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**Prof. Massimo G. Colombo**

## DOCTORAL PROGRAM IN MANAGEMENT, ECONOMICS AND INDUSTRIAL ENGINEERING

The Doctoral Program in Management, Economics and Industrial Engineering (DRIG) provides students with advanced education and the opportunity to do research activity in these scientific fields. The program allows students to build a solid methodological background, and it fosters the development of multi-disciplinary knowledge, an open minded approach to research activities, and the ability to address problems in an innovative way, while combining different perspectives and approaches.

The program is taught in English. It is composed of three different types of training activities.

### Main courses include:

- methodological courses relating to aspects relevant to research in management, economics and industrial engineering;
- thematic courses whose aim is to introduce students in state-of-the-art research in specific fields relating to the above mentioned disciplines: Business strategy, Organization & human resources, Finance, Economics and management of innovation, Industrial Organization, International economics, Regional and urban economics, Supply chain management, Operations, Facility management, Logistics and others.

### Elective courses and training in specific themes

These activities are customized according to the specific research interests of students. Their aim is to extend the scientific knowledge of students in specific topics and to introduce them to the international research community through the presentation of research work in international conferences.

### Thesis

This is the core of the program. Students are expected to develop state-of-the-art research competencies on an issue relevant to the scientific debate and to produce an original contribution that extends the available scientific knowledge on this issue.

The doctoral program covers three years. Students are required to spend at least one semester in a foreign research institution. The Department of Management, Economics and Industrial Engineering is qualified as hosting institution of the PRIME Network of Excellence established by the European Commission within the 6<sup>th</sup> Framework program. Hence students have access to the mobility support measures aimed at promoting international collaboration between the doctoral programs in the network. In addition, students are encouraged to attend doctoral schools and workshops organized by other institutions and to participate

in international scientific conferences. Presentation of an original research work in an international conference is mandatory for admission to the final exam.

In previous years, students have been hosted by well known foreign academic institutions such as CRIC-University of Manchester, SPRU-University of Sussex, University of Reading, University of Nottingham, London Business School, Trinity College Dublin, Université Henri Poincaré Nancy, IESE Barcelona, Chalmers University Göteborg, ETH Zurich, Harvard Business School, Columbia, MIT, UCLA and others.

The Faculty of DRIG includes, in addition to professors of the Department of Management, Economics and Industrial Engineering of Politecnico di Milano, several foreign professors: Adolfo Arata, Universidad Tecnica Federico Santa Maria, Valparaiso, Chile; Neil Gandall, Tel Aviv University, Israel; Benoit lung, Université Henri Poincaré, Nancy, France; Tom Svantesson, CEN, Sweden; Tereza Tykova, Zew, Germany; Mike Wright, University of Nottingham, UK; Frank Rothaermel, Georgia Institute of Technology, Atlanta; Bruno Cassiman, IESE Business School; Alan MacCormack, Harvard Business School; Dirk Czamitzky, University of Leuven; Erik Hultink, Delft University of Technology; Christopher Lettl, Aarhus School of Business; Joseph Sarkis, Clark University, MA, USA; Jaco Huisman, TU Delft.

The program has developed several research collaborations with private manufacturing and service firms, regulatory bodies, and other public research institutions: Value Partners, TXT e-solutions, D'Appolonia, Consorzio MIP, Fondazione Rosselli, Consorzio Politecnico Innovazione, IRER, Società Banknord GE.PA.FI. SIM, Siemens, Fondazione CEUR, Fondazione Politecnico, ANIMP-OICE-FONDAZIONE LUIGI DE JANUARIO, PIRELLI & C., EUROCONTROL, C.T.G. Italcementi Group.

Typical career opportunities opened up by the doctoral program include the following ones:

- researchers and lecturers in Italian and foreign universities;
- officials of research and training bodies operating as a link between universities and private sector companies;
- researchers in economics and management working in the research departments of private corporations, financial institutions and public bodies;
- consultants in leading management and strategy consulting companies;
- managers and entrepreneurs of innovative companies.

The research projects that are presented in the following section are typical examples of the research work carried out by DRIG students.

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# ESTABLISHING 3D-CE APPROACH IN PRODUCT DEVELOPMENT PRACTICES

Fabio Albizzati - Supervisor: Tommaso Rossi

## Research Context

In the current industrial competitive environment, integrating supply chain design and production process design with product design has become crucially important to improve supply chain capability and product development performance. Indeed, coordination of complex interdependencies among product, process and supply chain design decisions maximizes the operational and supply chain performance. Scholars recognize the three-dimensional concurrent engineering (3D-CE) as the approach enabling integration among product, process and supply chain design.

The 3D-CE approach extends the concept of the concurrent design of products and processes to the simultaneous and coordinated design of product, manufacturing processes, and supply chain allowing to create a product development environment in which constraints and requirements from different disciplines are considered as the design progresses. The core of the 3D-CE approach is integration. A stream of literature refers to integration as a composite process subsuming communication and collaboration processes. The communication process

consists in a set of coordinated activities adding structure to how departments interrelate. Whereas, the collaboration process consists in a set of unstructured and intangible activities enabling individuals and departments to work together, have mutual understanding and achieve collective goals.

A second stream of literature finds that organizations enable and facilitate integration and, in turn, communication and collaboration processes, selecting and implementing the most appropriate integration mechanisms in relation to the operating context.

Recently, in several industrial sectors, ranging from computer software development to automotive development, resources involved in product development projects are no longer centralized. Organizations migrate from centralized to global product development (GPD) practices. These emerging practices in product development exploit distributed and networked development processes in which development teams comprise individuals drawn from multiple countries and company functions. The transition to GPD practices requires organizations to enable and facilitate integration among individuals and functions

across time zones, languages, cultures and companies. Hence, as global team members are geographically distributed and separated by multiple time zones new ways to integrate processes must be incorporated in GPD practices.

Together with the migration from centralized to GPD practices in the industrial environment, the academic discussion focused its interest on what GPD is, why it should be done and how it should be deployed. Further, a stream of the academic debate discussed how integration mechanisms cope with problems arising from the global dispersion of product development resources focusing on mechanisms building trust, encouraging collective goals and promoting motivation among global team members. However, despite the academic interest on GPD practices, how to enable and facilitate integration among product design, production process design, and supply chain design in GPD practices and, in turn how to implement an effective 3D-CE approach, has not been clearly investigated.

## Research Objective and Process

The dissertation has the objective to investigate how organizations facilitate 3D-CE approach in product

development practices filling an empirical gap in the academic debate. Specifically the research objective is organized around a main question: how do high performing organizations facilitate 3D-CE in product development practices?

