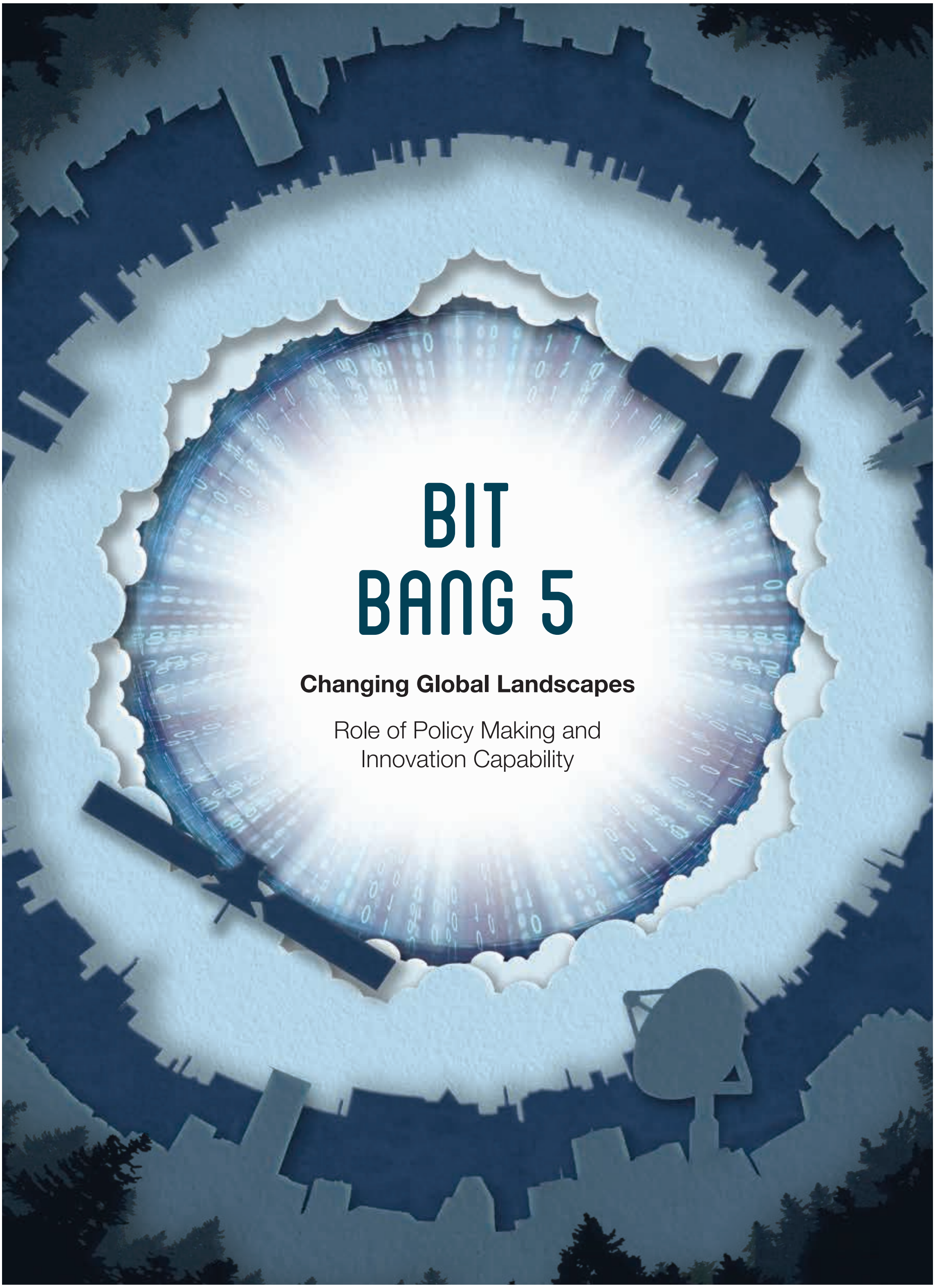

BIT BANG 5

Changing Global Landscapes

Role of Policy Making and
Innovation Capability

Yrjö Neuvo, Erkki Ormala & Elina Karvonen (eds.)

Aalto University's Multidisciplinary Institute of Digitalisation and Energy (MIDE)

Bit Bang 5

Changing Global Landscapes – Role of Policy Making and Innovation Capability

ISBN 978-952-60-3633-5 (pbk)
ISBN 978-952-60-3634-2 (PDF)

Cover: Matti Virtanen
Layout: Unigrafia / Riikka Hyypiä
Printed by: Unigrafia, 2013

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Foreword

The book you are just holding is fifth in the Bit Bang series of books produced as multidisciplinary teamwork exercises by doctoral students who during the academic year 2012-13 participated in the Bit Bang 5 course *Changing Global Landscapes: Role of policy making and innovation capability*.

In the academic year 2012-2013 altogether 24 students were selected to the course. As before, we were lucky to have students with highly varying cultural and scientific backgrounds. This year the discussion at the course meetings were fuelled by people from 14 different nationalities and from five Aalto Schools (Chemistry, Engineering, Electrical Engineering, Science and the Business School).

As a novelty compared to previous years the facilitating team was reinforced by inviting Nokia's Vice President, Dr. Erkki Ormala to co-teach the course with Professor Yrjö Neuvo, MIDE Program Leader and Nokia's former Chief Technology Officer.

The weekly lectures, literature work and writing the chapters for the joint publication set a good base for achieving the essential learning aims of the course: teamwork, multidisciplinary collaboration, and gaining global perspective and industry and business foresight. As textbook material and to support discussion and the team work the students used Ruchir Sharma's (2012) *Breakout Nations*, Richar H. K. Vietor's (2007) *How Countries Compete*, David MacKay's (2009) *Sustainable Energy without the Hot Air* and selected chapters from the earlier Bit Bang publications.

With the help of a group of energetic post graduate students, an updated management team and relevant reading we set out to seek answers to what makes the difference between the global market leaders and their followers. The students worked in six-person teams to produce chapters for this publication.

By the end of the autumn term four teams had produced four viewpoints to the nature of global competition. The question asked were: What kind of role a nation's higher education system has in bringing about and foster innovativeness and economic growth? (Chapter 1.1); Where does the potential for innovation-based growth lie in the nation-level? (Chapter 1.2); What is the potential of additive manufacturing and the possible effects its widespread adoption on the economical, societal and global levels? (Chapter 2.1); and What kind of development should take place in order for CleanTech to become a significant self-sustaining force and a national competitive edge? (Chapter 2.2).

In the spring term the groups continued with the same theme and developed more questions: How could the industries be renewed in order to find new national strongholds for global competence? (Chapter 1.3); How the creative industry is affected by digitalisation and how the business models in a variety of sub-industries could be changed accordingly? (Chapter 2.3); How does the rare earth elements industry correspond to the ever growing demand, and how could a European nation form a foothold in the industry's China-dominated value chain? (Chapter 2.4); How the governmental structures could be altered to better tackle the multifaceted challenges of our societies? (Chapter 1.4). We were intrigued by their answers – hopefully you'll also be!

