manufacturing technology (AMT) in Athletic Footwear manufacturing. Our premise is that this adoption represents a significant, even paradigmatic, shift in new product design and manufacturing capabilities for the athletic footwear sector. Furthermore, we place this adoption within the context of the oft problematic relationship between globalised athletic footwear value chains and sustainable development, and Industry 4.0 as an emerging phenomenon within this sector.
Central to this study is a German company which can be characterized as a Multi-National Enterprise (MNE) and Global Sporting Goods Company (GSGC), and its Global Value Chain (GVC) for Athletic Footwear. The GVC in this study encompasses the GSGC' headquarters in Herzogenaurach, Bavaria, Germany; its design and sourcing office outside of Ho-Chi-Minh City, Vietnam; manufacturing suppliers based in Vietnam and China; and providers of advanced manufacturing technologies and materials located in Germany.
The management problem central to this research is: "How is Industry 4.0 influencing manufacturing in the athletic footwear industry and more particularly its Global Value Chain Governance and Sustainability?"
This research has identified the following four research gaps which we intend to overcome:
1. While the body of literature on the governance of Global Value Chain (GVCs) and their sustainable development challenges is extensive, little is known about the adoption of AMT and its subsequent influence on GVC sustainability.
2. Few studies have attempted to theorise the development and use of Industry 4.0 technologies, particularly within the sporting goods industry setting.
3. There is limited understanding of the relationship between GVC governance and AMT's adoption and how such paradigmatic technology upgrading influences GVC governance.
4. The GVC literature has scantly explored the role of products concerning governance issues around development, design, and manufacturing. Instead, the literature perceives products as an outcome rather than a driver of governance.
Following an extensive literature review and a qualitative case study involving site visits, interviews, and document analysis over a period of almost three years, we arrive at five principal findings:
Firstly, we observe that across the GSGC' GVC, manufacturing suppliers reflect different AMT adoption levels and Industry 4.0 maturity, which are characterised by different forms of GVC coordination and control.
AMT mature suppliers are generally modular in their GVC linkage while likely to play a more valueadd role in their relationship with brand-buyers. Moreover, these suppliers also improve working conditions, which subsequently helps them remain competitive in the labour market. However, captive suppliers are less inclined to adopt AMT and show lower working standards.
Secondly, this study concludes that the governance of sustainability is disconnected from other areas of value chain coordination and control. Essentially, costing and forecasting are the GSGC' prime GVC governance foci and thereby drive manufacturing suppliers to adopt AMT with the principal objective to improve productivity and efficiency. Another principal governance focus of the brand-buyer is supplier flexibility, which contributes to these suppliers adopting AMT to increase control over delivery and product adaptability.
Third, the identified beneficial environmental sustainability side-effects of AMT adoption are improved energy efficiency and waste reduction and the strengthening of Occupational Health and Safety (OHS) standards and practices. Residual positive Social sustainability outcomes are growing wages and increasing worker skills and autonomy. However, we also observe a significant reduction in the number of employed workers across the GSGC' supply base, currently still to be examined in the GVC literature. Within this context, the literature is also scant on the new technologies' possible environmental impacts, such as the dematerialisation of products or processes' toxicity.
Fourth, AMT and Advanced Materials providers increasingly include sustainability related industry standards and guidelines in their product design specifications while more actively engaging Business Lead Initiatives (BLIs). The outcome is that adoption of their technologies increasingly drives environmental upgrading across GSGC' GVCs and the industry while bolstering the current industry self-regulatory regime.
Fifth, regarding products, we can conclude that these technology providers have a significant driving role given the importance of product design novelty in the competitiveness of Brands and Manufacturing Suppliers. As a result, we present an alternative to the widely published Buyer- and Supplier-driven value chain, the Product-Driven chain.
Overall, we must conclude that neither Environmental nor Social Sustainability considerations motivated AMT adoption. Instead, productivity and efficiency improvements are the primary drivers for AMT adoption in response to increasing wages and continued cost pressure applied by the brand-buyer. However, we observe that AMT adoption has Environmental and Social Sustainability benefits, while further research is required to investigate the possible negative impacts.

A MULTI-AGENT APPROACH FOR CLIMATE CHANGE NEGOTIATIONS

Paolo Gazzotti - Supervisor: Prof. Massimo Tavoni - Co-supervisor: Prof. Andrea Castelletti

Introduction

Climate change has become the most relevant, complex, and challenging problem of mankind in present times. It affects all countries around the planet yet in several different ways. The high level of heterogeneity of impacts complicates the evaluation of the best policies and mitigation strategies to be implemented by the different nations. Moreover, regional inequality further exacerbates the international negotiation and coordination process. The available benefit-cost optimizing Integrated Assessment Models — among the most influential models that climate scientists and economists use to assess optimal policies and inform policymakers — are rather limited in the representation of countries heterogeneity.
This is despite strong evidence of significant regional variation of mitigation costs and benefits, institutional capacity, environmental and economic priorities. At the same time, a more flexible framework to investigate the complex behaviors and distributed decisionmaking dynamics that take place in COP international negotiations is strongly needed.

Contributions

This doctoral dissertation consists of three main contributions, formalized in a collection of three papers.

Paper 1 provides the detailed description of RICE50+, a new Benefit-Cost optimizing IA Model with more than 50 independently-deciding representative agents. It pursues the following main research question (RQ1): *How can benefit-cost policy-optimizing Integrated Assessment Models be effectively improved, following the latest science, data availability, and properly accounting for regional heterogeneity?* Due to its high level of regional detail, the model (coded in GAMS and released as open-source) will support researchers in better investigating the role of heterogeneity in international cooperation, cross-country inequalities, and climate change impacts under a wide range of mitigation pathways and scenarios.

Paper 2 provides an extensive analysis of the benefit-cost assessments projected by the model. It addresses the following main research question (RQ2): *Which optimal policies are depicted as outcome of the RICE50+ model specifications? Which socio-economic projections take place under those scenarios' optimizations?*
Results assess optimal policies and their consequences under a wide range of assumptions on socioeconomic development, climate impacts, and preferences over time and inequality. As shown in Fig.1, the RICE50+ model highlights the importance of cooperation to drastically reduce emissions rate and meet the Paris targets, stated as economically optimal targets. Urgent and more ambitious mitigation policies confirm the strong necessity to stabilize the temperature increasing, but they alone are not sufficient to close the gap of disparities among regions. Indeed, the model points out a critical persistence of economic inequality among countries, exacerbated by climate damages, even under optimal policy trajectories. Economic progress needs to be both sustainable and inclusive, oriented towards resilient climate adaptation strategies. The results are surprisingly robust across the different socioeconomic scenarios, impact specifications and normative economic preferences adopted.

Paper 3 provides the description of a new agent-based negotiation framework, a novel approach to investigate the complex and distributed decision-making processes of international negotiation on greenhouse gases reductions. This tool is coupled with the RICE50+ model dynamics and is informed by its optimal benefit-cost assessments data to address the third research question (RQ3): *How to better model and integrate the distributed decision-making and complex political negotiation dimension in a flexible yet informative framework?*
Preliminary results show some quantitative participatory consequences for different individual multi-objective evaluations. They suggest that the emerging behaviours of such complex bottom-up modelled dynamics may support the research of the most influential conditions and levers for international cooperation.

Conclusion

This doctoral contribution aims at providing new tools and useful insights to both academics and policymakers, to better understand how heterogeneity affects climate change mitigation policies. It also contributes to better modelling the decision-driving forces in a complex and distributed setting like the COP international negotiations, eventually supporting the strenuous diplomatic action in the search for cooperation-enabling arguments.

THE TECHNOLOGICAL DEVELOPMENT OF SOCIAL ENTREPRENEURSHIP AND THE TRANSFORMATIVE INNOVATION SYSTEMS: TOWARDS A COEVOLUTIONARY DYNAMIC?