Although the research question might be termed as intermediate theory research, the gap in the academic literature regarding global product development practices places the present research in the theoretical continuum between the nascent theory research and the intermediate theory research. Hence, the research question is addressed adopting a case study methodology as it represents an appropriate fit among the research question, prior work, research design, and theoretical contribution. In detail, the research sample has been designed including few, focused, in-depth and best-in-class case studies. Data was collected through in-depth and semi-structured interviews on-site, recorded, and then transcribed in full-length to enhance data analysis effectiveness gaining from the information richness provided by an interview context. Empirical data were analysed both within-case and cross-case adopting a qualitative approach which consists of data reduction, data display and conclusions drawing and verification.

## Research Results

Case study results suggest that high performing companies, exploiting global product development practices in a context where the product architecture is modular and the product

development organization is global captive, facilitate 3D-CE (i) designing a modular product development process architecture, (ii) configuring an integration process consisting in communication, and (iii) implementing integration mechanisms comprising: standard specifications defining in advance design activities outputs; enterprise communication technologies formalizing product development process workflows and allowing specialists to access, distribute and store product data; and product champions promoting communication among specialists. On the contrary, high performing companies, exploiting local product development practices in a context where the product architecture is integral and the product development organization is local, facilitate 3D-CE (i) designing an integral product development process architecture, (ii) configuring an integration process consisting in collaboration, and (iii) implementing integration mechanisms comprising: co-location of specialists involved in the product development; face-to-face informal communication; and collaborative techniques. In conclusion research results suggest that distinct product development practices require a tailored 3D-CE approach consistently designed with the nature of the product development organization.

The findings provide contributions to both academics and practitioners. At the academic level, findings contribute to extend

literature on the global product development and the integration of product development and supply chain management addressing how high performing organizations facilitate 3D-CE according to distinct product development practices. Further, the research still contributes to theory as observations derived from the cases lead to formulate testable research propositions on how the elements facilitating and affecting 3D-CE are related to each other.

At the managerial level, findings contribute to design a two-steps process to establish an effective 3D-CE approach in product development practices, starting with defining the product development organization and followed by designing the 3D-CE approach. In detail, the first step - defining the product development organization - consists in defining the location of product, process, and supply chain specialists involved in the product development process. Whereas, the second step - designing the 3D-CE approach - consists in configuring processes and mechanisms facilitating 3D-CE consistently with the product development organization.

# STRATEGIC AND ORGANIZATIONAL RESPONSES TO RADICAL INNOVATION: THE CASE OF RENEWABLE ENERGY TECHNOLOGIES

Lorenzo Boscherini - Supervisor: Federico Frattini

## Rationale

European sustainability policies and liberalization processes created the conditions for stimulating the generation of electricity from renewables, opening the “doors” to the distributed generation paradigm. The emergence of renewable energies has a powerful effect on energy incumbents, which are entering a period of uncertainty. The use of the historical business models, based on the concept they provide a commodity, one-way flow of power from energy providers to final customers, is no longer sustainable. This phenomenon may be embodied within the well-known debate about the difficulties that incumbents experience to respond to radical innovation, which has been widely investigated in literature and is corroborated by many empirical evidences. Objectives and research strategy Understanding how energy incumbents respond to the emergence of renewables is the primary objective of this research. Literature analysis allows us to identify two main existing gaps: (i) a lack of a comprehensive understanding of the strategic and organizational approaches incumbents adopt in relation to radical innovations; (ii) a lack of a contingency view of the variables affecting incumbent's decisions in relation to radical innovation. The phenomenon-driven objective

and the state of extant theoretical knowledge on the topic, suggests that a theory-building research approach is needed for the purpose of this study. We used a preliminary theoretical framework to orient the empirical analysis by identifying the scope of the research and the main concepts and variables underlying our analysis. This led to the definition of three research questions: **RQ1:** What business models do energy incumbents adopt to respond to renewables? **RQ2:** How and why do contextual variables affect the choices of the business models undertaken by energy incumbents? **RQ3:** How does the choice of the business models affect economic performances of energy incumbents? Methodology and sample According to the theory-building approach and the complexity characterizing the energy generation industry, the use of rich qualitative data became of paramount importance. First, we studied both the energy generation and the renewable markets to select the European countries (Italy, Germany and UK) in which choosing energy incumbents; second, we identified the incumbent companies through direct interviews and panel studies. We built a sample of 11 energy incumbents, selected on the basis of a “polar types” sampling procedure (Eisenhardt

and Graebner, 2007). Data were gathered through 49 direct interviews with key informants through the use of multiple investigators (Eisenhardt, 1989).

## Findings

Multiple case studies answer to the RQs and led us to define three propositions which represents the emerging theory. The answer to RQ1 states that energy incumbents respond to renewables by adopting one of the following business models:

- the unconventional which entails: the unconventional operational approach; not integrated organizational structures; an integrated value chain approach; dedicated formal and informal coordination mechanisms, country structures;
- the hybrid which entails: the unconventional operational approach; integrated organizational structures; not integrated value chain; new operative roles; R&D open innovation and strategic collaborations with small firms;
- the conventional, which entails: the conventional operational approach; ambidextrous organizations; an integrated value chain approach; partnerships with EPC contractors and trading companies.

The answer to RQ2 states that the choice of the business model

is affected by the nature of the firm. In particular, large utilities tend to adopt the unconventional business model, municipals and private no listed companies tend to adopt the hybrid business model and industrial groups tend to adopt the conventional business model.

At the same time each business model adopts different strategic and organizational approaches according to the markets' and technologies' maturity and the level of support policies where incumbents operate. In particular, for the unconventional business model, entering, first, in low maturity and emerging markets leads large utilities to implement this business model by using the integrated value chain (IVC) approach, country subsidiaries and new functions while entering, first, in high and medium maturity markets leads large utilities to implement this business model by using the flexible integrated value chain (FIVC) approach and country business units. For what concerns the hybrid business model, entering in high maturity markets with high level of support policies leads municipals and private no listed companies to implement this business model by adopting the partial outsourcing value chain as owner (POVC Owner), the scouting manager roles and the collaborations with small firms while entering in medium maturity markets with medium support policies leads municipals to implement this business model by adopting the partial outsourcing value chain as General Contractor (POVC G.C.) and the R&D Open innovation approach. Finally, for what concerns the conventional business model, entering in mature technologies leads

industrial groups to implement this business model by adopting the hybrid or contextual ambidexterity and collaborations with EPC Contractors while entering in developing technologies leads industrial groups to implement this business model by adopting the structural ambidexterity and shared R&D departments.