In addition to the lectures and textbooks, the Bit Bang group made an intensive study tour to Beijing, China. The tour program and short reports of the company and institution visits are available in the appendices.

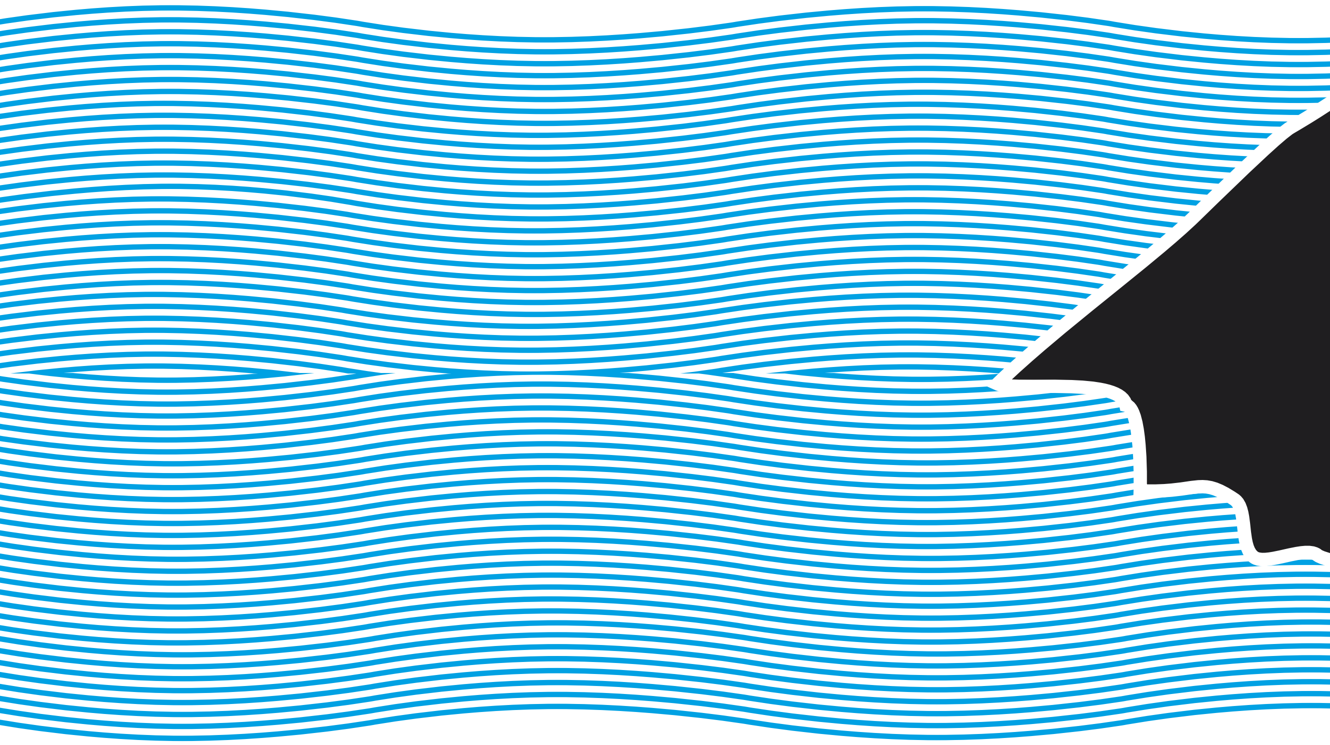
The Bit Bang courses are funded by the Multidisciplinary Institute of Digitalisation and Energy (MIDE) established in 2008. The unique nature of this course has raised a very positive interest in the academic community. The Bit Bang alumni network has grown during the years, connecting now over a hundred Aalto doctoral students and graduated doctors. We are proud of the community we've been able to gather around this very special and thought-provoking course.

We want to give our special thanks to our tutors and former bit bangers Somaya Arianfar, Pyry Kivisaari, Evgenia Litvinova and Tatu Lyytinen for their tireless work with their teams and valuable advice whenever needed.

We also greatly appreciate the contribution of high level external speakers representing government, industry and academia. The presentations and discussions gave invaluable insight into the issues studied. We wish to thank sincerely the speakers for their involvement in the course. Their role was essential in the success of the course.

As before, we wish you captivating moments with the book!

Yrjö Neuvo, Erkki Ormala & Elina Karvonen



1
Creative government

1.1 University marketized: higher education as a primus motor for growth?

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Abstract

In a world where possessing raw materials or manufacturing commodities are not sufficient for long-term economic success, innovativeness and a knowledge-based economy form the basis for prosperity. In this report, we discuss the link between a nation's higher education system and its ability to bring about and foster innovativeness and economic growth. In particular, we will concentrate on (a) governmental actions that are available for shaping the higher education system to better respond to the need for innovativeness, and (b) the roles that universities play in the national innovation system. Some of the questions we address include: How strong a link is there between the education system and nation's innovativeness? How important is industry-academia collaboration? From the perspective of a knowledge-based economy, what would an ideal university be like? To answer these questions, we summarize key findings from the literature, which are then used describe two plausible future scenarios for universities. One of the scenarios describes a university in an imaginary nation in a "clean slate", and the other in a developed nation with an established higher education system. The aim of this report is not to give specific recommendations for policymakers, but to present the key factors and decisions that should be considered in future higher education strategies.

Keywords: higher education, university marketization, industry-academia collaboration, entrepreneurship, scenarios

1 Introduction

The academic world is facing substantial changes in its operational environment globally. The enrolments in tertiary education have increased 75% globally since the year 2000 (UNESCO, 2012); and at the same time, there is an ongoing general trend of cutting costs. These factors are driving the development called *university marketization*. Universities are involved in the generation of economic wealth: a survey of Stanford alumni by Eesley and Miller (2012) revealed that if all companies having their roots in the university would form a nation, it would comprise the world's tenth largest economy! Even though the success of these companies is not typically based on technology developed at the university, it emphasizes the role of university in educating talented individuals who can create wealth that benefits the society. Indeed, societies increasingly expect their universities to directly serve the needs of the society rather than promoting science and education for the sake of science itself. This means that universities are expected to respond more rapidly to changes in the needs of industry, educate more people in areas that bring more profit to the society, participate actively in solving global economic and environmental challenges, and, increasingly, educate people with bright ideas to start new successful businesses.

However, outlining "the correct mission" or "the best strategy" for a university in the depicted situation is challenging. Basic research based on curiosity cannot (and should not) be sacrificed for commercial values, because basic research is the foundation for both solving big problems such as climate change and for new technological innovations that also create economic growth. On the other hand, collaboration with other societal actors (industry, non-profit organizations, and government) plays a crucial role in applying science and transferring knowledge. The traditional knowledge transfer and interchange between universities and big companies have created many success stories in developed countries, but this will not be enough to ensure future prosperity. The strategies of universities also depend on where they are located, so that, for example, universities in the developed and developing countries may need very different strategies.

