Innovation Systems for Sustainability
An empirical analysis of the role of domestic and Swedish MNCs in Brazil's innovation system

Rita Santos Senise
To Cleto and Maria (s)
whom have inspired my life
Acronyms and Abbreviations

ABDI: Brazilian Agency for Industrial Development
ANPEI: National Association for Research, Development and Engineering of Innovative Enterprises
BNDES: National Bank for Economic and Social Development
BRIC: Brazil, Russia, India, and China
CAPES: Coordination for the Improvement of Higher Education Personnel
CNDI: National Council of Industrial Development
CNPq: National Council for Scientific and Technological Development
CO2: carbon dioxide
DfE: Design-for-Environment
FDI: foreign direct investment
FINEP: Brazilian Innovation Agency
FNDCT: National Fund for Scientific and Technological Development
GDP: gross domestic product
GERD: gross domestic expenditure on R&D
GSM: global system for mobile communications
IBGE: Brazilian Institute of Geography and Statistics
ICTs: information and communications technologies
IMF: International Monetary Fund
IPI: tax exemptions on industrialized products
IR: income tax reduction
IS: innovation system
IT: information technology
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<th>Acronym</th>
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<tr>
<td>KTH</td>
<td>Royal Institute of Technology</td>
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<td>MCI</td>
<td>Brazilian Ministry of Science and Technology</td>
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<td>MDG(s)</td>
<td>millennium development goal(s)</td>
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<td>MNC(s)</td>
<td>multinational corporation(s)</td>
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<td>NIS</td>
<td>national innovation system</td>
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<td>NIC(s)</td>
<td>newly industrialized countrie(s)</td>
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<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
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<td>PDTI</td>
<td>Program for the Development of Industrial Technology</td>
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<td>PITCE</td>
<td>Industrial, Technological and Foreign Trade Policy of Brazil</td>
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<td>PINTEC</td>
<td>Industrial Survey on Technological Innovation</td>
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<td>R&amp;D</td>
<td>research and development</td>
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<td>SECTES</td>
<td>Secretariat of Science and Technology of the Minas Gerais State</td>
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<td>S&amp;T</td>
<td>science and technology</td>
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<td>STI</td>
<td>science, technology and innovation</td>
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<td>SDGs</td>
<td>sustainable development goals</td>
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<td>UNCTAD</td>
<td>United Nations Conference on Trade and Development</td>
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<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
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"Our lessons come from the journey, not the destination" said Don Williams, Jr., American novelist and poet. Transitions to a sustainable future are like journeys of learning. They intersect and connect through the knowledge and skills gained, by modifying tendencies, and building the socio-economic and environmental systems of tomorrow. A sustainable future is a yet unclear destination, and the roads leading there seem highly uncertain. The only way forward is through the potential opportunities presenting themselves; by evaluating whether those openings bring us closer to, or take us further away from, that which is desired. It makes sense that the concept of the "journey" is so central to sustainability, a field within which we are all moving to examine trends, likely scenarios and future developments. In this voyage we have met challenges, persistent changes, and unexpected issues.

Reflecting on how this thesis work would unfold, I promised myself that I would observe Brazil and Sweden from different perspectives, taking into account fundamental cross-cultural interactions. After working towards this goal for some years, I can now say that we are at present embarking on new pathways leading to the future: we are already, in fact, changing the present. Understanding how Brazil and Sweden are effectuating such change is much more fascinating than one might think.

I feel that this thesis work represents a contribution to the longer journey towards sustainability, undertaken with the involvement of different actors from both countries. This research considers all actors involved in that journey – Brazilian and Swedish government agencies, academia, researchers, companies – and demonstrates how they mutually support one another, and how they are taking into account the future events of technological, environmental, economic, and value-oriented change. In particular, the present work is interested in how national and foreign companies and organizations contribute to innovation in Brazil. In this task, it pays special attention to Swedish companies, which are global forerunners in the promotion of innovation strategy. Interestingly, this work also coincides with a period that highlights Brazil’s potential in the field of innovation. From a strategic innovation perspective, science and research has not received adequate attention from the country’s policy makers, and for decades the country has missed out on this development.
Despite this, Brazilian science has interesting historical roots in the 1950s with the creation of the National Research Council (CNPq), the contribution of which has culminated in the undeniable efforts of the current Brazilian government in emphasizing science system, in order to meet the social challenges and advance the country’s development.

I have also had the pleasure to be hosted by Sweden, and to develop this work together with the Royal Institute of Technology (KTH). Sweden, a fascinating country, characterized by remarkable scenery, nature, and culture, with an outstanding performance in the field of science and technology development provided me with a very stimulating and inspiring environment. KTH – an exciting scientific "niche" – was undoubtedly the most suitable place for development of my interdisciplinary research. Besides finding great colleagues at KTH, I also found an appropriate place where my ideas increasingly matured and were scaled up with respect to natural resources, innovation systems in transitions, and innovation systems for sustainability. The five papers included in this work represent not only an attempt to tackle various research issues. They are also a result of the Brazil-Sweden knowledge network, emerging from a context of interactions between disciplines, dynamic researcher cooperation and discussion. It was in such a context that the ideas behind the papers were established, the writing undertaken, and perhaps even more importantly, the research methodology established.

In 1941, Stefan Zweig, an Austrian playwright and writer, published the book "Brazil: Land of the Future". The country has taken many decades to make it to that point. For many reasons, the promise of Zweig’s text has been refuted, since such a future has been postponed in face of the well-known challenges of tackling the technological and social deficiencies that have hobbled the country’s development. Finally, it seems that for contemporary Brazil, "tomorrow is now": it is time for the country to get going, to take off, and to confirm Zweig’s reflections. Although this work focuses on the Brazilian experience, its inspiration – as suggested in the beginning of this preface – lies in the future, in what we expect, in what we will do, and in what we have contributed to the long journey ahead of us, towards sustainability.
Acknowledgments

First and foremost, I want to thank two people in particular: Professor Folke Snickars (Royal Institute of Technology, KTH) and Professor Walter Leal (Hamburg University of Applied Sciences).

I have had the privilege to have Professor emeritus Folke Snickars as my supervisor, mentor, and friend, and he truly made a difference in this work. Professor Snickars’ expertise and dedication, allied with his appreciation of science, and his sensibility proved a stunning and talented combination with respect to the "guidance" of my doctoral experience. It was under his tutelage that I developed a focus and became a researcher. It was though his persistence, understanding, and kindness that I completed this work. As I look back on all that has happened – so many meetings, reflections on the "ins and outs" of empirical research, and finally the work towards the conclusion – I doubt that I will ever be able to convey my appreciation fully. Whatever the future holds, I thank you, Folke.

I also have had the pleasure of having my dear and illustrious counterpart, Professor Walter Leal, as my co-supervisor, and without his motivation and encouragement I would not have considered a doctoral career. Professor Leal’s vast knowledge skill in many areas, and vision, as well the assistance he provided me in writing reports and at all levels of the research project, added considerably to my doctoral experience. He gave me the inspiration to develop my research topic at a unique moment in time when the innovation field in Brazil was largely uncharted. I have greatly appreciated our co-production over the past years; many of the ideas in this thesis stem from our inspirational collaboration. Walter, I can never be thankful enough for this opportunity and all the valuable lessons you taught me.

A very special thanks also goes to Professor Hans Westlund (Deputy Head at the Department of Infrastructure and Planning, KTH), for taking time out from his busy schedule to serve as my external reader. I benefited greatly from his excellent comments and critique during the writing, which expanded the scope of this work. I have also appreciated the valuable input from Professor Marcus Asplund (Department of Industrial Economics and Management, KTH), who gave comments that went along way in to improving the quality of the work.
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I recognize that this research would not have been possible without the financial assistance of the Brazilian Agency for Higher Education (CAPES); the Scientific Agency of the Minas Gerais State (FAPEMIG), Brazil, and the Swedish Agency for Innovation Systems (VINNOVA). I also express my thanks to agencies of financial assistance for the international communication of my doctoral research: Knut and Alice Wallenberg’s Stiftelse; and Ångpanneföreningens Forskningsstiftelse.

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Stockholm, January 2013

Rita Santos Senise
Abstract

The intellectual roots of the innovation system (IS) approach lie in attempts to understand the complexities of interactive relations in the innovation process. This thesis departs from the systemic view that ISs rest on a co-evolutionary process, in which on the one hand technical and economic spheres interact with policies and institutions, and, on the other, those spheres affect the natural environment. There is also evidence that ISs have access to the state-of-the-art flows of knowledge, which is perceived positively in terms of international or trans-border scientific and technological cooperation.

Comprised of a covering essay and a set of publications, this thesis is structured as a combination of five papers containing findings of the research carried out. The qualitative research design analyzes sustainability as a desirable theoretical construct towards which the development of ISs should be oriented. As such, special attention was given to both the theoretical arguments that relate to sustainability and the importance of a shift into a new technological regime oriented towards environmental issues in ISs. A systematization of the two main theoretical analyses of ISs has been also emphasized in the thesis as interactive learning and evolutionary technological change theories, which originate respectively from Schumpeterian and neo-evolutionary Schumpeterian views.

In Edquist’s view (2001, p.35) "there is a strong need for further conceptual and theoretical development of the IS approach. The best way of doing this is by actually using the approach in empirical research". How the shift of ISs to environmental sustainability can come about and how they can be brought together systemically is still a largely unexplored field of research. Accordingly, the aim of this thesis is to conceptually advance an understanding of the IS as a flexible and useful approach to encompass the environmental sustainability dimension.

To address this, the thesis develops a conceptual framework for ISs that is oriented toward sustainability; based on the interactive, resource, and environmental views; and tested empirically. The conceptual framework is illustrated empirically in the case studies of the Brazilian subsidiary of the Swedish multinational Ericsson.
Abstract

and the Brazilian multinational USIMINAS, with focus placed on their interactions with the Brazilian innovation system. Since the cases belong to different sectors, there are variables between the multinationals in terms of the nature of innovation capacity. The contrast between the two cases in terms of technological regimes proved very interesting, and hence formed the core of the thesis. The IS approach has been gaining ground in academic circles, as well as in the field of public innovation policy-making in industrialized and newly industrialized countries. The findings of the current study suggest that ISs for environmental sustainability can be categorized as evolutionary, natural resource based, and internationally oriented. In the context of newly industrialized countries, the internalization of ISs has been perceived through effects of research and development in multinational firms, technology transfer and the international trade of capital goods. The understanding of ISs and the internationalization phenomenon in relation to sustainability warrants further studies; notably studies are required that examine the internationalization of ISs, empirically viewing this from the perspective of both industrialized and newly industrialized economies.

**Key words:** Innovation Systems, Technological Change, Environmental Sustainability, Multinationals, Cross-cultural transfer of Science and Technology, Brazil, Sweden
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Paper III: Santos, R. "Sustainability and Technological Capability Accumulation
Paths in the Brazilian multinational USIMINAS: an assessment of theory and
practice", Submitted to Journal of Energy Engineering for publication. This paper has
also been accepted for presentation at the International Conference on
Environment and Industrial Innovation – ICEII 2012 (2-3, June 2012, Hong Kong,
China).

I. COVER ESSAY
1. Introduction

The innovation system (IS) approach has described the science and technology (S&T) as critical inputs to affect, modify and determine the economic performance. As a relatively recent phenomenon, further analysis might be valuable to gain insights about ISs, their systemic failures and gaps. The argument put forward in this research is twofold. First, is the implication that IS rest on a co-evolutionary process, in which technical and economic spheres on the one hand interact with policies, institutions; and on the other hand affect the natural environment. Second, ISs have access to the state-of-the-art flows of knowledge, which is positively perceived to the extent of how technological innovation is becoming globalized (Coe and Helpman, 1995; Carlsson, 2006).

Increasingly, it is being stressed in the literature that the IS approach would be enriched by the trend in globalization of technology. For example, Archibugi and Pietrobelli (2003) suggest the potential benefits of international exploitation of technology produced nationally and how they become widely spread outside ISs boundaries. As said by Archibugi and Pietrobelli (2003, p.862) “the globalization of technology offers new opportunities for development. But they are by no means available without deliberate effort to absorb innovation through endogenous learning”.

Countries’ capacity to absorb innovation depends in part on the overall array of investments and ISs policy choices. ISs however, differ across cultures, social relations, and levels of institutional structures. In Nelson (1993) ISs are often considered as an outcome of path dependent evolutionary processes and they are clearly defined by the social and institutional conditions, historical and cultural identity of a particular country. Pitelis (2010) also shows the effect of national culture on countries’ innovation performance in relation to their capacity to access international markets. Pitelis’ view might be applicable notably to newly industrialized countries (NICs) that are experiencing industrialization and economic growth. NICs have been increasingly active across national borders based on their potential to catch up technologically, and to their recent, rapid industrialization. Despite its importance, few quantitative empirical studies have directly underscored the salience of environmental dimension to ISs. This introductory chapter details the purpose of the study, offers a justification for the research, and defines objectives and aims.
1.1 Background to the Work

As far as the concept of ISs is concerned, the links amongst S&T policy and economics emerge as an important contingency. From the most basic definition of a system as a group of interrelated elements forming a complex whole, the idea of ISs is to provide a frame for the analysis of the market diversity and S&T actors, the dynamic of institutions and their co-evolution with organizations (see Lundvall 1992; Freeman 1995; Nelson, 1993).

This study presents a systematization of the two main theoretical streams of ISs. Special attention is given to interactive learning and evolutionary technological change theories, which originate from the Schumpeterian and neo-evolutionary Schumpeterian views (Nelson and Winter 1982; Freeman 1987, 1995; Lundvall 1992; 1998).

Nelson and Winter, Freeman and Lundvall attach importance to institutional settings to support the innovative capacity of firms1, while knowledge and interactive learning play a central role in the process of technological change.

The thesis provides a conceptual framework drawn from the theories of ISs, and illustrated empirically in two case studies of multinationals relating to the Brazilian innovation system. Leshem and Trafford (2007) suggest a conceptual framework as a "theory-testing sorts of studies". Likewise, as said by Rudstam and Newton (cited in Leshem and Trafford, 2007, p.96): "a conceptual framework, which is simply a less developed form of a theory, consists of statements that link abstract concepts to empirical data…. Theories and conceptual frameworks are developed to account for or describe abstract phenomena that occur under similar conditions". A conceptual framework appears therefore, as a useful guide to the understanding of the systemic view of IS, which has high degree of interdependence among the various components of science and technical change, learning and innovation (see Edquist and Hommen, 1999). This systemic view highlights the idea of knowledge generation as a process dependent on the dynamic linkages between firms and S&T organizations, regulation, buyers and suppliers. Following Westlund (2006) it is possible to reflect knowledge-creating and transfer in ISs taking place through formal ties, transaction-

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1 In this thesis the terms firms or companies are often used interchangeably. In O’Sullivan and Sheffrin (2003), business (enterprise or firm) is an organization engaged in the trade of goods, services, or both to consumers. Company is a form of business organization (O’Sullivan and Sheffrin, 2003, p.29).
links, networks between firms and firms and other actors, or spillovers that result from unintended knowledge flows.

What does sustainability really mean for ISs? ISs involve quite explicitly the importance of the "economy-S&T-society", as a mutual influence of technology productivity, stocks of human-built capital, social values, consumption patterns, human development and culture. Today’s increasing focus on ISs for sustainability appears to be an interplay of "nature-economy-S&T-society", affecting ecological limits, physical flows of matter and energy, users of natural resources, and environmental impacts of products and processes. Cash et al. (2003) support the idea of sustainability as a social and also adaptive process, in which knowledge and learning play a central role.

For the sustainability analysis, the study is based on the seminal work of Kemp (1999) and confirmed that Kemp's theory (2008, 2011) is related to a change in technology systems or technological regime shifts to environmental sustainability. Precisely, environmental sustainability is first mentioned in IS analysis by Segura-Bonilla (1999) and has been more recently discussed by Smith, Stirling and Berkhout (2005), Stamm, Dantas, Fischer, Ganguly and Rennkamp (2009), Melville (2010). The study also uses conceptual insights from Brezet’s model (1997) that illustrates the way in which technological trajectories may be perceived along levels of environmental improvements (Papers II, III, V).

In NICs – even industrialized countries – ISs have until recently been decoupled from sustainability issues. This is mainly because governmental actions have created different policy frames for innovation and environment, with a deficit of institutional dialogue between these areas. An agenda for ISs of inclusive sustainability may be seen as the way to determine targets to countries boost competitiveness and "green" growth. In this regard, biodiversity, environmental limits, industrialization, climate adaptation, natural resources, energy efficiency and consumption have all play and important role.

ISs are often considered basically "national". In Vargas (2004) different perspectives of ISs have a complementary character, and the specific dimension of analysis (for instance "national") primarily reflects the type and object of study. Lundvall (2007) supports the use of adjective "national" and suggests that it has become even more important to be explicit about the dimension of ISs as globalization is the focus of attention.

Since the 1980s, Brazil’s government has issued policies of innovation, but for instance, the country’s S&T resources have failed to transform into productivity and competitiveness. As a consequence, the Brazilian innovation system has changed
largely due to the growing importance of foreign capital in the national economy. Over the past fifteen years, Brazil’s economy went through a dense internationalization process. To a large extent, the Brazil’s international inclusion in the global market, results from the significant role of multinational corporations (MNCs) in the country’s economy. The generation R&D carried out by MNCs included processes of adaptation, assimilation and knowledge transfer to the Brazilian market (Papers II, IV, and V).

The globalization process, which has been closely associated with the R&D activities of MNCs, refers to international collaboration and science-based exports. Apart from a focus on the international role of R&D, there has been limited research exploring the international linkages across ISs. Carlson (2006, p.65) states: "...in view of the fact that most studies focus on national innovation systems, it is not surprising that little direct evidence is found that innovation systems are becoming global... However, at these lower levels there has been little work done with a view toward internationalization of systems".

Undoubtedly, remain open to ideas and arguments of the recent theorizing on IS. Edquist (1997, pp.28-29) writes one of the most complete syntheses of IS to date and points out: "...innovation system does not deserve the status of a theory of innovation, but must be called a conceptual framework or approach. There is a strong need for further conceptual and theoretical development of the innovation approach, in order to name the innovation system approach as a theory".

In terms of methods to conduct research in ISs, Edquist (2004, p.202) also argues: ..."the basis of the innovation system approach should be investigated empirically, by using qualitative as well as quantitative observations. Theoretically based empirical work is the best way to straighten up the innovation system approach; the empirical work will, in this way, serve as a disciplining device in an effort to develop the conceptual and conceptual framework”.

The IS approach is conceptually challenging. The motivation behind my research reconciles my curiosity with the conviction that theoretical advances in the IS approach seem to be the way to build up this concept; from the recombination of known structures to reinterpretation in a new context. This study proposes to examine the premises of "environmental sustainability" as desirables in the IS approach.

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2 Multinational corporations (MNCs) or MNEs usually comprise companies established in more than one country and so linked that they may co-ordinate their operations in various ways (OECD, 2005).
1.2 Aim and Scope

The aim of this thesis is to advance the understanding of the IS approach as a research tool with gaps that need to be filled. Specifically, the goal is to examine the theoretical basis of IS as a flexible and useful approach to encompass the environmental sustainability dimension. To address this, the thesis develops a conceptual framework for ISs oriented toward sustainability, based on the interactive, resource and environmental views, and tested empirically in two case studies relating with the Brazilian innovation system.

There are a number of reasons why NICs should be brought into the process of technological regime shifts to sustainability, and why the institutional structure is to bring this about. The way that ISs can be influenced by institutions (in particular by the STI policy and environmental policy) and the way they can be brought systematically together is still a large unexplored field of research. This study highlights "policy" as an invaluable instrument to stimulate ISs towards environmental sustainability, escaping lock-in into unsustainable technologies. In this view, and within the outlined aim and objective, the study addresses research questions, which are reflected in Papers II-V:

RQ1 How do levels of environmental improvement in product innovation contribute to the sustainability in the (Brazilian) IS? (This question is reflected and responded in Papers II, III and V).

RQ2 To what extent has STI policy contributed to the promotion of linkages between R&D and sustainability in science and engineering based clusters and Regional ISs? (This question is reflected and responded to in Paper IV).

RQ3 How does (Brazilian) IS interact with sectoral technological trajectories and environmental sustainability? (This question is reflected and responded to in Paper V).

Empirically, the thesis is based on two case studies, precisely about a foreign-based company with activities in Brazil, Ericsson Telecomunicações S/A as the Brazilian subsidiary of the Swedish multinational Ericsson; and the Brazilian multinational Usinas Siderurgicas de Minas Gerais S/A (USIMINAS). They are illustrated by the sectors of "information and communication technologies (ICTs)" and "steel", based on contrasting technological regimes, both playing a prominent role in the Brazilian economy.

The IS approach is multidisciplinary. This study does not intend to demonstrate expertise in all of areas; but rather to demonstrate sufficient understanding in each context in order to demonstrate expertise where these areas intersect.
The choice of a Swedish subsidiary is due to the potential involvement presently, and prospectively of Swedish multinational companies in Brazil, based on the technological efforts of their affiliates. To a large extent, Swedish investment flows in Brazil reflect increasing integration of NICs into the world economy. For decades, Brazil has been a major trading partner of Sweden and a major production location for Swedish companies, and this close relationship comprises a historical partnership between these two economies. Swedish and Brazilian governments have pointed out in the additional protocol signed October 2009 to the Program of Industrial Exchange in high technology. Since then, ABDI and VINNOVA have entered into cross-border cooperation on the basis of the countries’ collaboration in STI. The protocol also emphasized the strategy that both Swedish and Brazilian governments have the goal to increase investments and trade.