The answer to RQ3 states that business models embraced strategic and organizational variables which explain, better than others, different economic performances according to contextual variables where they are applied. In particular: (i) in the unconventional business model: the IVC with country subsidiaries and informal coordination mechanisms in mature technologies and low maturity and emerging markets leads to higher economic performance than the FIVC with country business units and formal coordination mechanisms; (ii) in the hybrid business model: the POVC Owner with the mixed value proposition and collaborations with small companies in high mature markets and larger firms, leads to higher economic performance than the POVC G.C. with the R&D open innovation approach; (iii) in the conventional business model: the FIVC with the structural ambidexterity in mature and developing technologies, leads to higher performance than the FIVC with hybrid and contextual ambidexterity. Theoretical implications This work can benefit research in the innovation management field. Our study identifies the main strategic and organizational choices characterizing different business models, overcoming

the lack of a comprehensive vision on incumbents' response to radical innovation. This study goes down in the analysis, trying to identify the relationships which characterize different approaches and the effects in designing the entire business model. This brings to light also new organizational models (e.g., the hybrid ambidexterity) adopted by incumbents. In addition, this study contributes to analyze business models through a contingency view, highlighting that strategic and organizational choices can be explained in the light of the path dependency theory. Finally, this work gives a strong contribution to the energy management literature adopting a contingency approach which analyzes the impact of incumbents' strategic and organizational choices adopted in different contexts on economic performance.

## Managerial implications

It is necessary to remember that the output of this research project is an emerging theory about the energy incumbent's response to radical innovation that needs to be further tested and validated. The research provides several insights for energy incumbents' managers. The main contribution is given by the contingency approach analysis that allows managers to understand what are the strategic and organizational choices, within each business model, that lead to higher or lower performances if applied to different contexts. This is useful for incumbents that have already set their strategy, in taking decisions on organizational choices, and for incumbents that are approaching renewables and need to find the better option available for their company.

## SUSTAINABILITY OPERATIONS STRATEGIES: THE IMPACT OF HRM AND ORGANISATIONAL PRACTICES ON THE TRIPLE BOTTOM LINE

**Annachiara Longoni** - Supervisor: **Raffaella Cagliano**

The aim of this research is to understand how sustainability in terms of the triple bottom line can be developed in operations strategies via Human Resource Management (HRM) and organisational practices (e.g., teamwork, training, and employee involvement). Sustainability is increasingly an essential element of companies' strategies and core processes given the recognised need to ensure the future of humans and the earth for long-term success (Porter and Kramer, 2006; Accenture, 2010); however, the definition and implementation of operations strategies embracing the triple bottom line are still open issues. In fact, companies are facing three key problems. First, they find it difficult to define and implement the sustainability programs best suited to their organisation given the wide variety of technologies, certifications, managerial and control methods proposed by regulators, certification entities, consulting companies and the literature. Second, they are struggling to optimise trade-offs among sustainability dimensions because a program can enhance one dimension while reducing the others. Finally, they encounter difficulties in integrating sustainability operations strategies with the chosen operations management system, such as

lean manufacturing. Moreover, although the operations-management literature has focused mainly on technical aspects, HRM and organisational practices may also be relevant to enhancing programs effectiveness and directly impacting sustainability. To this end, the study has been divided into three phases: problem setting, problem solving and problem extension. The problem setting phase empirically tests whether HRM and organisational practices should be implemented to attain higher environmental and social performance and thus establishes whether these practices should be considered when developing sustainability in operations. Evidence is derived from data on 377 companies in the assembly industry that participated in the International Manufacturing Strategy Survey 2009. The results show that some HRM and organisational practices are related to sustainability. In particular, training exerts both a direct positive effect on environmental and social performance and a positive interaction between social programs and performance. Worker involvement and incentives have a direct positive impact on social performance. Teamwork is highlighted as a relevant practice in

implementing successful environmental programs. To interpret the significant and non-significant relationships suggested in problem setting phase and sustainability in a holistic fashion, the problem solving phase explores how HRM and organisational practices might be leveraged to define and implement sustainability operations strategies in terms of the triple bottom line to optimise trade-offs. Empirical results are provided via 11 explanatory case studies in the food industry. Organisational responsibility (top-management commitment, cross-functional teams and sustainability-related roles in operations) and worker commitment (training, worker involvement and bi-directional communications) have been identified to positively impact sustainability. Specifically, organisational responsibility and worker commitment define the set of environmental and social programs, composing sustainability strategies and optimising trade-offs; worker commitment is also crucial in implementation, enhancing the effectiveness of the programs, mitigating trade-offs due to implementation, and directly impacting sustainability. In problem setting and problem solving phases, only environmental and social programs have been

considered; programs directly related to the economic and operational aspects have been excluded. However, in problem extension, the inclusion of operations-related programs is considered. Specifically, lean manufacturing has been considered the most significant program given its recognised role in increasing operational and firm performance, as well as the current discussion in the operations management literature about its impacts on environmental and social performance. This phase of the research focuses on the role of organisational responsibility and worker commitment to sustainability in achieving integration between lean manufacturing and sustainability operations strategies. Evidence was gathered from 5 cross-industry case studies and 5 case studies in the food industry. The results show that HRM and organisational practices related to lean manufacturing facilitate organisational responsibility and worker commitment to sustainability. Moreover, organisational responsibility positively impacts the definition of lean bundles (Just-in-time, Total Quality Management and Total Preventive Maintenance) optimising trade-offs and a new set of integrated lean sustainability programs. These latter programs leverage both sustainability and operations principles to enhance overall sustainability. Additionally, worker commitment enhances implementation of the lean philosophy to positively impact the role of environmental programs in the mitigation of economic-environment trade-offs by continuous improvement.