Francesco Gerli

Abstract
This dissertation is a collection of four papers that consider the technological development of social entrepreneurship and the evolution of innovation systems towards the solution of societal challenges. Within innovation systems, I specifically focus on supportive institutions – especially "intermediary organizations" as ecosystems, clusters, and their activities – as knowledge and technology transfer programs.
Social entrepreneurship has undergone a complex transformation in recent years. The fundamental traits of this transformation are the hybridization of (social and commercial) missions and managerial structuration. A more recent trend has emerged and been reinforced by the pandemic crisis that refers to the increasing role of technological opportunities within the field of social entrepreneurship, which can enable innovative approaches to societal challenges while scaling entrepreneurial solutions. Thus, a substantial fraction of social entrepreneurship is evolving towards social-tech entrepreneurship. Meanwhile, innovation systems and their institutions are increasingly oriented towards solving grand-challenges, unleashing transformative innovation, and abandoning objectives related to mere GDP-measured economic development.
Transformative innovations are defined as innovations organised to realise concrete visions of change that affect societies and economies. They can contribute to socio-technical transitions that are necessary to solve the grand-challenges by adopting transformative approaches based on a holistic character of innovations that are technological, behavioural and social. Thus, the dissertation theoretically relates these two dynamics. It frames the discussion within the coevolutionary socio-technical perspective depicted by Geels (2005; 2014; 2020).
As such, the dissertation is guided by the following research question: "Does a coevolution between the technological development of social entrepreneurship and the transformative characterisation of innovation systems occur? If so, how?"
To investigate this broad theme, I review the literature on social entrepreneurship and innovation systems to identify four main research gaps:
1) There is a lack of systematic attention on social entrepreneurship and social enterprises as organisational players in transformative innovation and as the potential beneficiaries of transformative innovation policies.
2) There is scarce evidence regarding which systemic configurations enable social entrepreneurship to evolve into social-tech entrepreneurship.
3) There is no evidence about ecosystemic configurations that involve social entrepreneurship and the supportive institutions of innovation systems. There is a lack of debate about whether the systemic approaches exploited for technological and innovation development of commercial entrepreneurship can be translated to social entrepreneurship.
4) There is scarce (and mostly anecdotal) evidence about the specific characteristics of technology transfer processes for social entrepreneurship and the different ecosystems that can enable these processes.
In filling these gaps, I set my empirical analysis mainly in the European and the Italian context. Generally, I exploit a mixed methodology based on critical pragmatism.
My data derive firstly from two surveys. The first was distributed among Italian social enterprises and the second among fellows of Ashoka, the largest global social entrepreneurship network. Secondly, I also conducted semi-structured interviews and collected secondary document data. The survey data are analysed using descriptive statistics, cluster analysis, pairwise non-parametric tests and logistic regressions. Qualitative data are exploited using single- and multiple-case methodological approaches.
The dissertation yields several important findings. First, I consider the following question:
"Does social entrepreneurship potentially demonstrate an organisational character consistent with the attributes of transformative innovation?" I discover that a cluster of organisations within social entrepreneurship (38% of surveyed enterprises) fully displays the attributes of transformative innovation policies, attributes that refer to social and geographic inclusiveness, orientation towards solving grand-challenges, reflexivity through impact evaluation and inclusive governance, and the experimental capacity to generate alliances through interorganisational partnerships. Nonetheless, these organisations also require reinforcement of their technology and knowledge intensiveness to become full protagonists in an integrated socio-technical evolution.
Second, I consider the following question: "Which partnership relationships enable the technological development of social entrepreneurship? Which configurations do they resemble?" The results demonstrate the absence of statistically significant associations between relationships with single institutions belonging to triple-helix frameworks (namely, government, industry and academia) and technology adoption by social enterprises.
Conversely, interactions with other social entrepreneurs and innovators are associated to technological advancement. I emphasise the current lack of appropriate supportive systems able to respond to the specific nature of social enterprises. Moreover, the scarce integration of institutions from triple and quadruple helixes (the latter also involving socially-minded actors and civil society organisations) hinders the technological development of social entrepreneurship.
Third, I consider the following question: "Are current ecosystemic approaches (as innovation clusters) developed by supportive institutions suited to the technological development of social entrepreneurship?" I analyse the European Clusters of Social Innovation model, which includes social economy organisations within innovation clusters led by cluster organisations. I discuss this as a potential localised ecosystemic approach for the technological development of social entrepreneurship, discovering that cluster-based approaches can slightly produce Jacobian externalities among heterogeneous organisations, externalities that may be suitable for technological development. Nonetheless, I recognise that cognitive rather than physical proximity impacts clustered social entrepreneurship. Cluster models with the most technological development potential require low specialisation on social entrepreneurship, flexible membership and openness. These observations lead me to question the cluster model, push for evolution towards living-lab ecosystems and consider re-imagining clusters as tools to aggregate demand-side needs.
Fourth, I consider the following question: "Which traits should an innovation ecosystem for technology transfer towards social entrepreneurship display?" I observe that innovation ecosystems that are already hosting technology transfer processes for social entrepreneurship demonstrate a problem-oriented characterisation, a tendency towards generating hybrid socioeconomic value and collaborative but structured governance. I also recognise that different ecosystemic models are suitable for the transfer of highly standardised "enabling" technologies and non-standardised "core" technologies. I demonstrate that the perception of the idiosyncratic character of social compared to commercial entrepreneurship appears as a variable affecting the relationship between ecosystem models and technology transfer and discover that the transfer of "core" technologies can also occur within technology supply-side driven ecosystem models that open up to new actors as social enterprises.
This dissertation's findings reveal that a coevolutionary dynamic between the technological development of social entrepreneurship and innovation systems and their supportive institutions is not only conceivable but also is (gradually) in process. Social entrepreneurship might represent an agent of "system entrepreneurship" pushing towards the transformative, open and boundary-spanning character of innovation systems and institutions that is necessary to solve grand-challenges.
Keywords: social entrepreneurship; coevolution; transformative innovation, innovation systems, technology transfer

FRAMING THE MECHANISM OF CO-PRODUCTION OF PUBLIC SERVICES WITH VULNERABLE CITIZENS

Eleonora Gheduzzi - Supervisor: Prof. Cristina Masella

The world's increasing serious challenges have forced public service organizations and other public institutions to rely on the efforts and resources of several actors in the service ecosystem, including the general public. In this sense, the general public becomes not only a user of the service delivery process, but also a key resource for improving it. Among the several forms of public engagement, coproduction is the one that ensures an equal and fair contribution of all the actors involved. In the last decade, co-production has come 'back into fashion', but this extraordinary interest has risked enchanting its audience. Although some elements of co-production have been discussed widely, some major gaps still need to be clarified: (i) what happens at the interface between public service organizations, citizens and key service stakeholders and (ii) how do these interactions shape the process of value co-creation, with a specific focus on value co-destruction?
Within this scenario, the involvement of vulnerable citizen in co-production initiatives is debated widely. While their involvement would increase democracy and inclusiveness in public services, vulnerable citizens might not have the capabilities, motivations and conditions for participating in coproduction initiatives. To clarify this ongoing debate, it is important to further explore the coproduction of public services when involving vulnerable citizens. To investigate these issues, this thesis seeks to address the following research objectives: RO.A. How does co-production of public services influence the co-creation (and co-destruction) of the positive (and negative) effects when involving vulnerable citizens?
RO.B. How does co-production of public services occur in terms of the interaction dynamics among the actors of the service system when involving vulnerable citizens?
The first research objective was investigated through three sub research questions, and the second research objective through two research questions. For each sub-research question, one paper was developed, resulting in five appended papers.
To underline the unexplored areas of research and summarizes the contributions of the five research questions, I organised co-production as a process composed of antecedents, process and (positive and negative) effects within a service ecosystem.
Abductive logic was used to investigate these research objectives and the related research questions.
In particular, the process of value co-creation (RQ1) and value co-destruction (RQ2) were assessed using a case study methodology. Then, the analysis of the value co-creation process ended with a systematic literature review that aimed at supporting practitioners and researchers in monitoring the effects of co-production (RQ3). The analysis of interactions during co-production with vulnerable citizens followed a two-steps path. First, theoretical research was adopted to develop a new coding scheme for analysing the interactions (RQ4). Then, a case study methodology was used to investigate the mechanism of co-production at the nexus of the interactions (RQ5).
Regarding the first research objective, the results revealed that co-production with vulnerable citizens is possible and can co-create value, per se. At the same time, its adoption is arduous, time consuming and challenging, as it can also lead to the co-destruction of value. Therefore, the mechanism is ascribable to the dynamic process of value co-creation described in the public service management literature because: (i) co-production can lead to the co-creation and co-destruction of value; (ii) value co-creation and value co-destruction can coexist and change over time; (iii) co-production's effects can have an impact on several actors in the service system. To ensure prompt identification of the coproduction barriers and failures, the findings suggested a practical approach consisting of four iterative steps/phases—Plan, Do, Check, Act—through which the effects of co-production are periodically monitored and adjusted through corrective actions. These findings make practitioners more aware of and informed about the barriers that can arise before, during and after co-production activities with vulnerable citizens, enhancing their early detachment. Moreover, they encourage practitioners to be flexible and patient when planning and scheduling co-production workshops, providing them two valuable communication strategies and practical recommendations.
Regarding the second research objective, the results proved the concurrency of all the forms of public engagement during co-production with vulnerable citizen. Despite the intrinsic dynamism, the process of co-production can be organised into two phases. The first phase (sharing and comparing) is characterised by the lower forms of public engagement and personal and experiential content. The second phase (organising and conceptualising) is associated with the higher forms of public engagement and characterised by abstract and general content. This second phase coincides with the turning point for starting the process of co-designing public services. Given the high mutability and dynamic nature of these phases and forms of public engagement, the facilitator is responsible for preventing the group from losing the focus of the discussion by adopting communication strategies or applying tools. These results provide useful insights on how to structure co-production workshops when dealing with vulnerable citizens. Furthermore, the thesis informs practitioners about the mechanism through which vulnerable citizens start to co-produce. Finally, the results emphasise the importance of recruiting a skilled and experienced facilitator to facilitate this mechanism throughout the workshop
In conclusion, this thesis makes a theoretical contribution to the field by unveiling the two gaps in the current body of literature and by enriching the debate about the involvement of vulnerable citizens in co-production initiatives. Moreover, the results contribute to real-world practice by informing and supporting practitioners and researchers in monitoring and encouraging the co-creation of value during co-production with vulnerable citizens.

APPLYING ARTIFICIAL INTELLIGENCE TO FAULT DETECTION AND DIAGNOSIS IN MANUFACTURING

Masoud Jalayer – Supervisors: Prof. Carlo Vercellis, Prof. Carlotta Orsenigo

Research problem and motivations:
Automated fault detection and diagnosis (FDD) is one of the most important sub-fields of smart manufacturing, which can cut the operating costs and enhance the reliability. The recent advancements in computer processing and digital technologies equipped practitioners to start practicing data-driven FDD. Applying Artificial Intelligence to these models enables the manufacturers to monitor the condition of machines and the quality of products in an agile, precise, and autonomous manner. However, there are still some open issues in the field that hinder achieving an effective AI-based FDD system. Some of the most important issues that this thesis addresses are as follows:
Fault Feature Identification: To achieve a precise FDD system the diagnosis model must achieve a high level of understanding about the feature signatures. The machinery fault types make unique and complex signatures that need an effective feature engineering framework to be developed.
Learning in Noisy Conditions: Most of the proposed FDD methods can achieve high-accuracy diagnosis results, only if the signals are recorded in absence of disruptive noises, which is an idealistic scenario. Hence, when dealing with noisy datasets and real-world situations, these FDD models get poor performances. There is still a wide gap to fill and obtain a high precision FDD on noisy conditions.
Synthetic Data Generation: Deep learning models need datasets with sheer number of instances for each class. In the real world, however, such large datasets are not always at hand and it makes most of the proposed FDD solutions futile or unreliable. To overcome this problem, creating synthetic samples to oversample and augment the dataset can be an effective solution. However, generating synthetic samples is a very delicate and difficult task that still requires so many advancements.
Automatic Image Annotation: To obtain a powerful Automatic Visual Inspection (AVI)system, the manufacturers must present a high-quality dataset, that is accurately annotated and that has an adequate number of samples for each defect type. Annotating an image requires skilled workers to spend a considerable time and create them manually. On the other hand, for the rare defects, it is not feasible to use the conventional generative algorithms, since these algorithms do not annotate the objects within the fake images. Therefore, there is an open gap in the literature for proposition of a generative algorithm that creates fake images with precise annotations.