USIMINAS is Brazil’s second-biggest steelmaker and ranks amongst the biggest domestic multinational corporations. USIMINAS has consolidated its competitive advantage to supply domestic and external markets, and important is the company’s commitment in the internationalization process of the Brazilian steel industry. USIMINAS is a remarkable example of an accumulated experience between technology imports or foreign technological inputs (active absorption) and domestic technological improvements (the effective development of improvement capabilities).

1.2.1. Structure and Composition of the Thesis

The thesis consists of two parts comprising this covering essay and a combination of five papers (Figure 1). The covering essay is presented over five chapters, including this introduction: Chapters 2 and 3 set the work in context, Chapter 4 looks at research development, and Chapter 5 summarizes the introduction.

Chapter 2 looks at theory surrounding ISs and environmental sustainability. It provides a summary for the analysis of the co-evolution of technology, institutions and organizations. The chapter also highlights the theoretical arguments of sustainability and environment, as well as the evolutionary approach to technological change and sustainability. Chapter 3 turns to STI policies and industrial development with focus on the Brazilian experience. The chapter introduces Brazil in the context of the BRICs group, describes the country’s innovation policy and aligned with S&T priorities. The chapter also presents aspects of the Brazilian internationalization process and the challenges faced by domestic multinational corporations in the field of R&D.
Chapter 4 presents the development of a conceptual framework in the context of macro-micro levels of NISs, associated with ties of knowledge interactions to provide the basis for environmental sustainability. Chapter 5 summarizes conclusions of the thesis, argues about its limitations, and suggests future studies.

![Thesis Structure Diagram](image)

**Figure 1** Thesis Structure and major elements: RQ1, RQ2 and RQ3 refer to Research Questions reflected in Papers II-V

The case study of the Ericsson subsidiary yielded three articles, which are referred to as *Paper II, Paper IV and Paper V*. The case of USIMINAS is reported in the third article. *Paper II* addresses the adaptation of the Ericsson subsidiary’s R&D unit in the host innovation system. This article is co-authored with Eduardo Oliva, Director of R&D of the Ericsson Telecomunicações in Brazil; and Professor Walter Leal, Head of the Research and Transfer Centre Applications of Life Sciences Hamburg University of Applied Sciences. *Papers I and III* are single authored. *Paper I* reports on STI in Brazil and Sweden. *Paper III* has investigated capability-accumulation paths in the context of a case example from the steel sector, and was reviewed by the former R&D Manager of USIMINAS, Eduardo Tonnelli. *Paper IV* goes further in terms of an analysis concerning interactions between the Ericsson subsidiary and the regional host, Campinas innovation system, clustering and policymaking. It is co-authored with Professor Walter Leal, and Evando Mirra, Senior Researcher at the Brazilian Agency for Industrial Development (ABDI).

*Paper V* presents a sectorial analysis of technological trajectories. As a theoretical extension to *Papers II, III, IV* this article is co-authored with Evando Mirra and
1.3 The Research Journey

Giddens' study of the "double hermeneutic" cited in Mackenzie and Ling (2009), informs the following reflections on the research journey that led to the production of this thesis. By this term, Mackenzie and Ling refer to the way in which "research" and "researcher" interact. Mackenzie and Ling (2009, p.50) point out: "a researcher cannot be part of the context of research without having an impact on that context at the same time as the context is impacting upon the researcher". It is well known that any research journey presents challenges. In this particular journey, the choice of research topic was not immediately obvious; defining questions, designing data collection and analysis methods, managing and communicating research all presented difficulties at times. The research may, however, be described as exciting: an act of going outside of the borders of traditional methods, a long distance research journey between Sweden and Brazil. It was a "journey not linear" as suggested in Mackenzie and Ling (2009), through which I engaged in a diverse cultural experience, in light of different contexts, situations and cultural backgrounds; and shifting perspectives, insights and demands.

The task highlighted the importance of aligning research with university and professional priorities, expertise and personal experience. This is to say that the research journey was conducted within my own professional experience, i.e., through travel upon or across my doctoral study (research journey) and professional activities (work journey) simultaneously. As such, I have been a 'participant observer' in my study. In the work context, the research topics were closely related to my prior work experience with the Secretariat of Environment and Sustainable Development (SEMAD) of Minas Gerais State in Brazil.

It has been an interesting journey at the dynamic boundary between the known (the logical, certainty limits) and the unknown (unexpected) borders. The first step was to formulate a plan for shifting that boundary, drawing up my professional experience. This also required thought and discussions with my supervisor, and reflection with Swedish and Brazilian experts. At the intermediate steps, I generated analysis, data and information useful to reuse and adapt in the final step.

Undoubtedly, the vital last step in the journey made the results of the research useful – it made those results to be fully applicable to my professional activity.
During the data gathering process, which extended to three phases of extensive fieldwork, I had access to different sources and diverse strategies. The exploratory study phase, in January 2004, refers to a period of a preliminary contact with the National Association for Research, Development and Engineering of Innovative Enterprises (ANPEI) in Brazil. It aimed to identify information to the frame of reference for the choice of the case studies. ANPEI database offered information-oriented sampling, and data collection took place between February and April 2004, through periodical visits to the office in São Paulo. I was also a participant observer at the ANPEI annual conferences over subsequent years (between 2005 and 2009), and also eventually in technical seminars.

The second phase, which took place between April 2004 and 2007 comprised extensive field works in Sweden and Brazil, and consisted of different components such as questionnaires, expert consultations and events (seminars, conferences, technical meetings and workshops). The constructs of each questionnaire (see Appendix I and II) were based upon recommendations from the OECD's Frascati Manual (2002); they were refined based on concepts, definitions and methodology adopted from the OECD's Oslo Manual (1996).

In the second semester of 2004, face-to-face interviews were conducted in Brazil and Sweden with staff of the Brazilian Innovation Agency (FINEP) and the Swedish Agency for Innovation System (VINNOVA) to map the impact of STI policies in both countries. The technique of cross checking with a third interviewee proved helpful in clarifying and obtaining the precise details of specific projects. In 2005, double-checks of specific events and updates were made by e-mail and/or by phone. In 2005 and 2006, in-depth interviews and questionnaire application were conducted with managers and technicians of R&D units and environmental departments of Ericsson (in Sweden and Brazil) and USIMINAS. The aim of these activities was to obtain information on the company’s technology and innovation strategies. Extended data gathering, validations, double/triple checking and follow-ups were carried out from October 2006 to November 2009 on the basis of visits, update emails and phone calls.

In 2008, additional face-to-face interviews were carried out with experts at the KTH School of Industrial Engineering and Management in Stockholm. In Brazil, semi-structured interviews were conducted at the Brazilian Agency for Industrial Development (ABDI). The aim was to pursue ideas and gather information for Papers III and V. The second and third phases refer to my period of generating research outputs. This includes the publishing process, participation in national and international conferences, and successful grant applications. Research activities
improved the effectiveness of my abilities in scientific writing skills, research analysis and evaluation.

The third phase took place mainly in Brazil and it allows me to undertake a review of the gathered information. It gave me a chance for critical thinking, examining diverse ideas and reaching conclusions. Through this exercise, it became apparent that I needed more local information, to identify the implications of the research subjects, and better understand how questions had been addressed. My research had gaps, which needed to be filled. For this purpose, during the years 2008 and 2009, I was an observer at the Secretariat of Science and Technology (SECTES) of Minas Gerais State. As part of a multi-disciplinary R&D team, I was exposed to the complete spectrum of R&D projects, following the development of concepts to their application and the development of leading-edge (regional and national) systems of STI. In sum, the research journey coupled differences between the two countries in terms of cultural orientation, diversity, apprenticeships and knowledge ability, culturally sensitive communication, and human motivations that affect the conduct of research across cultures.

1.4 Research Design and Methods

This section describes the research design and methods deployed in this study based primarily on qualitative information. Research strategy was sought to overcome the researcher’s limitation to combine retrospective interpretation with the view on events that taken place after the case study methodology. In this context, Leonard-Barton (cited in Figueredo, 2006, p.26) suggests that “one of the challenges for the researcher in doing a long-term study like this is to cope with the difficulty of reconstructing cause and effect of past events”. Much more than a researcher’s critical perception, the requirement for a long term qualitative study includes training, practice and continued work and may generate a potential for the development and the improvement of ideas and feedbacks. Understanding a search for knowledge as open and dynamic, suggests a useful perspective for a long term qualitative study.

1.4.1 Research Strategy

Figure 2 illustrates the research strategy, which is based on Maxwell’s qualitative model (2005). Maxwell provides steps to planning qualitative research, and presents
the components to the research design and the ways in which they interact or may affect and be affected by one another. My study was designed to conduct tasks in Sweden and Brazil. While the qualitative research steps in Sweden referred to the research design and grounded theory; the qualitative inquiry, case studies and other research methods took place in both countries. Tasks in Sweden have provided a foundation, background, and context for the research; besides, they have established a bridge between the research project and the extant knowledge base.

![RESEARCH DIAGRAM](image)

Figure 2: Conducting my research

The Maxwell’s model addresses five components to the qualitative research design:

**Goals:** Why is this study worth doing? What issues do I want to clarify? What practices/policies do I want to influence? Why do I want to do this study, and why would anyone care about the results?

**Theories and beliefs:** What do I think is going on with the issues, settings I plan to study? What theories, beliefs, and prior research will guide/inform this research? How will I understand the issues I am studying?

**Research Questions:** What specifically do I want to understand by doing this study? What do I not know about the things I am studying that I want to learn? What questions will my research answer, and how are these questions related?
Methods: What approaches and techniques will I use to collect and analyze my data, and how they constitute an integrated strategy?

Validity: How might my results and conclusions be wrong? What are the plausible alternative interpretations and validity threats to these, and how will I deal with these? How can the data that I have, or that I could potentially collect, support or challenge my ideas about what’s going on? Why should I believe my results?

This study has largely been about why and some about what to sharpen up and advance the ISs idea. "What" I actually do in conducting this study? What do I want to know? Studies point to the continued importance of a rich field of qualitative research to discuss the notion of ISs (see Van de Ven and Poole, 1996). About addressing the questions of choice: Why ISs? Why environmental sustainability? Central to this, is my interest to the array of new ideas, practices, purposes, applications and outcomes that shape research agenda in ISs. My background and professional experience have also played an important role in the research choice. Having acquired knowledge of both applied sciences on the one hand and natural sciences on the other, I may catalyze an exchange of ideas between the exciting fields of research in ISs. As Strauss and Corbin (1990, pp. 35-36) argue: "the touchstone of your own experience may be a valuable indicator for you of a potentially successful research endeavour".

1.4.2. Methods

In Van de Ven and Poole’s view (1996) the use of mixed qualitative methods is proper to the study of innovation. Accordingly, the research involves different methods to explore the IS approach through various data sources, and it is based primarily on qualitative information gathered via case study and survey. Networking, archival analysis, and theoretical analysis also provide updated data to contextualize Papers II and III (case studies) and Papers I, IV, and V. Document analysis is used as means of supplying data. Scott (cited in Connell, Lynch, Waring, 2001, p.28) offers a "logical explanation to the consideration of documentary sources to qualitative research. The following paragraphs describe the research techniques focused in this study".

Networking techniques refer to a means of the active, purposeful creation of nodes of individuals (or organizations), which are tied (connected) with a focus to establish linkages (see Kathleen, Martin and Hirshman, 2009). Different forms of networks
have influenced the spread of ideas and practices in the research, for example the usual face-to-face and small group meetings often interspersed with telephone calls or electronic communications. Indirect communication, including media interactions such as web meetings were used to discuss topics of the research with Swedish and Brazilian experts. Networking provided general background support for ideas and arguments presented in Papers I-V. (or organizations), which are tied (connected) with a focus to establish linkages (see Kathleen, Martin and Hirshman, 2009). Different forms of networks have influenced the spread of ideas and practices in the research, for example the usual face-to-face and small group meetings often interspersed with telephone calls or electronic communications. Indirect communication, including media interactions such as web meetings were used to discuss topics of the research with Swedish and Brazilian experts. Networking provided general background support for ideas and arguments presented in Papers I-V.

Case studies design closely follows Yin’s study (1994). Yin suggests the following stages to the application of a case study methodology: design and conduct the case; analyze the case construct validity and evidence; and develop the conclusions and implications. The case studies selection was preliminary informed from sources provided by ANPEI reports, addressing a set of multinationals (Brazilian and foreign) whose reflects the performance of innovative companies. A follow-up step referred to an eligibility list containing a subset of Brazilian and Swedish-owned companies. The following case studies were selected to predict contrasting results: the Brazilian subsidiary of the Swedish Multinational Ericsson and the Brazilian multinational USIMINAS. This choice is briefly explained, first, and because cases illustrate characteristics of two industrial sectors of extreme differences in technological intensity. A justification is also based in terms of the sectors’ value added to Brazil (through jobs creation including the supply chain; and the development of new products and processes). The conduction of case studies comprised semi-structured interviews with key interviewees, including directors and managers of R&D, senior researchers and managers of the departments of environment and sustainability. To undertake "data gathering" two sequences of five interviews were carried out in each company during the period 2005-2008. The first sequence aimed to gain understanding of their practices and policies; the second to become acquainted with the interviewees. Semi-structured interviews as data gathering technique were used to understand interviewees’ personal beliefs, opinions and insights. The second sequence refers to the use of in-depth interviews from a questionnaire application (Appendix I) consisting of a series of inquiries for the purpose of gathering information from
respondents. The case study method represents the core of the research providing data to Papers II, III.

Qualifier Survey was used as the method to gather information from selected Swedish and Brazilian STI organizations, based on their profiles of policy, planning and programs. As Isaac and Michael (1997) said: "the use of survey is to answer questions that have been raised….to analyze trends across time, and generally to describe what exists, in what amount, and in what context" (Isaac and Michael, 1997, p. 136). Accordingly, in 2004 data and follow up data in 2005, 2006, 2007 were collected through the use of questionnaires (Appendix II) to report on what’s going on and what’s next in STI in Brazil and Sweden. Open-ended questions were also used to assess opinions and facts from 26 interviewees in Brazil (ANPEI and the Brazilian Innovation Agency FINEP) and Sweden (the Swedish Agency for Innovation System VINNOVA). In 2008, semi structured interviews were conducted together with ABDI with the aim of providing data for Papers III and V. The survey provided background data, which were used to contextualize the case studies and analysis to Paper I’s development.

Archival/Qualitative document analysis provided information to Papers IV, V. Where possible, supporting data was obtained from documents to provide a background, as well as to examine any documents referred to during the interviews. What distinguishes archival analysis from other research methods according to May (1997) "is the information available through archival analysis before one’s own research has begun" (May, 1997 pp.160-161). The focus was the critical examination of the documents rather than simple description.

Theoretical Analysis was suitable to synthesis of my research work, as useful method to that allows the researcher to gain new insights in an interdisciplinary approach. Bentz and Shapiro (1998, p.141) assert that "through a theoretical inquiry (analysis), new knowledge can be created by means of combining, extending, and integrating existing research areas. This means making use of cross fertilization". Review of IS literature is rooted in different theoretical domains – economics theory, organizational theory, technology and innovation management, and strategic management – and in this range of theoretical contributions there is a plurality of definitions and interpretations. Theoretical inquiry was useful for analyzing data from an array of concepts and categories, trends and patterns in IS literature. An important use of the theoretical analysis was the examination of previous research findings in the IS
approach to assess the degree to which the thesis is congruent with those approaches used in previous studies. In this respect, previous studies staged in the same case studies were invaluable sources.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Research Methods</th>
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<tr>
<td>Paper (I)</td>
<td>Descriptive</td>
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<tr>
<td></td>
<td>Qualitative Survey through the use of questionnaire (Appendix II) and open-ended questions.</td>
</tr>
<tr>
<td>Paper (II)</td>
<td>Interpretive</td>
</tr>
<tr>
<td></td>
<td>Case Study through structured interviews using the questionnaire application (Appendix I). Theoretical Analysis.</td>
</tr>
<tr>
<td>Paper (III)</td>
<td>Interpretive</td>
</tr>
<tr>
<td></td>
<td>Case Study through structured interviews using the questionnaire application (Appendix I). Theoretical Analysis.</td>
</tr>
<tr>
<td>Paper (IV)</td>
<td>Review and Conceptual</td>
</tr>
<tr>
<td>Paper (V)</td>
<td>Review and Conceptual</td>
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Table 1: Research Methods used in Papers I-V

Table 1 presents a brief categorization of each paper. Research methods used individually in Papers I-V show that triangulation was used as qualitative research design, mixing use of survey with interviews, case study, theoretical analysis and document analysis. Interpretive description in Papers II and III provides a grounding for the conceptual analysis in Papers IV and V. Paper I – as a descriptive paper – is a research essay that intends to present organizational structures to support innovation from different dimensions.

1.5 Outline of Papers

This section sets out to provide a summary of the findings presented in Papers I-V, their results and relative importance and role of each in the thesis context. The papers provide an overview of literature to be used in the study of ISs, and they share a common theoretical focus on environmental sustainability. The contextual conditions of each paper contribute to the overall research that this thesis details.

Paper I presents a qualitative study of the role of organizations in the promotion of "innovation" as a tool to boost the country's competitiveness, sustainable development and growth. Paper I is the ground for subsequent papers. Papers II and III present
case studies of multinationals, their interactions with NISs, and their efforts to achieve sustainability. The context of Paper II is further developed in Paper IV. As a qualitative study, Paper V examines interactions between technological trajectories of MNCs subsidiaries and provides foresight on the task of identifying long-term trends in sustainability.

A proposition permeating the empirical evidence of the papers is the importance of corporate R&D activities. Whilst R&D has been emphasized by some authors (for instance Cohen and Levinthal, 1990), corporate conditions for sustainability have been the focus of others (Brezet 1997; Kemp, 1999). Papers II, III, IV and V bring these two streams together by advancing the idea that in analyzing R&D there are reasons to include sustainability along with the corporate aspects.

Paper I is entitled "The Dynamics of Public and Private Entities as Promoters of Innovation: sustainable development and growth". In specific, this study assesses major streams in the qualitative survey conducted together with ANPEI, the Association for Research, Development and Engineering of Innovative Enterprises (Brazil) and VINNOVA, the Agency for Innovation Systems (Sweden). Respectively, ANPEI and VINNOVA are public and private organizations charged with promoting "innovation" as the country’s competitive advantage. The aim of the paper is to examine the role of ANPEI and VINNOVA in national innovation systems (NISs), a priori taking into account similarities and differences between private and public organizations. Since innovation emerges in a systemic perspective, ANPEI stimulates the interactivity between industries and developers, while VINNOVA focuses on researchers, developers, creative thinkers, and institutions (legislation and the rules).

The paper discusses implications for public and private organizations under the contrasting conditions of Swedish and Brazilian NISs, with emphasis on the "Triple Helix" model in the task of the multiple reciprocal relationships among institutional settings (public, private and academic) at different stages in the promotion of innovation.

As a research strategy, a qualitative survey (Appendix II) was conducted in order to gain an understanding of the strategies employed by both ANPEI and VINNOVA. The findings indicate that in Brazil the cooperation among government, universities, and society is gradually making its way into the national and regional policy agendas. The "Triple Helix" depends on the country’s initiatives to better interactivity between political decisions, industry, and society’s demands to actively engage in R&D. ANPEI’s performance in promoting technological innovation results from interactivity between actors, organizations and the institutions in which they prevail, where the
(Federal and/or State) legislation and the rules can encourage innovation or make it difficult.

In Sweden, the "Triple Helix" model has created a systematic approach to advance the innovation agenda in order to attain economic growth. The Swedish triple helix model is based on a "strong and successful" collaboration of academia, industry, and government, to achieve an economy focused on the capitalization of knowledge. VINNOVA’s efforts have been frequently in need of adjustments and development in order that the public agency functions efficiently in dealing with funding and technological support in different research systems. Analysis of contrasting conditions in the two countries and the different levels of Swedish and Brazilian NISs’ development provide background to Papers II, IV, and V.

Paper II, entitled "Strategies for competitiveness and sustainability: Adaptation of a Brazilian subsidiary of a Swedish multinational corporation" details a case study’ analysis, illustrating a qualitative analysis of the Brazilian subsidiary of Ericsson’s efforts in R&D. The paper aimed to analyze the subsidiary and its technology-related activities, in terms of their implications for the Brazilian innovation system. The qualitative analysis utilized data gathered through interviews conducted with leading managers and researchers of the subsidiary’s R&D and Environmental units. Data collection obtained from structured interviews (Appendix I), concerns interviewee's opinions and insights. Supplementary data gathering, clarifications, validations and double/triple checking were carried out on the basis of semi-structured interviews, phone calls and emails.

Paper II examines the information and communication technologies (ICT) sector, working towards a transversal and comprehensive view of levels of innovation and sustainability. The ICT sector was chosen for its decisive impact on other industry sectors, and because it represents an economically privileged branch in both Sweden and Brazil. The sector is characterized by a technological trajectory demanding new diversified services, with decreasing costs and prices, and high intensity in R&D, requiring short innovation cycles, in order to respond to productivity and competitiveness demands.