Finally, worker commitment is crucial to implementing lean bundles for positive impacts on environmental and social performance. Thus, the research has theoretical and managerial implications. The role of HRM and organisational practices in sustainability development is empirically proven. Then, some guidance regarding configuration of HRM and organisational practices to enhance sustainability in terms of the triple bottom line in operations is provided. Specifically, organisational responsibility and worker commitment enable to manage the decision making process to define the set of sustainability programs. They provide the complex organisation needed to create a virtuous circle combining top-down and bottom-up approach to sustainability. In this way it is possible to optimise trade-offs thanks to proactive problem solving and an innovative approach to improve traditional, inefficient business processes and programs by means of sustainability development. Worker commitment is also crucial to effectively implement the set of sustainability programs facilitating and enhancing programs adoption and mitigating possible trade-offs emerging in the implementation phase. Finally, worker commitment, diffusing more sustainable behaviour also in day-to day activities, directly impacts on sustainability performance. Moreover, organisational responsibility and worker

commitment to sustainability allow to integrate the sustainability strategic orientation of the company and the lean philosophy so that lean bundles are designed and implemented including sustainability principles and sustainability programs are defined and implemented enhancing lean principles. This study has also several limitations and might require further research to overcome such limits and extend our knowledge. Considering the methodology, in the problem setting phase, the limitations concern mainly the measures of constructs. Instead, considering the problem solving and extension phases a broader sample would be needed in order to generalize and test results. In terms of content, no specific measure or analysis is performed to investigate organisational culture, individual and team behaviours that might be fundamental in sustainability achievement. But this is out of scope. Future research might look at these concepts adopting the right unit of analysis and methodology. On the other side interesting extension of the research might be the identification of the organisational model to achieve sustainability, optimising trade-offs at the supply chain level.

## THE ROLE AND DESIGN OF THE OUTBOUND SUPPLY CHAIN FOR THE INTERNATIONALIZATION OF FASHION COMPANIES IN EMERGING MARKETS

Antonella Moretto - Supervisor: Gianluca Spina

The focus of the analysis is specifically dedicated to the fashion industry: in this research a definition of fashion that includes under the same umbrella from the massmarket to the high luxury products as well as different product categories (i.e., clothes, accessories, bags, shoes, and underwear) is adopted.

The fashion industry has emerged as critical from a practitioner and researcher point of view, because of its complexity, dynamism and economic importance. Moreover, fashion industry has since long attracted the attention of researchers in the area of operations and Supply Chain Management (SCM). The analysis of the fashion industry underlines the existence of the important challenge of internationalization of fashion companies in emerging markets: by paying attention to internationalization, outbound supply chain (i.e., the set of companies and activities that distribute and deliver the products from the manufacturer to the final customer) has seen a growing utilization in order to create linkages with customers' needs. By analysing the literature about the internationalization of the fashion outbound supply chain, we identified some important gaps.

First of all, the literature about the internationalization in the outbound supply chain focuses on retail, with little attention devoted to the other elements of the outbound supply chain. Secondly, the literature is still poor about the implementation of e-Commerce for the fashion companies. Thirdly, the literature does not analyse the management of the outbound supply chain processes by considering an international and not a local perspective. Then, the literature about the involvement of supply chain in the PD process especially focuses on the inbound supply chain (i.e., the supplier network); without considering the outbound one and adopts a static and local perspective, without considering the influence of the internationalization. According to these considerations, the research aims at studying the configuration of the outbound supply chain in the context of internationalization of fashion companies. In this study configuration means the combination of structure of the outbound supply chain as well as management of the related processes. The identification of the configuration of the outbound supply chain will be investigated by analysing

which external contingent variables might influence it. We gained the overall objective by identifying the main structures of the outbound supply chain (by considering both the physical and the e-Commerce outbound supply chain), the main archetypes of outbound supply chain processes (i.e., demand management, order management, distribution management, inventory management, customer service), and the main archetypes of the integration between outbound supply chain and Product Development (PD) management. Each of this point was analysed with the purpose of linking them to the main features of foreign countries. In order to answer the research questions, a research framework was developed, consistently with two organizational theories, namely contingency theory and behavioural internationalization process models. In order to perform this analysis, we used a case-based methodology, composed of an exploratory and an explanatory phase, by involving leading Italian fashion companies and by studying their outbound supply chain in USA, Japan, Middle-East, Brazil, Russia, and China. The former is composed of 21 exploratory case studies and 53 brands investigated through secondary data thanks to an

archival data analysis; the aim of this phase was the tailoring of the detailed research framework and the identification of the structures of the outbound supply chain. The latter is composed of 10 in-depth case studies; the aims of this phase was the identification of the main archetypes of outbound supply chain processes and of the integration between outbound supply chain and PD; these results were finally used to identify the main configurations of the outbound supply chain in foreign countries.

Thanks to the cross-case analysis performed with the exploratory case studies, we were able to identify five main archetypes for the structure of the physical outbound supply chain, namely *full control*, *variegated retail*, *agent based*, *distributor based*, and *full crossbreeding*. Each of these archetypes was tailored according to the contingent variables: first of all, we were able to identify which country variables drive the adoption of each archetype of the structure of the outbound supply chain. Moreover, we tried to figure out whether firm variables might also influence the selection of a certain archetype: for each of them, the main company's features were identified. This result is consistent with previous literature because previous research suggests that different countries and firm characteristics could require the adoption of different configurations. Through the analysis of secondary data as well as exploratory case studies, we were able to identify also four main archetypes of the e-Commerce outbound supply chain, namely *direct on-line*,

*intermediated on-line*, *multi-brand on-line*, and *shopping club on-line*. We could also identify the main features of each archetype in terms of country and firm variables. Moreover, we were able to highlight a link between the structure of the physical outbound supply chain and the structure of the e-Commerce outbound supply chain. These results are innovative from a research point of view and consistent with previous literature in this stream. On the other hand, the cross-case analysis of explanatory case studies was used to identify the main archetypes for each of the outbound supply chain processes, i.e. demand management (*structured*, *unstructured*, *qualitative*, *outsourced*), order management (*high control*, *partial control*, *agile*, *proactive*), distribution management (*prioritized*, *reactive*, *low attention*), inventory management (*localized*, *centralized*), and customer service (*direct control*, *partial outsourcing*, *full outsourcing*). For each of them, the answers provided by the cases were used to understand whether the selection of the archetype depends on the structure of the outbound supply chain (e.g., demand management), the country-specific variables (e.g., order management) or both of them (e.g., distribution management and inventory management). Firm variables, such as company size, do not appear relevant in discriminating among the archetypes instead. Moreover, the cross-case analysis was used also to identify the main archetypes of PD

management (*glocal*, *hybrid*, and *stylist oriented*) as well the linkages among PD practices and country specific variables (firm variables and outbound supply chain structure do not appear relevant). Moreover, qualitative answers were also used to identify relationships among different processes, such as demand management and PD management, demand management and order management, etc. These relationships were used to identify four comprehensive configurations of the outbound supply chain; moreover, we identified common behaviours among different countries (i.e., Usa and China; Middle-East, Brazil, and Russia; Japan; Italy) and so for each of these four groups we were able to identify the main features in terms of country specific variables, structure of the outbound supply chain, archetypes of processes of the outbound supply chain, and archetypes of PD process with the related PD practices. The four configurations of the outbound supply chain are *formalized*, *delegation-based*, *squeezing*, and *double configuration*.