The Proposed Frameworks:
RQ1 – "Can we introduce a novel feature extraction or feature engineering technique which better reveals the fault type signatures?"
In the 1st paper, we presented a feature engineering solution which uses a wider range of techniques and combines the Fourier and Wavelet domains as well as the signal statistical features. We determined the correlation between different pairs of the feature diagrams which demonstrate that these feature domains are not much correlated and are capable to generate unique spectra. To examine the efficiency of the proposed feature engineering, a comparison panel is set up where the classification performance of three DL architectures is tested on different feature combinations. The results put stress on the effectiveness of the proposed feature combination on all three DL-based fault classifiers.

RQ2 – "Can we develop a novel classification algorithm to enhance the performance of FDD systems in imbalance and noisy conditions?"
In the 2 nd paper, we answered this question by developing a novel hybrid classifier that employs a W-ELM classifier that is capable of learning from rare patterns, coupled with a novel bi-path deep learning architecture comprising both LSTM and CNN blocks. Using the feature engineering framework that had been proposed in the 1st paper alongside the bi-path architecture, the proposed framework was able to alleviate the adverse effects of noisy samples and reach excellent classification accuracies. The effectiveness of the proposed framework is verified by four dataset settings with different imbalance severities and signal-to-noise ratios. After conducting the comparisons using some state-of-the-art FDD algorithms, it is demonstrated that our proposed framework can reduce the misclassification ratio and can significantly outperform the other methods. Achieving comparatively high performances under noisy conditions is an important advantage of the proposed framework, while it does not need any hand-crafted denoising preprocessing techniques requiring employees with expert knowledge of signals.

RQ3 – "Can we develop an effective generative algorithm to synthesize realistic samples, suitable for signal-based FDD frameworks?"
In the 2 nd paper alongside the proposition of a novel hybrid classifier, we have employed a state-of-the-art generative model, called Gradient-Penalty Wasserstein GAN, whose generative architecture is designed to be compatible with the complex characteristics of the rotating machinery signals. The novelty of our oversampling solution is in implementing a state-of-theart GAN model for rotating machinery signals and adjusting its discriminator with a CLSTM architecture. The experimental results with different levels of data scarcity, demonstrate the effectiveness of the proposed model in representing the real signals. The results also make it discernible that employing the proposed model has noticeably improved the classifier's performance. Therefore, it is expected that the industries and practitioners that face the limited number of samples, use our proposed GP-WGAN model to synthesize realistic signal bursts and enhance the quality of their datasets.

RQ4 – "Can we develop an effective AVI system for industries with limited annotated datasets?"
The main contribution of the 3rd paper is to propose a generative algorithm based on GPWGAN architecture, which generates both high-quality defect images and defect-free images. The proposed algorithm is designed such that it can randomly blend the reproduced defect and defect-free images and synthesize fake images while it automatically annotates the allocated defects. It is the first time that such a data augmentation system is designed that can regenerate the annotations simultaneously, hence the proposed system can also be successfully applied on other research fields e.g., medical diagnosis. Another contribution of the paper is the employment of Faster R-CNN with a state-of-the-art backbone, FPN-ResNet-101, which can extract the complex features that the object detector requires and improve the detection accuracy. The comparison results on two industrial datasets applying a range of imbalanced severities indicate the effectiveness of the proposed augmentation technique and of the detection algorithm. Therefore, we believe that the industrial practitioners with a limited number of annotated samples or highly imbalanced data can benefit from the implementation of the proposed AVI system.

Conclusions and recommendations:
Altogether, this thesis presents numerous advancements in the field of FDD by applying novel AI-powered solutions. An effective FDD system helps the industry prevent the machinery breakdown, occupational incidents and product loss which can drastically cut the manufacturing costs. On the other hand, it makes the manufacturing systems less dependent on the human judgement and skilled workers. The proposed frameworks, successfully and effectively improve the reliability and accuracy of the FDD systems and outperform the other state-of-the-art solutions on different real-world datasets.
The main industries that can directly benefit from the results of this study include petroleum, foundries, semiconductors, power plants, automotive, food and agriculture, textile, and pharmaceutical plants.

LEAN 4.0: BEYOND LEAN PRODUCTION A LOOK INTO THE SYNERGETIC NEXUS BETWEEN TWO DISRUPTIVE PARADIGMS

Bassel Kassem - Supervisor: Prof. Alberto Portioli Staudacher

The Lean Production (LP) paradigm that was born out of the Toyota Production System in the 1950s set out a culture of continuous improvement not only in the production area but also across the supply chain and all areas of operations management. Through its tools and practices that formed the House of Lean, manufacturing companies from all sectors were able to improve their operational performances. This organizational paradigm evolved over the years benefiting from the advancements of technologies offered by the industrial revolutions, and Industry 4.0 (I4.0), the fourth one, is a case in point. I4.0, a technology-driven paradigm based on the amalgamation of advanced technologies, offers real-time data and ensures interconnection among all the resources of a manufacturing environment.

The discussion around the interaction between the two paradigms and whether it exists or not started ever since the birth of I4.0 in 2011. The discussion shifted from wondering about the existence of interaction to explaining whether it is synergetic or not. A few years into the latter side of the discussion, the synergetic nexus gained momentum across academic and managerial fields. However, the way this nexus unfolds and the relative benefits is still in the making and thus holds the potentials for further investigation. This research tries to contribute to building this body of knowledge and to explain even further the synergetic nexus between two disruptive paradigms, to be called "Lean 4.0".

For the sake of simplification, we divide the levels of synergy into three: high, middle, and low.

The first level is the high level or the strategic level. This is the approach in which digital transformation and therefore the implementation of I4.0 technologies ensue in manufacturing companies. Here, the genealogy of LP prevails. Through a case study research, it is shown that the digital transformation of high LP adopters is in itself lean while the digital transformation of low LP adopters is not. High LP adopters exhibit what we call a "sustaining digital transformation pattern", a pattern consisting of small batches of I4.0 implementations, focused, and consecutive upon the depiction of each batch's learning points. Intrinsically, it is a continuous improvement project. Low LP adopters instead do not exhibit a lean transformation, they simply do it in major blocks and a disruptive way across all areas, hence the name "Disruptive digital transformation pattern".

Second, the interaction between I4.0 technologies and LP pillars constitutes the middle level or the tactical level. The systematic literature review shows a bidirectional relationship between some of the LP pillars stemming from House of Lean and all I4.0 technologies. The foundation of the house of Lean could be considered as the foundation of I4.0, in the sense that LP is built on standardized and stabilization in processes that pave the way for proper digitalization and implementation of I4.0 technologies. Though the research does not indicate that JIT and Jidoka, the two building blocks of the house, have an enabling effect on I4.0 technologies, they are the most empowered by them. The Lean 4.0 paradigm building blocks are JIT 4.0 and Jidoka 4.0, it is the result of the enabling power of all technologies on the two pillars and more specifically IIOT and Big Data. The largest nodes of interactions belong to these four, and most of the interactions take place in the production area. Lean 4.0 seems to follow the trajectory of LP; they are both implemented heavily in production in addition to supply chain and other operations management areas. In addition to highlighting the areas of concentration of Lean 4.0, the research confirms the positive impact the various interactions have on operational performances. The ceiling of the house of Lean 4.0 is similar to that of LP and, aligned with what I4.0 promises, Lean 4.0 is focused on improving productivity, quality, reducing time and cost-related performances.

Finally comes the last level, which is the low level or the operational. Through a survey-based methodology, the research tackles what we call the functional level, the level of the lean digital tools. This part of the research surveys the adoption level of selected lean digital tools from the practice and the literature. It attempts at closing the circle by including the practitioners as well and proves the importance of connecting the research and the practice worlds. Italian and European manufacturing companies are currently adopting extensively tools that the literature does not focus heavily on, while the least adopted tools are discussed in the extant state of the art. Nonetheless, manufacturers appreciate those tools and consider them satisfactory; they are committed to digitalization and continuously incorporate new digital tools in their operations.

It is also proven the contribution of implementing these digital tools in improving operational performances, some more so than others.

Both high lean and low lean adopters could make use of the strategic level of the research dissertation when embarking on their digital journey. Managers can use the digital transformation framework and the associated results to benchmark themselves against other companies with similar characteristics.Through the middle level of interaction, managers wanting to introduce I4.0 technologies into their lean operations could do so according the current lean tools and practices they adopt. Practitioners on both sides of the market could make use of the functional level. Both the users and the suppliers of the digital tools will get to have a broader view of the existing tools in the market, compare their expectations on where such tools could be of benefit to the company's performance and others' experience in using such tools.

This research contributes to enriching the body of knowledge on the topic and presents the managers the first steps in the empirical validation of the interaction. They can make use of it to compare their current state of operations and the expected one, to ultimately apply lean 4.0 in their operations and reach the expected benefits.