ICT analysis in the case of Ericsson Telecomunicações S.A is based on Brezet’s (1997) model, outlining levels of innovation and the improvement in sustainability which can be expected. The paper identifies different levels of innovation, representing: continual "product improvement", in terms of resource efficiency through pollution control; "redesign", focusing on issues such as minimizing the energy use at several stages in the product lifecycle; and "functional innovation” or changes to infrastructure and organizations to fulfill functionality.
The Ericsson subsidiary case demonstrates these levels of innovation and reflects how they contribute to the sustainability of the Brazilian innovation system regarding technology and eco-efficiency. Findings from this study indicate that interactions with the host innovation system and contribution to its sustainability are steered by directives of the programs offered at a global scale. According to Ericsson’s global strategy, the focus on is to decrease the environmental impact and improve the energy efficiency of its products.

An issue for future research is to investigate how capabilities in R&D, as well as scientific and technological partnerships, impact upon the future orientation of Ericsson in Brazil, as well as its insertion into the host innovation system. Investigation of this issue would need to include the empirical verification necessary to obtain more extensive conclusions about the subsidiary’s role in the local S&T infrastructure and capacity building, interactions between a multi-stakeholder partnership, and host-home knowledge flows and sustainability.

*Paper III* is entitled "Technological Capability Accumulation Paths and Environmental Sustainability: The Case of The Brazilian Multinational USIMINAS". The motivation behind the paper is to illustrate a case study that presents a contrast to the Ericsson case (*Paper II*) in terms of technological regime, R&D intensity, sources of technology, appropriability and the distinction between users and suppliers.

As research strategy, structured interviews were conducted with R&D and Environmental units (*Appendix I*). This study draws on conceptual and empirical literature addressing technological capability accumulation paths in the context of the steel sector. It examines the USIMINAS case, placing focus on the company’s levels of technological capability along energy efficiency and environmental sustainability issues.

Using Brezet's (1997) model, the paper examines the movement of a product through levels of innovation linked with environmental improvements and TC (Technological Capability) accumulation in the steel sector. Brezet’s (1997) model is extended to the steel sector and further, to the analysis of environmental sustainability in the sector.

The Brazilian multinational USIMINAS illustrates technological capability paths through the learning process. As the stock of knowledge increases exponentially, USIMINAS is not able to develop new technology using knowledge exclusively accumulated in-house, and it sources complementary knowledge by means of R&D partnerships. For the development of technologically new or improved products and processes, the company has developed collaborative R&D, a technology focus, and engages in co-development with (foreign) technology suppliers. The company had
built up innovative capability by working with suppliers and buyers to design better, more flexible, and energy and material-efficient products for desired production rates.

The findings of the paper report that as far as product capability is concerned, USIMINAS engages continuously in the accumulation of capabilities to design and develop its own steels along the lines of an environmental friendly iron making process. Technological capability-accumulation in USIMINAS has been characterized by a shift from continuous use of external sources of knowledge to strategy to align these sources with in-house capabilities. The company achieves levels of environmental improvement from incremental innovation to redesign of products, resulting in changes in the availability and quality of material and energy sources, and emissions. Environmental interactions with the Brazilian innovation system occur through a collaborative supply chain process for the control of environmental effects throughout the product life cycle.

*Paper III* suggests future studies regarding the calculation of CO$_2$ emissions from the production processes of the company, and performs analysis of aggregate company behavior to observe rates of technological substitution, efficiency, and environmental improvements. *Papers II and III*, based on cases studies of MNCs from contrasting technological regimes provided a core contribution to the thesis.

*Paper IV* elaborates a comprehensive vision for the convergence between sustainability and ICTs first elaborated in *Paper II*. Entitled "Innovation Systems and Sustainability: An approach for Regional Clustering and MNCs Subsidiaries", *Paper IV* analyses the ties as cooperative linkages between R&D units of telecom subsidiaries and the host country’s regional innovation system. Such linkages are empirically examined in the context of the regional innovation system of Campinas, which represents Brazil’s leading telecom agglomeration, fostered through governmental policies. Equally, endogenous efforts by the region's scientific institutions and extra sources such as the setup of subsidiaries of MNCs have been conducive to the growth of the region clustering telecom firms.

The research strategy involved data from document analysis. Data was obtained from ANPEI; semi-structured interviews and informal discussions with researchers (networking techniques) based in the Campinas region.

*Paper IV* emphasizes the question of how (and to what extent) the Brazilian STI policy has contributed to the promotion of cooperative linkages between R&D and the science-based Campinas telecom agglomeration. The state of R&D incentives in Brazil has earned distinguished marks, and brought about significant improvements and changes. It has, however, mostly sought to benefit certain sectors, such as telecommunications. As a legal frame for the sector, the Informatics Incentives (IT)
Law no. 10176 has been crucial to increases in the technological efforts of telecom subsidiaries, in terms of engaging in R&D investment, and partnerships with local universities and research centers. Paper IV demonstrated the integrations of the Brazilian subsidiary, Ericsson Telecomunicações SA into the Campinas telecom agglomeration as part of the regional innovation network. The IT Law has fostered scientific knowledge linkages between Ericsson Telecomunicações and the innovation system of Campinas. The case of the Swedish subsidiary illustrates the interactions of the R&D unit with the host IS, and its scientific integration with local universities.

Overall, the findings suggest that although the IT Law and other incentives (such as the R&D Tax Credit and Innovation Law) are expected to increase firms’ technological efforts, up to now there is no definitive evidence to support their ability to generate positive environmental externalities. The question is to what extent these policies have additional or crowding-out effects on firms’ environmental R&D expenditures. A more environmentally concerned Brazilian STI policy is a condition for addressing long-term sustainability issues. In this context, a primary condition is a framework that can act as a “crossover” between "environment policy" and "innovation"; and, further, better coordination among (or a merger of) existing Brazilian environmental policy and technology policy.

The paper recommends that future research could focus on providing analyses of both implications for policy-making aimed at fostering science-clusters in RISs; and the implications of environmental regulations in the process for generating competitive advantages and improving attractiveness for FDI in the Campinas region. It is also suggested that future research might provide analysis of the policy-making implications and of whether existing government measures have enhanced Campinas cluster’s social capacity to absorb more advanced (environmental) technologies.

Paper V, entitled "Technological Trajectories and Sustainability: Trends in Brazilian Subsidiaries of Swedish Multinational Corporations", focuses on the technology trajectories that are observable across sectors or industries, and addresses the way in which they refer to the direction of technological advances of products and levels of environmental improvements. This is illustrated by certain sectors of Brazilian subsidiaries of Swedish MNCs as organizational units with ability to positively influence the technological absorptive capacity of the host country.

As research strategy, qualitative document analysis provided the data needed to contextualize the sectors’ choice. Data was obtained from ANPEI and the Technological Innovation Survey (PINTEC). Semi-structured interviews were also conducted at the ABDI to gather technical information as means of supplementing other data.
This study views the final sectors’ choice based on Pavitt’s taxonomy (1984) and the premise that R&D intensity differs greatly across sectors. Selected sectors were pulp and paper, electrical machinery, and information and communication technologies (ICTs). Their respective technological outputs – supplier-dominated, specialized suppliers, science-based – characterize the core set of industrial sectors in the growth of Swedish and Brazilian economies.

Adapted from Brezet (1984), Paper V illustrates the way in which technology trajectories are associated with levels of environmental improvements in the selected sectors. Technology trajectories are empirically examined through product innovation (by using a time scale) and levels of environmental improvement (by factors of impact reduction). They are associated with (a) radical and incremental innovations that are constantly happening in products and processes, such as: a successive, incremental process of environmental optimization in relation to a product; and (b) a sequence of steps towards radical innovation, associated with new products to redefine the market in a new socio-environmental structure.

Pulp and paper’s innovation strategy is based on minor incremental product and production improvements. With a dynamic interplay between customer supplier-relationships and R&D base, the electrical machinery sector is to tackling the greatest impacts across the products lifecycle, which may reach factors of environmental impact reduction. Trends in ICTs technological trajectories encompass continuous innovations in energy efficiency. As a discontinuity at any point, they may be interrupted by a new technological course or radical innovations in products and processes, evolving user interfaces. Additionally, the paper addresses environmental and innovation policy implications for these sectors in Brazil.

Paper V discusses the strategic position that ICTs play within the innovation system’s knowledge chain. However, there is much uncertainty in the future development of ICTs. Efforts have been made to understand the emergence of ICTs, and to assess scenarios of their future impacts on the economy, environment, and society. This study has shown that the innovative behavior of the Swedish subsidiaries and their performance in the environmental sustainability are highly defined by the sector’s characteristics or determinants. A further study could assess trends, uncertainties, scenarios of future developments and strategies for ISs and sustainability that are associated with sectoral implications, efficiency improvements (time, energy and environment), technological trajectories, and the increasing demand for products and services.

Table 2 shows the contribution of the Papers 1-V to understanding ISs for sustainability. Based on concepts derived from Brezet (1997); Kemp (1999); and
Freeman (1996), *Papers II-V* analyze IS framework, in which environmental intervention is matter most likely to condition alternatives towards sustainability. Paper I argues that public and private-specific policies are necessary to meet ISs for sustainability. Appendix II was used to identify aspects of the Science, Technology and Innovation Policy that can strengthen sustainable ISs. Appendix II subsidized Papers II and III to use innovation as the implementation of a new or significantly improved product, which results, in reductions in environmental impacts of resource use, including energy, such as emissions of pollutants and depletion of natural resources.

Though *Papers II-V* emphasize the "environmental" dimension as strategic to understanding ISs for sustainability, the researcher acknowledges the importance of a mode of action in ISs that results from the intersection of three dimensions of sustainability – economic, social and environmental. The "triple sustainability" is a priority condition for organizations, policies and institutions whose interactions determine the innovative performance in ISs.

<table>
<thead>
<tr>
<th>PAPERS I-V</th>
<th>Contribution to Understanding Innovation Systems for Sustainability</th>
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<tbody>
<tr>
<td><strong>PAPER I</strong></td>
<td>Overarchng description of National Innovation Systems (ISs). Recommendations on policy-making in ISs for environmental sustainability.</td>
</tr>
<tr>
<td><strong>PAPER II</strong></td>
<td>Focus on multinational corporation interactions with home-host country ISs versus technological innovative efforts to achieve competitiveness and environmental sustainability.</td>
</tr>
<tr>
<td><strong>PAPER III</strong></td>
<td>A comprehensive vision for the convergence between Regional Innovation Systems (RISs), clustering and environmental sustainability.</td>
</tr>
<tr>
<td><strong>PAPER IV</strong></td>
<td>Focus on the technology trajectories that are observable across sectors or industries, and addresses the way in which they interact with ISs and environmental sustainability.</td>
</tr>
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*Table 2: Outline of the Papers Contribution*

*Papers II, III, IV and V* focus on the attainment of "environmental sustainability", that require companies new entrants to achieve improvements in competitiveness, and environment (including long-term dynamic efficiency, resource productivity and environmental pollution). Companies need to find ways to address production, assimilation or exploitation of products, processes, management methods or business that bring social-economic and environmental benefits. Ideally, companies that cooperate with suppliers, research centers and universities, adopting "eco-efficiency"
practices have a great contribution towards sustainable ISs. This means, companies that develop new or improved products at competitive prices, increasing value, reducing gradually the environmental impacts, optimize the amount of materials and energy, and extend the life cycle of the products. The findings of Papers I-V identify venues for further research to the concept of ISs, which should be significant or not be negligible in all three dimensions of sustainability.
2. Theoretical Considerations

The state-of-the-art in IS approach based on interactive learning, and evolutionary theory of technological change comprise the theoretical background for this study. This chapter offers an overview of the literature review. A first reflection is the understanding of what defines a "system" and how it is structured by components, factors and parts. One of the founders of the scientific Theory of Systems, Von Bertalanfly (1988) defined a system as "elements in standing relationship". As important contribution, Bertalanfly's model emphasizes interrelated elements as inputs, outputs and feedback mechanisms to perform the system's achievements. A distinction between complex and simple systems is also useful for the way understanding ISs. Katz (2006) discusses simple systems based on predictable behavior, small number of components and few interactions among them. While complex systems are those, which cannot be captured by a single perspective tend to remain in a dynamic stability, based on continuous novelty that cannot be fully explained by attributes of functionally. Any system involving technical, economic, societal and personal dimensions has been classified as complex system. Katz (2006) argues that ISs are complex systems. Notably, theory in IS has been influenced by the seminal work of Richard R. Nelson, Sidney G. Winter, Bengt- Åke Lundvall, and Christopher Freeman. Authors’ observations in the following sections 2.1, 2.2, 2.3 summarize the main theoretical streams to this study.

2.1 The Evolutionary View

An important review to the emerging field of evolutionary economics is the publication of Nelson and Winter (1982) titled "An Evolutionary Theory of Economic Change". In this study, Nelson and Winter suggest a theoretical framework at the intersection of different disciplines\(^4\) to mostly define the design of the

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\(^4\) From systems and thermodynamics theories derive the fundamental difference between open and closed systems, the design of qualitative change, path dependency and multi stability. From the biology, the concept of variation gives rise to new species and population approach in opposed to the typological approach proposed by neoclassical theory. The organizational theory, explicitly introduces the notion of organizational structure and internal conflict mediation.
qualitative change in technology and routines of firms and industries; and provide a critical view to the neoclassical economics as being incipient in the interpretation of dynamic competitive among firms.

One can say, the greatest advance in the evolutionary economics in relation to the neoclassical is precisely in recognition of the importance played by the learning in the process of technological change. Dosi and Malerba (1996) indicate key elements that make up the evolutionary theory, including learning as the key mechanism in the process accumulation of knowledge, with different degrees of complementarity. Dosi and Malerba understand knowledge – knowledge creation and diffusion – as the primary source to the innovative process. In Edquist (1997, p.7) the convergence between learning and evolutionary approach appears to be entirely clear: "...learning is one mechanism through which diversity is created... Learning might even be an element in the process of selection".

According to Dosi and Malerba (1996), while the emergence of new products, processes and technologies increase the diversity; the "selection" mechanism became the element that affects the variety of actors in the economic system. Dosi and Malerba show that "institutions" shape the learning process, tending to evolve together the technology, organizational forms, market structures and firms strategies.

The diversity – technical, institutional and organizational – is the basis for the evolutionary analysis of the innovative process in ISs. In this regard, the heterogeneity of resources and skills are the ground to building variations between firms and their levels of competitiveness in ISs (Cohen and Bacdayan, 1994). Firms’ competition strengthens the dynamic of ISs, precisely through their efficiency, effectiveness, and through their capacity in production and diffusion of innovations. In Cohen and Bacdayan (1994), while firms expand their knowledge basis to incorporate new "routines", in the same time they assess strategies, structure and skills to ensure their survival.

Cohen and Bacdayan (1994) support the idea that routines are path dependent events. The issue of path dependent behaviors has been analyzed in terms of organizational learning, and in this regard Cohen and Bacdayan (1994, p.55) write: "the relation that exists between innovative learning processes and routines are patterned sequences of learned behavior involving multiple actors who are linked by relations of communication in the firms". One of most distinctive feature in firms are path dependency and learning, which tend to perpetuate routines and procedures over time – path dependence explains how some organizational decisions are influenced by decisions taken in the past.
2.2 Interactive Learning Theory and Tacit Knowledge

Knowledge has been increasingly regarded as the most critical resources of firms and economies. In this way, the emergence of the evolutionary theory highlights the importance of knowledge. Dosi and Malerba (1996); Nelson (1993); Nelson and Winter (1982) support the premise of knowledge interactions, that is confirmed in Lundvall’s analysis (1992, p.1) that "knowledge is socially embedded and the process of learning is predominantly interactive".

A particular focus has been to the importance of tacit knowledge as a source of competitiveness, involving advantages in capacities and abilities between firms. Admittedly, in firms, technicians and practitioners share a tacit (practical) knowledge to foster expertise, as a collective endeavor, including factors as network, skills, and routines. Nelson and Winter (1982) suggest the use of knowledge as "tacit resource", which lies in an organization’s structure through the routines that the firm maintains.

The learning process has been described to the use, generation and dissemination of tacit knowledge, consisting of a collective activity that integrates the experience of individuals, and organizations. In this regard, Lundvall (1992, 1998) has directed his attention to role of the tacit knowledge in the learning process linked to the interactions between different social actors that, in turn, reflect the institutional conditions. In Lundvall’s idea, tacit knowledge is viewed as the base of the learning, which is shaped by the broader institutional context. This is to say that the institutional context in ISs may support or prevent knowledge linkages and interactions, through which individuals develop learning processes and translate learning into innovations.

2.3 Institutional Settings and Innovation Systems

After the systemic approach to innovation and ISs, the firm has been re-defined as an organization referred to learning, within an institutional context (Nelson and Winter, 1982; Freeman, 1987; Lundvall, 1992, Edquist, 1997). Elsewhere, Edquist has argued that ISs rests on the role of institutions and organizations, involved in every possible stage of innovation process. Edquist (1997, p.43) argues: "innovation systems are
normally defined in institutional terms”. Notably, Edquist and Johnson (1997) provide also useful writing to describe the IS approach, in regard to institutional setting:

"Innovation systems are comprised by institutions as sets of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals and groups" (p. 43).
"Innovation systems include organizations as they are formal structures with explicit purpose and consciously create" (p. 47)
"….the relationship between institutions and organizations influences innovation processes, and thereby also both the performance and change of innovation systems" (p. 59).

Important organizations in ISs are firms – suppliers, customers or competitors in relation to other firms – universities; state agencies as public innovation policy agencies; and the markets organizations and as organizational forms. In this systemic view of IS, the firm innovates through interactions with institutions and organizations to the creation, development and exchange of different types of knowledge. The traditional linear model of innovation⁵ goes beyond the role of basic science and neglects the interaction between different actors; while, the evolutionary and neo-Schumpeterian model highlights the systemic factors such as the "interaction" in the process of innovation.

ISs may reach national, sectoral, regional or local dimensions, which have been used to the analysis and interpretation of the diversity of institutions and organizations that interact as elements of a system. The term "National System of Innovation (NIS)" was introduced by Freeman and Lundvall in the late 1980s. The authors highlight the context of institutions – mainly from the policy makers–which may contribute to the development of technological skills and the process of interactive learning. The critical review and analysis on "NISs" – notably, the contribution of Freeman and Lundvall – seek to understand the innovative performance of firms and economies, and the primary link between national

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⁵ The basic linear model of innovation posits a process that moves from one stage to another: Basic Research -> Applied Research -> Development -> Diffusion/production. The linear model of innovation was described in Godin, Benoit (2006). It prioritises scientific research as the basis of innovation, and plays down the role of later players in the innovation process.
institutions, at the macro-level, to the actors in the system, which result in a complex set of relationships.

2.4 Technological Change and Environmental Sustainability

Why sustainability? Sustainability is a broad concept with growing confluence with futures thinking, imagining desirable futures. Considering the multitude of its definitions, one can argue that it extends beyond the environment to include a constructionist perspective on economic development, climate, society, education, ethics and technology. In this way, bio-physical limits interact strongly with sustainability intentions for the future, together with other categories of limits such as in economic and social.

Today's research in sustainability has focused on scenarios of future developments. For instance, to assess the effects of a Gross Domestic Product (GDP) growth decoupled from the total amount of matter and energy. Yet, one must speculate about social interactions surrounding at each stage of the economic cycle versus lifecycle assessment as production life time, use and disposal.

Technological change can address environmental issues, and, in this way, play a key role for sustainability. Precisely, the process of "technological change", which has been described in terms of the Schumpeterian view, refers to the trilogy called invention, innovation and diffusion. This Schumpeter (1942) distinguished three stages in the process of technological change by which a technology permeates the marketplace. Invention constitutes the first development of a scientific (or technical) new product or process, while innovation is accomplished only when the new product or process is commercialized, that is, made available on the market. Diffusion refers to the importance of continuous learning by individuals and firms. All of these stages comprise the complex process of "technological change", which result in the cumulative socio-economic and environmental impacts of new technology in an IS, in its respective institutional and organizational structure.

This thesis closely follows that of the Kemp study. In a major study, Kemp (1999) has found the significance of evolutionary theorizing on technological change aiming to move into a more environmentally sustainable direction. It draws attention to the links between technological change, institutional change, and a growing environmental awareness at the supply and demand side to address environmental problems. In Kemp (1999) appears the idea of co-evolution of technology lock-in,
resource management and policy tools to understand how social, technical and environmental systems have evolved together. About ISs for sustainability, the co-evolutionary view became a focus of attention for policy makers. They have been facing a demand of selection between an existing (dominant) standard lock-in technological system and an optimized (changed) clean technological and sustainable system.

It is likely to be necessary for policy-makers to focus on how alternative types of environmental policy instruments affect the rates and directions of technological change; or to focus on how the effects of environmental protection interfere with the success or failure of new technologies. An existing controversy in environmental policy refers particularly to its effectiveness. A question is to what extent environmental policy provides incentives for firms to adopt a cleaner technology; or to turn R&D investments into innovations as new pollution control equipment for environmentally harmful products. Jaffe, Newell and Stavins (2005, p.168) conclude: "the efficiency of environmental policy depends on its consequences for technological change, and also there is a potential role for policy aimed directly at the stimulation of environmentally beneficial technological change".