# THE ECOLOGY OF EUROPEAN VENTURE CAPITAL

Anita Quas - Supervisor: Fabio Bertoni

My thesis, structured as a collection of three papers, tackles different aspects of the ecology of European venture capital. Venture capital is considered by policy makers as a key ingredient to develop an economy based on knowledge and innovation (European Commission 2010, p. 23), because it is the most suitable financing mode for high tech entrepreneurial ventures. These firms are important drivers of the innovation and employment growth of the countries in which they operate (Audretsch & Thurik, 2001; Audretsch, 1995; Stam & Garnsey, 2008; Westhead & Cowling, 1995). Unfortunately, the information asymmetries and agency problems typical of these firms make them financially constrained and force them to abandon some of their profitable projects (Hall, 2002; Stiglitz & Weiss, 1981; Stiglitz, 1985) although these firms do prefer internal funds for financing these investments; (iii. Scrutinizing firms before providing capital (Chan, 1983) and monitoring them afterwards (Lerner 1995), venture capital investors alleviate information asymmetries and agency problems in the capital markets and relax portfolio firms' financial constraints. However, there is still a huge number of high-potential firms

that are financially constrained, especially in Europe (Rosa & Raade, 2006). European policy makers are trying to follow the USA example to develop an efficient European venture capital market. As a matter of fact, the governmental interventions in Europe are much more important than in the USA. However, despite the efforts of policy makers, European venture capital market is smaller than USA one (Kelly, 2011).

The venture capital markets are typically not homogeneous. Independent venture capital investors and venture capital affiliated to firms and to banks co-exist in the same ecosystem. Moreover, the government itself designed its own venture capital programs. Interestingly, European venture capital ecosystem is characterized by a wider heterogeneity of actors with respect to USA. In Europe, the importance of captive venture capital investors, i.e. non-independent investors, is much more important (Bottazzi, Da Rin, & Hellmann, 2004, 2008).

As the general introduction reported in **Chapter 1** explains, the aim of this thesis is to analyze some of the characteristics of European venture capital ecosystem. In particular, we aim at studying

the VC ecology, i.e. the roles of the different venture capital investor types in venture capital ecosystem, and the relationships between them. The research questions that this work aims at answering are **1) Does each venture capital investor type has its role in the European venture capital ecology?** and **2) How do different venture capital investor types play their roles in Europe?** The research is conducted on a sample of venture capital investments in European firms. This kind of study can shed new light on the criticalities of European venture capital market and provide recommendations on appropriate governmental interventions to address them.

**Chapter 2** investigates whether each venture capital investor type has its role in the European venture capital ecology, by *studying the investment patterns* of independent venture capital investors, corporate venture capital investors, bank-affiliated venture capital investors and governmental venture capital investors. I and my co-authors analyze the relative investment specializations of each investor type along several dimensions that characterize investments (e.g., syndication, duration and exit mode) and investee companies (e.g., industry

of operation, age, size, development stage, location and distance from investor's premises at the time of the investment). Our findings indicate that venture capital types in Europe differ markedly in their patterns of investment specialization, especially governmental venture capital on the one side and private venture capital on the other. We compare our findings with evidence from the USA and find some interesting differences, notably regarding independent and governmental venture capital investors. The second part of the thesis aims at studying *how* different venture capital investor types pursue their respective roles, and in particular *how they contribute to firm success*. Since the most sticking differences in the European investing patterns emerge between private venture capital and governmental venture capital, the third and fourth chapters of this thesis focus on each of these investor types.

In **Chapter 3**, I and my co-author study the most typical and traditional form of private venture capital: the independent venture capital. This investor type aims at realizing firm potential and have a capital gain from its investments. A strong contribution of independent venture capital investors to the success of their portfolio firms is the relaxation of financial constraints. In particular, we investigate how independent venture capital affects the sensitivity of young high-tech firms' employment policies to the availability of internal capital, by alleviating their financial constraints. We find

that the sign of the employment cash flow sensitivity (ECFS) depends on the ability of the firm to generate internal capital. Moreover, we observe that ECFS is stronger for smaller firms. Independent venture capital investors prove to be able to relax firm's ECFS only when firms produce positive cash flows. Independent venture capital investors also improve the ability of high tech entrepreneurial ventures to attract high-skilled labor, especially when ECFS is most pronounced. In **Chapter 4** we study how governmental venture capital pursues its role and contributes to firm success. Literature suggests that the direct impact of governmental venture capital on firms' performance is often poor. However, governmental venture capital can have an indirect impact on firms' performance and increase firms' probability of receiving other forms of financing. Governmental venture capital's role is therefore fostering private venture capital investments in the most risky segments of the industry. In particular, we evaluate governmental venture capital effectiveness in certifying high tech entrepreneurial ventures to private venture capital investors, which encompass independent, corporate and bank-affiliated venture capital investors. Using a sample of governmental venture capital-backed high-tech entrepreneurial ventures and a matched sample of non governmental venture capital-backed firms, we estimate the probability of receiving a first round of private venture capital. Furthermore, we evaluate whether private venture capital

investments originated by governmental venture capital certification are at least as successful as other private venture capital investments, by estimating firms' probability of receiving a second round of private venture capital and of achieving a successful exit (IPO or M&A). Results show that firms certified by of governmental venture capital are more likely to receive a first round of private venture capital than the matched sample. Moreover, after the first round of private venture capital, firms invested by governmental venture capital are more likely to receive a second round of private venture capital financing and to achieve a successful exit than other private venture capital -backed firms. These results support the view that governmental venture capital positively influences the development of the private venture capital market in Europe, by increasing the number of successful private venture capital investments in high-tech entrepreneurial ventures. In **Chapter 5** I summarize the results of the thesis and the implications of my work, presenting also some directions for future research. Lastly, in **Appendix A**, I describe more in details the database used in this thesis, the VICO database.