ON THE INNOVATION OF INSURANCE: INSURTECH AND THE FUTURE OF THE INDUSTRY

Davide Lanfranchi – Supervisor: Prof. Marco Giorgino

Insurance value is clear both from an economic and social point of view, being dealing on one side with the negative consequences of economic activity that would occur in its absence and providing, on the other one, a social protection mechanism. The current panorama for insurance companies is changing, with the increasing dimension and disruptive nature of digitalization and the emergence of a new phenomenon, labelled with the term "Insurtech". Practitioners, traditional insurance companies and new entrants, such as startups, are more and more interested in the possibilities arising from digital technologies from artificial intelligence to blockchain.
Digital technologies are impacting insurance sector in several ways, and literature studying this phenomenon is emerging in last years, studying time by time different dimensions, starting from how the spectrum of insurable risks is evolving, until how insurance companies can create value leveraging on digital technologies.
Despite emerging literature, the impact of digital technologies on the insurance sector is a topic far from being exhaustively studied, showing wide space for potential areas of future work from both an academic and a practical perspective. Hence, this thesis aims at further contributing to the emerging literature studying how digital technologies are adopted by insurance players and are transforming insurance sector and insurance activity itself. To properly identify the most relevant area of research and properly answer to this question, we must consider that insurance sector nowadays is affected and moulded by many driving forces, such as the evolution of the competitive arena, the high regulatory pressure, the increasing attention to sustainability and, not least by importance, the recent emergency brought by Covid-19 pandemic. Insurance players not only have to operate in a context affected by those forces, consequently reshaping their efforts and objectives, but as well they can leverage on digital technologies to respond to those forces and keep maintaining their role.
Five papers compose current thesis.
First paper aims at contributing to the understanding of the rationales of insurance innovation initiatives in response to Covid-19 pandemic and their nature and role in innovating the sector.
Indeed, the historical context of Covid-19 provides a suitable case to understand the relevance of exploiting technology to react quickly to traditional and newly emerging risks.
Focusing on the initiatives put in place by the most influential insurance companies at world level, we have framed the innovation mechanisms in the industry, highlighting four rationales underpinning these initiatives (Adaption, Expansion, Reaction and Aggression), which differ according to relevance of the technology in use and innovation to the portfolio of risks covered.
Second paper contributes to the understanding of digital technologies impact on insurance in the light of evolving competitive arena, studying whether insurance companies improved their efficiency in recent years by relying on new technologies. Indeed, while the positive impact of digital technology on insurance companies' efficiency is expected, literature assessing it empirically is scarce, when it comes to recent technological change. Focusing on the US public P&C insurance sector in the period 2012-2018 and relying on both nonparametric (two stage DEA) and parametric (SFA) approaches, it emerges that on average insurance companies were not able to leverage on technological innovations to improve their efficiency.
Third paper contributes to the understanding of digital technologies impact on insurance in the light of evolving competitive arena by investigating the relation between financial (and insurance) intermediation role in the market and Decentralized Finance (DeFi). By relying on a twofold qualitative methodology, first involving document analysis and then experts in two dedicated focus group meetings, it emerges how Decentralized Finance does not eliminate financial intermediation but enables new ways of performing it, where decentralization fosters that no single entity can accumulate sufficient monopoly power. However, DeFi inherits from underlying technologies risks such as fostering illegal behaviours and making authorities supervision more difficult.
Fourth paper studies how digital technologies may help insurance companies (and regulated financial institutions in general) in dealing with high regulatory pressure, investigating the phenomenon of RegTech. Building on a systematic literature review of academic and public authorities' contributions, this work provides a comprehensive multi-dimensional framework to organize and present the main knowledge and results on the concept, to contribute to an objective understanding of RegTech. Results show centrality of digitalization and data, whose quality and integrity are of extreme relevance as aggregation, combination, analyses and modelling enable a vast majority of applications.
Last paper investigates how digital technology and sustainability interact in the development of innovative sustainable Insurtech (and Fintech) solutions. To identify the relative meaningful archetypes, we created a proprietary dataset containing thousands of solutions developed by Fintech startups at world level, analysing the information using explorative clustering analysis. Seven archetypes emerge, from Sustainable RegTech, to Sustainable Data and Technology until Inclusive Fintech & Insurtech. From our research, it emerged that Fintech plays a valuable role in expanding the spectrum of sustainable finance products and services beyond the most commonly studied sustainable finance solutions, capable of paying attention to all the (economic, environment and social) aspects of sustainability.
Research in this thesis suggests how digital technologies may provide a valid support to insurance sector actors to innovate and respond to the many driving forces that are nowadays affecting the sector itself. This thesis aimed at contributing, in a threefold way, to academicians, authorities and practitioners: to academic literature on insurance value creation, contributing to a better understanding of new digital technologies affect some of the most important activities of insurance value chain, on insurance innovation, by providing a rationalized view of relevant technology-enabled initiatives, and on insurance intermediation, investigating the phenomenon of decentralized insurance; to practitioners, by providing a clear view of how new digital technologies can support them in their activities in the light of the different driving forces and, as the application of those technologies in the sector is a complex phenomenon, supporting them with a rationalized view of possible applications depending on the current problem they aim at solving or on the specific situation in which they are; to authorities by providing support on how themselves may leverage on technology to perform their activities, and then by aiming at clarifying their view on how technology is adopted in the sector. Furthermore, authorities may benefit from this research in better understanding how the sector may evolve in the future.

UNTANGLING CONVERGENCE DYNAMICS: HOW INDIVIDUALS CONVERGE WHEN COLLABORATIVELY ARTICULATING A NEW STRATEGIC DIRECTION

Silvia Magnanini – Supervisor: Prof. Roberto Verganti

The adoption of collaboration as the main ingredient for successful transformation initiatives has coincided for organizations with the opening of a Pandora's box. On the one hand, it sparked change across different areas of the company by including a new variety of perspectives and resources. On the other, it confronted managers and project leaders with the inevitable need to manage a dramatically increasing level of complexity.
Consider General Electric that in the 2000s was internally articulating the new "Ecoimagination" vision and its sustainability values through a series of collaborative workshops with key stakeholders from different business functions. A more recent initiative is that of IBM's Corporate Social Responsibility team, which in 2017 undertook a monthly-long exercise to define a new roadmap for digital transformation by engaging a selected number of employees via an open digital platform.
Both examples suggest how running such transformational initiatives requires facing several challenges: balancing the goals and perspectives of different actors within the same area of direction, ensuring engagement in projects that last over time and orchestrating new forms of collaboration (e.g. virtual teams or large groups) that make interactions more distributed and unpredictable.
Within this scenario, one of the most salient collaboration challenges revolves around convergence.
On the one hand, distant viewpoints need both to be included and aligned towards a shared understanding of the direction of change. On the other, a sense of cohesion needs to be ensured throughout the process despite the unpredictability and dynamicity of the environment.
As a response, Complex Adaptive Systems (CAS) Theory has been increasingly adopted to investigate how social systems collectively adapt and self-organize in facing complex business environments. Collective behavior in groups emerges much like the one manifested by a flock of birds. Individuals in the group keep cohesion and agreement by interacting according to simple rules and adapt to internal and external stimuli in the environment as a whole. Convergence in a group emerges as a social phenomenon that allows individuals to develop a shared interpretation of the changing environment by exchanging meaning and information.
In opposition to a static and linear perspective of convergence, a recent line of research has called for further attention to the dynamic nature of convergence, pointing out a new paradigm for studying the phenomenon as an emerging and evolving process. While several studies have started investigating this topic from a cognitive perspective, the social and collaborative side is less clear. Collaboration in fact enhances connectivity and adaptability among individuals, it inevitably opens up the potential for information overload and tensions between agents with different perspectives and goals. Yet, it is unclear how to collaboratively manage interactions locally so that convergence can emerge at a collective dimension.

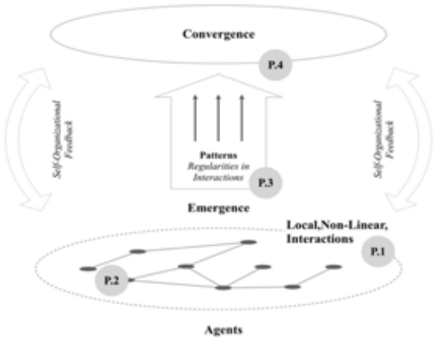

Fig. 1
Thesis Theoretical Framework

Based on these premises, this research incorporates the call to attention to the dynamic nature of convergent phenomena in groups from a Complex Adaptive Systems Theory perspective. Besides, it shifts the focus from the output of collaborative processes on the process itself, an aspect that is still underexplored in the literature. Thus, the following research question has been formulated for the whole research: **How do individuals converge at a collective level when they collaboratively articulate a new strategic direction?**
Within this macro-objective, the aim of this dissertation is two-fold. The first sub-objective compares the influence of alternative collaborative methods on convergence. Based on a longitudinal field experiment, the first paper (see P.1 in Fig. 1) tests the influence of two collaborative methods (i.e. selection, synthesis) on convergence of ideas. The second objective aims to shed light on the dynamic process through which individuals converge as a group when collaboratively articulating a new strategic direction. Thus, three empirical studies explore this topic from multiple perspectives. Paper II focuses at an individual level (P.2), investigating how people perceive synthesis during a convergence process. Paper III embraces a more dynamic stance, exploring how patterns (i.e. recursive schemes of interaction) (P.3) emerge when people synthesize different contributions to converge towards a new strategic direction. Finally, paper IV reconciles the two previous perspectives by investigating how individual cognitions influence convergence (P.4) when people collaborate in a group.
The dissertation advances several contributions to both theory and practice. From a theoretical point of view, this work brings clarity on the emergent process that enables individuals to converge towards a new strategic direction through a collaborative approach. Paper I introduces the role of synthesis, which allows individuals to mutually take others' points of view by integrating different perspectives.
This infuses a sense of internal cohesion among individuals and facilitates collective knowledge propagation over time. Building on findings from this first study, papers II, III explore the process of convergence through synthesis at different levels, contributing to highlight the positive perception of tensions in synthesis to create a new meaningful outcome in a process of collaborative visioning, and the role of tensions as enablers of convergence as they trigger different schemes of integration among ideas. Finally, Paper IV complements the findings from the first study by identifying how different forms of convergence emerge and evolve over time. Last, this research also has some valuable implications for managers. In particular, this work addresses stakeholders within the organization such as community managers, project leaders, professional facilitators, and team members who can monitor group dynamics and progress for selforganization. First, we translate CAS self-regulating norms into a set of collaborative rules to foster convergence during different kinds of organizational transformation initiatives. In particular, Papers I and II suggest some collaborative mechanisms as *"simple rules"* to foster cohesion and selfregulation within large groups. Secondly, papers I, II and III offer a set of guidelines to effectively employ synthesis to integrate different perspectives while articulating a new strategic vision. Finally, Paper I and IV suggest provide several insights to orchestrate different forms of convergence, helping individuals to develop a shared understanding of new strategic direction over time.