In this report, we discuss how governments can have an important role in increasing universities' impact on the economy, most importantly by either facilitating or regulating the university-industry interplay. Facilitating would mean, for example, making joint projects between academia and industry more attractive through tax relief, whereas regulation would mean requiring public universities to have at least a minimum amount of industry collaboration and new start-ups to secure their public funding. Also, the intellectual property rights (IPR) laws are a crucial way for a government to steer how efficiently potential ideas in academia transfer to commercial use. Effective IPR practices transfer the best ideas from academia to new businesses without disturbing the inventor's scientific work, but at the same time secure the inventor's share of the economic benefits. One additional way to increase knowledge transfer is to simply educate entrepreneurial skills to more students and graduates.

We also explore the joint effects of university marketization and increasing demands for universities' societal impact. As illustrated in Figure 1, we study the links between higher education and innovation and universities' ways of creating more business in the society. The scenarios at the end of this report are meant to provide new insights in university operations in the future for different types of countries.

We note that even though we touch upon some other aspects of universities' new role in the unpredictably changing global landscape, we mostly treat universities as sources of innovation and economic wealth, which can be directly measured. Furthermore, we do not discuss fields, such as the arts, social and human sciences, whose economic effects the current instruments do not measure holistically and as such their economic impact is probably underestimated in different indices. Other roles of higher education such as solving the big problems (climate change, healthcare), and civilizing the society are simply deemed out of scope consider this report as well.

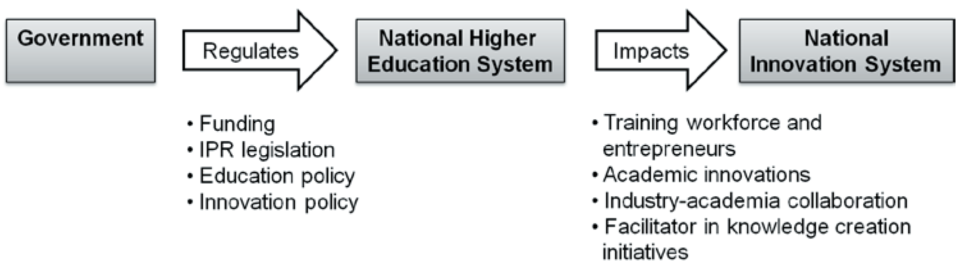

Fig. 1. Scope of report

The report is organized as follows. In Section 2, we describe university marketization and in particular, concentrate on the government's role in controlling this development. In Section 3, we establish a link between the higher education system and the national innovation system. Here, the focus is on the industry-academia interface and its impact on creating new commercial successes, such as technological innovations and process improvements. We also discuss the entrepreneurial environment and the role of the university in generating start-ups. After these, Section 4 will elaborate the links between government, the higher education system, and competitiveness by presenting scenarios for two illustrative nations with different initial states: (1) a nation with a well-established higher education system, and (2) a nation in "a clean slate", i.e. a developing nation. For both cases, a plausible future path will be discussed. Finally, some conclusions are drawn in Section 5.

2 Governments and university marketization

Significant reforms have been made to national higher education systems recently. For example, almost all European countries have undergone a reform in higher education governance since 1995 (EU, 2008) and developing nations are also facing major changes, such as the rise of the private education sector (see Jamshidi et al., 2012; The World Bank, 2008). In the past four decades, most of the developing nations, including the MENA (Middle East and North Africa) countries, have invested a substantial proportion of their total GDP (5%) on their educational systems to expand and improve them (The World Bank, 2008). As elaborated below, the reasons for these reforms are twofold: (1) the mismatch of demand and supply in higher education globally, and (2) the changing role of the university as a societal actor.

Jamshidi et al. (2012) discuss the reasons for increased demand for higher education. First, the world's population is growing, particularly in most developing countries. This, together with the rise of the knowledge-based economy, has created an *overall increase in demand*. For example, according to an estimate by UNESCO (2009), the amount of tertiary students globally grew some 53% between 2000 and 2007 (from 100 to 150 million). At the same time, specific educational needs are increasing. For example, there is demand for religious education or employment-driven growth in business or computer sciences (Sanyal and Johnstone, 2011). This kind of demand can be labelled *differentiated demand,* and it is particularly pertinent for developing nations.

Second, while both types of demand (*overall* and *differentiated* demands) have been increasing, there is simultaneous pressure to cut public spending (Sanyal and Johnstone, 2011). For instance, a study in the U.S. shows that state investment on a per-student basis, adjusted for inflation, is at an historic low (Kirwan, 2007). On the other hand, the cost of higher education is increasing. For example, the average public funding per undergraduate engineering student in Finland increased from 3000€

to 4150€ between 1997 and 2007 (Korhonen-Yrjänheikki, 2010). As a conclusion, the higher education systems are meeting increasing demand and diminishing resources and this is generally happening in all parts of the world.

The role of the university seems to be changing, too. According to Heap (2008), universities "…are now seen not only as creator of knowledge and sources of learning and education, but also as drivers of innovation." Indeed, governments are pursuing competitive advantage through higher education reforms. For example, the EU-wide Lisbon Agenda sees universities as "crucial factors in the drive to improve competitiveness and innovation" (Hagen, 2008). This changing role from independent teaching and research institutes towards accelerators of economic growth is clearly revealed in the university reform act of 2009 in Finland. Among the key targets for the reform are: diversification of funding bases, allocation of resources to top research and areas with strategic focus, and strengthening the role in the innovation system (Niinikoski et al., 2012), which all seem rather non-traditional in the university world. Overall, it seems that the Humboldtian model that emphasizes the university's role as an independent teaching and research institute is no longer the goal of the governments.

2.1 University marketization

So what are the governments doing, then? According to an EU report about European reforms (EU, 2008), changes are made in multiple directions: new ways to steer the education system have been introduced (e.g., contracts between the state and universities), new higher education sectors have been established (e.g., universities of applied sciences), private higher education services have gained ground, and many initiatives have been made to encourage collaborative research between public (university) and private (companies) sectors. According to the report, two major trends can be concluded from these reforms: institutional *autonomy* is increasing, but so is the *accountability* and performance measurement.

Institutional autonomy can be divided into four dimensions (EU, 2008): (1) organizational autonomy, which refers to the right of the institution to decide on its own organizational structure, (2) policy autonomy, which refers to the right to determine student and staff selection and the teaching and research portfolio, (3) financial autonomy, which includes the ability to decide on internal resource allocation and diversify sources of income (e.g., tuition fees), and (4) interventional autonomy, which means the level of accountability requirements. As mentioned earlier, autonomy in general is increasing, though this is very limited to cases 1, 2 and 3 above.