# DIFFUSION OF INTEGRATED CARE PATHWAY INITIATIVES IN HOSPITALS

## The Leverage of 'Institutional Work' on Multidisciplinary Team Innovation

Giovanni Redaelli - Supervisor: Emanuele Lettieri

Hospitals are emphasizing the introduction of Integrated Care Pathways (ICPs) to institutionalize a multidisciplinary approach to care. Key processes, such as stroke management, are in fact fragmented in multiple activities in different units or departments which often do not fully coordinate with each other. Such lack has well-reported drawbacks, such as heterogeneous patient outcomes, inefficient use of resources and preventable risks against patient safety. Despite the interest toward ICPs, hospital managers are still struggling to obtain a large diffusion of ICPs initiatives across units and departments. The consolidated (and evidence-based) notion that ICPs are highly cost-effective innovations, in fact, clashes with the evidence that only a marginal number of teams has engaged in their production. In particular, only few professionals collaborate in teams to innovate the process of care. Building on this premise, the present PhD dissertation seeks to understand the mechanisms and conditions that explain the diffused engagement of teams in the production of ICPs in a hospital. The dissertation is organized in two stages. First, it seeks to explain the *emergence* of an innovative team in

a professional context. Both research and practical evidence, in fact, indicate that professionals (such as head physicians) prefer to (1) remain encapsulated in their unit to preserve their autonomy and (2) preserve their practice rather than innovate it. The initiation of an ICP intervention thus represents an occasion to explain how and why head physicians renounce to their autonomy and join a team that has primarily an innovation purpose. Second, the dissertation seeks to explain why and how the emergence of innovative teams becomes a diffused practice in a hospital. In so doing, the present research allows identifying the possible interventions that might be introduced to achieve the expected result of diffusing multidisciplinary innovations in a professional context.

**Methodology** – The nature of the research questions and the theoretical gaps in current literature required a theory building approach for both the emergence of team innovation and the diffusion of a new practice (i.e. ICP interventions) in professional contexts. A grounded theory approach is, in this regard, implemented through two multiple case studies. In particular, for research question

# 1 (what are the conditions that explain the initiation of an ICP intervention in hospitals?), 15 teams were selected – with the purpose of comparing cases of ICP initiation following (1) an external request from Regions; (2) a bottom-up dynamics; (3) a top-down request from the management. 25 informants (for a total of 280 pages of transcript) were involved to understand the conditions and inputs that allowed ICP initiation. For research question # 2 (what are the conditions that explain the diffusion of ICP initiative in a hospital?)- instead, 16 hospitals were selected – with the purpose of comparing cases of successful diffusion of ICP initiatives, cases of “pockets of best practices” and cases of no diffusion. 54 informants (which include 15 of the previous informants; for a total of 701 pages of transcript) were involved to understand the conditions and inputs that supported the diffusion of ICP initiatives. In both scenarios, line-by-line analysis of transcripts and Pratt et al.'s (2006) approach to data coding supported the identification of theoretical categories from the empirical data. Within-case and cross-case analysis supported the definition two theoretical models. The transferability of both models was addressed with 9 interviews with key

informants in UK hospitals (for a total of 97 pages of transcript).

**Findings** – With regard to the emergence of team innovation in professional context, the cases support a relatively parsimonious model. ICP interventions were initiated, in fact, when team reflexivity and participative safety were present at team level and motivation, opportunity and ability toward ICPs at the individual level.

These conditions were sometimes present by default, but often had to be triggered by specific interventions from management. A privileged strategy of intervention involved middle managers' active support of teamwork. Such “co-production strategy” was able to introduce and speed up ICP initiatives, but also triggered mechanisms of “crowding out”. The diffusion of ICP initiatives occurred instead in those hospitals that have enacted an interplay between practice work and boundary work, i.e. two forms of institutional work that were meant to establish new forms of structural, cultural and cognitive arrangement between professionals. Practice work and boundary work were conducive of ICPs as they overcame the resistance (or inattention) that professionals had toward process-thinking and open boundaries. Notably, hospitals' involvement in just one form of institutional work (either practice work or boundary work) resulted in the emergence of “pockets of best practices”, i.e. sporadic but high-quality ICPs.

**Implications** – This research expands our knowledge on the diffusion of multidisciplinary

practices in professionalized contexts. The role played by practice work and boundary work reveals the centrality of the institutional perspective to explain the diffusion of change among professionals. In this regard, professionals' (and teams') agency was primarily moved by the structural, cognitive and cultural arrangements in which they were embedded. Professionals and teams adhered to these institutional pillars in order to gain legitimacy and comply with a generalized behaviour. The research also indicates how the active enablers of institutional change were primarily “embedded agents”, i.e. top and middle managers who used their “embeddedness” to exert an influence on professionals' agency. Their social position conditioned the nature of the interventions deployed. Managers, in fact, were careful to avoid any situation of “institutional conflict” in support the process of institutional change. Past research has typically downsized the role of managers in professional contexts, suggesting that they can be only “diplomats” – being constrained by their information asymmetry toward professionals. Our results indicate an almost opposite notion, i.e. managers used their social position to connect dispersed professionals and drive the diffusion of ICP initiatives.

Middle managers have in particular emerged as the key enablers of institutional change. The research points out the forms of institutional work and co-production which they endorsed to drive the change.

The findings concur to shed a new light on the centrality of middle managers in the process of institutional change. They move beyond the simple “translation” of top managers' strategy and introduced autonomous and comprehensive sets of interventions to alter the boundaries and practices within the hospital.

Overall, the research provides a few insights for top and middle managers willing to push the diffusion of ICP initiatives in their hospital. The dissertation includes a set of “successful” interventions that managers introduced for such purpose. Against a traditional backdrop of change management initiatives –create urgency, address teams' needs etc. – the findings suggests an alternative approach, i.e. invest on a modification of the institutional pillars in which professionals are embedded. Interventions like the redefinition of facilities to support boundary spanning, the qualification of Quality Units, the definition of a clear set of methodologies, language and concepts, etc. can meet this purpose. The co-production strategy had a valuable contribution to the diffusion of ICP initiatives only when it created the conditions for teams' autonomous work. When this strategy substituted professionals' teamwork, a disincentive, crowding-out, mechanism was observed.

## EFFICIENCY IN THE ITALIAN EDUCATIONAL SYSTEM: WHICH ROLE FOR ACCOUNTABILITY, AUTONOMY AND CHOICE?

Piergiacomo Sibiano - Supervisor: Giuseppe Catalano

**ACCOUNTABILITY, autonomy and choice are the watchwords of contemporary education reformers around the globe** (Woessmann *et al.*, 2009 – p. xi). Years of debate about the issue of quality of education and its determinants have led to reforms that contain these ingredients. Although the aim – improving the educational level and doing it for all – was clear since the beginning, the path to follow is not straightforward. The huge debate about how to effectively and efficiently produce education led to the so-called **market-oriented** reforms (Chubb and Moe, 1990; Bartlett and Le Grand, 1993; Le Grand, 2003). This new institutional setting decisively contributed to reverse the two cardinal doctrines of public administrations: “shifting the emphasis from **process** accountability towards a greater element of accountability in terms of **results**” (Hood, 1995 – p. 94). A new stream of literature conceptualised this reform process in a framework called **quasi-markets**, whose the most representative work is by Bartlett and Le Grand (1993). This theory merged choice, competition and autonomy in a unique theoretical framework for the public sector. **Markets** means that competitive independent providers replace the monopolistic state ones; **quasi** because organisations are not necessarily out to maximise their profits, and purchasing power is expressed in voucher rather than

money (Bartlett and Le Grand, 1993). In other words, schools (whether public or private) are autonomous, and they compete for students, which “bring” money (throughout the voucher mechanism).