BUYING FAST AND SLOW. A DUAL-PROCESS APPROACH TO INVESTIGATE YOUNG CONSUMERS' ONLINE IMPULSE BUYING.

Marco Mandolfo - Supervisor: Prof. Lucio Lamberti

Impulse buying embodies a distinctive class of purchasing behaviours that lack conscious preplanning, involve a powerful emotional charge, and arise spontaneously upon confrontation with a buying occasion. This buying behaviour has recently gained an upswing due to the spreading of e-commerce, whereby internet-enabled platforms offer sizeable possibilities to achieve immediate gratification through extensive product accessibility and delivery convenience. Given its notable economic impact, marketing practitioners have consistently explored tactics to promote impulse buying in the online context.
Impulse buying has also attracted academic research delving into the contradiction between goal-directed and spontaneous purchasing decisions. Furthermore, policymaking has widely examined measures to foster consumer protection against the detrimental consequences of excessive impulse buying.
These perspectives, however, have often relied on the implicit assumption that buying behaviours result from either a reflective decision or a sudden urge. An alternative to this strict dichotomy is examined in the present doctoral thesis. Based on recent developments in consumer behaviour and consumer neuroscience, this research sets out to provide a richer conceptualisation of online impulse buying behaviours through the theoretical lens of the Reflective-Impulsive-Model of consumer behaviour. Following such a dual-system approach, this work posits the existence of two modes of psychological processing that drive online impulse buying: the reflective and impulsive systems. The former is conceived as responsible for high order mental operations, which involve a slow and effortful decision-making process, whereas the latter is devised as in charge of fast and effortless behavioural responses. The research is structured as a collection of four research papers focusing on young adults, who represent an acknowledged portion of online impulse buyers. Paper 1 sets out to draw the state of the art of the current methodological practices to assess impulse buying. Through a systematic literature review, the paper addresses the methodological debate and describes current methods as well as emerging investigation techniques in impulse buying research.
Paper 2 investigates the extent of involvement of reflective and impulsive processes in online impulse buying, providing the first empirical application of the Reflective-Impulsive-Model. Through an experimental investigation combining neurophysiological responses and selfreports, results advance evidence in favour of integrated processing between the reflective and impulsive systems. Paper 3 then tests marketing tactics in form of sales promotions that practitioners can employ to foster impulse buying leveraging reflective and impulsive responses. Survey data show that impulsive responses are influenced by promotion-induced affect and personality traits, while reflective responses are affected by the reward typology.
Lastly, Paper 4 explores approaches that policymakers can introduce to modulate the emergence of online impulse buying. The paper introduces three nudge-based interventions: designing for interactional friction, engaging in distraction, and timely provision of feedback. Overall, the doctoral research advances several contributions to theory and practice. Theoretical contributions to consumer behaviour research include (i) the conceptualisation of online impulse buying as a dual-nature construct, (ii) the understanding of the temporal ordering and magnitude of neurophysiological activations during impulse buying, and (iii) the identification of forms of sales promotions affecting reflective evaluations and impulsive reactions. The research also advances methodological contributions, including (i) a consolidated overview of the research approaches to assess impulse buying and critical analysis of their fit to different research goals and contexts, (ii) the test of a multimethod approach combining physiological correlates and self-reports, and (iii) the conception and test of an experimental paradigm to elicit online impulse buying in an ecological setting. Third, the research offers two noteworthy implications for marketing practitioners, namely (i) the identification of an extensive variety of tactics to prompt online impulse buying leveraging on reflective and impulsive triggers, and (ii) the possibility to hone predictive models combining neurophysiological responses and self-reports. Lastly, this work advances two contributions and recommendations to policymakers, such as (i) the conceptualisation of nudge-based interventions to regulate the occurrence of excessive impulse buying, and (ii) the introduction of initiatives promoting ethical awareness and responsibility.

DIGITAL TECHNOLOGIES IN VALUE CO-CREATION PROCESSES: THE EXPERIENCE OF MUSEUMS.

Camilla Marini - Supervisor: Prof. Deborah Agostino

The dissertation is presented as a collection of three papers which aim to analyze digital value cocreation in cultural institutions, referring to museums as the empirical setting.
Value co-creation - defined as a dialogue and a complex system of interactions within users and the service provider, in which the engagement of all the parties is the result (Prahalad and Ramaswamy 2004) - plays an important role in the redefinition of the relationship between museums and users (Mitchell, Linn, and Yoshidda 2019). Museums have been redefining their role as traditional end elitist cultural institutions (Kelly 2004), moving from a curatorial-oriented approach toward a user-centered approach (Falk 2016). Users become key actors for museums to collaboratively create forms of value that go beyond the economic and financial aspects (Scott 2009). Moreover, the diffusion of digital technologies (i.e. virtual reality, augmented reality, multi-touch screens, mobile apps...) brought deep changes in the way museums design and manage the cultural experience, by proposing interactive and personalized experiences (Giannini and Bowen 2019). Also, thanks to online digital technologies such as online platforms and mobile app, the museum-user system of interaction became even more complex (Micoli, Caruso and Guidi 2020). Museums need to implement digital skills and manage the opportunity to get in contact with a wider audience (Kleinhans et al. 2015) since the cultural experience escaped the physical dimension of the onsite visit (Galani and Kidd 2019) and it expanded in time, by including the moments before and after the museums visit (Kirchhoff, Schweibenz and Sieglerschmidt 2008). Digital technologies brought even criticalities such as the negotiation of curatorial authority (e.g. user generated contents) (Barry 2013; Pulh and Mencarelli 2015), and the risk of extreme gamification and the management of technical obsolescence (Khan et al. 2022).
In this scenario, the importance for museums to redesign their relationship with users, by adopting a value co-creation approach, is increasingly being considered as an important part of the museums' digital transformation process (Romanelli 2020). The cultural management literature extensively discusses the contributions of digital technologies in the museums cultural experience (e.g., Kéfi and Pallud. 2011); however, few studies analyze the role of digital technologies in the value co-creation process (e.g., Antón, Camarero and Garrido 2018; Kirova 2020). Additionally, various research focuses on value as the final outcome (e.g. Ireland, Brown and Schofield 2020), neglecting to address the system of interactions behind it and entailing both the museum and the user perspectives.
2 The dissertation investigates how digital technologies enable value co-creation processes, in museums' context, by answering following research questions: (RQ1) How do cultural institutions enable digital value co-creation models; (RQ2) What are the enablers and obstacles related to digital value co-creation, in cultural institutions?
The research includes a multiple perspective which entails museum, end users, facilitators and mediators, by applying the Co-Creation Framework (CCF) by Ramaswamy and Ozcan (2018) to the empirical setting of museums. Each of the three papers brings new evidence on the phenomenon. The dissertation is based on qualitative research methodologies (Yin 2013). The research purposefully focuses on Italian museums as a significant empirical context. Being characterized by the recent evolution of inclusive processes and the adoption of digital technologies, it represents a favorable context for the study of the design and management process of value co-creation.
Paper 1 connects to the RQ1 and it focuses on the way museums rethink themselves through a value co-creation approach. The article presents a multiple case study (Yin 2013) in which the CCF has been applied to four museums' projects that have digital technologies at the core of the visitor experience, both onsite and online. A set of interviews with projects' managers and technicians was analyzed through Nvivo coding and then a triangulation with secondary sources (i.e. project's documents, websites and social media) was applied. This study allowed me to identify three levels through which museums redesign themselves through a digital value co-creation process, the role of digital technologies as *humanizing* tools and to integrate the CCF with the *contents* element.
Paper 2 and Paper 3 relate to the RQ2 and they both refer to the same case (WORTHY - World Wars Toward Heritage for Youth). Nevertheless, the papers tackle the overarching research question from two different but interconnected perspectives of analysis. In particular, the Paper 2 investigates what inter-actions are behind digital value co-creation in cultural institutions, by adopting the end-user perspective; the Paper 3 discusses the contribution of digital technologies in the value co-creation process, by analyzing the phenomenon at the intersection of museum and end-user perspectives. Both of the papers adopt a single case study methodology applying the coding analysis to a set of interviews that involved key actors (i.e. families, museum staff, project manager, teachers, local municipality) and a focus group (with students). Paper 1 allowed me to detect the inter-actions at the basis of a digital value co-creation process in museums (i.e. learning and sharing actions). Paper 3 was fundamental to define the role of digital technologies as both obstacles and enablers to value cocreation processes, in the cultural experience. The overall findings highlight that digital value co-creation in museums has its core in contents co- 3 creation (i.e. personal narratives and user generated contents) and collective curatorial processes.
Museums have been further shifting from a user-centered toward a relational-based approach in which they rethink themselves by using digital technologies as *humanizing* tools. It emerged that users are not simply co-creators rather they have the role of co-curators. Also, digital technologies can play the role of enablers or obstacles, according to a trade-off logic.

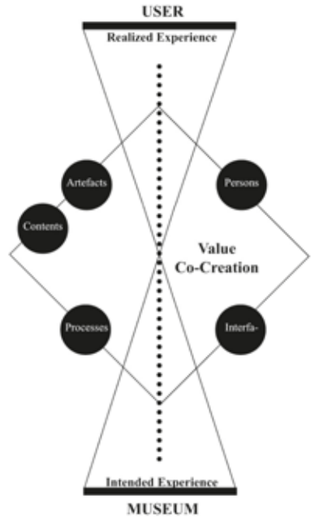

Fig. 1
CCF by Ramaswamy and Ozcan (2018), as revised by Marini and Agostino (2021) for the application to the museums field.