An institution should nevertheless be accountable for the policies it follows, the decisions it makes, and the possible effects of them on the society. Therefore, for every kind of autonomy that is given to the universities, they should still be held accountable by the society. For instance, universities are still accountable for those students who are blocked from higher education due to the student selection policies or applied tuition fees. And universities are accountable for the quality of education that is delivered to the students. Thus the universities are accountable against the society for the talents that are wasted due to not having the proper bed for growth. The universities are still accountable for the results and subjects of research that might harm or benefit the society (Kirwan, 2007). They are accountable even for the research subjects that are abandoned and never carried out because of the research policies followed. Although universities are given financial autonomy, they should still be responsible for how the money is invested, specifically for that part of their budget that still comes from taxpayers' money. In general, despite the given autonomy to the universities, they are still not a private sector industry. Thus, quality never should be sacrificed for the sake of quantity, either for the graduated students or for the research carried out.

Autonomy and accountability are the key ingredients of what we refer to from here on as *university marketization* development. Wedlin (2008) discusses the university marketization process and presents three general features of the development. First, the social rationalization for the university's aims and mission, which means the changing role of the university as a societal actor, as explained in the previous subsection. Secondly, Wedlin (2008) states that there are changes in the regulation and control of universities, and that these changes are often built on logical market principles such as competition and freedom of choice. While this can imply less regulation, it can also imply softer-than-before regulation means, such as policy statements. In other words, institutional autonomy is increasing, but governments are coming up with softer means to drive universities towards national objectives. Thirdly, Wedlin (2008) brings up financial autonomy, and simply put, the ambition of universities to make money. Already, for many universities, the incoming funds consist of tuition fees, sponsored research, private donations, etc., in addition to the governmental funding.

2.2 The role of the governments

The governments' role in university marketization is not so much to act as a leader, but rather more like a steerer. As often stated (e.g., Green, 2012), governments are bad at picking winning technologies, or on a more general level, "picking the winners". A recent example from Finland (see Academy of Finland, 2002) is biotechnology, which received heavy R&D investments in the late '90s and early 2000s without notable commercial successes to this date. The experts we interviewed brought this up as an example of how government agendas do not lead to commercial success if the business environment is not suitable. Thus, in higher education reforms and more generally in research policymaking, the government's role should be an enabler and facilitator. Next, we discuss two key areas in this respect: *funding* and *legislation*.

A key governmental role is to provide funding for higher education, though there are major differences in the national funding systems with respect to how primary, secondary, and tertiary education funding is arranged. For instance, in contrast to

OECD countries and others such as South Korea and China where the governments are reducing public funding from the universities and putting more investment into primary education (Salmi, 2009), the MENA countries have invested public funding mostly on the tertiary and secondary levels during the past decades (The World Bank, 2008). This exemplifies well the differences in higher education steering policies; countries that share more public funding on the university level are on a different trajectory compared to (most of the developed) countries that are driving university marketization. Where university marketization gives the opportunity to respond to the growing demand and the emergence of new and dynamic sectors of the industry, heavy public investments seem to serve the needs of the public sector and might even decrease a nation's competitiveness among other nations.

Nations also differ in the amount of funding available for higher education (Sanyal and Johnstone, 2011) and in the principles of how public funding is shared. That is, the funding can be gratuitous or competitive, meaning that the amount of funding can be tied to some quantitative indicators, such as the number of completed degrees or scientific publications. According to our interviewees, countries differ a lot in this respect. For example, in the U.S., funding typically comes from a publicly funded foundation, which can be very selective when allocating research funds. This has led to a system where the minority of universities gets the majority of the research funding. In European countries, in contrast, funding is a lot less competitive and funds are often spread evenly according to, e.g., number of staff or students, which leads to a very different university portfolio. In many countries political agendas also play a role. For example, in Finland regional politics can override educational politics when the role and funding of universities located in sparsely populated areas of the country are considered.

Funding is just a part of overall legislation that is the main governmental tool for steering university marketization. It was mentioned earlier that university acts can be used to effectively control the autonomy of universities. For example, the legal status of the university can change. In Finland and Portugal, the latest reforms allowed transforming public universities to foundation-based universities, thus allowing them more autonomy and access to private funding (Niinikoski et al., 2012). In Finland and the Netherlands, universities of applied sciences have been introduced. But there are also other important areas of legislation apart from direct university laws. In particular, we emphasize invention-related legislation, or Intellectual Property Rights (IPR)-related legislation. As discussed later (Section 3.2), IPR plays a key role in industry-academia collaboration, which is one of the main drivers of innovation and a knowledge-based economy.

2.3 Summary

In summary, there is a strong worldwide tendency for governments to accelerate the development of university marketization, and this is happening in practically all parts of the world. Even though nations differ in this respect, the overall trend is that universities are gaining more autonomy. At the same time, they are measured more carefully, and the share of competitive funding for higher education seems to be increasing. While governments should not dictate research policies or try to choose “winning technologies”, they still play a significant role in setting the stage for university-based value creation and innovativeness. In particular, the role of the funding system and the overall legislation, IPR in particular, should be emphasized. This will be elaborated further in the next section.

3 University in the national innovation

What is the role of universities in the innovation system? In the Global Innovation Index (INSEAD and WIPO, 2012) (see Figure 2) there are five inputs that enable innovative activities: (1) Institutions, (2) Human capital and research, (3) Infrastructure, (4) Market sophistication, and (5) Business sophistication. The index is calculated from two main output pillars: (6) Knowledge and technology, and (7) Creative outputs. The input from universities is included under the pillar of Human capital and research, which contains Education, Tertiary education, and R&D. In what follows, we elaborate further the role of universities in the national innovation system.

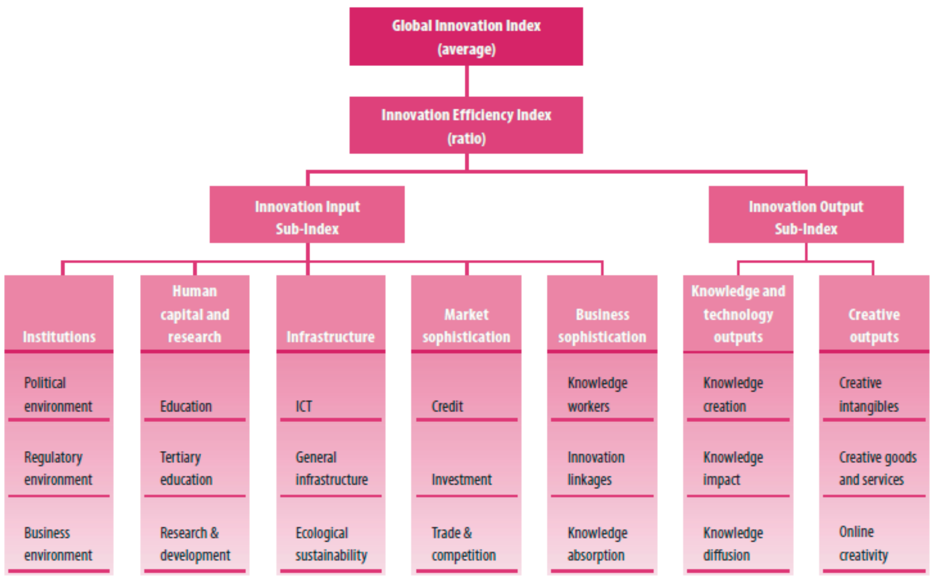

Fig. 2. The Global Innovation Index Framework (INSEAD and WIPO, 2012).