While some questions appear to understand the relation between environmental regulation and technological change: How alternative types of environmental policy instruments affect the rates and directions of technological change? How effects of environmental policies interfere with the success or failure of new technologies? Scholars have analyzed the effect of environmental policy on technology adoption and diffusion, Magat (1987) and Ulph (1998) for instance. In 1987, Magat analyzed the effect of environmental policy on technology adoption and diffusion, comparing environmental policy instruments (market-based and regulatory instruments called command-and-control) environmentally-related taxes, subsidies, emissions trading, permits, effluent standards, and technology standards, Magat shows that all instruments induce incentives to innovation; and technology standards induce innovation and emissions reduction in the same time.

Ulph (1998) verified the two competing effects of pollution taxes and command-and-control standards on the levels of R&D. As conclusion, Ulf finds both "increasing" effects on costs and on incentives to investments in R&D direct effects are observable as reduction of product output and reduction of incentives in R&D.

Insights between environmental policy and innovation are found in the so-called Porter hypothesis (Porter, 1991) to a "win-win" situation – i.e. that all parties could possibly benefit from it. That means, environmental policy improves competitiveness, by stimulating innovation, which enhances the firm’s productivity.
In the same way, Porter and van der Linde (1995) affirm that strict environmental regulations lead to an increase in productivity of market output. The question is, how such environmental regulatory may be applicable to ISs for sustainability, expecting that the use of environmental policy tools may stimulate environmental innovations, renewable energy technologies, R&D and pollution prevention to meet socio-environmental-economic goals.

The co-evolutionary process in ISs includes pressures on resource availabilities, environmental conditions and shifts in technological regimes (techno-environmental regimes), which results in the techno-environmental impacts (e.g. the loss of biodiversity, water and soil pollution, waste). Techno-environmental regimes presuppose patterns of production of organizations (firms, buyers, suppliers) underpinned by technological trajectories, which may be associated with accumulated knowledge, available skills, and environmental impacts. In Gray’s (1989) technology can be perceived as being simultaneously as both the case or as a way to solve environmental problems. One can say the use of technology minimizes the energy and resource inputs, and brings at the same time social-economic alterations (materials and energy efficiency increases in production and consumption). This implies in environmental problems with high degrees of complexity.
3. Science, Technology and Innovation Policy in Newly Industrialized Countries (NICs): the Brazilian Experience

Brazil occupies an outstanding position, mainly for the country’s GDP (gross development product) worth of 1572 billion dollars or 2.54% of the global economy, ranking among the world’s ten leading economies (IMF, 2011). Brazil’s GDP is projected to grow 3% in 2012 and 4%-5% in 2013. FDI inflows into Brazil have been affected by the natural resource factor, but they are largely attributable to the presence of a sizable market and low-wage labor. Brazil has been successful in attracting FDI and ranks as one of the most interesting destination amongst industrializing countries, through its well functioning legal system, its structural reform of trade and its financial liberalization policy.

G. Arbix, the President of the Brazilian Innovation Agency (FINEP) (pers. comm., May 19, 2011) outlined three key types of government strategies for S&T: The first strategy on a limited capacity-building in science and in organizational aspects, which presents programmatic restrictions for R&D, technology diffusion and learning. The second refers to S&T policy issues that contribute to the partial incorporation of technical knowledge in the productive process. Such policy might not be sufficient to ensure the country’s technological upgrading so as to “take off” – as in the case of of industrializing countries. The third strategy seeks significant achievements in S&T, as well as R&D efforts that form an integral part of the economy – this strategy characterizes industrialized countries that have been able to successfully establish innovation. As Arbix remind us, the Brazilian strategy for these two outstanding components, "science" and "technology" do not yet interact to sustain the country’s economic growth. This chapter briefly presents STI in Brazil, as well as targeted programs aimed at developing these priority fields.

3.1 Brazil in the Context of the BRIC group

From the 1990s, the economic success achieved by NICs is due to the positive aspects of the exploiting of their comparative advantage in labor-intensive products, their emphasis on industrialization and the opportunities offered by the international trade. In the post-war period, NICs have tried to integrate S&T with economic development
and some of these countries have ascended to a BRIC (Brazil, Russia, India and China)\(^6\) economic status in the world system. According to UNCTAD (2010), annual average growth rates of real GDP of BRICs in 1992-2007 amounted to 9.5%, in case of China, and 6.5, 2.6, 2.7, respectively in the case of India, the Russian Federation and Brazil (UNCTAD, 2010, pp. 422-428).

The BRIC’s thesis by Goldman Sachs (Firzli, 2011) discusses the economic trends and points out that China and India by the year 2050, will become the global dominant suppliers of manufactured goods and services, while Brazil and Russia Federation will be similarly dominant as suppliers of raw materials. Brazil’s potential program on renewable energy also ranks the country in favorable global position. Since the economic crisis of 2010, growth in the BRIC countries has also declined, because they are closely linked to the global economy, mainly to the industrial countries through financial flows. However, compared with the growth of traditional industrialized nations, the economic figures are still impressive.

Brazil ranks third most attractive destination for foreign investments amongst BRICs. The country’s incentive structure is stronger than in India and Russia, offering significant financial incentives to attract business as tax holidays for investors and exception from import value-added tax (VAT). Most foreign investments in Brazil have been made with a bias on the technological aspects of the economy.

It is well known that adaptations of products, processes and materials are the main type of R&D that MNCs do outside their home country. Except in the case of countries like China and India, MNCs have taken advantages of local expertise, since these countries offer technology leadership in certain fields (Gryczk, 2010). These countries are in fact gaining on importance in international trade of high-tech products and knowledge-intensive business services. Brazil offers capacity building in certain areas (e.g., in biofuels) that allow the use of local strengths in R&D of new products

\(^6\) BRIC is an acronym used to the prominent countries of Brazil, Russia, India and China, which are seen as potential economies to be at a similar stage of newly advanced development. The acronym was coined by Jim O’Neill, Goldman Sachs, in a 2001 report entitled "Building Better Global Economic BRICs" It has come into widespread use as a symbol of the shift in global economic power away from the developed G7 economies towards the developing world (Firzli, 2011). BRIC countries share opportunities and common challenges. South Africa joined the Group at the third Summit in Sanya, China in April 2011. The agenda of BRICS meetings has considerably widened over the years to encompass topical global challenges such as international terrorism, climate change, food and energy security, Millenium Development Goals, international economic and financial situation.
and processes. Gryczk (2010) points out "evidence of a relatively slow, but inevitable technological change in all BRIC countries" (Gryczk, 2010, p.91).

In this concern, government plays a major role in influencing the rate of technological change by means of R&D investments, S&T policy, patents, and competitiveness. The Brazilian experience show decision to acquire high technology capabilities based primarily on the desire to exploit relative advantage in skilled labour and engineers. Brazil’s strategy is to lessen technological dependence, which is conditioned on the country’s existing technological capacity, S&T human resources, and infrastructure.

BRICs have a common goal of industrial upgrading, though with different degrees of emphasis, and different strategies of state intervention. Overall, Brazil, Russia, India and China have upgraded their traditional export sectors, with increasing of efficiency and value-added in their production and marketing, e.g. consumer electronics, and electrical components. The four countries have also moved into some new product lines, such as biotechnology, telecommunications, electronic equipment. BRICs have realized the need to catching up with advanced economies, which require better performance in higher technology production and exports; besides to diversify their economic links geographically, and to reduce the excessive trade dependence on select markets. In particular, Brazil’s industry development and its insertion into the global economy face the government’s decision about pros and cons of controversial issues of the country to become a commodity exporter of natural resources.

It is undeniable that the BRICs countries have the challenge to significant efforts in the accelerating technological change. This is conditioned by the countries’ capacity of technology assimilation and indigenous technical efforts to diffuse technologies within the country. It also depends on the BRICs countries' economic diversity, social policy, and development of networked human capital. Today, eleven years later of the O'Neill’s neologism the BRIC acronym became a component of economic forecasts and business. Brazil, Russia, China and India are increasingly gaining importance, not only economic but also political. BRIC countries have recently initiated national plans and policies on energy efficiency, climate change and adaptation. The emission targets of each country are differentiated, with relation to air pollution and climate, as well as they have distinct sustainability strategies. They also differ in terms of guidelines for environmental policy. While Brazil has more advanced positions, Russia, China and India have worked for the enforcement of environmental laws and One can say that the BRICs socio-economic development has
not yet ensuring the improvement of the country’s sustainability levels and environmental performance.

3.2 The Science, Technology and Innovation (STI) Policy: To what extent is it environmentally oriented?

S&T policy, which plays a role in generating scientific and engineering research and development, has considerable potential to enhance a country’s response to societal challenges. Historically, the Brazilian S&T policy built up its institutional framework through the creation in 1951 of the two country’s public agencies, the National Council for Scientific and Technological Development (CNPq) and the Coordination for the Improvement of Higher Education (CAPES). The agencies aimed to clearly advance research and S&T, and represented remarkable contribution to the country social development through S&T and education.

With considerable budgets, CNPq and CAPES have taken a somewhat research community view of what S&T is. As discussed by Viotti (cited in Serafim and Dias, 2010, p.27), in the 1990s, "innovation was incorporated in the very core of the S&T policy", and the Brazilian S&T policy has become closer to industrial policies, with focus on private companies and competitiveness. Rather than result of political pressure from stakeholders, strategically, this was an action on behalf of the scientific community to update the S&T agenda (Serafim and Dias, 2010). This change has greatly benefited the innovation process in Brazil, as well as influence the key role R&D play in national companies’ choices about to work on. In fact, following Serafim and Dias (2010) innovation for competitiveness suggest strictly economic frame in the Brazilian STI policy. Overall, STI in Brazil has kept distance of the linkages between policy outputs in pursuance of decisions, policy outcomes as societal consequences, and issues as human intervention on the biophysical environment.

An important instrument in the federal R&D funding in Brazil refers to the sixteen sectoral funds by the Ministry for Science and Technology, established by law during the period 2000-2002. These sectoral funds better detailed in Paper I, introduced targets for government to benefit selected firms’ R&D projects, and they are partially used for joint ventures between the public and private sector. Sectoral funds are in the prospect of additional sources of funds to strategic sectors of the country and they play a role in the regions North, Northeast and Central-West since at least one third of each sectoral fund has been spent in these areas of the
country. The eventual analyses of sectoral funds and their respective credit instruments have shown impacts mainly in the technological efforts. Despite the importance of programs in the scope of S&T, Serafim and Dias (2010, p.26) make the point that "sectoral funds have been seldom evaluated". In order to determine what extent sectoral funds are environmentally oriented is necessary to verify which funding mechanisms predominate in the production of S&T, and whether they are including environmental issues.

Similarly to other instruments used to foster innovation at the firm level – such as the fiscal incentives law, the Informatics Law, the Innovation Law and the R&D Tax Credit Law – the sectoral funds are institutional funds with the aim to increase firms’ technological efforts and R&D expenditures, levels of productivity or exports. Although the funds aim to benefit firms, up to now there is no evidence to support their ability to add or crowd-out effects on firms’ environmental R&D investments.

Recent efforts of the government to make S&T more "environmentally-oriented" refer to the National Fund for Scientific and Technological Development (FNDCT). Between 2007 and 2010 the FNDCT introduced significant changes to support S&T in the Amazon region, committing resources to a range of research initiatives in the areas of climate change, biofuels, and energy. Brazil has advanced and, even with disabilities, taken the first steps required to review STI policy in the context of sustainability. The STI institutional deficit remains a challenge with priority to critical areas such as energy management, energy efficiency, and energy use and preservation coupled with clean technologies.

My experience at SECTES (see item 1.4) offered me insights into the local view of policy makers on S&T policy, which sees such policy as being designed to support education and research, and to focus on Minas Gerais State’s economy areas like mining, agriculture, water, and energy. Policy-makers at SECTES take a somewhat economic view of what S&T is. The challenge is to take a view of economic and market incentives as instruments of environmental policy to be included in guidelines of the STI policy. Rather than a hierarchical structure of organizations, the task of S&T systems is to take into account sustainability and environmental aspects, along with other cultural and economic factors, so that both societal benefits and the preservation of natural resources are enhanced.

Significantly, the international community has acted in favour of S&T for sustainability. An important point has been the work of the Task Force on STI towards meeting the Millennium Development Goals (MDGs, UN, 2000). This Task Force target the principles of sustainable development into country’s S&T policies to reverse the loss of environmental resources. The recent UN Conference Rio + 20
agreed to propose sustainable development goals (SDGs) to succeed the MDGs in 2015. The agenda of SDGs offers an opportunity for sustainability to move to the mainstream of STI policy, considering that ideas of "innovation" and "green economy" could be interrelated in the ground concept of sustainability.

Brazil’s task is to rethink the bases of Brazilian STI policy reorienting such policy towards STI planning, evaluation and reform, in order to support an enabling condition for environmental sustainability. This rethink relates to the competence of the Brazilian scientific community and policy-makers to define parameters for investments in environmental R&D. Thus, better co-ordination of the Brazilian STI policy and environmental policy is a condition that must be taken into account in both the rationale of the scientific community and by policy makers. The following three points are seen as critical to this task: (i) the understanding that STI are elements that are embedded in the subject of environmental preservation; (ii) the recognition that environmental policy must takes into account the STI component and vice versa; and (iii) the acknowledgement that in the current policy bases, the S&T capability is insufficiently linked to natural resource endowment.

3.3 The Innovative Behavior

The search for technological capacity building has commenced shortly after the economic opening in Brazil from the beginning of the 1990s. This *momentum* has referred to a strategic plan for technology support and capacity-building efforts. The implementation of the "Programme of Support to Industrial Technological Capacity- Building (1990)" and the "Brazilian Programme of Quality and Productivity (1993)" led to the Government to support projects and research at industrial level, and provide a basis for the development of public-private partnerships. Despite positive results, Brazilian companies in general, still find themselves falling a long way behind the goal of reaching the standards currently required for global competition.

Data from the Brazilian Development Bank (BNDES, Annual Report 2012) show evidence of negative outputs for Brazilian companies, with their high costs of physical infrastructure, insufficient R&D effort, weak ties with universities and research centers. There is also the occurrence of emerging small business without productive interaction and cooperation, especially in terms of new technologies. Two aspects highlight the Brazilian technological performance: "tenuous” industrial competitiveness in all highly aggregated complexes and technological contents; and
the limited number of large Brazilian entrepreneurial groups.

In order to overcome this technological deficit, the Brazilian State has promoted mechanisms of incentive for the development of technological innovation of product and processes. The "IT Incentives Law" no. 10176 was approved in January 2001 by the Ministry of Science and Technology (MCT). The IT Law was designed to stimulate the development of national R&D projects and to provide tax-exemptions on Industrialized Products (IPI) and Reduction of Income Tax (IR). It requires beneficiary companies to allocate stipulated annual investments to R&D, consisting of 5% of their revenues brought in through IT goods and services. In turn, this 5% is distributed for in-house applications (2.7%), and the remaining 2.3% must be allocated to research or education centers or institutes, part of which must compulsorily be spent in the Northeast, Amazon or Mid-West regions and part of which must be deposited into the FNDCT.

The actions under the updated Industrial, Technological and Foreign Trade Policy (PITCE) directives fell into a variety of categories, requiring new legislation, regulatory changes, and financial strategy. Two central pieces of legislation directly linked to innovation and technological development are the Innovation Law no.10.973/2004 and, the R&D Tax Credit – known as the "Good Law" no. 11.196/2005, which was voted in 2008. The Innovation Law sets out a host of provisions to encourage R&D and strategic partnerships between universities, research institutions and firms. It regulates technology transfer between agents; and provides subsidies and funding for these activities. Brazilian R&D Tax Credit grants exemptions on a number of value added and social contribution taxes, incurred on innovation projects (tax deductions may reach 30% of expenses on innovation).

As the UNESCO Report (2010) shows between 2002 and 2008, the intensity of gross domestic expenditure on R&D (GERD) increased by 10%, from 0.98% to 1.09% of GDP. Over the same period, GDP grew by as much as 27%, from R$ 2.4 trillion to R$ 3.0 trillion. Thanks to the economic growth, in 2010, Brazil invested 1.3% of GDP. The goal is to raise science spending to 2% of GDP by 2020. Brazil lags however, behind BRIC countries in terms of R&D investments.

Another critical issue is that although R&D investments in Brazil have grown considerably in recent years, the rate of innovation in companies remains low, according to UNESCO Report. Today, Brazil has 58.3% of its researchers working in universities, 5.1% is in the government, and only 37.3% is in business (in China, for example, 66.4% of researchers is in the business sector).

In the understanding that the country’s industrial technological knowledge base remains restricted in terms of critical mass of R&D and patenting, the government has
invested in mechanisms and laws of incentive as mentioned. As well as, the government has directed attention to proposals that aim to strengthen the R&D system. For instance, the recent launched mobility program "Science without Borders", focuses in areas of special interest for the country. Science without Borders’ objective is to consolidate the STI in Brazil by means of international exchange, includes scientists and industry personnel and the strategy envisioned aims international partnerships and the internalization of Brazilian universities and research centers and their interaction with foreign partners.

Mostly R&D activities in Brazil have taken place in universities, even though the specific legislation – the Innovation Law – has allowed the number of university-industry partnerships to steadily increase over the last few years. Especially, companies in some states – São Paulo and Minas Gerais –, and in some sectors – state owned and private companies in the electricity, petrochemical, oil and gas sectors – have gone into partnership with universities in order to gain access to technology development, knowledge assimilation and operational expertise. Still remain incipient the role of inter-organizational networks in influencing mutual and interactive learning, and the country’s technological development. Weak ties between university-industry in technology collaboration networks have characterized the Brazil’s innovation system, and networks with the involvement of researchers, industrialists, and government staff to build a stronger basis for R&D. Brazil thus, faces a major challenge to intensify innovation and competiveness, requiring the creation of conditions to business R&D, and greater interaction between the public and business research communities. Leal (2002) emphasizes how important innovation is to Brazil as an industrializing country, and as it strives to realize its economic potential.

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The mobility program aims to launch the seeds of what could revolutionize the Brazilian R&D system: students and researchers with international experience of high competitiveness and entrepreneurship.

Twenty three Swedish universities are participating in the Ciência sem Fronteiras program. During the 2013 and 2014, higher education institutions in Sweden will welcome a total of over 2,000 Brazilian students. Seats will be available at the undergraduate and postgraduate (master) level.
3.4 Multinational Corporations and the Internalization of the Brazilian Market

"Internalization theory" proposed by Rugman in 1981 (cited in Archibugi and Pietrobelli, 2003) offers a frame for the study of the MNCs. But Archibugi and Pietrobelli (2003) prefer the expression "globalisation of technology" to describe the forms of internalization of R&D adopted by MNCs. Archibugi and Pietrobelli suggest that globalization of technology falls into three categories: the international exploitation of technology produced on a national basis; the global technological collaboration; and the global generation of innovations, which refers to the MNCs and R&D both in the home and host countries. This refers to acquisitions of existing R&D laboratories or R&D centers investment in host countries.

According to Carlsson’s analysis (2006, p.1), the globalization of technology refers to "the way NISs are becoming internationalized, even if the institutions that support them remain country-specific". Carlson discusses how MNCs take advantages through knowledge spillovers and knowledge absorption and how internalization of R&D is about. Carlson reviews NISs as vehicles for internalization of technology, and how to estimate the importance of the relationship with MNCs. Carlson (2006, p.1) argues: "on the extent that the far more numerous studies of internationalization of corporate R&D discuss innovation systems at all, they point to the continued importance of national institutions and policies to support innovative activity, even though that activity is itself becoming increasingly internationalized".

Traditionally, the process of internationalization of the Brazilian economy has been based in the presence of MNCs and their significant R&D investments in the country, contributing to its modernization, and resulting in a more competitive economy. In the 1990s, Brazil adopted the trade liberalization and FDI liberalization, expecting that this strategy would promote the development of the country’s a virtuous circle of innovation and industrial development. The volume of FDI inflows in Brazil surprise positively. According to data released by the Central Bank of Brazil, at December 2010, the country's FDI totaled US$ 60.4 billion. This was reflective of an annual growth rate of 63.9 per cent, the highest since 2000. FDI should reach U.S. $ 65 billion in 2012.

Innovation research carried out in Brazil by the IBGE’s Industrial Survey on Technological Innovation (PINEC 2008) provides data for subsidiaries of MNCs quite active in R&D and foreign companies as more innovative than domestic companies. Between 2006 and 2008, about 61% of foreign companies introduced innovations, compared to only 38.41% of domestic companies. Data displayed some
advance on the percentage of innovative industries in Brazil. They grew 21% over the past eight years as compared to 31.5% in 2000, and investments on R&D grew about 48% in 2005 as compared to 2008.

The influx of Swedish FDI to Brazil traditionally characterizes the capital mobility and diffusion of embodied technologies from North to South. One can say, the number of over 200 subsidiaries of Swedish MNCs in Brazil is significant, while their operations turn over USD 14 Billion per year (Swedish Chamber of Commerce, 2011). To a large extent, Swedish MNCs illustrates quite well the engagement of foreign subsidiaries in R&D. They have established R&D units in Brazil and some of them have diffused innovation in both production processes and product design (Veracel, Scania, Relacom, AGA, Alstrom, Electrolux, Skanska, Tetra Pak, Ericsson and Sandvik). This has been characterized as a technological effort of strong penetration of "certain sectors" of MNCs in the Brazilian economy8. The case of the telecommunications sector shows the experience of technological accumulation capabilities. In this regard, Ericsson subsidiary in Brazil has a successful process of technological accumulation, due to its increased R&D investments mainly to benefit from the fiscal "advantages of the IT Law". The former Ericsson Excellency Systems Development Center was created only to adapt equipment to the Brazilian market. In 2001, Ericsson's R&D lab in Indaiatuba (São Paulo) was opened and over the years, the local team has developed competences and capabilities. Currently, Ericsson's R&D's unit researchers create software programs, which have been used in global machines.