**Have the promises of market-oriented reforms been broken?** According to the empirical literature relying on data coming from standardized tests, students in school systems with greater accountability, autonomy and choice perform substantially better. However, several countries do not seem to will a change towards these reforms. The main reasons can be two: on the one hand any study, especially in the economics of education field, has some caveats, so they can be disputed. On the other hand, it is the policy-maker who has to decide to implement a certain policy or not, according to their values. This is the case of Italy: a typical example where students’ achievements are poor and accountability, autonomy and choice are present but mitigated. Moreover, Italy is one of the countries that showed a decreasing performance in the last ten years and even under the OECD average (OECD PISA, 2009).

This thesis aims at investigating the determinants of the (in) efficiency of the Italian educational system. Further, a focus on the presence of the private sector and its outcomes

compared to the public one has been conducted. Finally, through a qualitative inquiry, information about the actual school autonomy and accountability in Italy shall be given.

**“Italy shows marked geographical variation in educational achievement:** a key question is whether this is related to exogenous factor or to the characteristics of the education system” (Boarini, 2009 – p. 51). This is the first issue addressed in the first chapter of this thesis: the efficiency of Italian educational system and its determinants. We analysed the system efficiency at two levels: regions and schools.

To estimate efficiency scores, a non-parametric technique called DEA (Data Envelopment Analysis) is used. The units of analysis are the 18 Italian Regions, and the focus is on the lower-secondary education. The teacher:students ratio and the PISA 2009 scores were chosen, respectively, as the input and the output. Then, a second-stage Tobit regression was used to detect the factors affecting efficiency. The results corroborate the difference between North and South of Italy. What (should) alert the policy-maker is that the Regional socio-economic context appears as the key determinant of efficiency, rather than the school system. Secondly, the school level has been considered. In this case only a Region has been

chosen: Lombardy. The aim of this analysis is twofold: (i) first, “baseline” efficiency scores are derived and related to a wider set of characteristics that can affect the performance of schools; (ii) second, a procedure is proposed to derive “adjusted” efficiency measures to assess the managerial efficiency of the schools. The quantitative approach is based again on two-stage DEA. In a first step, inputs are resources used by schools, while outputs are average scores obtained in a national standardised test. In the second stage, efficiency scores are regressed against a set of external variables (e.g. percentage of disabled and immigrant students, school size, rural/urban area, etc.). The residuals and predicted values of the second stage regression are then used to “adjust” initial efficiency scores for taking “environment harshness” into account, and derive information about “managerial” efficiency. The results show that managerial efficiency is, on average, negatively related to baseline efficiency; that is, there is – again – a major role of external variables in affecting efficiency scores.

**The debate about the comparison of public and private schools performance is of particular relevance in Italy** – which is the issue discussed in the second chapter –, both from an academic and institutional perspective. With reference to the former, the empirical evidence from international datasets (especially OECD-PISA) and previous literature seems to suggest that public schools outperform private ones. For the first time, a new dataset to analyse the relative performances of public and private schools in Italy has been used. Data come

from the National Institute of the School System Evaluation (*Istituto nazionale per la valutazione del sistema educativo di istruzione e di formazione* – hereafter, INVALSI). As for measuring the effect of attending a private school, we compared different techniques: IV regression and Propensity Score Matching. Both techniques allow us to overcome selection bias and endogeneity problems. The main results, based on the preferred IV approach, are that private schooling attendance has a positive effect on Math scores for (relatively) richer students and those enrolled at school in a non-urban area, when considering grade 6 (also grade 5 is included in the analysis); instead, it exerts a negative effects on Math scores for students attending primary schools, especially for immigrant students, but a positive effect on Reading scores for disadvantaged students (those who are “relatively” poorer). These findings shed more light on the heterogeneity of the so called “private school effect”, that is they claim for a more cautious interpretation of the role of private schools in the Italian context.

**School autonomy is the last dimension analysed.** The aim of this analysis is to show that, despite of weak formal autonomy, school principal’s perception and willingness can determine different degrees of school’s autonomy and proactivity even in very centralised systems (like the Italian educational system). The Italian setting is interesting because of its particular institutional characteristics: that is an “incomplete” school autonomy. The methodology employed is a qualitative survey. Thirty-five Italian principals have filled in a

non-standardised questionnaire. It has been constructed according to a theoretical framework, which embodies three critical dimensions emerging from the literature. The first group of questions were related to the governing body, the second to the school climate (intended as the relationship between principal and teachers) and the last group to accountability issues (i.e. evaluation policies and relationships with stakeholders and competition). Three archetypes have been found:

- **Entrepreneurial** - the strategies to be followed and the tools to be used are defined well beyond what the law strictly prescribes. This character has a strong vision that allows creating and introducing new practices;
- **Chaotic** – many actors (principals, parents, teachers) argue their opinion but, at the end, there is not a shared decision at school level. Someone just gives it up;
- **Bureaucratic** – this character only observes the law. It does not feel to have to do anything without or beyond the law prescriptions.

**Conclusively**, the analysis showed a system – the Italian one – profoundly affected by the context. Thus, the contribution of this thesis consists in arguing that diversification process is not avoidable even in centralised systems. A set of indicators, which take into account all the diversity (such as in the analysis of adjusted efficiency), should be used in order to define school funding criteria and incentives/disincentives of the system. Finally and more importantly, what is a priority is to intervene on actors’ motivation.

# INTERNATIONAL KNOWLEDGE SPILLOVERS AND CLIMATE-FRIENDLY TECHNOLOGIES

Yan Wang - Supervisor: Paola Garrone

The thesis empirically analyzes the role of international knowledge spillovers in climate-friendly technological change. The final goal is to add empirical evidence to the debate on policies and strategies that support the mitigation of climate change. The development and diffusion of new climate-friendly technologies are necessary to reduce carbon emissions without hindering economic growth (IPCC, 2011; Popp, 2011). The three papers that are included in the dissertation aim at improving our understanding of a crucial element of climate-friendly technological change, i.e. whether and how it arises from innovative activities of other countries. To this aim, the thesis focuses on carbon emissions from energy uses, and considers two groups of new energy-related technologies, i.e. renewable energy (RE) and energy-efficient (EE) technologies. Research questions and motivations of individual papers are illustrated in the following sections, but the main arguments that led me to identify the objectives and structure of dissertation are worth being discussed here.

a. Carbon emissions cannot be curbed if RE and EE shares do not increase significantly. The *diffusion* of RE and EE technologies is necessary to reduce, respectively, carbon intensity (CI, carbon emissions carbon per unit of total primary energy supply), and energy intensity (EI, total primary energy supply per unit of GDP).