Jeffrey et al. (2002) define the national innovative capacity as "the ability of a country as both a political and economic entity to produce and commercialize a flow of new-to-the-world technologies over the long term". The industry, universities and various government sectors all play major roles in the national innovation system by interacting with one another. In this system, universities are seen as actors that affect the creation, development, and diffusion of innovation (Mowery and Sampat, 2006). Within this broader definition, universities place the knowledge base for capacity building of professionals in a wide spectrum of fields. Also, beyond maintaining basic science education, universities are generators of new ideas through their research departments. Naturally, research and development (R&D) practices are prominent sources of innovation.

3.1 Multiple roles of the university

Betts & Lee (2005) present five mechanisms through which universities can boost national R&D:

1. University as Trainer – the university's role in providing a steady supply of skilled graduates to the local economy.
2. University as Innovator – direct generation and commercialization of knowledge by universities working fairly independently of the private sector.
3. University as Partner – university as partner provides technical know-how to firms through agreements.
4. University as Regional Talent Magnet – the presence of a university in a region increases the attractiveness for talented innovative entrepreneurs, scientists and engineers.
5. University as Facilitator – the university can facilitate networking among those involved in the high-tech community from the private and public sector.

We emphasize that innovation often occurs outside academic environments as a result of inventive thinking and creative experimentation (Mowery and Sampat, 2006). As the different roles listed above show, however, universities can play many roles, such as in providing a forum for the exchange of ideas between different R&D communities (facilitator), in making research outputs more accessible to researchers in industry than to government research laboratories (innovator) and, more importantly, in training future industrial researchers (trainer, talent magnet) (Jeffrey et al., 2002).

There are many approaches on how the higher education system should be utilized to foster innovation. One approach is the so-called *linear model* (Mowery and Sampat, 2006), which means that by expanding public funding to enhance basic research, the university can be a critical contributor to economic growth. Mowery and Sampat (2006) explain that expanding basic research funding is both necessary and sufficient to promote innovation. On the other hand, they also argue that funding basic research is quite an inefficient means for improving innovation performance.

Another view of the role of university research in the national innovation system is focusing on the *contrasting norms* between academic and industrial research. University researchers have been giving significant contributions to the technology development as well as basic research in the industrial laboratories. Mowery and Sampat (2006) point out that the norms of academic research differ significantly from industrial research. For academic researchers, it is crucial to be the first to publish and disclose in order to gain professional recognition and advancement. In the industry, however, secrecy and limitation of disclosure are considered important for competitive advantage.

In the third conceptual framework by Mowery and Sampat (2006), research is carried out in a more *interdisciplinary, pluralistic, networked innovation system*. This approach is different from previous models that mainly concentrated on companies and university research without considering the links to other research institutes. The third framework gives the possibility to associate with greater inter-institutional collaboration and more interdisciplinary research. This can increase diversity inputs to the innovation process, and it reflects the modern innovation system.

The last conceptual framework is *the role changing model*, which has increased interaction among institutional and industry actors. In addition to a linkage between an institute and industry, each party can also take the role of the other. Thus, universities can pursue entrepreneurial tasks and companies can have an academic role in sharing knowledge (with each other, or by publishing) and giving high-level training. This model allows a more industrial role for a university to apply, and industrial activities are imitated at university simulation laboratories.

In light of all frameworks mentioned above, the link between university and other institutes and companies seems to be critical. The interaction between university and industry has been growing, and this has brought along changes in internal norms, rules, and the culture of the university. As networking and collaborative innovation processes are both increasing, the role of IPR to support the innovation process and commercialization is emphasized, as will be discussed next.

3.2 Industry-academia collaboration and the role of IPR

According to Maskus (1998), IPR – together with taxation, investment regulations, production incentives, trade policies, and competition rules – comprise the regulatory system that is essential for how much foreign direct investments a nation is able to attract. There is also empirical support (e.g., Lee and Mansfiel, 1996) indicating that strong IPR legislation increases foreign investments. So IPR is important for national success at large. But here we limit the discussion to how IPR can foster (or hinder) industry-academia relationships and university-based innovativeness.

IPR is essential in combining the openness and publicity of academic research with university marketization (Bruun, 2003). The first big question related to commercialization of research is who owns the rights to research results that are achieved with what we call *open research,* i.e., research without external partners involved. Here, one general trend has been that universities take institutional ownership (WIPO, 2011) of inventions and pursue commercialization through centralized offices. In Finland (see Ministry of Trade and Industry Finland, 2006), the researcher has the primary rights to inventions created under open research. It seems, however, that most commercially successful innovations are made under a *collaborative research* agreement ('*contract research*'). This typically involves external funding coming from an external actor (a company) that also dictates liabilities related to the research. In layman's terms: research is collaborative if there is an external party who provides funding and can (even partially) decide what is being researched and how the results can be published. In the case of Finland, the institution (university) owns the primary IPR. In this setting, the only way an external party can gain the IPR is a separate contract that defines how IPR are shared.

Indeed, in the latest university reforms (see EU, 2008), governments have encouraged and enhanced the link between universities and industrial innovation. This creates complex institutional landscapes that influence the creation, development and dissemination of innovations. Even though measuring and characterizing all of the impacts of universities in the national innovation system is a cumbersome task (as also pointed out by our interviewees), we will exemplify how IPR can influence industry-academia collaboration and, in particular, we illustrate how IPR rules could be agreed in such projects. Because covering all possibilities on how collaborative contracts should be designed is out of the scope of this paper, we limit ourselves to an illustrative example. (For an extensive analysis, see Hertzfeld et al., 2006.) Furthermore, we provide some ideas on how sophisticated contracts could be designed for the purpose of creating new incentive structures in industry-academia projects.

We consider a joint-research project between three parties: the university, a university researcher, and an external party (e.g. a company). All parties agree that they jointly elaborate common exploitation rules allowing each partner to exploit the industrial-academy collaboration outputs. These rules will be based on, for example, a European Commission contract and the collaboration agreement. Next, it is discussed which are the key things to agree on.

‣ **Definition of knowledge ownership at different project stages.** First, the ownership of knowledge can divided into three different stages:

1. *Background (pre-project) knowledge* – pre-existing knowledge, which was brought and contributes to the collaboration project by each partner before the project starts;
2. *Foreground (during-project) knowledge* – the knowledge developed during the collaboration project;
3. *Sideground (post-project) knowledge* – the knowledge further developed based on the outcome of the collaboration project afterwards – or within the project but outside the scope of the project.

‣ **Usage of IPR.** Second, the basic rules of IPR ownership and usage in different stages of knowledge creation need to be agreed on. A typical way to agree on the ownership of knowledge, reflecting the time dimension discussed above:

- Regarding any original contribution or *background knowledge* brought into the collaboration, the contributing member owns the IPR.
- Regarding any new *foreground knowledge* generated during the project, as a result of a cooperative activity, the IPR belongs jointly to the members contributing to this knowledge.
- Regarding any *sideground knowledge* generated based on the result of the project, the IPR belongs to the member that developed this knowledge.