The dissertation contributes to the academic debate into developing a digital value co-creation framework for cultural institutions (Figure 1), capturing and integrating different perspectives and, consistently with that, providing scholars with a systemic approach to digital value co-creation in cultural institutions. The contribution is practitioner-oriented for its managerial implications. The studies provide cultural managers with actionable knowledges about how to redesign themselves consistently to a digital value co-creation approach, moving from a technological-centered perspective toward a relational-based strategy.

DESIGN AND MANAGEMENT OF MASS-CUSTOMIZED FACTORY LOGISTICS SYSTEMS: INVESTIGATION OF INNOVATIVE MATERIAL HANDLING TECHNOLOGIES AND DATA-DRIVEN APPROACHES

Emilio Moretti - Supervisor: Prof. Elena Tappia

Customer requirements are evolving, resulting in higher demand uncertainty, increasingly customized products, and shorter delivery lead times. In several industries, companies are responding by implementing the mass customization strategy, that entails offering wide product variety at competitive prices and within short lead times. Although beneficial from a sales perspective, this strategy requires producing goods in small batches and sharply increasing the number of parts and materials to be handled within the factory. Hence, it increases the complexity of factory operations, encompassing not only production activities but also factory logistics activities, that include the internal transportation and warehousing of raw materials, components, and finished products. A growing focus is being put on factory logistics by both academics and practitioners in recent years, following the realization that the business value obtained from manufacturing operations deeply relies on the factory logistics system performance: a large portion of the overall execution time of the entire manufacturing process arises from logistics tasks, also considering that delays and errors in factory logistics activities may represent a major cause of failures of production. Moreover, with a wider and wider variety of raw materials and parts needed for the production of customized products, the amount of inventories on the shop floor has an increasingly relevant impact on the efficiency of manufacturing operations. In other words, the performance of factory logistics and production systems are strictly related: efficient and smooth production activities are possible only if the right materials are delivered to production stations in a timely way, but without piling up an excessive amount of inventories. Therefore, the evolved market scenario is shifting the attention towards the synchronization of material flows within the factory, defined as the provision of the right parts to production units at the right moment in time or, more in general, as the coupling of work systems that are linked by material flows, and presented as a way to efficiently cope with small product batches and wide ranges of parts while keeping a high efficiency and reduced delivery lead times to customers. At the same time, technological advancements and adoption are proceeding at a pace faster than ever. Material handling solutions providers are proposing new automated systems, designed to store and handle small bins in a flexible way, that could match the evolved requirements of factory logistics. At the same time, digital technologies are getting pervasive in the wake of Industry 4.0: they enable gathering and elaborating large amounts of data about production and logistics systems and processes, thus paving the way for the development of new data-driven approaches for decision-making. Therefore, in a scenario where companies are implementing mass customization and where technological development is faster than ever, this PhD thesis deals with the design and management of mass-customized factory logistics systems. With "mass-customized factory logistics systems", this thesis refers to factory logistics systems synchronized with production, thus able to support production activities in an efficient and effective way when the mass customization strategy is adopted. The findings of this PhD research are formalized in a collection of five papers (three journal papers and two conference papers) and can be summarized as follows. First, the thesis proposes an exhaustive overview of the possible options, in terms of technologies and managerial practices, that allow improving the synchronization of material flows within the factory: seven clusters of managerial and technological levers related to synchronization are identified through a structured literature review and organized into a classification framework; the framework is then applied in four industrial cases as a tool to map the choices made by companies and their implications in terms of synchronization. Then, this PhD thesis investigates how innovative material handling technologies can be integrated in mass-customized factory logistics systems, also assessing their impact on the synchronization of material flows. Focus groups, involving managers from both manufacturing companies and material handling solutions suppliers, are performed to select a specific technology to be investigated, i.e., the vertical robotic storage and retrieval system (VRSRS), deemed as particularly suitable since it is based on mobile robots which are able to both navigate the shop floor and enter the storage racks, thus seamlessly integrating the storage, picking, and transportation activities of materials inside the factory. An analytical model, based on queuing networks, and a discrete-event simulation model are developed to assess the factory logistics system performance, and the related production system performance, in a context where the VRSRS is used to feed assembly stations with parts, also considering alternative layout choices in terms of number and size of factory supermarkets. Results show that a part feeding system based on VRSRSs performs best (i.e., ensures shorter replenishment lead times to production stations and shorter idle times of production stations due to materials starvation) with small production batches, hence effectively supporting mass-customized operations. Moreover, once fixed the number of supermarkets, their replenishment lead time improves if supermarkets are smaller: therefore, the adoption of VRSRS may allow saving space in the shop floor, that is a critical resource especially in mass-customized factories, while at the same time improving the performance of the replenishment system. Lastly, this PhD thesis explores how data can be leveraged to support decision-making within factory logistics systems. Data-intensive decisions (i.e., decisions affected by a large number of parameters, which cannot be efficiently and effectively managed by a human analyst alone, and/or decisions traditionally based on average data, which could be replaced with information concerning the real-time shop floor status) are searched within the literature about the design and management of factory logistics systems and then, for each decision, a more in-depth literature review is carried out, also looking at different research fields, to identify a data-driven approach which could integrate or replace the currently available ones. Hence, two types of data-driven decision-making approaches are proposed in this thesis. The first is a combined optimizationmachine learning approach for the design of hybrid part feeding systems: after being formulated, the approach is applied to an industrial case where its performance is compared with the one of a traditional optimization-based approach. Results show that the proposed approach allows estimating the optimal solution, while at the same time requiring lower data collection effort and no specific skills. The second approach is a scheduling method for a fleet of mobile robots feeding production stations with materials, based on the use of real-time data concerning the robots and the shop floor status: after presenting the approach, a novel agent-based simulation model is proposed to compare its performance with the one of a traditional scheduling method based on average and static data.

DYNAMICS OF SOCIOTECHNICAL INTERDEPENDENCE IN THE FOURTH INDUSTRIAL REVOLUTION

Mattia Pedota – Supervisors: Prof. Luca Grilli, Prof. Lucia Piscitello

Summary

The Fourth Industrial Revolution (4IR) is shaking business models, labor markets and the international competitive landscape. The ongoing process of digitalization and intelligent automation is likely to have complex and unpredictable effects spanning the economic, sociocultural and intellectual spheres of human activity. Within this context, the present work investigates the dynamic intertwinement between two complementary pillars of economic activity: technology and human skills. Among the latter, it delves into creativity, the skill that is most conducive to innovation (and thereby technological progress). The complexities of this research endeavor can be summarized as follows:

• even before taking skills into account, one should realize that technologies are interdependent and complementary among themselves. Such interdependencies manifest not only at the material level, but also at the level of knowledge and heuristics. While this is generally true for any kind of technology, 4IR technologies make it particularly explicit. The systematicity of 4IR technologies, their complementarities in adoption and the patterns of coevolution among their trajectories of development have to be duly considered to build a coherent understanding of the 4IR as a dynamic sociotechnical phenomenon.

• At the firm level, there is widespread consensus on 4IR technologies requiring an ICT upskilling of the workforce to show their full productive potential. However, especially in the light of the previous point, it is unclear whether different subclusters of 4IR technologies (based on their technical features and complementarities in adoption) require different extents of ICT upskilling. Furthermore, it is unclear whether the ICT upskilling should be directed mainly toward ICT-specialized personnel or also toward the rest of the workforce.

• While ICT skills determine the ability by workers to exploit 4IR technologies toward productive ends, creativity underlies their capability of enhancing and recombining them in novel ways. This peculiar skill lies at the basis of the dynamic, evolutionary character of 4IR technologies and skills as a complex sociotechnical system. The dissertation conceptualizes a recursive relationship between technological progress and creativity, whereby they mutually enhance each other. This virtuous circle may start at the level of the individual/small group within the firm and then diffuse to the whole organization, eventually microfounding technological and socioeconomic progress in the whole society. These issues are investigated through four papers, employing a heterogeneous set of epistemological approaches and methodologies, ranging from econometrics to case-study based theorizing and pure theory building. Paper A develops an extension to Giovanni Dosi's seminal theory of technological paradigms (1982), conceptualizing the possible formation of aggregate paradigms due to a dynamic process of epistemological interdependence between subparadigms. This theoretical architecture is grounded in a case study on the evolution of additive manufacturing, one of the enabling technologies of the 4IR. The case study combines and triangulates a qualitative historical account of the evolution of AM (based on scientific papers and specialized technical treatises) with a quantitative analysis of trends in scientific publications and patents from the early 1960s to the present time. The empirical findings corroborate the underlying theory, showing clear patterns of epistemological interdependence in CAM, CAD and additive fabrication processes, the foundational subparadigms of additive manufacturing. We expect that epistemological interdependence and aggregate paradigms will become helpful theoretical constructs to make sense of the coevolutionary dynamics of 4IR technologies, which are highly dynamic and combinable.

Paper B features an econometric analysis on a database of 21,934 italian firms, with a twofold purpose. First, it aims to complement the findings of Paper A from a firm-level perspective, by capturing possible subclusters of 4IR technologies based on patterns of conjoint adoption. Second, it aims to investigate to which extent these different subclusters relate with an ICT upskilling of ICTspecialized personnel, or an ICT upskilling of the whole workforce. The analysis has been performed on the whole sample as well as three subsamples based on firm size (small, medium and large), to capture possible differences along focal dimensions as size varies. Results suggest the presence of definite patterns of conjoint adoption of digital 4IR technologies (i.e. augmented reality, big data analytics and cloud computing) on the one hand, and physical 4IR technologies (i.e. 3D printing and robots) on the other, although they do not mutually exclude each other. As expected, the propensity toward digital 4IR technologies has a stronger association with ICT upskilling, but also the propensity toward physical ones has a positive and statistically significant association with it. Interestingly, both propensities are more strongly related to the conjoint ICT upskilling of both ICT-specialized and nonICT specialized personnel, rather than the selective upskilling of either of the two.