Otherwise, only in recent years, Brazilian companies have conducted their R&D activities globally to be closer to the market and to gain access to know-how. The decision of Brazilian companies making FDI since the 90's is a way to sustain their growth achieved internally in previous periods. About this late process, the proposal was to increase in exports, international acquisitions, as well as the consolidation of Brazilian trademarks in foreign territory. The primary focus of foreign investments was the establishment of overseas production units, sales offices and technical support services to ensure exports. Foreign investments are attributable to commercial goals, driven to especially Latin American countries, playing important role in the markets exports.

Since 2000, the internalization of Brazilian companies has risen rapidly, reaching such a level of competitiveness and international respect. Brazil is highly

8 The auto industry (Volvo) is an example of the gradual process of accumulation of technological capabilities by subsidiaries of foreign companies. Other examples refer to segments in the machinery: electrical equipment, aerospace and defense, engineering and construction.
competitive in some high demand international commercial sectors such as food, cellulose, petrochemicals and iron ore.

The Brazilian multinational energy corporation Petrobras – as pioneer in international expansion – and the mining company Vale, formerly known as Vale do Rio Doce are example of remarkable technological alliances and internationalization of R&D activities. Brazilian top ten multinationals stand out as global players. This is also part of a peculiar process, in which multinationals from the BRICs countries expect to play a role in the global economy. In Cyrino, Oliveira and Barcellos’s view (2010, p. 93) "Brazil’s international insertion is still extremely timid, when compared to developed countries and those countries, which are deemed to be at a similar stage of newly advanced economic development".

According to Cyrino, Oliveira and Barcellos (2010), the internationalization of the Brazilian companies is intrinsic and possibly critical to the development of the economy over the next few years. As the limitation for the international expansion is the low involvement of Brazilian companies in R&D. Motivation is the development of products and services, which derive from intensive efforts to create new technologies, applications for patents and global product development. The relationship with international suppliers, customers and competitors also represent a way of internationalisation and international growth of the Brazilian companies.

The Brazilian Development Bank (BNDES) has increased support to the internationalization. Since 2009, its subsidiary based in London, as an investment holding company, has the task to support Brazilian companies in the international market. In May 2010, the BNDES created its new subsidiary, EXIM Brazil, an export credit agency with the purpose to finance or raise capital of companies undergoing the internationalization process. BNDES’s international operations represent a governmental endeavor to consolidate the competitiveness of the Brazil’s economy in the global market.

Apart flows of private investment, the internationalization of R&D occurs through other number of ways (OECD, 2008). This includes transnational scientific collaboration or joint ventures, co-authorship of publications and intellectual property rights, international mobility and availability of skilled human resources. As the case

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9 Vale do Rio Doce (CVRD), Petrobras S.A., Gerdau S.A, EMBRAER S.A, Votorantim Participações S.A, Companhia Siderúrgica Nacional (CSN), Camargo Corrêa S.A, Odebrecht S.A, Aracruz Celulose, Weg S.A., Itau Unibanco Holding, Eletrobras, Banco do Brasil, Bradesco. The internationalization of Brazilian companies is dominated by the private sector, although state-owned enterprises also play a role (BNDES, 2012)
of this researcher, skilled human resources based overseas to remain in contact with
the home country is also be expected to promote the internationalization of R&D,
through diffusion of the knowledge and experience gained

In this chapter, the researcher develops a framework that highlights the importance of environmental sustainability in ISs. It is presented in line with a series of theoretical accounts that are considered relevant and useful with regard to the aim, questions and analysis of the research. Closely following Melville (2010, p.4) "a framework for issues spanning IS and environmental sustainability may encompass the full range of analysis levels and theoretical perspectives". The framework presented here illustrated the cases of the Brazilian subsidiary of the Swedish multinational Ericsson and the Brazilian multinational USIMINAS S/A.

The framework draws upon the theoretical views of Freeman (1995); Lundvall (1992); Nelson (1993); Nelson and Winter (1982); and Kemp (1999). It is associated with the systemic view of ISs, which recognizes that they involve a variety of actors to the interactive process of innovation, "within and beyond the firm". From this systemic view, innovation transcends the sphere of the individual firm, being dependent of the "new" knowledge that is tacit, and encoded or explicit; and dependent of the continuous interaction within the firm and between firms and institutions.

From this systemic approach, Nelson and Winter (1982) see the interactive process as a way in which explicit and tacit modes of knowledge can affect the firm’s absorptive capacity. Nelson and Winter suggest that the status of both the tacitness and explicitness of knowledge can differ within an interactive process (an idea supported by Dosi and Malerba (1996). Recent studies suggest the evolution of a NIS based on the importance of firms as micro agents that compose its knowledge base and interact with its macro structure of policies and rules Dosi and Malerba (1996).

The underlying assumption of this framework is that macro (policy-oriented) and micro (individual firm) levels interplay in NISs forming a setting where the overall process of innovation and the diffusion of technology can both be applied in order to address issues of sustainability. The study of NISs from the evolutionary perspective thus allows a macro-micro framework (Figure 3).

The "national" specific-analysis of ISs by Freeman (1987), Lundvall (1992), and Nelson (1993) is the level at which the structure of ISs is revealed in industrializing countries (as well as in industrialized countries). Freeman, Lundvall, and Nelson agree that "NISs" is the appropriate level of analysis for primarily focus on the country’s
knowledge base, practices, policies and guidelines. Freeman (1987, p.1) defines NIS as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies". Lundvall (1992) highlights the performance of NIS as the main factor of interaction through which country-specific patterns of scientific, technological and economic specialization over time affect linkages between producers, suppliers, users and the science system. Before presenting a discussion of the framework employed in this thesis, the concept of NIS is examined in terms of its sectoral approach and relation to sustainability.

![Figure 3: Macro-Micro levels in National Innovation System(s)](image)

### 4.1 National Innovation Systems (NISs)

On the supply side, public intervention in NISs focuses on the role of government to correct science, technology and innovation market failures, namely through building human resources, R&D, and addressing institutional mismatches between (public) knowledge infrastructure and market needs. In the NISs of newly industrialized economies, market failures in industrial and technological development often persist unaddressed.

A synthesis in Goulder and Mathai (2000) suggests simultaneously two market failures in the non-appropriability of returns: (i) one market failure attributable to external costs from environment, (ii) and one attributable to innovation. In this context, Jaffe, Newell and Stavins (2005, pg 1) argue: ..."market failures associated with environmental pollution interact with market failures associated with the innovation and diffusion of new technologies...these combined market failures provide
a strong rationale for a portfolio of public policies that foster emissions reduction as well as the development and adaptation of environmentally beneficial technology".

This double market failures associated with environmental pollution, innovation, and diffusion of new technologies, provide a reason for public policy intervention in NISs. In this case, policy-makers are required to focus on the ways in which alternative types of environmental policy instruments affect the rates and directions of technological change. They may focus on how the effects of market policy instruments as pollution taxes, subsidies, permits, effluent standards, market barrier reductions and technology standards provide incentives to companies to engage in R&D. Or policy-makers may drive attention on how environmental policy instruments minimize impacts on the use of energy, resource inputs and materials; and thus on public goods (see Ulph 1998).

The idea of the interaction (co-evolution) between NISs and sectoral patterns of innovation has been particularly important. This is consistent with various empirical studies that have previously shown that the interactions between innovative firms, technological trajectories, the science system, and users vary across sectors, and they are considerable affected by country-specific institutional factors (Castellacci 2009; Nelson, 1993). Correspondingly, some studies point out sector-specific technological trajectories and specialization patterns over long periods of time (Archibugi and Pianta, 1994; Pavitt, 1984), which have contributed to the approach taken in relation to NISs.

Empirical studies have also emphasized Kemp's analysis (1999) and have related Kemp's theory (2008, 2011) of technological change to environmental sustainability. Kemp refers to changes in production processes that go beyond the control of particular pollutants and are referred to as technological regime shifts. Notably, in NISs technology plays a role in any shift from production improvements to environmental sustainability. Prospective technologies will therefore be important for this transition.

The policy level has a significant role to play in the shift to sustainability, and affects the entire NIS. Regulations and governmental decisions affect in particular innovation strategies, industrial strategies, environmental regulations, and upstream linkages between suppliers and innovative firms. According to Lundvall (1998), through a wide variety of policies, schemes and regulations, policies can directly affect cooperation patterns, inter-sectoral linkages and university-industry collaborations.

Castellacci (2009) also argues that a broad range of other country-specific factors of a social and cultural nature have affected NISs. In fact, NISs, as such, are shaped
by, the degree of cooperation in the system and, in a related manner, the intensity of
inter-sectoral linkages and the exchange of knowledge. As suggest by Powell and
Grodal (cited in Castellaci, 2009, p. 341) "network interactions and systemic
relationships are in fact embedded in, and co-evolve with, a complex set of social and
cultural factors that are specific to a given national framework". Social capital defined
by Westlund and Adam (2010) in terms of the relations between individuals in
networks, and the social, and economic benefits that result from those relations, also
increases the efficiency of action and cooperative behavior: this is hence central to
value creation in NISs.

4.2. Knowledge, Technological Change and
Evolutionary Processes

While Mokyr (2000) describes the study of evolutionary phenomena whereby key
units of analysis over time include ideas and techniques, Fleck (2000) analyses the co-
evolution of artifacts, knowledge and organizations in technological innovation.
Mokyr and Fleck have in common their emphasis on the importance of mechanisms of
selection, as well on the relevance of knowledge in shaping technological change.

Mokyr (2000) puts forward practices, artifacts and firms as useful units of
analysis for the processes of natural selection over successive generations, adaptation
and, variety. Fleck (2000) insists on the importance of interdependence between the
three units, and discusses the scale or unit at which, the evolutionary framework
becomes most revealing in terms of replication, variation, selection and differential
transmission. Fleck writes that this scale ranges from the artifact-activity to sets of
ideas such as the knowledge base for individual firm.

Mokyr demonstrates knowledge as the set of useful knowledge, $\Omega$, and the set of
prescriptive knowledge, $\lambda$. Useful knowledge resides in practices and $\Lambda$ is the
application of knowledge in technology. In a contextual analysis, Mokyr (2000, p.54)
said: "mapping from the set of useful knowledge $\Omega$ to the set of feasible techniques $\lambda$
must be one of the central notions in any revolutionary model of technology"; while
in Fleck (2000, p. 255) "a focus purely upon knowledge... makes the evolutionary
problem very tough. It is difficult to put boundaries around an idea... a focus on the
knowledge underlying the development of technology is also necessary but not
sufficient”. As in the case of a firm, useful productive knowledge $\Omega$ cannot be fully
codified, but involves tacit elements – both technological and organizational – that
can be learned only through practice. Firms apparently have different capacities to do
this, and *learning* is complex as a consequence of deliberate investments in activities designed to improve performance. Fleck and Mokyr’s studies draw attention to interactions between "what" knowledge and "how-to" knowledge in technological change.

Kemp (1999), nominally writing about the policy instruments for promoting environment-enhancing technical change, emphasizes the role of policy-makers, and suggests that the design and use of policy is associated with institutional arrangements to a degree greater than the details of policy instruments. In terms of Kemp (1999, 2008, 2011) the co-evolution of technology and the environment has become the focus of attention for policy-makers, who are required to select between an existing (dominant) standard lock-in technology and an optimized (changed) clean technology. One can say the formulation of institutional policy for sustainability has to consider how alternative types of environmental policy instruments affect rates and directions of technological change, and analyze how the effects of environmental protection efforts interfere with the success or failure of new technologies. Without *marked-based* policy instruments as financial incentives for businesses to exceed control targets, *command-and-control* policy instruments for pollution control force firms to use technology-based standards, which specify the method, and sometimes the equipment, that firms use to comply with a particular regulation.

4.3. Conceptual Framework

Given the potential for value creation in the IS domain, and in order to ground the framework structure, the study assumes that *ISs for environmental sustainability are evolutionary, natural resource-based, and internationally oriented.* This concept expresses the efficiency with which an IS generates value from the use of natural resources, (non-renewable) energy resources, and non-energy primary products. The added-value of the evolutionary view refers to the interactive process of knowledge, learning and capacity building as the way to in which ISs escaping lock-in into unsustainable technologies. At national level, ISs for sustainability lie mainly in the linkages constructed between economic activities, production and user practices, the whole range of institutions that form an NIS, and cultural and social infrastructure. This presupposes that NISs with a basis in S&T capacity-building and knowledge access *manage observable environmental impacts.* The primary implication of this is co-ordination across a set of policies, including S&T policy, innovation policy, environmental policy, economic policy, industrial policy, and ultimately social policy.
This framework is consistent with the study of NISs using the micro and macro level variables. As suggested by the Organization for Economic Co-operation and Development (OECD) (1999) in the NIS analysis, while the scope of the micro level is the individual firm, the scope of the macro level is institutional. According to the OECD’s guidelines (1999): "the micro level focuses on the internal capabilities of the firm and on the links surrounding one or a few firms, and examines their knowledge relationships with other firms and with non-market institutions in the innovation system" (OECD, 1999, p.24).

Macro Level

At the macro level, the framework underscores the mediating role of policies to link variables as strategies of firms/sectors with the natural environment, and with the innovation and overall process of the technology diffusion. Kemp (1999) discusses that policy influences the direction of technological trajectories and technical-environmental shifts in firms, for instance towards cleaner technologies, which refer to the significance of induced technological change. In Kemp’s view, escaping lock-in into unsustainable technologies goes beyond of the policy instruments to include technological conditions, structural and cultural factors. In this context, the framework considers the importance attached to the set of established policies as institutional arrangements (Lundvall, 1992; Nelson, 1993) to the issue of environmental technological change in NISs.

Figure 4 shows a traditional NIS model. Primarily, the model focused on S&T as source of innovation and competitiveness, with emphasis on basic research, management of S&T investment, training of human resources and R&D personnel. As the concept of NIS advanced, it was addressed over development of frameworks in the analysis of the knowledge used in innovation, in terms of S&T structure, and in the view of the complexity of the inputs and outputs for R&D.

In industrialized economies, since the 1970s, S&T for innovation became the focus to enhance competitiveness and industrial development. However, it is only in recent years that industrializing countries have integrated understanding of innovation, S&T and human resources in the formulation of national strategies affecting the economy, trade and industry. Since the 1990s, these countries have assessed the role of S&T and innovation policies, given emphasis to the acquisition of technological capabilities. Overall, recent trends on (industrialized and industrializing) countries have incorporated the NIS approach through dynamic
networks of STI policy, R&D centers, universities, firms and governmental agencies and actors to mediate knowledge flows within and across national borders. Policymakers are increasingly propelling to include international linkages in their STI policy focus, to exploit knowledge flows across NISs borders, though the establishment of global-techno scientific collaboration and the internalization of nationally-produced innovations.

Figure 4: Macro level: STI Policy targeting National Innovation Systems

Metcalfe (2003, p. 97) has contributed a great deal to the understanding of STI policies, describing:

"Science policy to manage and fund the accumulation of knowledge in relation to the natural phenomenon, by creation and support of appropriate organizations, as well research laboratories and universities. Technology policy to manage and fund the accumulation and application of practical knowledge needed for particular productive activities, including transfer of technology from overseas and the transfer of scientific knowledge into wealth creation. Appropriate organizations may be research laboratories, universities and firms. Innovation policy to encourage the transfer of science and technology knowledge into application by ensuring that necessary complementary resources (e.g. capital finance) are available, by supporting entrepreneurship and by, protecting intellectual property".
A "crossover from innovation to environment" is a condition for sustainable NISs, and this implies a rationale for STI policy and environmental policy to facilitate the process away from unsustainable technological changes. McCormick (2001, p.21) points out: "environmental policy corresponds to any (course of) action deliberately taken (or not taken) to manage human activities with a view to prevent, reduce, or mitigate harmful effects on nature and natural resources". Figure 5 illustrates a rationale for STI and environmental policies in NISs, through:

i) A legal agreement or a merger of environmental and S&T policies, or better co-ordination in order to combine entire technological system (product, production chain) with skills (institutional structure), raising resource productivity to reduce use of natural resources.

ii) Policy instruments as environmental market-based incentives in a cost-benefit perspective, such as taxes and subsidies to place right price signals on natural resources (e.g., on carbon-based energy).

iii) Actors (R&D centers, universities, firms, S&T governmental agencies and policymakers, environmental governmental agencies and policymakers, developers and business sectors) interact with each other to exploit internalization of research and innovation through (local/global) techno-scientific collaboration.

iv) Interaction between macro-macro variables (social structure, STI, and environmental policies) focused on long-term technological impacts, when NIS is optimized in sustainable terms. Kemp (1999) suggests scenarios of long time period over 50 years for a new technology system or regime, in which policymakers act as socio-technical alignment actors, rather than promoters or regulators.

Figure 5 can be ideally extended to reinforce the links between STI policy, macroeconomic and industrial policy, social and environmental and development policy. Policy guidelines to advance S&T, taking into account principles such as environmental sustainability, beyond equity and social cohesion, ethical principles, and culture. At the macro-level, NISs for environmental sustainability give relevance to ecosystems of economical and ecological values, as well to natural resource stocks, considering their importance as feedstock for advanced technologies. The effects of STI and environmental policies to better energy efficiency and to the development environmental technologies may, in the long term, be among the most important factors of success or failure of sustainability efforts in NISs. Particularly, environmental and STI policies with large economic impacts (for example, those intended to address global climate change) can have significantly effects on NISs to meet policy goals.
Figure 5: Macro-level emphasizes STI and Environmental policies targeting National Innovation Systems. The framework generalizes Freeman (1995); Lundvall (1992); Nelson (1993); Nelson and Winter (1982) and analyzes NISs as a macro construct composed of complex structure of S&T actors (R&D centres, universities, government agencies and policymakers), rules and policies. NISs for sustainability can therefore, be conceptualized from the perspective of environmental actors (government agencies and policymakers), firms, business development, and adoptions of environmental rules and policy; and the consequences of that over NISs’ natural resources, market factors and culture. In essence, the framework at the macro-level seeks to model NIS as an environmental and institutional given, in the context of a stock of natural resources, and a set of actors that mediate STI linkages and (tacit and explicit) knowledge flows within and across national borders.
Micro Level

While the macro scope refers to the institutional setting of policies for achieving environmental sustainability, the micro level is the individual firm. The micro level focuses on the internal R&D capabilities of the firm and the linkages surrounding it. Knowledge cooperation between firms and non-market institutions are also examined. In the evolutionary view, the firm might be re-defined within a broader institutional context (Nelson and Winter, 1982; Freeman, 1995; Lundvall, 1992; Edquist, 1997). This is to say, the firm innovates through interaction with other organizations to create, develop and exchange different types of knowledge.

As new knowledge is gradually codified, its assimilation requires tacit elements of learning embodied in people and organizations. Thus, firms’ absorptive efforts are necessary; firms must absorb the tacit elements of technology in adaptation and management stages. If absorptive capacity constitutes the firm’s ability to value, assimilate, and use new external knowledge, this ability is a function of investments in R&D (see Cohen and Levinthal, 1990). As Westlund (2006, p.45) argues: "in the case of deliberate, formalized transaction-links, and networks, between firms an firms and other sectors the formalization is in itself a confirmation of the firm's willingness to invest in a link with a longer duration than a pure market transaction…the reasons for the emergence of these fixed links/networks are not the firm's wish to enjoy informal enjoy informal knowledge and information spillovers and other outcomes of flexible inter-actor interactions – but to internalize knowledge within the fixed network, often a corporate grouping”.

Another important assumption relates to the role of R&D units in firms, which undertake activities, relating to the selection and employment of new technologies and applications. R&D units are considered to engage in knowledge generating activities, and the impact of that knowledge is not bounded within the firm, but can spread among firms, industries and countries. Through competitive advantages, R&D units have performed distinctive roles in the formation of knowledge linkages and networks (Cantwell and Iammarino, 2000). In the same way, Edquist (1997) shows knowledge linkages to be useful in making possible the description, understanding, and explanation of, and influence over, the innovation processes of firms. Figure 6 shows the scope of analysis at the micro level, which is adapted from Böh and Zawislak’s model (2004) of absorptive capacity and knowledge linkages. Böh and Zawislak suggest that R&D units interact with ISs to absorb technical or scientific knowledge.
Micro level analysis of the Firm

While science links refer to the absorption of scientific knowledge from cooperation with partners such as research institutes or universities, technology links refer to the absorption of technical knowledge from cooperation with suppliers and buyers in product development. Scientific or technical knowledge via cooperative interactions with foreign partners are here forward called global science links and global technology links respectively. Cooperative interactions with local partners are designed by the terms local science links and local technology links. The model presupposes that a combination of scientific and technical knowledge generates technology – confirmed by Nelson and Winter’s view (1983) on technology as knowledge, combined by pieces of information from investigation or instruction, facts, classified or codifiable knowledge and also know-how, tacit knowledge that is complex and difficult to systematize.