Of course, there are other ways to agree on the IPR. For example, it can be agreed that all IPR related to direct project-related new knowledge in the *post*-project stage are transferred to the project and thus become jointly-owned or company-owned knowledge.

The rules related to usage should also govern potential revenue sharing. These shall be defined before or during the project in the collaboration agreement and with detailed conditions related to ownership of the project results. The main goal of the collaboration agreement is to set the ground rules for individually or jointly exploiting the outcome of the collaboration project to ensure that each partner‘s tangible and intangible investment in the project are protected.

- Various scientific and technological developers participate in the collaborative research, development and integration team. While working together in the development of the project objectives, they can also develop, or co-develop, their own independent, but integrated, applications that could be exploited separately.
- Property rights related to single activities are very clearly split between those partners who can claim ownership of stand-alone activity or part of it.
- Because a project is a collaborative venture, participants will agree among themselves on allocation of the project results. Thus, the IPR ownership of the results related to the integrated project solution will be shared between contributing members considering their bearing of project costs.
- Other arrangements, such as sublicensing, are subject to the owner’s approval.

As mentioned earlier, IPR is one of the most critical and complicated factor in the industry-academy collaboration. The above is only one example as a suggestion on how IPR can be considered and agreed on in a collaboration project. With clear IPR access and rights, that will maximize the sources and pre-knowledge that would be brought into the project, protect each partner’s tangible and intangible investments, and ensure that the outcome of the projects would be properly and efficiently exploited. As a new and attractive avenue, the use of options is briefly presented next.

- **Option contracts.** Options could be utilized in industry-academia projects to share risks and provide incentives. Options are mostly used in financial markets, but they are increasingly used in other areas, such as private contracting between companies. Here we discuss the use of option contracts for R&D collaboration – an idea which is already widely applied in internal operations (e.g., Dixit and Pindyck, 1995; Luehrman, 1998). As an example of a collaborative contract, Uppsala University uses options in their innovation support framework (Uppsala University, 2011). For example, they have established a company called UU Projekt AB, which can contribute funding to cover the patent application costs. They also help cover project management costs of an R&D project. In the project, however, specific milestones are agreed on beforehand, where both of the parties have an *abandon* option for the project.

  The main motivation for the use of options is the uncertain nature of research projects, which can hinder many good opportunities when one of the parties (here, the university, researcher, or an external party) is not willing to participate due to high financial risk and uncertainty about the end result. Note that the relevant risks are not only financial. For example, the researcher can carry the risk of not being able to publish results. As an example of a direct IPR option, consider a contract where the company has *the right but not the obligation* to decide on IPR usage only after the main results are achieved. For example, it can decide whether the university or the researcher gets the IPR, or whether the results are handled as trade secrets. While this is naturally attractive for the company, the academic partners would need an incentive to participate. In this case, the company should have different costs relating to its options: (a) it could release the IPR without cost (other than the project cost itself), (b) it could pay a lump sum (say, 100,000€) for the IPR but allow publishing of the results that do not endanger commercialization, or (c) it could claim the results as a trade secret and pay a lump sum plus a percentage of all generated revenue for the academic partners. In this way, the academic side gets rewarded either by a publication or financially, whereas the company decreases the risk of losing critical IPR or paying too much (in a commercial sense) for useless new knowledge. We acknowledge that this kind of contract might be cumbersome to establish, but the basic principles should be applicable to projects of this nature.

3.3 Educating entrepreneurial skills

The university's role as a trainer and talent magnet is also increasing. And in many countries, start-ups and growing small businesses have become key contributors to the economic and employment growth due to their dynamism and their capacity to exploit the local knowledge base. Recently, it has been recognized that it is the task of higher education institutions to mobilize university graduates for entrepreneurial careers, enhancing their entrepreneurial skills and providing support for their business start-ups (Hofer et al., 2010). These tasks can be accomplished through both entrepreneurship education and a start-up support framework. The OECD report by

Hofer et al. (2010) concludes that for university technology transfer to be productive in the creation of spin-offs, the university must adopt a strategic approach to the commercialization of its intellectual property portfolio.

However, Astebro et al. (2012) point out that start-ups by recent university graduates in general outnumber faculty spin-offs by at least an order of magnitude. The counterpoint goes after the transferring of ownership of intellectual property from professors/employees to universities, which has been adopted in several European countries. Astebro et al. (2012) also concluded that transforming university goals and practices toward increasing start-ups led by faculty might not be the most effective way for universities to stimulate entrepreneurial economic development. However, even though it is not sufficient by itself, many studies agree on the need for nurturing the entrepreneurial spirit through universities. Next, we explore the best university practices to foster innovative entrepreneurship skills among young graduates.

‣ **Entrepreneurship education.** Entrepreneurship is a management and leadership style that involves pursuing opportunities without regard to resources currently controlled. Most scholars agree on the fact that entrepreneurship can be taught, and that educational programs can positively influence an individual's entrepreneurial attributes (e.g., Matthew et al., 2012). Even those studies that are sceptical about the relationship between entrepreneurship courses and start-up rates of graduates (e.g., Astebro et al., 2012) agree that such courses can only have a positive impact on students' entrepreneurial motivation.

Kauffman (2009) emphasizes that human understanding, ingenuity, and inventiveness will become ever more critical to creating a sustainable future. Consequently we will need people who know how to implement new ideas and make them accessible to large populations. A comparison of American colleges indicates that the number of courses about entrepreneurship increased over 20 times between 1985 and 2009 (Kauffman, 2009). In the curriculum of most universities, there are courses addressing this subject. However, the courses are left for an elective group and would be pressure on engineers and technology students to enroll in the courses.

Curricular components needed to successfully develop entrepreneurial skills can include the following (Matthew et al., 2012):

- Courses in negotiation, leadership, new product development, creative thinking, and introduction to technological innovation
- Curricular and co-curricular opportunities to increase awareness of entrepreneurial career options
- Sources of venture capital
- Techniques for protecting ideas through patents and other measures
- Ambiguity tolerance
- The characteristics defining the entrepreneurial personality
- The challenges of each stage of venture development

One issue about these courses is that the educators themselves often do not have practical entrepreneurial experience. Also, it is expensive to follow experimental problem-solving-based education other than the traditional "talk and chalk" style lectures. The target and benefits of the entrepreneurship courses are not bounded with start-ups; more broadly they are also helpful skills for individual student's self-actualization and innovativeness. These students could end up in established companies; however, they will be engines for innovation by meeting international challenges.

Even though the idea of an "entrepreneurial university" might appeal to policy-makers, one should consider how much personal characteristics and attitude can be replaced or enhanced by the formal education system. For example, as the authors of this paper are all PhD students and potential entrepreneurs, we identified a few potential questions that can be used to characterize the entrepreneurial mindset:

1. What are people's problems out there in the world? Can I find solutions?
2. What do people want and they cannot get?
3. What is out there that could be or should be?
4. What can I produce that would make life easier for people?
5. What could I design to save people time, effort, energy and money?
6. What products or services exist out there but are not working as well as they could?