Paper C is a conceptual piece with a structured empirical illustration. While it is well-established that creativity fosters technological progress, the other way round is much less investigated, and predominant theories tend to regard technology-driven creativity enhancement as a coarse-grained, exogenous amplification (e.g. search engines facilitating exploration, or CAD software improving visualization). By contrast, building on Mihály Csíkszentmihályi's systems model of creativity (1996), we propose that new technologies complement creative skills by enlarging the domain of symbols and tools at the employees' disposal. The framework developed throughout the paper sheds new light on the intertwinement between employees' components of creativity, dynamic heuristics renewal and contextual influences in the face of technological change. It also offers an empirical illustration through the case of AM in Luxottica, showing the relevance of this contribution to the 4IR context.

Paper D is a purely theoretical piece developing a dynamic sociotechnical perspective on organizational creativity. While Paper C explores the relatively underresearched link from technological progress to creativity, Paper D conceptualizes the dynamic bidirectional relationship between the two, by integrating insights from the constructionist tradition in IS research with creativity research. Although the paper features no empirics whatsoever, it draws most of its realworld examples from the 4IR, emphasizing the relevance of the feedback loops between technological progress and creativity enhancement to the 4IR context.

These four papers, when viewed together, depict a dynamic mosaic of sociotechnical interactions in the 4IR. 4IR technologies seem to group into digital and physical clusters, as suggested by patterns of conjoint adoption (Paper B); Paper A lays the theoretical foundations for interpreting such clustering in terms of aggregate paradigms, conceptualizing the possibility of epistemological interdependences in their trajectories of improvement. In this context, human skills are of paramount importance, not only to exploit the productive potential of 4IR technologies in static terms (Paper B), but also to dynamically propel the improvement along their trajectories (which are probably interdependent, as implied by Paper A) and even create new trajectories. Papers C and D delve into creativity as the main microfoundation behind such incremental and radical improvements, by exploring underresearched and increasingly relevant aspects of its interaction with 4IR technologies: domain-driven complementarities and self-reinforcing sociotechnical interactions.

TOWARDS A MODERN MAINTENANCE PRACTICE IN MANUFACTURING BY EMPOWERING INFORMATION MANAGEMENT AND INTEGRATION

Adalberto Polenghi - Supervisor: Prof. Marco Macchi

The digital era in which we are living is changing the way manufacturing companies are managing their physical assets. The search for operational excellence asks for holistic and integrated methodologies for the management of machines as well as embracing the digital transformation to unseal the production system state. Hence, maintenance is more central in company strategy given its capability to gather insights from the shopfloor. This is causing maintenance to evolve towards a more modern practice. Nevertheless, this evolution should be accompanied by an adequate information and data management strategy. Maintenance makes the integration of data and information a pillar so to exploit asset-related decision-making as well as to support decisions of other organisational functions, which should be grounded on the knowledge of the current production system state. Therefore, this PhD Thesis aims at investigating the management and integration of information to boost a modern maintenance practice, driven by the digital transformation and by the Industrial Asset Management. To this end, data modelling and ontology engineering are applied, each for a specific goal, but with the underpinning objective of promoting suitable management and integration of relevant information. Data modelling is used to support maintenance managers for the strategic decision regarding the eventual restructuring of the company's maintenance processes, and to plan the integration of the required information systems. This is based on the development of a methodology that is able, through the formalisation and instantiation of a reference data model, to depict the current state of the maintenance process in terms of: completeness of the process itself, integration of the information systems, and completeness of the needed data and information. Then, ontology engineering is applied to support tactical and operational decisions. The developed ontology, called ORMA (Ontology for Reliability-centred MAintenance), rooted in the developed data model, has a modular structure, which integrates product and process knowledge in addition to the asset-related concepts. ORMA is developed thanks to AMODO (Asset Management Ontology Development methOdology), which stems from available ontology building methodologies, accompanied by a compendium that fosters knowledge reuse in the maintenance domain. ORMA can support maintenance decisions at both tactical and operational levels, also given its modularity.

At tactical level, the multi-attribute criticality analysis is formalised to semantically coordinate multiple facilities. At operational level, the ontology can infer product feasibility based on current asset state to promote a shopfloor-synchronised decision-making. The proposed data and ontological models are applied and verified in real industrial manufacturing contexts. The data model is applied for strategic decisions in an automotive company to guide them towards the restructuring of their information systems stack supporting the maintenance process. Instead, ORMA is firstly applied in a food company with multiple facilities to semantically align the realisation of the criticality analysis. Then, ORMA is also applied in a Flexible Manufacturing Line where the data from the shopfloor are elaborated via health state detection algorithms, proper of Prognostics and Health Management. After updating and reasoning of the ontological model ORMA, the augmented information is displayed on a web-based dashboard for cross- functional decisions, namely, maintenance and production. Therefore, both the data model and the ontological model empower the information management and integration for maintenance in manufacturing companies. The management is specifically supported by the data model that organises where the flows of data and information. This reflects in a better organisation of the maintenance process and of its information systems. A better management of the information is promoted also by ORMA, where the terminology is fixed so to unify multiple perspectives. Moreover, ORMA empowers the integration of information given its capability to integrate augmented information from the shopfloor to support a cross-functional decision-making.

Concluding, the application of data modelling and ontology engineering unveils their potentialities in helping the evolution of maintenance towards a modern practice, leveraging upon data and information pushed by the digitalisation and the managerial changes asked by the Industrial Asset Management. In so doing, maintenance could address short, medium, and long-term decisionmaking, centred on the asset as relevant to generate value for the company.

BUSINESS MODEL EXPERIMENTATION: A SCIENTIFIC APPROACH TO STRATEGY AND ENTREPRENEURSHIP

Silvia Sanasi - Supervisor: Prof. Antonio Ghezzi

The business model is an established construct in strategic management, seen as the unit of analysis to describe the realization of a firm's strategy in terms of the value created for target customers, the way it is delivered to them, and the mechanisms through which the firm captures value back from the market. However, the debate regarding the theoretical definition of the business model concept is still ongoing, yet rising critiques on the legitimacy of the business model as a concept *per se* rather than just representing "strategy in new bottles". On the other hand, an increasing body of research recognizes the business model as a potential source of innovation in and of itself, encouraging further theorization and investigation of the business model innovation phenomenon. Recent studies suggest that the view of the business model as a static picture of the logic of a firm may be the source of the doubts arising in current literature; they thus propose a rather dynamic view on the business model as a tool to address change and development processes taking place within the firm.

The investigation of so-called *business model dynamics* thus overcomes the ontological perspective adopted by the current debate over the business model which, up to now, failed to grant full legitimacy to the business model's existence as a concept of its own. Rather, by adopting a phenomenological stance, the study of business model dynamics elevates the business model as the unit of analysis for evolutionary phenomena related to a firm's strategy. Within business model dynamics, the business model is as a device that enables managers and entrepreneurs to discover new market opportunities and embody them into new products, services, or even entirely new ventures, while simultaneously building the infrastructure needed to support them.

According to the extant literature, business model dynamics refer to all the alterations to the firm's business model that enable it to produce sustained value creation throughout time, such as the developmental or change processes taking place in both entrepreneurial and incumbent firms. Business model dynamics may for example encompass *business model innovation*, aimed at discovering new value creation and capture, *business model validation*, accomplished to ensure the viability of a firm's business model choices, business model scaling efforts, to grow the business model following its market validation, as well as the pivots firms set in place in their business model to face adverse events.

On the other hand, the way firms carry out business model dynamics is currently object of extensive investigation. In particular, emerging scholarly and managerial accounts are increasingly reporting evidence of how business model dynamics can be enacted, hinting that their enactment involves the use of experimentation on the firm's business model.

While experimentation to enact business model dynamics originated from the entrepreneurship world as a response to high levels of uncertainty and the need to "make do" with the limited resources at their disposal, experimenting is not only a startup's matter.

Established firms may also find themselves dealing with ever-evolving environments and unforeseeable conditions, such as when launching novel business models, calling for rapid and continuous experimentation. Experimentation involves the application of a rigorous and almost "scientific" method to validate the key assumptions underlying the firm's business model. Similarly to natural scientists, who employ the scientific method to test (and potentially falsify) their theories about nature, managers and entrepreneurs become theorists in search for validation of the hypotheses they formulated regarding their business and its potential viability on the market.

In practice, business model experimentation takes the shape of running experiments on business model alternatives, embodied into business model hypotheses, before committing significant resources to any. After evaluating the results of their experiments, firms must decide whether their hypotheses are falsified and pivot their business model, revising some of its key elements to match the newly found knowledge on its underlying assumptions or, in case they are validated, to continue and persevere with the business model as planned.

However, the current body of literature lacks the necessary "cumulativeness" for theory building on the use of experimentation to enact different business model dynamics and are disproportionately focused on selected business model dynamics (i.e., business model innovation). As a consequence, the scholarly understanding of business model dynamics appears fragmented and lacks a unified framework, as well as the understanding of how experimentation can support the enactment of different business model dynamics within firms. To address this gap, this dissertation aspires to extend the current scholarly understanding of the way firms can enact different business model dynamics by leveraging experimentation.

The dissertation builds on a collection of five intertwined studies which address this macrogap through different means and from different perspectives.

Each section is devoted to explaining the underlying rationale behind the collection of papers, unveiling the theoretical roots upon which the collection of papers is based, as well as the research gaps identified and the methodologies employed to tackle them.

BIG DATA ANALYTICS AND SUPPLY CHAIN PLANNING: BRIDGING THE TECHNOLOGICAL AND MANAGERIAL CONSIDERATIONS FOR TECHNOLOGY APPLICATION AND ADOPTION

Jinou Xu – Supervisor: Prof. Margherita Pero

The increasingly turbulent global environment has inextricably intertwined research on digital technologies with operations and supply chain management (OSCM). While there is no doubt that managing supply chains needs more than good planning, supply chain planning (SCP) makes up an essential component that aims to develop feasible plans considering requirements and constraints, thus, providing guidance to consequent operations and execution. The recent advancement of big data analytics (BDA) sheds light on promising opportunities in SCP to collect and process data at a higher speed (i.e. velocity), with higher granularity (i.e. volume and variety), and for more extended scopes(i.e. value and veracity). Yet, despite the emerging research interests, extant contributions are developed in evident silos that either focus on the development of BDA applications as decision-support instruments and models for specific SCP activities, or generally discuss the impact of BDA on organizational performances considering supply chain management as a broad discipline. This thesis presents a collection of three papers to bridge the siloed perspectives of BDA in SCP by establishing a comprehensive understanding of the two interrelated themes: *uncovering the technological potentiality* to address the fit between the technological specificity of BDA and SCP; and *conducting appropriate adoption management* to structurally embed and diffuse BDA application into the business processes of SCP.