In this study, the Böhe and Zawislak’s (2004) model is refined, and extended to include "environmental links" (Figure 7), which are suggested with basis on the knowledge linkages that may contribute for environmental sustainability. The researcher assumes "environmental links" as result of absorbion of (technical) knowledge that is tacit, and codifiable (scientific) knowledge, and as being conducive to sustainable technological changes in NISs. R&D units of firms interact with NISs to absorb scientific knowledge combined with engineering practices, skills and procedures embedded in technical knowledge. Environmental links may occur:
i) If R&D units absorb scientific knowledge from local universities, and research institutes (science links) that cooperatively undertake environmental and energy R&D. Environmental links can develop technology-push types of innovation or radical, discontinuous innovations for resource/energy efficiency and environmental breakthroughs, minimizing the resources used in producing a unit of output, throughout the entire life-cycle.

ii) If R&D units absorb technical knowledge to develop incremental innovations from the experiences of engineers in the production process, and from suppliers and buyers. According to Freeman (1996), incremental innovations are continuation or relatively minor changes to existing processes and products. Mostly incremental innovations tend to emerge from practice, and they are frequently developed in response to the market needs, with effects in the growth of productivity. After argue that most technological change has based on incremental improvements within existing production modes, Kemp (1999) analyses as they may not be enough for achieving environmental sustainability. Firms which are able to integrate "scientific-technology-environmental" links under one roof are in a position to achieve environmental sustainability. Firms can use scientific and technical knowledge to bring about R&D, leading to better energy efficiency and environmental outputs, leading to sustainable technological changes in NIS.

Policy intervention at the micro level has potential for inducing or forcing environmental links and technological change because they induce and/or require firms to invest in environmental protection efforts. In terms of effects on technological change, there are two ways, in which environmental policy intervention can be compared. First, one can ask – both with theoretical models and with empirical analyses – what effects alternative instruments have on the rate and direction of relevant technological change. Second, one can ask whether environmental policies encourage an efficient rate and direction of technological change, or more broadly, whether such policies result in overall economic efficiency (that is, whether the efficient degree of environmental protection is achieved). In contrast with command-and-control regulations, market-based instruments can provide incentives for firms to use scientific and technical knowledge to innovations for environmental and resource/energy efficiency technologies. Enhanced understanding of environmental links as socially constructed as well as embedded in institutional (policy) contexts represents an interesting source of future research.
Figure 7: Micro-level analysis of the Firm and their S&T and environmental interactions with National Innovation System(s). The framework identifies "the R&D units of firms" such as the innovation agents to compose the (tacit and explicit) knowledge base at the micro level of NIS. With potential to introduce technological novelty capable of changing NIS for environmental sustainability, R&D units undertake the selection and employment of new technologies and applications. Conceptualizing NIS leads to insights on how the micro-macro levels of innovating actors interact to achieve environmental sustainability. The framework suggests that the innovating actors—universities and R&D centres, buyers and suppliers, and collaborative networks—have choice over which S&T and environmental institutions may interact with them with best support for sustainability. The Böhe and Zawislak’s model (2004) is refined to explicitly include environmental links as being conducive to sustainable technological changes in NISs.
4.4 The Case of the Swedish Subsidiary
Ericsson Telecomunicações S/A (Paper II)

With fast innovation cycles, the dynamic ICT sector has the highest innovation intensity and a relatively strong importance for breakthrough innovations. It is characterized by the use of conventional R&D, and S&T sources of innovation, and by the presence of externally and internally networked scientific knowledge. This sector relates to multiple technological trajectories, comprising a dynamic technological regime closely related to users and to scientific linkages.

According to Pavitt’s taxonomy (1984), ICT is a science-based sector, with a high degree of R&D intensity and rapid development of underlying sciences. In this regard, the Brazilian subsidiary Ericsson Telecomunicações S/A develops new products or processes and has a high degree of appropriability from patents and tacit know-how. One of the main reasons for Ericsson in Brazil to increase its investment in R&D was the fiscal benefits provided by the IT Informatics Law. Based on the concession of IT Law incentives, the subsidiary has established partnerships with Brazilian universities and research institutes. This seems to constitute a virtuous circle, in which the subsidiary benefits from financial incentives while growing its technological competence.

In 1990, the Brazilian subsidiary became part of the global software development effort, for both domestic and foreign markets. The R&D center in Indaiatuba, is exclusively focused on the world-wide responsibilities in the development of software for a global telephone commutation platform. As an R&D unit with a global role, the center has contributed to global R&D programs. It also transfers technology to other sister subsidiaries, presupposing high technological capabilities in order to compete on world markets. As suggested by Cohen and Levinthal (1990), subsidiaries with global R&D roles tend to have strong S&T links with sister subsidiaries, access state-of-the-art input worldwide and develop new knowledge or technologies.

Ericsson subsidiary’s analysis is based on qualitative information (Appendix I) and follow-up data gathering and validations (2005-2008, 2008-2009), with Paper II and Paper IV as complementary sources of data. At the micro level, Ericsson subsidiary develops (global) technology links, which are carried out along with sister subsidiaries. Locally, the subsidiary’s R&D unit doesn’t access a supplier–buyer base as external innovation source in product development. Local technology links with host partners are nonexistent.

(Local) science links exist through projects with home-base implications, which contribute to the scientific integration of the host (Brazilian) innovation system with
research infrastructure in diverse regions of the country. The subsidiary’s R&D unit brings knowledge sourced locally into the organization by science links, through cooperative applied research projects between local universities or research institutes.

*(Global)* science links develop from Ericsson’s corporate R&D and sister subsidiaries based on applied research (long-term projects) between local universities with foreign partners and R&D networks (Swedish headquarters and research institutes). Long-term projects refer to areas such as optical components and photonics, optical systems and networks, optical amplification, third generation mobile phones, wireless networks. As for *global* environmental links, applied research in energy and product development is undertaken at Ericsson’s headquarters, which transfers environmental guidelines simultaneously to all subsidiaries.

Ericsson’s environmental and energy R&D activities are highly centralized. Ericsson’s work is managed globally in applied R&D to evaluate stage-by-stage energy use, in generic telecom and datacom systems, including GSM and third generation (3G). Products have been designed with environmental considerations in mind, which are implemented at each step to minimize energy consumption, and to reduce the drain on natural resources. An important aspect has been the Design-for-Environment (DfE) program, which concentrates on reducing the volume and weight of the product in relation to its capacity and processes efficiency throughout all life cycle stages.

The subsidiary does not link with local universities and research institutes to undertake environmental and energy R&D. Mostly, local environmental interactions have been collaborative *suppliers-buyers* across the product chain, embracing product take-back, reuse and recycling, and extended producer responsibility. The subsidiary interacts via a collaborative supply chain process across the product for potential energy savings – during production, distribution and supply, installation and operation. The focus is on product scope rooted in technologies associated with energy and environmental improvements.

At the *macro level*, policy-making interventions in R&D in the ICT sector occur through the Information Technology (IT) Law, under which companies must provide for the investment of resources in local R&D in IT-related activities. The IT Law imposes mandatory annual investments, which represent at least 5% of company’s gross revenue from the sales of IT services and goods in the Brazilian market. The fiscal incentives of the Innovation Law and the R&D Tax Credit benefit the sector and encourage companies’ R&D units to strategically partner with universities, and research institutions. A question might be to what extent these policies have led to
additional or crowding out effects in relation to the Ericsson subsidiary’s environmental R&D expenditures. Overall, the Brazilian environmental regulations incorporate prevention and "polluter-payer" principles, regulating the use of environmental resources, inspections, and the granting of licenses. However, there is a gap in the national policies of environment and innovation, and this prevents them from being instrumental in promoting improved R&D and innovation agenda of ICT goods, services, and systems.

4.5 The Case of the Brazilian Multinational USIMINAS S/A (Paper III)

The less dynamic steel sector engages primarily in process-oriented innovation, and R&D activities predominantly serve internal purposes. The sector requires managers with cross-functional skills, specialists in product design as well as a qualified workforce that is able to adapt new technologies. According to the Pavitt taxonomy (1984), steel is a scale-intensive sector. As scale-intensive firms are found in bulk materials and assembly, their source of innovation arises out of experience and is mostly internal. The perceived risk of adopting radical innovations has only induced incremental and cumulative changes in this sector. In this category, most innovations involve process and engineering redesign.

USIMINAS’ internal sources of technology lie in its R&D center and production engineering. External sources of technology include interactive learning with specialized suppliers. Inputs from science-based firms are also of some importance (advances in the techniques of large-scale computer modeling offer opportunities for building and testing of prototypes and pilot plants).

Since USIMINAS created its R&D center in Ipatinga (Minas Gerais) in the 1970s, the unit has had a local role encompassing activities from the adaptation of products to local engineering. Recently, the unit has invested to reduce energy expenditures in the use of steel, and has developed products of lower weight. The company’s continuous efforts to underlie its learning process and operational performance have had the support of specialized suppliers, mostly in the production and, use of advanced machinery and equipment. Learning opportunities and inputs from suppliers have also likely influenced the company’s product design. Technological trajectories have also been defined with suppliers as sources of new technology. Yet, USIMINAS is associated with consistent R&D, through long-term,
personnel training, and development of a technological infrastructure through R&D partnerships.

At the micro level, from qualitative data (Appendix I) and Paper III’s additional information it appears that the USMINAS R&D unit illustrates technological capability-accumulation paths in the late industrializing context. USMINAS is an example of the benefits of accumulated experience between technology imports or foreign technological inputs (active absorption) and domestic technological improvements (the effective development of improvement capabilities).

(Global) technology links develop through access to foreign sources of innovation (foreign buyers and suppliers), and the purchase of technical assistance and training (particularly from Nippon Steel Corporation). The somewhat strong link between R&D and foreign technology partners can be explained since imported technology under Japanese oversight has provided the most important initial input into technological innovation and learning at USMINAS.

Global links make possible the continuation of the company’s technological follow-up and have been conducive to indigenous learning. This means that USMINAS’ technological capabilities have their roots in various processes set up by company’s own efforts and conditioned by its learning approach. (Local) links with host country partners have had no impact on USMINAS’s product technology. (Local) science links with local universities and research institutes are generally limited to the outsourcing of particular tasks such as extension services, training, tests and analysis.

(Global/Local) environmental links are based on a long-term effort to develop energy R&D and conjoint environmental analysis in product development with foreign and local technological inputs. The R&D unit absorbs technological knowledge from specialized suppliers to generate incremental energy process technologies for the environmental optimization of flat steel products. Environmental interactions with the innovation system may occur through a collaborative supply chain process to control environmental effects throughout the product life cycle.

At the macro level, both the the R&D Tax credit and the Innovation Law aim to stimulate innovation and competitiveness, and they represent a real opportunity for the steel firms to strengthen ties with universities and research centers; and to profit out their R&D investments by the use of the R&D Tax credit as a way to achieve production excellence. The steel industry is subject to Brazilian federal, state and local environmental laws and regulations: command-and-control policies that regulate the discharge of effluents and emissions, the handling and disposal of industrial waste,
and other regulations (i.e., permission, prohibition, standard setting and enforcement) for the protection of the environment.

4.6 Case Studies and Interactions with the Brazilian Innovation System

The Ericsson subsidiary and USIMINAS are examples of firms, which can be defined as partly integrated into the Brazilian innovation system. This part integration might be an indication of institutional failures or gaps into the national (Brazilian) innovation system. Firstly, it might indicate gaps in the STI and environmental policies. Notably, this might point to failures in the existing technology programs concept, which intends to promote co-operation between companies, research institutes, and skilled R&D personnel in technology transfer and diffusion. Second, gaps may refer to inefficient degrees of internationalization of the national economy. Third, systematic failures occur in the Brazilian innovation system to follow a particular technological path (as a leader or follower) in this or that field, these failures encompass an incipient innovation rate with concentration on incremental innovations.

At the macro level, in both cases the main issues relate to the Brazilian environmental regulatory and the STI policy. USIMINAS shows remarkable technology links between its R&D unit and foreign suppliers, and uses these in order to transfer technological knowledge in product development process. In this way, the "technological catching-up" – which is associated with absorptive capability – seems to be a way for USIMINAS to interact with the Brazilian innovation system. As far as USIMINAS technological capability paths are concerned, their cumulative nature relates to opportunities within the NIS. This relies mainly on the R&D unit’s effectiveness in adapting, modifying, and diffusing new technologies.

The Ericsson subsidiary case shows limited environmental interactions with the host innovation system. Its R&D unit is dependent upon Ericsson’s headquarters, which centralizes environmental technological know-how that is tacit and therefore not easily transferred from one site to another. While Ericsson Telecomunicações doesn’t interact with host partners through technology links, it is better positioned in terms of host scientific interaction. One of the main reasons for Ericsson in Brazil to increase its investment in R&D lay in the fiscal benefits to be gained from the IT Incentives Law. Based on the concession of incentives (exemption of VAT tax and deduction of 50% of income tax), the subsidiary has established partnerships with
Brazilian universities and research institutes. This involves a positive feedback, in which the subsidiary benefits from financial incentives, while growing its technological competence.

Ferner (1997) describes host-home ISs as dynamic and subject to continuous adjustments and changes. Obviously, the Ericsson subsidiary's R&D faces divergent local institutional, cultural and economic conditions. Ferner shows evidence of the "country-of origin effects"; even the most global MNCs still appear to be strongly rooted in their country-of-origin. For this reason, it is also important to understand certain overarching characteristics of NISs. The Brazilian innovation system is incremental, and its competitive performance experiences trade fragilities in sectors of high added value and high technological content. In contrast, the performance of the Swedish innovation system is knowledge-intensive with stability in the macroeconomic scenario influencing high levels of venture capital availability both for early stage and growth equity.

The high performance of the Swedish innovation system10 is due, among others reasons, to the country’s industrial structure, which is international-oriented. With a number of R&D-intensive multinational corporations, the industry is characterized by high technology specialization. According to the OECD Science, Technology and Industry Outlook 2012 "Sweden – in view towards meeting the Europe 2020 R&D intensity target– is considering a preliminary national R&D target of 4% of GDP. Based on its recent research bill, for the period 2009-2012, the Swedish Government has increased R&D expenditures and identified strategic areas for research and innovation, in particular, medicine, technology, and climate (OECD Outlook, 2012, p.1)".

### 4.6.1 Implications for Environmental Sustainability

*Papers II and III have* suggested that the technological attributes of sectors determine the environmental sustainability of NISs. In the scale-intensive pattern

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10 According to the OECD’s latest Science, Technology and Industry Outlook (2012), Sweden R&D expenditures increased to around USD 12.5 billion in 2010, a GERD to-GDP ratio of 3.40%. In 2009, industry funded 59% of total GERD, while government funded 27% and 10% was funded from abroad. This last has grown sharply over the decade as the R&D system has become increasingly internationalized. Sweden ranks highly in international reports on Science and Technology indicators such as those regularly published by the OECD or Eurostat. In 2009, Sweden invested a 3.75% of the GDP in R&D, a rate well above the US (2.77 %) and slightly higher than Japan (2.44 %) (OECD Science, Technology and Industry Outlook 2012, p.2).
(steel), with relatively low innovation cycles, the environmental technological change has been focused on *end of pipe* technologies used in production processes. This often consists of short-term solutions simply added to existing production systems without modifying them. End of pipe technologies leave the original process and product substantially unchanged, and usually do not reduce the quantity of harmful pollutants or energy use in the innovation system. The environmental technological change in this sector consists of incremental improvements of existing technologies. This comprises the diffusion of technologies in existing production modes. The science-based pattern (ICT sector) is renowned for the rapid pace of development and technological change. ICT trajectories encompass continuous innovations in quality and efficiency. They may be interrupted at any point by a new technological course or by radical innovations in products and processes, or evolving user interfaces.

![Figure 8: Different levels of environmental improvements in the ICT and steel sectors](image)

Figure 8 based on Brezet's model (1997), illustrates implications for technological trajectories and levels of product environmental optimization for long-term sustainability within both the science-based pattern (ICT sector) and scale-intensive pattern (steel sector). Brezet (1997) shows a sequence of s-curves of innovation and outlines the move of a product through the process of innovation that constitutes a technological trajectory. The vertical axis shows the factors of reduction of the
environmental impact of a product. The horizontal axis is the time scale, at which the product takes to environmental improvements.

While the steel sector relies on incremental innovations (end of pipe) at Level 1, the ICT life cycle works through improved disassembly, product distribution, as well reuse and energy-use reduction with respect to all components. This means energy saving, reduced use of harmful chemicals and increased use of recycled material. Life-cycle techniques make possible the use of minimal energy to maximum effect for ICTs user groups. At Level 3, the most important opportunity is the dematerialization potential. Fulfillment of functionality may result in factors of impact reduction. The overall impact on environmental sustainability within ICT may vary, depending on the applications. Efforts have been made to understand the emergence of ICTs, and to assess scenarios of their future impacts on the economy, environment and society (see Hilty, 2008). Considerably, more work needs to be done to determine the sector’s contribution to sustainability, and how its (environmental) positive impacts on the Brazilian innovation system might be addressed.

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<th>Some aspects of analysis and comparison in the two cases</th>
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<tr>
<td>Ericsson Telecommunications S/A</td>
<td>USIMINAS S/A</td>
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<td>ICT Sector</td>
<td>Steel Sector</td>
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<tr>
<td>✓ high degree of R&amp;D intensity</td>
<td>✓ medium degree of R&amp;D intensity</td>
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<td>✓ high level of appropriability</td>
<td>✓ medium level of appropriability</td>
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<td>✓ breakthrough (and incremental) innovations</td>
<td>✓ incremental innovations</td>
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<td>✓ externally and internally networked scientific knowledge</td>
<td>✓ technological capability accumulation</td>
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<td>✓ knowledge conversion and acquisition process</td>
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<td>Innovation Trajectory</td>
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<td>Research intensive product/service innovation (Pavitt</td>
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<td>In-house production engineering, suppliers of capital goods (Pavitt taxonomy, 1984)</td>
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<td>scale and product-process interactions (Pavitt taxonomy,</td>
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<td>1984)</td>
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<td>Energy Demand / Environmental Aspects</td>
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<td>✓ Energy-intensive industry</td>
<td>✓ Energy-intensive industry</td>
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<td>✓ Life-cycle techniques</td>
<td>✓ Predominant use of add-on technologies such as end-of-pipe solutions to pollution control</td>
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<td>✓ Product redesign</td>
<td>✓ Clean technologies</td>
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<td>✓ Dematerialization</td>
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<td>✓ Clean technologies</td>
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<td>S&amp;T Interactions with host country NIS / home country</td>
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<td>✓ (Global) environmental links</td>
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Table 3: Analytical Summary of the Two Cases
Table 3 reviews some aspects of analysis and comparison in the two sectors, based on the Ericsson subsidiary and USIMINAS cases. It shows that cases may be positioned within Pavitt taxonomy (1984) with relevance to innovation trajectory and source of process technology. Some aspects of comparison are added: environmental, energy demand, S&T interactions with host-home country NISs in the case of Ericsson subsidiary, S&T interactions with home country NIS and /foreign suppliers in the case of USIMINAS. The two cases characterize inter-sectoral differences in terms of production. The design, manufacture, operation and disposal of ICTs differ from the production system of steelmaking, which comprises extraction of natural resources, conversion of these resources into raw materials, and manufacture of steel finished products. ICTs account potential for energy use and both are related to energy intensive industry and carbon dioxide emissions. One can say a NIS -specific structural factors affect energy use and carbon dioxide emissions in steel and ICTs manufacturing companies and influence the choice of processes involved in production. Further empirical work would be supportive of analysis in the two cases, providing extension in the study of both sectors to determine to what extent the carbon dioxide emission of steel and ICTs have contributed to the carbon intensity of the Brazilian NIS.
5. Discussion and Conclusions

It has been said by Lundvall (1992, p.13) that "definition of the innovation system must be kept open and flexible". This work represents an attempt to use the diffuse concepts and adaptable boundaries that underlie the study of ISs in order to include the environmental sustainability context. Chapter 5 aims to put the findings of the research in a broader perspective, synthesize and review hypotheses, and give suggestions for future studies. This research has raised questions that are in need of further investigation. One of the main features of this study lies in the contrast between the two cases (Papers II and III) in terms of technological regimes, which proved very interesting and thus formed the core of the thesis.

5.1 Brazil's Innovation System:
Why to make the shift to sustainability?

The conclusion of this thesis is that interactions between the Brazilian innovation system and sectoral patterns of innovation exist and they are determinants to frame the NIS-specific conditions for environmental sustainability. Brazil has deepened its specialization in resource-based industries (supplier-pattern) with low technological opportunities and traditional manufacturers (scale-intensive), in which technical choices are mostly made from a cost-cutting perspective with medium technological opportunities11 as suggested by the Pavitt taxonomy (1984). A peculiarity of the Brazilian innovation system in Gonçalves and Simões (2005, p. 423) "is that science sector – with the greatest technological opportunities – has a very limited R&D-based innovation effort", particularly with regard to the ratio of graduate staff employed in R&D to the total employment of firms carrying out R&D.

The group of industries producing intermediary goods in scale intensive sectors (chemicals, oil refining, basic metals, rubber and plastic products, non-metal mineral products and pulp and paper) and some of the conventional engineering industries comprise the most competitive industries in Brazil, and have developed technological capabilities beyond their production capabilities. However, overall, the intensive

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11 classification of the Brazilian sectoral/industrial patterns according to the Pavitt taxonomy (see Gonçalves and Simões, 2005)
sectors have been a likely focus for Brazil’s status of a "passive NIS" particularly in respect to R&D activities.