These questions are relevant enough for most people to get motivated and inspired. What entrepreneurship courses do is teach the skills needed to answer them. Every student should be able to extract unique skills and learn how to use them in solving global challenges and ultimately give them value in the established market system.

‣ **Start-up support framework.** Building an entrepreneurial ecosystem around higher education and research should ensure the meaningful engagement of a wide range of stakeholders who share in the risks and rewards. According to Hofer et al. (2010), start-up support services could be in the form of entrepreneurship centres and technology transfer units, which offer would-be entrepreneurs and those already in the start-up process consultation and access to networks and premises. In addition, they provide direct support to a start-up: mentoring, grants, incubation facilities (see Figure 3). The Aalto Center for Entrepreneurship (ACE) is a good example in this regard. ACE was operationally launched in September 2010 and has already listed nine start-up companies in its success stories.

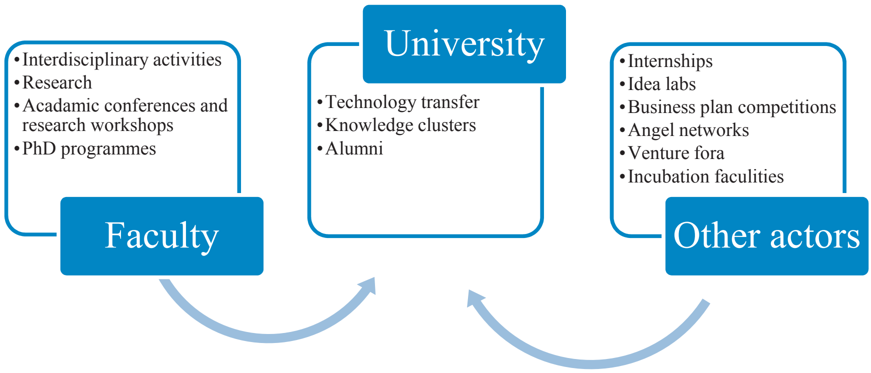

Fig. 3. Example of a Complete University Entrepreneurship Initiative (Hofer et al., 2010)

Hofer et al. (2010) studied entrepreneurship support in developing countries and found that in 11 out of the 16 universities, more than half of their entrepreneurship support is covered through grants from government, international organizations and the EU. Thus, public funding seems to be a key driver. Hofer et al. (2010) also list key success factors (see Table 1), which include the multidisciplinary background of students, university alumni, political support and autonomy of entrepreneurship centres, among other things.

Table 1. Success factors for a start-up support system (Hofer et al., 2010).

Students	Resources	Back up	Delivery
• Multidisciplinary backgrounds • Inspired to pursue excellence • Reflexivity and curiosity	• Professors • Start-up grants • Low turnover of staff • Alumni	• University (vision and leadership, cross-faculty support, international connections) • Political support • Demand for new firms	• Single window for students • Autonomy of entrepreneurship centres • Business incubation facilities, networks • Potential investor collaboration, • Entrepreneurship education and start-up support work "hand in hand" • Customised and 1-1 support • Competitions, guerrilla marketing

3.4 Summary

To summarize the discussion above, universities play a critical role in the national innovation system as a workforce trainer, as a source of innovation, as a collaborative partner, as a talent magnet, and as a facilitator in innovative networks. In particular, it was discussed how important industry-academia collaboration is and how IPR can have a big impact on collaborative partnerships. According to the experts we interviewed, sharing IPR is not a minor detail in industry-academia collaboration; rather, it can be a major obstacle for many companies, which results in avoiding joint projects with academics. If the legislation emphasizes the rights of the university, the result can be that many potential ideas and inventions are left to universities, which in general are not very successful in the commercialization of inventions (WIPO, 2011). The ways IPR impacts industry-academia collaboration and, in general, university-based innovativeness seems twofold. First, the mechanism how IPR is shared within the university can have an impact on the commercialization of potential inventions. Arguably, if a person owns the IPR, there is a greater probability for commercialization in the form of entrepreneurship. Second, there seems to be room for improvement in how the results from joint projects can be shared between academic and industrial partners. Here, the current trend seems to be that the role of the university as IPR owner is emphasized through legislation. Whether this is the right direction, considering innovations and national competitiveness, remains an open question. We have presented some key factors that play a big role in establishing these partnerships, and we have also presented some ideas on how IPR sharing and commercialization could be further improved.

We also note that while setting IPR in place is a *necessary* condition for such partnerships, it is not *sufficient*. This means that even though academic collaboration would be a possibility for a company, it does not mean that it is an attractive possibility. Indeed, more understanding of why companies should pursue academic joint projects is needed. For example, developing better indicators to measure the utility of such projects could create more opportunities for industry-academy interactions. In general, more information is also needed on measures of industrial-level capacity, investment, and innovation creation.

We also discussed how universities play a big role in entrepreneurial activities. An *entrepreneurial university* is not afraid to maximize the potential for commercialization of their ideas and create value in society and does not see commercialization as a significant threat to academic values. Also, entrepreneurial universities are not all about spin-outs or start-ups; rather it is the implantation of skills needed to cope with the dynamic, multicultural and uncertain world that is still full of opportunities. Our study of this matter reveals that the traditional research and freedom of universities could incorporate activities targeted at entrepreneurship. However, to increase their positive impacts, universities should relate social responsibilities and ethics to their entrepreneurship educational activities. After all, innovation needs an immense spirit and a constructive attitude about the opportunity to be seized.

4 University scenarios

Scenarios are widely used as a decision support in strategic planning. Schoemaker (1995) discusses scenario generation steps starting from scope definition and identification of major stakeholders to development of quantitative tools and generation of decision spaces. Here we adopt a less systematic approach, presenting two plausible scenarios for an ideal university. In this respect, our approach is in line with Schoemaker. Our scenarios do not try to predict the future, but they try to imagine a possible realistic and achievable future.

Thus the aim of this section is to offer alternative visions on how tertiary education institutions could advance their industry collaboration activities to create wealth in the surrounding society. In the previous chapters, the role of governments has been discussed, as they create the frame of reference where universities and companies operate. Similarly, the role of universities in creating innovations or helping companies to create them has been considered. However, what can universities with different backgrounds do in practice to enhance their role as creator of prosperity in the surrounding society?

4.1 Type of university

Consider a situation where a university has decided to create a new strategy for its future to achieve the above-mentioned goal. Above all, it needs to set its focus very clearly, because there are several different types of tertiary education institutions with different aims. For instance, Salmi (2009) has listed four basic types: research university, teaching university/college, community college, and open university. In these scenarios only the *research-oriented universities* are discussed, even though teaching-oriented institutions create wealth, e.g., by offering knowledge transfer flow to companies and society and training a highly educated workforce in a wide variety of fields. However, only research-oriented universities can play all the roles of developing research and development activities as described above in Section 3.1. Thus, in the scenarios we consider the role of a research university as Trainer, Innovator, Partner, Regional Talent Magnet, and Facilitator.