Firstly, BDA is an aggregated term referring to the application of advanced analytics on big data to assist decision-making by extracting knowledge and insight and gleaning invaluable information, thus, it is constituted by heterogeneous big data sources, BDA models and techniques. The prominence of BDA applications need to be assessed at a more detailed level in the realm of SCP addressing the following research questions:

RQ1a: What are the prominent big data sources, BDA models and techniques for SCP processes and activities?

RQ1b: How does BDA technology align with the SCP process need?

RQ1c: How would BDA technology impact the future of SCP?

Secondly, as the impact of BDA application is dependent on the organizational intention of use, it is necessary to integrate the managerial consideration revealing the mechanism in the organizational BDA adoption decisions. Based on the literature on technological innovation adoption and the resource perspective, the thesis investigates:

RQ2a: What are the determining factors for BDA adoption decisions in organizations and supply chains?

RQ2b: How do the determining factors influence the organizational BDA adoption decision for SCP?

Lastly, the final piece of research extends beyond the adoption decision since the intention of use is only necessary but not sufficient for the organizational transition towards a BDA-embedded SCP. Grounded in the resource perspective and the resource orchestration theory, the thesis further provides answers in addressing the adoption process of BDA integration and incorporation via the following questions:

RQ3a: What resources and capabilities are required to facilitate BDA adoption for SCP?

RQ3b: How can resource management and orchestration facilitate BDA adoption for SCP via structuring, bundling, and leveraging?

To these aims, this thesis is developed in three consecutive stages with a mixed-method research design including a systematic literature review, a Delphi study, and multiple case studies.

The systematic literature review presents the results from an exhaustive survey to extant publication on the first and second research objectives, synthesizing the current development of BDA technology in SCP and the determinants for BDA adoption decisions. The result affirms the increasing trend of research interest in the field and the potential of unstructured big data and predictive analytics in SCP. The determinants for adoption are grouped into technological, organizational, and environmental dimensions with reference to the TOE framework. Some examples are *big data quality and BDA availability and stability* for the technological dimension; organizational *readiness, capability,* and *structure* for the organizational dimension; and *BDA adoption by competitors and regulatory environment* for the environmental dimensions. The study highlights three distinctive roles of BDA for SCP based on the characteristics of big data source (i.e., *what*), the objective of BDA use as the indented outcome (i.e., *why*), and changes to SCP due to the use of BDA (i.e., *how*). Consequently, the determinants for adoption decisions are dependent on the expected roles of BDA for SCP. The Delphi research triangulates the findings from literature with contributions from an expert panel on the first and second research objectives. It presents a more detailed assessment of the *fit* of specific BDA models and big data sources on individual SCP activities, as well as on the *significance* and *likelihood* of projections related to the expected impact of BDA on individual SCP activities. A k-mean cluster analysis identifies three groups of projections providing implications on the action priority for BDA adoption for SCP. Investigation of the BDA adoption process is developed with a focus on the resources and capabilities necessary for the transition, and the managerial actions in developing and orchestrating these resources. Analysis of the empirical data reveals hints on the need to synchronize individual, organizational and technological resources and capabilities, contributing to the identification of three stages in BDA adoption in organizations to support SCP. The *structuring* stage focuses on the development of a resource portfolio for BDA integration, leveraging on the existing organizational culture and individual business knowledge, with the acquirement of individual technological skillset and BDA development resources and capabilities marking the end of the process. The *bundling* stage concerns the BDA system development and the integration of business knowledge in the systems, joining the organizational resources and culture to the established technological competence. Lastly, the *leveraging* stage relies on the organizational culture and change management capability, to communicate the benefit of the BDA system and to standardize processes and governance mechanisms for the internalization and institutionalization of the new technology. As a whole, the thesis presents a pathway of BDA adoption for SCP, providing support to the evaluation of BDA applications, framing of BDA adoption decisions, and management of resources and capabilities for the BDA adoption process. Results from this study enrich the discussion on determinants for BDA adoption decision, indicating the necessity to consider the issue as context-, time- and scop-dependent. The effective adoption of BDA requires integration of business peculiarities and assures the alignment with the business strategy and need, while resource and capability internalization in the final stage of adoption is essential since BDA systems are in need of constant adaptation, updates, and maintenance. It should not be overlooked the human dimension in BDA adoption, which involves the change of roles of human planners and the behavioral aspects toward technology acceptance. This dissertation contributes to the existing discussion on BDA in OSCM literature, bridging the technological and managerial perspectives to establish a holistic view of BDA application and adoption. It conceptualizes the alignment between BDA technology and SCP process need, and enriches empirical evidence to research on supply chain technology adoption based on the resource orchestration theory. To practitioners, this thesis sheds light on how to translate the expected impact of BDA into actual momentum, integrating and accommodating BDA in daily processes to support SCP.

CREATING A SHARED VISION: HOW COGNITIVE DIVERSITY CAN SUPPORT SENSEMAKING IN THE FRONT END OF INNOVATION

Federico Paolo Zasa – Supervisor: Prof. Roberto Verganti – Co-Supervisor: Prof. Tommaso Buganza
Tutor: Prof. Claudio Dell'Era

Research Background

In a world full of uncertainty, firms innovate to create value for their users. Roberto Cooper, inventor of the renowned Stage-Gate model of Product Development, highlights that the recent pandemic has further enhanced the need for responsiveness which companies already experienced. Developing innovative products which are meaningful to users requires that these products are tailored to their changing needs. Thus, innovation means making sense of what is changing in the environment and developing a coherent vision. Previous literature has mostly addressed how a vision can be diffused in an organization once it has been defined. Lessis known about how a vision can be generated Innovative visions are created during the so-called front end of innovation: the first and fuzzy stages, where previous experiences, knowledge, and desires for the future are merged together. During the front-end of innovation, diversity in knowledge, experience and cognitive processing are desired. For this reason, different individuals work together in elaborating the shared vision. This dissertation addresses the vision creation process during the front-end of innovation, focusing on two variables: the cognitive diversity of individuals involved, and the social construction process leading to a shared vision.

Research Objectives

This thesis aims to provide clarity over the sensemaking process at the front-end, exploring how cognitive diverse individuals develop a shared vision. To achieve this objective, I address three different sub-objectives. First, I explore the discourse surrounding the cognitive processes taking place during the front-end of innovation. I perform a systematic literature review, which helps to develop a framework highlighting a cognitivist and constructivist perspective on sensemaking. Second, I explore how a shared vision is created and diffused inside an organization at three different levels – at the individual, team, and organizational level. The third sub-objective addresses the retroaction effect, which a vision, once constructed, may have on the individual visions of each person inside the organization.

Findings and contributions

The findings bring contributions from two perspectives, concerning the role of diversity and how a shared vision can be constructed. First, the literature review highlights an overlap among a current tension in sensemaking theory and cognition at the front-end of innovation. According to a cognitivist perspective of Sensemaking, diversity provides value because of complementarity. Diverse individuals process information differently; thus, a diverse team has a more comprehensive overview on a problem. According to a constructivist perspective of sensemaking, diverse teams are better in constructing a shared vision; they have different constructing behaviors, and their collaboration contributes to more innovative visions. Study II adds to this latter perspective, highlighting a difference in how individuals construct a vision. Innovators are individuals who adopt innovative work behaviors. Innovators develop visions which are central in their network, thus they synthesize visions from throughout their organization. Collaborators are individuals who wish to collaborate and exchange ideas. Collaborators develop visions which are central to a smaller set of similar visions, meaning they synthesize a particular set of visions which are already similar. Study III shows that the vision is important at the team level: observing a set of 10 design teams we find that they explicitly work on the vision in their development process. The vision becomes a boundary object which helps teams to work together. Study IV extends this finding to the organizational level. It is often difficult to keep large groups tied together and oriented to a common goal they feel ownership for. At the organizational level, a shared vision acts as a coupling mechanism inside the loosely coupled organizational system. Finally, when a shared vision exists, this influences individual thinking. Study V highlights that an organizational vision is not equally shared by everyone and that even over time not all employees tend to align with it. Overall, the findings from these studies allowed to develop a framework which shows how diverse individuals contribute to a shared vision. Individuals may develop their vision on their own, sourcing the ideas of their peers and their own experiences. On the other hand, the vision may come from a group, who has developed a vision together. These two visions may coincide or be different (Figure 1). This framework allows to summarize previous theories on diversity, shared vision development and sensemaking. Sensemaking starts with chaos, when no vision exists. Visionary individuals develop their vision alone, while a collaboratively developed vision leads to ownership. The intersection of these two axes highlights two further situations: Visionary alignment, where an individual has synthesized the collaborative vision; and visionary rebelliousness, where an individual consciously rejects the collaborative vision.

Contributions

This work contributes to theory in several ways. First, breaking the dichotomy among a cognitivist and constructivist approach to sensemaking. Second, highlighting that sensemaking occurs during visioning through the dynamics of participating and understanding. Third, showing that diversity may be leveraged for sensemaking through dynamics of alignment and collaboration. Last, stressing the value of individual sensemaking through rebelliousness or synthesis behaviors.
The dissertation has also some methodological contributions: Study II advances the idea of a cognitive network for vision analysis, while study II and IV discuss the value of analyzing the output of a construction process to assess alignment among individuals.
The work also contributes to managerial practice, exploring two different areas off sensemaking: I clarify sensemaking as cognition, highlighting that boundary objects and boundary bridging individuals can help to establish a shared way of thinking. Also, I contribute to the sensemaking as action, highlighting how concrete goals linked to the vision provide clear and meaningful indications for action.