While Brazil may be "catching up", regarding its improved performance of technology in certain areas, it has failed to reduce the gap vis-à-vis the leaders. Brazil has been a case of passive (incremental) NIS, with incipient ties between science and industry, a profile in technological adaptation, and a frequent practice of accessing foreign technology. In the Brazilian case, this is particularly important, given the large participation of MNCs in most sectors of the industry. While acquisition is an operation of foreign technology inputs for production processes, assimilation requires indigenous technical efforts to diffuse product design technologies to the local market; and improvement refers to developing in-house R&D.

PINTEC (2008) data shows that R&D units of MNC subsidiaries operating in Brazil usually provide technological adaptation services and products to other South-American markets. Moreover, data inform firm’s ranking of innovation with a relatively weak situation of the ties between academy-industry and research institutes in Brazil. As revealed in the answers of respondents of the survey carried out at ANPEI and FINEP (Paper I, Appendix II), the low level of firm integration with universities and research laboratories is influenced by the low degree of formalization of R&D activity in Brazilian firms.

The shift in the conditions for Brazil’s innovation system to "catch-up" is necessarily delimited by the institutional setting. This refers to public policies, to the country’s R&D infrastructure, and to technological capabilities and skills available in companies. Opportunities to catch up process rely on the science-based sector and patent-intensive industries. With a high degree of R&D intensity and rapid development of underlying sciences, these sectors are able to develop radical technological change and its derivative – a change in the demand for skills and infrastructure. This involves the country’s capacity building in areas like engineering and in the interdisciplinary areas that integrate the environmental sciences, to make possible advances in sustainable technological development. One can say that, firms belonging to the science-based sectors are more likely to introduce environmentally and technologically changed products and/or processes than those belonging to others sectors.

12 For instance, the case of the Brazilian agri-food system, considered a leading industrial complex of the national economy with higher growth rates, higher export rates, and leading in biotech and software applications.
Brazil has a huge impact on the environment in terms of resource consumption, due to for instance large-scale and coal-based energy production and extensive deforestation (Stamm, Dantas, Fischer, Ganguly and Rennkamp, 2009). The country has to rethink its STI policy’s bases, in order to focus on the evolution of institutional arrangements, where environmental goals in need of innovation are translated into R&D programs. The country has integrated research and education, but steps toward strengthening its science and technology capacity, with emphasis to the areas of engineering and natural sciences, as well as increases in advice, collaboration, and many other factors are also needed.

A rationale for Brazilian government intervention to facilitate environmental technological changes is needed, especially through the use of the market-based policy instruments, including pollution charges as cost-benefit incentives to provide sufficiently low-cost technologies or clean-up processes. Yet, while a set of Brazilian economic policies – including deregulation, privatization and FDI liberalization – have been part of the nation’s strategy to catch up technologically, they have not been articulated in an environmental or socially responsible way with investors or with the government sector. The economic benefits of FDI in Brazil are well known. Even though, due to its natural resources, FDI benefits in the country involve tailoring technologies to the context of the exhaustibility of the resources involved and long-term environmental impacts.

Minor or incremental change has been the most frequent type of environmental innovation in the Brazilian Innovation System, together with environmentally innovative applications of existing products and processes. The use of end-of-pipe solutions to change the overall environmental impact, or to underline consumption and production models, is however generating the problem. Minor or incremental changes tend only to prolong the life cycle of earlier technologies.

A possible solution would be for Brazil to advance in the areas of energy, biotechnology, renewable energy, and bio-fuels. In doing so, Brazil might carve out a niche in the area of environmental technology. Juma and Konde (2002) suggest that countries explicit about their interest in operating in specific niches are more likely to benefit from technological catching-up patterns and co-operation with larger firms in the industrialized countries. Niches create opportunities for the use of more efficient technologies and facilitate processes of learning, and firms in these fields could be supported to develop technologies and diffuse them into the economy. Whilst there is some evidence that NISs towards sustainability are science-based, the Brazilian innovation system still needs to put in a large effort to deal with the limits of its incremental condition.
5.2 Foreign subsidiaries of MNCs

versus domestic MNCs

The presence of natural resources by itself has not been a sufficient reason for FDI to take place in Brazil. FDI has been attracted especially by the large domestic market and government policies, and been directed towards the technology-intensive industrial and (more recently) services sectors. As "protagonists" of the country’s industrial modernization the Brazilian-based affiliates of MNCs, in general invest in the country to adapt products and processes developed in their countries of origin. In some cases they take advantages of local technological expertise.

What differentiates Brazilian MNCs from those of other industrialized countries is precisely the composition of advantages: different types of qualifications of manpower, different levels of technological capacity and governmental policies. Foreign MNC affiliates in Brazil have a number of advantages over domestic firms, as they have higher productivity, a more qualified labor force, and a higher degree of trade integration.

As confirmed by PINTEC (2008), firms which are wholly or partially controlled by foreign capital have presented a higher propensity to introduce new products/processes than those wholly controlled by Brazilian national capital. The technological intensity of firms either wholly or partially controlled by foreign capital is considerable higher that of national firms. Briefly, Brazilian national companies present higher or as high technological intensity in a number of sectors that do not present high technological opportunities as textiles, for instance. Mechanical machinery and office machinery are the only sectors with intermediate or high opportunities in which national companies compare to their foreign counterparts. The higher technological effort made by foreign-controlled firms is in line with their better innovative performance. Even though limited in scope, these firms and activities employ a larger graduate staff in R&D than that of their national counterparts.

Cases studies of Ericsson’s Brazilian subsidiary and USIMINAS (Papers II and III) show that gaps between the innovative activities of each company are also largely determined by their respective sector’s technological imperatives. This is to say that the innovative behavior of foreign subsidiaries of MNCs and their environmental performance as compared to domestic companies is also defined by the sector’s determinants. Policy effects are expected to accelerate the convergence of the host country’s technology and productivity with those of MNCs’ home countries. Importantly, foreign owned MNCs innovative behaviour depends on the host
country’s institutional settings, such as public policies to support environmentally beneficial technologies.

A focus should be given to the potential of R&D outsourcing and collaboration as mechanisms to enhance the competitive capability. Outsourcing may be perceived to foster linkages between MNC affiliates and domestic companies in ways that promote environmental technological change. In addition, more explicit R&D collaboration may be a way to profit and "solve" environmental problems (see Ausubel and Langford, 1997). Outsourcing is used to transfer complete in-house R&D activities to outside suppliers. Outsourcing helps companies to respond more flexibly to market or technological uncertainty while maintaining innovation capacities. It tends to mean defining performance targets (i.e., energy and environmental outputs) to be achieved by the external provider.

Whilst collaboration occurs from mutual expertise, basically in non-competitive areas — e.g., collaboration among (foreign and domestic) companies within a supply chain, in non-competing sectors using similar technologies, or in non-market areas such as environmental protection. Nevertheless, joint R&D activities allow subsidiaries to strengthen their bargaining power vis-à-vis foreign technology suppliers. Positively, R&D outsourcing and other forms of direct interaction as collaboration may increase demands on environmental and STI governmental policies due to their effects on the market.

5.3 Implications for Sustainability Issues in Innovation Systems

This study develops a conceptual framework to advance the understanding of the IS approach. Consistent with the theoretical view of environmental sustainability, as well as the analysis and research diversity offered by ISs, the framework reveals three implications. First is that the environmental policy context matters. The policy implications of the IS shift are considerable for sustainability.

Environmental policy has gained little attention in ISs, though an upcoming policy tendency is present in the synthesis between STI and policy instruments for environmental and natural resource management. With relatively little interactions, STI and environment are rooted in different domains (respectively, the innovation/industrial policy domain and policy design that takes due account of market-based incentives). Innovation policy, with the purpose of increasing economic growth, is based on evolutionary economic theory. Despite differences in rationales,
however, environmental policy and innovation policy need to be sensitive to the conditions of the ISs, which will ultimately condition that IS’s success in terms of sustainability.

A point of analysis developed from the "framework" presented here is that in wiring up the IS for sustainability, a core focus must be to address consistency between different segments of the policy areas able to positively affect segments of R&D. These segments vary widely between different types of firms and sectors (Papers II, III, IV and V). At the micro level, the implications of policies are inherently uneven, particularly at the firm level, and range from those that are obstructive and reactive to external/internal environmental strategies and regulation, to firms that undergo routine environmental upgrades, and have strategies and standards with a high environmental profile.

In advancing a sustainability agenda within ISs, it is important that the framework direct attention towards the neglected climate mitigation policy. Whilst markets in tradable carbon permits may have an important role to play, climate policy has the task to promote renewable energy technologies and energy efficiency, achieving a long-run transition to a low carbon economy.

Second, the notion of knowledge is advanced as the core approach with respect to achieve sustainability through the IS. The significance of the entire knowledge life-cycle – i.e., knowledge creation, knowledge evaluation, knowledge integration and knowledge application – must be supported within an IS. An implication of acknowledging the importance of knowledge lies in the recognizing the need for a stronger knowledge-based approach to environmental issues than that generally practiced in STI policy and analysis.

At the micro level of a NIS approach to sustainability, the framework emphasizes that firms add value to their existing knowledge in collaborations with science and users-supplier. The science links result from the firm synergetic networks with knowledge-producing organizations (universities research centers, technology-providing firms) to develop environmental technology R&D. User-supplier links added to the production chain develop green process technologies. The presence of experts is also important. As highly competent technically individuals, experts act as receptors of technological developments, building effective knowledge networks and facilitating linkages between organizations.

The third implication advanced through the framework lies in the notion of adaptation or the ability to change (or be changed) to fit changed circumstances. Adaptability is to be understood here as the ability of a NIS to adapt itself efficiently to environmental technological change, growth, and conservation, based on the
reduced use of resource-intensive products and processes, and reduced environmental impacts associated with life cycle analysis. An adaptive NIS is therefore a system that is able to fit regulations; policies; entrepreneurial cultures; and other social, institutional, and cultural factors in order to better cope with, manage, or adjust to (environmental) technological change opportunities (or risks) and timing. One can say the NIS forms a suitable platform for dealing with the variability in sectoral technological trajectories, due to its ability to adjust to sectoral R&D intensity, the sectoral rate of innovation (innovative output) and innovation regimes. Paper V shows variability in three sectoral technological trajectories, based on Pavitt and discusses classification, and how they fit with the Brazilian innovation system.

The study also argues that ISs for environmental sustainability are perceived positively as being internationally-oriented. This is perceived in terms of trans-boundary imperatives of international environmental problems, such as climate changes impacts, ozone layer depletion and loss of biodiversity, which are felt regionally and globally. Trans-boundaries impacts and resources cut across ISs boundaries and require international cooperation. The way they are addressed necessarily depends on STI capacity building, and the business practices, economic value chain, and social and political conditions, of the IS in which they are located.

Another approach concerns the internationalization of technology, which may be referred to as the international generation of R&D carried out by MNCs. A focus of foreign investments has been the establishment of overseas R&D units, originally in order to undertake adaptation work or to complement those production activities taking place in host countries that have played a role within their market exports (especially NICs).

In host countries, the R&D units of foreign MNC subsidiaries internalize S&T knowledge assets within the source firm. As Puttitanun (2006) explains "the technology that a multinational firm owns is unique so that when it serves a new market, it can achieve a monopoly profit...and there is a need to internalize knowledge assets as a way of inhibiting profit dissipation through imitation" Puttitanun (2006, p.270). Non-motivational barriers to knowledge transfer have normally been conceptualized in terms of factors such as causal complexity, tacitness, and absorptive capacity. However, sources of potentially transferable subsidiary knowledge are to a large extent created on the basis of deliberate or formal relations to external partners like customers, suppliers, universities (Ericsson case analysis in Paper II); and knowledge inputs from a local cluster – e.g., high quality research institutions (Paper IV).
A key point has been the host country’s governmental strategies to attract R&D-intensive foreign investment, by making clear the potential benefits of foreign knowledge transfer and interactions with indigenous S&T units. Policy instruments, which may be both fiscal and financial, have been seen as the way to provide public incentives for R&D. This is the case of the Brazilian Innovation Law and the R&D Tax Credit Law, which define the norms regarding offering incentives to companies that implement innovation and development within the country. An important example of such R&D incentives is the Brazil’s Informatics (IT) Law, which grants industrial tax incentives provided that firms belong to the information technology sector. As shown in Papers II and IV, the IT Law has provided to Ericsson subsidiary in Brazil with benefits not only defined in terms of fiscal incentives but in terms that bring advantages in terms of the company’s technological expertise, partnerships with local universities and research institutes and product innovation.

The internationalization of technology is discussed in this study upon the basis of experiences gathered from Brazil and Sweden. R&D by foreign affiliates of Swedish MNCs has gradually influenced Brazilian economic growth and productivity. As is the case in countries with higher involvement in international cooperation, and bilateral commercial and scientific relations, Brazil and Sweden have developed complementarities. They both seek the international exploitation of innovative know-how and technologies by means of trade, the granting of licenses and cooperation. Brazil has ample natural resources and vast growth potential, while Sweden has the capital and technology skills.

Interestingly, the mobility of researchers is one of the most frequent targets of S&T policy-making in the field of internationalization of R&D (Crest Report, 2008). The importance of human resources and mobility has been emphasized in order to disseminate R&D and knowledge across borders of ISs. My doctoral research plays a role in this context.

In Nelson and Rosenberg’s view (1993, p.5), there is "no sharp guide to just what should be included in the innovation system and what can be left out view". Therefore, the IS approach allows us to ask different kinds of questions. The unexpected answers to these questions may, in turn, lead to new considerations. In this open and flexible perspective, this study sets out to develop a conceptual framework providing specific propositions in relation to a number of theoretical variables. However, the study may require additional refinement because simple cause-effect relations are rarely found in the deterministic approach of IS. It is my hope that this study will inspire further research in the area of IS and sustainability,
NISs in transition and the related processes and components that impact upon policy making.

5.4 Limitations of this Study

The most important limitation lies in the cross-disciplinary quality of the research, which is an unavoidable aspect of the study of ISs. The research basis is from paradigm shifting in theories and concepts, at the analysis of propositions, involving different disciplines. As theoretical sources, the research uses advances in evolutionary theory, precisely in recognition of the importance played by learning in the process of technological change; and includes concepts derived of the theory in technological change and environment. In brief, the research integrates thinking from disciplines, i.e. from the fields of evolutionary, technology, environment, sustainability, and applies them to the present context.

A challenge to this cross-disciplinary research has to do with the analysis of different knowledge domains, which requires not only the examination of extensive bodies of literature but the inclusion of citations and references from that literature. In addition, the preparation phase for Papers II, III, and V required researcher mobility among S&T professionals, networks and extensive communication, considerable time and attention spent among the disciplines involved. Interdisciplinary research, as noted above, requires the utilization of conceptual frameworks from a range of disciplines in the research questions. While this is challenging in the initial stages of the project, positively it offers perspectives and theories that advance the understanding of the IS approach.

Another limitation has to do with the extent to which the findings can be generalized beyond the cases studied. While the research strategy was theoretically based, the fact that only two cases were included might be seen as yet another limitation. However, the choice of cases was clearly more important than the number of cases, especially, since the researcher was concerned with comparing different cases of technological regimes.

While case studies allow for in-depth analysis, they present clear limitations in terms of scope. The present research examines contrasting case studies in terms technological profiles, and the objective – to learn more about the behavior of these companies in relation to IS – limits more generalized findings.

The research strategy used "triangulation" or different methods and forms of data collection to examine the cases from diverse perspectives, and to enhance validity and
request of quality. Admittedly, the study shows a need to undertake further empirical evaluations to better understanding of how findings can be generalized to other different contexts. Taken together, these limitations open opportunities for postulating possible and preferable futures research.

5.5 Implications for Future Research

This study, which utilizes a conceptual framework, data, and analysis, has resulted in specific questions in need of further investigation. Three implications, discussed below, can be drawn from the findings in this study.

First, given the importance of institutions play in the IS setting, one recommendation would be a policy study to investigate how funding, program designs, and support strategies address market and systemic failures in environmental technological innovations. Boulder and Mathai (2000) show that market failures may occur simultaneously by non-appropriability of the returns on investments in innovation and external environmental costs. This double-market failure associated with environmental pollution, innovation, and diffusion of new technologies emphasizes the role of policy intervention in ISs.

This has relevant ramifications for future studies in ISs within a range of policy instruments to eligibility, regulations and strategies aiming coordinate STI to research and development in environmental technological innovations, with emphasis on renewable energy technologies. In this regard, both environmental policy and climate mitigation policy play a role.

Research questions that might be asked include: What are the advantages and disadvantages of market policies vs. STI policies in dealing with the market failure of environmental technology development? What direct and indirect incentives do newly industrialized countries’ government to develop and diffuse environmental and renewable energy technologies? How effective are newly industrialized countries’ STI policies to research and development in environmental innovations compared to the practices of industrialized counties? How compatible is STI policy, climate mitigation policy and environmental policy in newly industrialized countries as compared to industrialized economies? Does the strategic industrial policy that is pursued by the BRICs nations accelerate or hamper environmental leapfrogging?

Second, a further study might assess the relation of sustainability and internationalization of ISs. Carlsson (2006, 65) writes: "in view of the fact that most studies of innovation systems focus on national innovation systems, it is not surprising
that little direct evidence is found that innovation systems are becoming global”.

Recently, cross-country analysis have focused on the internalization of ISs (Coe and Helpman 1995; Carlsson, 2006), associated with the impact of the different forms of the globalization of technology (Archibugi, and Pietrobelli, 2003); and the interaction between overseas R&D resources and the host-country’s innovation system (Cantwell and Iammarino, 2000; Ferner, 1997).

Further research might investigate a conceptual framework – grounded in variables of sustainability – to define implications of the internationalization of ISs in newly industrialized countries. Research examines specific issues and addresses questions of how: How ISs in newly industrializing countries interact with international technological innovation systems? As research becomes more internationalized, how can ISs in industrialized countries benefit from increased environmental and energy R&D spending in newly industrialized countries? How likely is an industrialized-industrializing country’s consensus with regard to international STI policies?

Third, research should be undertaken to introduce environmental sustainability as a new element for the structural analysis of NISs. Mapping NISs is still based on traditional indicators (such as R&D expenditures, S&T human resources, patents, non-R&D inputs, production, high-technology products). Indicators to measure the trends of a NIS to meet environmental sustainability are hampered by a lack of data and information. It would be interesting to assess a set of qualitative and quantitative indicators to be used regard of NISs’ use of resources and energy at sustainable rate. Mapping NISs for sustainability points to issues or conditions related to biodiversity, compliance, diversity and opportunity, product and technology impacts.

In addition, future studies might focus to examine Swedish and Brazilian interactions in ISs. While Sweden is a global leader in innovation, Brazil has experienced a sound expansion in the number of innovation agendas in the last decade. A hypothesis to explore is whether the two countries have conditions to experiment with NISs collaboration schemes for sustainability. It is the view of this study that the benefits of international exploitation of technology will most likely be distributed across Swedish and Brazilian NISs.

Relatively, limited research has been done to investigate ISs with the perspective of environmental sustainability, and many research questions beg further investigation. In particular, citations in this thesis as Stamm, Dantas, Fischer, Ganguly and Rennkamp (2009), Segura-Bonilla (1999), Smith, Stirling and Berkhout (2005), Melville (2010), have developed explicit contributions that deserve researchers’ attention.
References


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Leal Filho, W. (2002), Teaching Sustainability at Universities: Towards Curriculum Greening, Peter Lang, Bern, Switzerland.


Lundvall, B-A (1998) "Innovation to an interactive process: from user-producer interaction to the national system of innovation", in G. Dosi, C Freeman, R Nelson, G Silverberg, L Soete (eds), Technical Change and Economic Theory (pp. 349-369), Pinter, London.


Stamm A., Dantas E., Fischer D., Ganguly S., Rennkamp B. (2009), "Sustainability-oriented innovation systems: Toward decoupling economic growth from environmental pressures?", German Development Institute (DIE), Bonn.  

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Appendix I

Technological Innovation Strategy and Practice (TISP) Questionnaire

The questionnaire targeted the following organizations participants in the Doctoral Research:

Ericsson Telecomunicações SA
USIMINAS (Usinas Siderurgicas de Minas Gerais SA)

Appendix II

Science, Technology and Innovation Policy (STIP) Questionnaire

The questionnaire targeted the following organizations participants in the Doctoral Research:

ANPEI - Brazilian Association of Research, Development and Engineering of Innovative Enterprises
FINEP - Brazilian Innovation Agency
VINNOVA - Swedish Agency for Innovation Systems
APPENDIX I: Technological Innovation Strategy and Practice (TISP) Questionnaire
GUIDELINES AND DEFINITIONS

In this Questionnaire, "innovation" is defined according to the Oslo Manual (1996, 2005) as new or substantially improved service, product or process for your firm. Innovation activities are all scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations. Innovation activities also include R&D that is not directly related to the development of a specific innovation (Oslo Manual, 2005, p.18).


From the point of view of your firm, some of the options relate to R&D:

- the firm can undertake basic research to extend its knowledge of fundamental processes related to what it produces;
- it can engage in strategic research (in the sense of research with industrial relevance but no specific applications) to broaden the range of applied projects that are open to it, and applied research to produce specific inventions or modifications of existing techniques;
- it can develop product concepts to judge whether they are feasible and viable, a stage which involves: i) prototype design; ii) development and testing; and iii) further research to modify designs or technical functions (Oslo Manual, 2005, pg.23)

Technological product and process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes.