CI and EI are the two precursors of carbon emissions, given the country GDP. A relevant part of the thesis will thus be devoted to the diffusion of RE and EE technologies.

b. Nevertheless, I am aware that still today *R&D activities* are crucial for the challenge of climate change mitigation. More particularly, R&D activities on RE sources and technologies will continue playing a role in the next years for the following reasons (IPCC, 2011): today most RE sources can provide competitive energy services only in certain favorable locations; some RE technologies have to be modified in order to be integrated successfully in the energy system; finally a few RE technologies are still in the nascent phase. In addition, countries that are followers in the domain of climate-friendly technologies should engage in domestic R&D for absorptive and adaptive purposes (Lanjouw and Mody, 1996; Popp, 2006; Bosetti et al., 2008). As a result, I will also analyze RE development.

c. *Developing countries* are called to play an increasingly relevant role in climate-friendly technological change. While only few developing economies are well positioned in the ranking of climate-friendly innovators (Dechezleprêtre et al., 2011), the diffusion of new climate-friendly technologies over less advanced countries is a priority. Developing countries

are already responsible for more than 50% of world carbon emissions and are expected to account for two-thirds of global carbon increase over the next 30 years (IEA, 2011a, b; U.S Energy Information Administration, 2011). The diffusion process will be studied in both developed and developing countries.

d. International technology transfers dominate the sector of climate-friendly technologies, because innovation is concentrated in a few countries, and new high-quality mitigation technologies are developed by a small number of advanced economies (Dechezleprêtre et al., 2011). At the same time, follower countries cannot limit themselves to importing new technologies, they should also engage in domestic R&D activities (see (b)). In order to overcome market, cost and infrastructure barriers to deployment, countries should also engage in the accumulation of operating and installation experience (learning-by-doing: Sagar and van der Zwaan, 2006; Clarke, 2008), an activity which is highly visible and whose benefits can spill over (Nemet, 2012). It thus seems plausible that technological change in RE and EE sectors is accompanied by an intense cross-country transfer of knowledge from R&D and learning. The most tacit elements of technological knowledge can hardly be acquired via market transactions (e.g. technology licensing). They

are more likely to be transmitted via *international knowledge spillovers* (IKS; Keller, 2004). Clarke et al. (2008) define IKS as technological change that arises from innovation activities of other countries, as distinct from domestic R&D, domestic learning-by-doing, domestic intra- and inter-industry spillovers. I thus concluded that IKS from both R&D and learning are a key input to climate-friendly technological change.

Based on these considerations, I targeted my efforts to studying IKS. Depending on the empirical setting I assumed IKS to be embodied in imported products or disembodied, and to arise from R&D or experience. At the same time, it appeared that the role of developing countries should not be overlooked, particularly with respect to the diffusion of new EE technologies, while developed countries can offer a more appropriate empirical test-bed for the development and diffusion of RE technologies, also because they are designing and enforcing appropriate policies to this purpose. Finally, the “disembodied” exchange of information is assumed to be particularly intense between more advanced economies, due to geographical and institutional proximity, i.e. knowledge externalities can occur through the Web, publications, patents, conferences, mobility of employees, students and scientists, and so on. Imports of capital goods are instead deemed the primary channel of technology transfer from developed countries to developing countries, because the latter have weaker and less frequent contacts with technological leaders. In sum two broad issues are empirically addressed in this thesis: the extent to which international knowledge spillovers determine the development and diffusion of new climate-

energy technologies; factors that enable technological knowledge to spill over internationally in these sectors (e.g. geographic proximity, established cross-country connections, or imports of intermediary products). Specifically, the first paper focuses on international knowledge spillovers, and tests two hypotheses: they are a significant input to the production of renewable energy innovations; they need connections between countries to arise. Relying on a knowledge production function, we model the innovation activities of 18 OECD countries throughout the 1990-2006 period. Our findings indicate that, after controlling for climate-energy policies, international knowledge spillovers contribute significantly to renewable energy innovations, and their effect is comparable in magnitude to effects of domestic R&D and human capital. Additionally, the stronger the linkages between countries, the more likely spillovers are of occurring.

In the second paper, we examine the effect of technology transfer from 24 developed countries on energy intensity of GDP, carbon intensity of energy use and labour productivity of 56 developing countries empirically. We model specific spillovers embodied in trade of capital goods (machinery and equipment) and find that the technological spillovers will lead to higher carbon emissions than if no spillovers occurred. Specifically, technological spillovers can significantly improve energy efficiency of the destination countries, which is expected to lead to lower carbon emissions due to the energy saving bias of technology spillovers. Technological spillovers have positive effect on the GDP per labour. Such an increase in labour productivity is supposed to result in greater carbon emissions due to output expanding effect of

spillovers. Regarding the effect of spillovers on carbon intensity of energy use, industrialization stages play a role. On the sample mean, the effect of trade mediated spillover is found to increase carbon intensity of energy use rather than lowering it. By contrast, inward FDI appears to be a potential channel in lowering carbon intensity of energy use. In sum, the emission-increasing influences of trade mediated spillovers due to higher labour productivity significantly outweigh the emission-reducing influences of technology transfer due to higher energy efficiency. The third paper focuses on the relationship between international knowledge spillovers and the diffusion of renewable energy technologies. I model the investment activities of 18 OECD countries in wind and solar PV technologies throughout the 1990-2006 period. In addition to spillovers from R&D, I consider international spillovers from experience, i.e. international learning spillovers. The impact of domestic learning effects is also explored. I focus on the experience that is accumulated in the installation and operation of renewable energy technologies for electricity production. Three hypotheses are tested: renewable energy investments are supported by international knowledge spillovers from R&D; they are supported by domestic learning effects; they are supported by international learning spillovers. Our findings indicate that while IKS arising from R&D knowledge stocks are not effective in inducing wind investment, they have positive and significant effects on the increase of PV capacity. Domestic learning effects are shown to foster the diffusion of wind and PV technologies, while international learning spillovers does not play a role.