TPP innovations involve a series of scientific, technological, organisational, financial and commercial activities. The TPP innovating firm is one that has implemented technologically new or significantly technologically improved products or processes during the period under review (Oslo Manual, 2005, pg.31).

A. Contact information

NAME of responsible person for information: 

Contact information Email, Phone, office address

B. Most important products/activities/services of your firm

Please give the three most important products/activities/services of your firm:

C. Main activities

What are the main activities of your firm?

- [ ] Production of consumer goods
- [ ] Production of raw materials
- [ ] Production of product parts and components
- [ ] Production of production equipment
- [ ] Wholesale business in consumer goods
- [ ] Wholesale business in raw and refined materials
- [ ] Wholesale business in product parts and components
- [ ] Wholesale business in production equipment
- [ ] Business services (engineering, IT services, Other)

D. Please provide information:

Your firm is:
- [ ] A manufacturing firm
- [ ] A service provider
- [ ] A wholesale business
- [Other]

Is your firm’s head office located in Brazil?
- [ ] Yes
- [ ] No, head office is located in (name country): 

PART A: Innovation on Products and Processes

1a. Funding and Support

Did your firm use any of the following types of programs sponsored by the federal (Brazilian) government during the last three years? q1a1
- [ ] Yes
- [ ] No

- [ ] Research and development (R&D) tax credits
- [ ] Government research and development (R&D) grants
- [ ] Government venture capital support
1b. Business activities: Production

Is your firm involved in the production of products and/or the supply of services? q1b1

If yes, indicate the source of the production technology (technical now-how and techniques) q1b2

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In-house (proprietary intellectual property)</td>
</tr>
<tr>
<td></td>
<td>(Local sources (local organisations))</td>
</tr>
<tr>
<td>1c</td>
<td>Foreign sources (e.g. production licenses)</td>
</tr>
</tbody>
</table>

1c. Transferring or selling technology

Does your firm transfer or sell technology to other firms (production licenses, patents, specifications, etc) q1c1. If yes, indicate the type of technology supplied:

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Marketing, distribution or sales technology</td>
</tr>
<tr>
<td></td>
<td>Production or processing technology</td>
</tr>
<tr>
<td></td>
<td>Product technology</td>
</tr>
<tr>
<td></td>
<td>Technical know-how and techniques</td>
</tr>
</tbody>
</table>

2a. Innovated products/services

In the last three years, has your firm introduced products and/or services onto the market, which were technologically improved or new to your firm? q2a1

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>/2</td>
<td>Products/services developed mainly by a third party</td>
</tr>
<tr>
<td>/2</td>
<td>Products/services developed together with third party</td>
</tr>
<tr>
<td>/2</td>
<td>Products/services developed mainly by my own firm</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
</tbody>
</table>

2b. Innovated processes

In the last three years, has your firm brought production processes into use, which may be considered technologically improved or new? q2b1.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Processes developed mainly by a third party</td>
</tr>
<tr>
<td>2</td>
<td>Processes developed together with a third party</td>
</tr>
<tr>
<td>2</td>
<td>Processes developed mainly by my own firm</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
</tbody>
</table>

3a. Research and development (R&D)

Please, tick or answer where appropriate

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Processes developed mainly by a third party</td>
</tr>
<tr>
<td></td>
<td>Processes developed together with a third party</td>
</tr>
<tr>
<td></td>
<td>Processes developed mainly by my own firm</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
</tbody>
</table>
Your firm is:

1. Engaged continuously in R&D
2. Engaged occasionally in R&D
3. Not conducting any R&D

### 3b. Innovation expenditures

Please, give the estimated innovation costs of your firm in the last three years incl. personnel costs and related investment expenditures q3b1

Please tick one or more of the following innovation activities if applied by your firm last three years. Subsequently, give an estimate of related expenditures. Please, tick ‘yes’ or ‘no’ for each innovation activity) q3b2

<table>
<thead>
<tr>
<th>Machinery / Equipment</th>
<th>Yes</th>
<th>Outsourced Research</th>
<th>Yes</th>
<th>Licenses / Advice</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation</td>
<td>No</td>
<td></td>
<td></td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Implementation</td>
<td>No</td>
<td></td>
<td></td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4. Technological innovation

Did your firm have technological innovations in the last three years? q4

4a. In the last three years, did your firm sell products/services that were not only technologically new or improved to your firm, but also technologically new or improved to the market? q4a1

4b. No technological innovative activities

If your firm had no innovative activities last three years. The main reasons for this are:

<table>
<thead>
<tr>
<th>Economic risks</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs too high</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Lack of qualified personnel</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Time to market</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Short of finance</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Demand risks</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Regulation</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Other: .................</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a. Innovation and the use of external information sources</td>
<td>Please, tick where appropriate</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------------------------------</td>
<td></td>
</tr>
<tr>
<td>Which external information sources have been used for your firm’s technological innovations</td>
<td>Source used</td>
<td></td>
</tr>
<tr>
<td>q5a1 Indicate Sources not used:</td>
<td>Group (from mother/daughter company)</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>New personnel</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Buyers</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>(Suppliers)</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Competitors</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Consultants</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Research labs</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Universities</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Innovation Centres</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Patents</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Scientific/Technical Literature</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Exhibitions/Conferences</td>
<td></td>
</tr>
<tr>
<td>............................................................</td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5b. Innovation and the use of internal information sources</th>
<th>Please, tick where appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which internal information sources have been used for your firm’s technological innovations</td>
<td>Source used</td>
</tr>
<tr>
<td>q5b1 Indicate Sources not used:</td>
<td>Purchasing function</td>
</tr>
<tr>
<td>.............................................................</td>
<td>Marketing and/or sales function</td>
</tr>
<tr>
<td>.............................................................</td>
<td>Research function</td>
</tr>
<tr>
<td>.............................................................</td>
<td>Development function</td>
</tr>
<tr>
<td>.............................................................</td>
<td>Engineering function</td>
</tr>
<tr>
<td>.............................................................</td>
<td>Production function</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Innovation in Partners</th>
<th>Please, tick where appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the last three years did your firm participate in partnerships with organisations on the development of technologically new or strongly improved products, services, and processes?</td>
<td>q6a 1 [ ] Yes 2 [ ] No</td>
</tr>
<tr>
<td>If Yes Please, tick your partners and indicate on the right also where this partner is located.</td>
<td></td>
</tr>
<tr>
<td>Partners</td>
<td>Other Relevant Partners</td>
</tr>
<tr>
<td>Brazilian</td>
<td>Foreign</td>
</tr>
<tr>
<td>Own group (Within own enterprise group)</td>
<td>[ ]</td>
</tr>
<tr>
<td>Buyers /users of products/services</td>
<td>[ ]</td>
</tr>
<tr>
<td>Suppliers of your firm</td>
<td>[ ]</td>
</tr>
<tr>
<td>Competitors/ Firms active in your markets</td>
<td>[ ]</td>
</tr>
<tr>
<td>Consultants/ Private institutes/consultancies</td>
<td>[ ]</td>
</tr>
<tr>
<td>Research institutes /Universities</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
### 7. Objectives of innovation

Please, tick where appropriate

<table>
<thead>
<tr>
<th>Objective</th>
<th>Not Important</th>
<th>Fairly Important</th>
<th>Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products/Market</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improving product or service quality</td>
<td>1 [ ]</td>
<td>2 [ ]</td>
<td>3 [ ]</td>
<td>4 [ ]</td>
</tr>
<tr>
<td>Labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce deployment/ costs of labour</td>
<td>1 [ ]</td>
<td>2 [ ]</td>
<td>3 [ ]</td>
<td>4 [ ]</td>
</tr>
<tr>
<td>SCR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulfilling socio Corporate responsibility</td>
<td>1 [ ]</td>
<td>2 [ ]</td>
<td>3 [ ]</td>
<td>4 [ ]</td>
</tr>
<tr>
<td>Materials/Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce material / energy consumption</td>
<td>1 [ ]</td>
<td>2 [ ]</td>
<td>3 [ ]</td>
<td>4 [ ]</td>
</tr>
<tr>
<td>Regulations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulfilling regulations and standards</td>
<td>1 [ ]</td>
<td>2 [ ]</td>
<td>3 [ ]</td>
<td>4 [ ]</td>
</tr>
</tbody>
</table>

### PART B Innovation and Environmental Sustainability Strategy

#### 8. Technology strategy

Please, tick where appropriate

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does your firm have a formal technology strategy? q8</td>
<td>1 [ ] Yes</td>
<td>2 [ ] No</td>
</tr>
</tbody>
</table>

#### 9. Sustainability strategy

Please, tick where appropriate

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does your firm have a formal sustainability strategy? q9</td>
<td>1 [ ] Yes</td>
<td>2 [ ] No</td>
</tr>
</tbody>
</table>

#### 10. Does your firm have any of the following: q10

Please, tick where appropriate

- Socio- environmental projects
- Environmental training programs for production staff
- Published mission statement in support of sustainability goals
- Product design programs that incorporate environmental goals
- Certified environmental audit (ISO 14000)
- Designated management team responsible for sustainability issues
- Product LCA programs

#### 11. Identify each of the following environmental problems is important is your firm’s sector of activity? q11

Please, tick where appropriate

1 ……….. 2 ……….. 3 ……….. 4 ……….. 5
1 = not a problem ………….5 = a serious problem

<table>
<thead>
<tr>
<th>Environmental Problem</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water pollution</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Soil pollution</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Air pollution</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Waste accumulation after the use of the product</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Energy use/demand in the production systems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

12. In the last three years has your firm implemented or conducted R&D on the following four types of environmental technology. Please, tick where appropriate q12

<table>
<thead>
<tr>
<th>Environmental Technology</th>
<th>Implemented a technology of this type?</th>
<th>Conducted research such as R&amp;D or scientific studies?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution control technology to prevent the release of pollutants into the soil, air or water</td>
<td>Yes [ ] No [ ]</td>
<td>Yes [ ] No [ ]</td>
</tr>
<tr>
<td>Waste treatment and disposal systems</td>
<td>Yes [ ] No [ ]</td>
<td>Yes [ ] No [ ]</td>
</tr>
<tr>
<td>Clean technology, or process-integrated production technology to reduce the energy use</td>
<td>Yes [ ] No [ ]</td>
<td>Yes [ ] No [ ]</td>
</tr>
<tr>
<td>Recycling technology to re-use materials</td>
<td>Yes [ ] No [ ]</td>
<td>Yes [ ] No [ ]</td>
</tr>
</tbody>
</table>

13. Does your firm conduct environmental technology R&D? q13

1 [ ] No
2 [ ] Yes, occasionally
1 [ ] Yes, continuously

If yes, considering the total budget your firm spend on R&D in the last three years, what percent of this budget was spent on environmental technologies? ........................................... %

14. Please indicate the information sources used by your firm to inform about sustainability and environmental technical solutions? Please check all that apply

<table>
<thead>
<tr>
<th>Information Source</th>
<th>Sustainability q14a</th>
<th>Technical Solutions q14b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your firm’s R&amp;D department</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Your firm’s environmental/sustainability department</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Your firm’s production department</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>An affiliated firm (parent firm, etc)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Universities</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
Which is the most important source for information about Sustainability?

…………………………………………………………………………………………………….. q 14c

15. a In the last three years, did your firm introduce process-integrated changes to your production technology to reduce the generation of pollutants, waste material and energy use? 
Please, tick or answer where appropriate

1 [ ] No q15a1 2 [ ] Yes q13a2

If Yes, please answer the following questions:

Is this technology:

Patented by your firm (or a patent application been made)?

Yes [ ] No [ ]

Has your firm received any forms of government assistance to introduce this technology?

Yes [ ] No [ ]

15. b How important were each of the following reasons for your firm’s decision to introduce this environmental technology. Please, tick or answer where appropriate

- Customer or consumer demand
- Shareholder or investor demand
- Comply with existing environmental regulations
- Comply with expected future environmental regulations
- Reduce production costs
- Pressure from environmental or NGOs groups

16. Please indicate the degree of importance of each of the following impacts of your product (good or service) and/or process innovations introduced during the last three years.

1=not relevant 2=………… 3=………… 4=………… 5=…………

- Reduced materials or energy per unit output
- Reduced environmental impacts
- Increased market visibility in Socio-Environmental Corporate Responsibility
- Met regulatory requirements
- Other ……………………

THANK YOU VERY MUCH FOR COMPLETING THIS QUESTIONNAIRE
APPENDIX II: Science, Technology and Innovation Policy (STIP) Questionnaire
GUIDELINES AND DEFINITIONS

The objective of the survey is to provide information on science, technology and innovation (STI) policy in Brazil and Sweden. Organizations are requested to provide a general overview of the STI in place and information on major changes that are taking place for the formulation of national innovation strategies. Questions are compiled according to the concepts and guidelines laid down in the Frascati Manual (OECD, 2002), Oslo Manual (1996, 2005) and adapted from OECD Science, Technology and Industry Outlook 2002.

The following definitions are based on Definitions below are based on the Glossary of the EU Integrated Innovation Support Programme and Frascati Manual (OECD, 2002).

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>innovation</td>
<td>the conversion of new knowledge into economic and social benefits</td>
</tr>
<tr>
<td>innovation system</td>
<td>the local, regional or national environment for innovative activity - in addition to companies it includes the research base, innovation finance, business support services and schemes, and the networks through which these components interact</td>
</tr>
<tr>
<td>governance (of innovation)</td>
<td>issues related to the involvement of stakeholders - scientists, industry, consumers and public authorities - in the process of innovation policy design, implementation and evaluation the measurement of performance against best practice as a means of setting goals for improvement - applied by firms to business processes (e.g. within their sector), or by national or regional policy-makers (e.g. in relation to support for the creation of a new technology-based firms)</td>
</tr>
<tr>
<td>indicators</td>
<td>quantifiable factors which serve as proxies for underlying behaviour of interest to policy-makers or others- a country's high-tech patent applications per million population is one indicator of its innovative capacity</td>
</tr>
<tr>
<td>innovation finance</td>
<td>all of the sources of finance available to high-tech start-ups in their early stages of growth - includes seed capital funds, informal investors, banks and venture capital funds</td>
</tr>
<tr>
<td>intellectual property rights (IPR)</td>
<td>defined rights to the exclusive exploitation of intellectual property granted by a national or supra-national authority - most commonly, patents, trademarks and industrial designs</td>
</tr>
</tbody>
</table>

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knowledge base the accumulating sum of knowledge on which the advance of a particular industrial sector relies - includes not just codified knowledge but also a tacit knowledge and knowledge embedded in plant and equipment

technology foresight the process of assessing the future needs and opportunities for the economy of a region or country, in the light of technological and market trends

research and development (R&D) Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.


REQUEST FOR INFORMATION

A. Contact information Please answer where appropriate

NAME of responsible person for information: ..........................................................
Contact information

B. Most important activities of your Organization Please answer where appropriate

Please give the three most important activities of your Organization: 1 ..........................................................
2 ..........................................................
3 ..........................................................

C. Type of Organization Please, tick only one answer

Your Organization is: 1 [  ] Public (Governmental)
2 [  ] Private
[  ] Other ..........................................................

PLEASE provide responses for Section 1 below, which addresses general STI policies and for those topics identified in Sections 2 through 7

1. The STI System

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1.1. Please provide brief information of policies for STI, emphasizing the following topics:
Main features of the National Innovation System (NIS) framework with focus on: (a) agents that constitutes the science and technology system, included higher education institutions; (b) agents that are grouped under the “firms”, or the group of the productive sectors; and (c) the public administration, including the different governmental levels. A definition of National Innovation Systems can be found in *OECD Dynamising National Innovation Systems* 14 (2002, *OECD, Paris*).

1.2 Provide features of the national budget on S&T expenditure (% of GDP)* and how it is distributed, or the geographical distribution of funds.
*Total S&T efforts (breakdowns by financing sources, economic sector and field of Science) /Gross domestic product.

1.3. Please provide information on the Intellectual Property Policy, considering guidelines that encourages and expedites the dissemination of discoveries, creations and new knowledge generated by researchers for the social benefit

1.4. Provide if available major changes in the legislative, administrative, organisational, institutional, or budgetary framework for the formulation and implementation of STI policy are related to national sustainability-related policies and strategies.

1.5 Indicate R&D expenditure (% of GDP) as Total R&D efforts (breakdown by financing sources, economic sector and field of Science) /Gross domestic product. Gross Domestic Expenditure on R&D -- GERD

2. Public sector R&D

2.1. Please describe policy related to public funding for R&D, including indicators on the amount of public budget devoted to R&D, and provide if available information on how such financing is distributed among the different levels of government. Indicate funding allocated to environmental research organizations.

2.2. Describe policy related R&D, performed by universities and public research organizations. In the case of Brazil, please inform if available, information on the public appropriation of R&D in those more urgent social-environmental aspects of the country.

3. Private-sector R&D and innovation

3.1. Please describe major measures related to the management and strategy intended to enhance public support for private sector R&D and innovation: Government direct R&D funding includes grants, loans and procurement. Government indirect R&D funding includes tax

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14 “the NIS framework implies a comprehensive perspective on policy design aiming at improving the overall configuration of the innovation system, notably as regards the reallocation of financial support to R&D, incentives for collaboration among firms and between public and private institutions, and reduction of the regulatory obstacles that hinder mobility of human resource” *(Dynamising National Innovation Systems, OECD, 2002, pp. 7-8)*
incentives such as R&D tax credits, R&D allowances, reductions in R&D workers’ wage taxes and social security contributions.

3.2. Provide an overview of R&D partnerships by industrial sector (universities, companies, government).

3.3. Please inform if public support for private sector R&D and innovation is devoted to to specific technology areas, such as biotechnology, nanotechnology, software and knowledge-intensive services.

3.4 Please inform about Governmental Programmes to support R&D and innovation in SMEs.

4. Collaboration among innovating organizations

4.1. Please describe major initiatives to promote collaboration among private and public-sector organisations, including estimated (i) proportion of innovation-active businesses collaborating with universities; (ii) proportion of innovation-active businesses collaborating with publicly-funded research agencies; (iii) proportion of SMEs collaborating in innovation; (iv) and proportion of large firms collaborating in innovation.

4.2 Describe Governmental initiatives to strengthen Joint research agreements or research centres, such as measures to promote stronger collaboration among firms, universities, buyers, suppliers, other enterprises or publicly funded research organisations.

5. Human Resources in the STI System

5.1. Please give an overview regarding R&D, human resources and technology to characterize the country’s STI system. Include indicators related to inputs (expenditures), outputs (results), and stocks (the available institutions and human resources).

5.2. Describe briefly if available: Government R&D personnel, Government researchers as a percentage of national total, Higher Education researchers, Total Business Enterprise R&D personnel per thousand employment in industry; Women researchers as a percentage of total researchers.

5.3. Provide information on training programmes fostering Human Resources for the industry-university cooperation, as well as education programmes for Infrastructure and Human Resources in S&T to boost scientific and technological studies, especially in the areas of environmental science and engineering.

5.4 Describe policy initiatives aimed at developing a continuing education curriculum to improve the expertise and technological capability of engineers.

6. Internationalization of R&D

6.1. Please describe policy initiatives to strengthen research excellence and STI performance by a better access to foreign sources of knowledge and by increased global cooperation between research organisations and innovation networks.
6.2. Describe policy initiatives to increase the attractiveness of the country on the worldwide R&D market, to successfully compete for R&D contracts and services and to attract more foreign investments in R&D.

6.3. Describe policy initiatives to: (i) international R&D cooperation to generate new scientific knowledge and technological know-how (e.g. the case of bilateral intergovernmental STI programmes); (ii) international R&D alliances, especially among SMEs.

6.4. Describe policy initiatives to facilitate the international mobility of researchers, and to foster international co-operation among researchers in universities and public research organizations, mobility of scientific and high-skilled personnel and to attract expatriate and foreign researchers.

7. Sustainability and Industrial Innovation-related policies

7.1. Globalisation – Please describe special programmes or initiatives in the industry sectors to respond to environmental global problems and international commitments and to foster competitiveness and sustainability performance in world markets.

7.2. Climate Change Adaptation Action Plan – Describe special programmes or initiatives to business, public sector organisations and other institutions incorporate the impacts of climate change into their strategy and plan-making processes.

7.3. Carbon Emissions Reduction Policy – Describe investments in research to develop cost-effective renewable and efficient energy technologies, improve the performance of carbon energy systems, and special programmes or initiatives to support R&D for new, clean energy systems and processes.

7.4 Corporate Sustainability Policy – Describe programmes to stimulate sustainable action among firms, e.g. in areas such as socioenvironmental management.

THANK YOU VERY MUCH FOR COMPLETING THIS QUESTIONNAIRE
II. ENCLOSED PAPERS

Paper I
Dynamics of Public Entities as Promoters of Innovation, Sustainable Development and Growth
Santos, R.

Paper II
Strategies for Competitiveness and Sustainability: Adaptation of Brazilian Subsidiary of a Swedish Multinational Corporation
Santos, R.; Oliva, E.; Leal, W.; Wennersten, R.

Paper III
Sustainability and Technological Capability Accumulation Paths in the Brazilian multinational USIMINAS: an assessment of theory and practice
Santos, R.

Paper IV
Innovation systems and sustainability: an approach for regional clustering and MNCs subsidiaries
Santos, R.; Leal Filho, W.; Mirra, E.

Paper V
Technological Trajectories and Sustainability: Trends in Brazilian Subsidiaries of Swedish Multinational Corporations
Santos, R.; Snickars, F.; Mirra, E.