4.2 Scenario in a "clean-slate" nation

It's 7:00 a.m. and the alarm wakes up Gadia. She gets ready for her first day at the Northern Mining University of Technology, located a fifteen-minute walk from her home. Gadia is one of twenty students who will be pursuing their doctoral degrees at the technical university, specializing in mining studies. Three hundred master-level students and five hundred bachelor students will also start their studies at her university. The highly specialized university offers degree programs in mining and mineral engineering, petroleum engineering, geomatics engineering, environmental and earth sciences, mining law, mining operations, mining health and safety, and mining business management. Gadia's university is one of the five mining universities established recently under a new higher education policy.

Gadia is a 28-year-old female, living in Panavia, the fourth largest city in Copperland. Her country is very rich in natural resources, especially precious minerals including gold, silver, diamonds, platinum, and it has huge oil and gas reserves. Most of the reserves are still unexplored, and the ones being explored and mined are controlled by multinational giants. The majority of the skilled labour and executives are foreign nationals, as the country lacks institutes for educating and training youth to work as professionals in the mining industry. Only 30% of the total labor force and 15% of the skilled labor and executives are locals, and very few mining enterprises are owned by the locals. The country held fresh elections last year, and the new government was keen on restructuring the educational policy. One of the key focus areas has been reforming higher education in the country, with a goal of increasing the employment level to 70% in five years from the current 45%. After the initiation of the new education policy, it is forecast that by 2018 the mining universities will be able to produce enough graduates to meet the growing demands of the mining industry (Figure 4). The new higher education policy also aims at creating most of the employment in the mining sector and also boosting mining entrepreneurship in the local communities as well as at a broader national level.

Fig. 4. Projected university graduates and jobs availability in the mining industry in Copperland

The highly specialized universities of mining are partially funded by the government of Copperland, while most of the income is generated solely by the universities. On average, all of the universities have managed to attract around 30% of the students from neighbouring countries who are funded by their governments. Another funding channel has been strong cooperation with the mining industry in the country as well as enterprises from neighbouring countries. Many multinationals are funding a substantial amount in the universities, as in couple of years they will be able to a have continuous stream of skilled labor and executives within the country. It is expected that by 2020, the mining industry will be providing half of the required funding for the universities (Figure 5). The multinationals are being granted subsidies in many areas, depending on the level of cooperation and funding. Companies with a greater interest in universities are given priority in future exploration and mining projects. The universities are also keen on increasing cooperation with the companies to raise funding, create internships and practical training, and boost quality industry research. The universities also aim at developing a strong patent portfolio and exploit those patents for the benefit of their own researchers as well as the collaborating companies to make use of these patents with flexible licensing agreements.

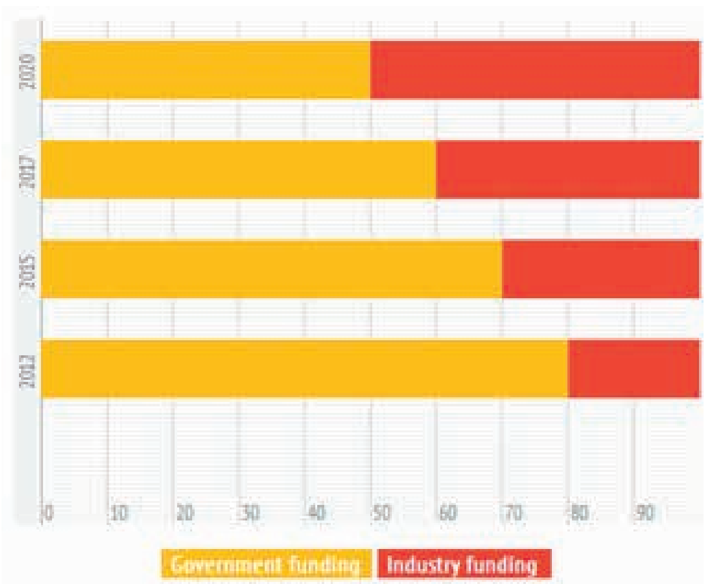

Fig. 5. Planned share of government-industry funding for a mining university

The new education policy also emphasizes that students should have an entrepreneurial mindset to make use of these patents in the form of new start-ups. This means that students also have good access to patents in their interest and the university can make very affordable licensing agreements. The original researcher that made the research leading to a patent has the primary rights to commercialize the patent, but these rights are often transferred to the university in case the researcher has no such interests. The universities are also involved in contract research, where the funding company also gets the IPR, as it is a very useful learning experience for the researchers participating in the project.

Gadia's university also offers an excellent infrastructure, including many high-tech computer labs, mining labs, and WIFI connectivity throughout the campus. Gadia has also been provided a free Internet connection at home so that she can access all the information from there. Her university is also e-connected with other universities, and she has the possibility to electronically attend any lecture or lab work at any other university, as all the lectures and lab work are broadcasted live through the Internet. All the lectures and lab work at these universities are archived, and she also has the possibility to view them later on.

During the inauguration ceremony at the university, Gadia was very pleased to know that her university has a top-notch faculty which is globally renown in their own domain. Most of the faculty consists of professionals, researchers, and academics of Copperlandic origin living abroad and have a number of years of experience in highly developed nations. The technical universities are also playing a great role in reversing the brain drain in the country, as many highly renown mining professionals and researchers have been living abroad due to limited opportunities in the local industry. Professionals and researchers returning to the country with years of expertise in their domain are gearing up new ventures, such as hosting international seminars and conferences on mining, publishing in top-notch international conferences and journals on mining, consulting local industry as well as advising many new start-ups. Due to all these activities, excellent university infrastructure, and close cooperation with industry, in a couple of years the mining universities of Copperland will be producing top researchers and PhDs in the field of mining and related disciplines.

It is expected that with the help of a new educational policy and other efforts by universities and industry, Copperland will be a highly specialized country for mining and related technologies. Due to the strong emphasis on innovation and entrepreneurship, and as a regional hub for mining-related education and research, it is expected that in the next five years the country will jump from its current rank of 192 on the Global competitive index to around 90. Similarly, the country is expected to rise in the Global innovation index from its current rank of 183 to 75. All in all, the universities are highly committed to making themselves and the surrounding network of collaborative companies the owners of the key technological and other innovations made in the mining area.

4.3 Scenario in a developed nation

Martin finished teaching his class at noon and heads for the cafeteria for lunch with his colleagues. It was going to be a long day – four hours of teaching, marking exams and two chapters of a PhD thesis manuscript to comment on. Martin prefers to concentrate on teaching and student issues on certain days, which leaves him free to practice research without interruptions on other days. He is also free to plan his own schedule according to the need.

Martin has worked hard to achieve his current position as a professor at Primus University. He had produced first-class research in his own field, which was duly noted among several university talent scouts, but then he decided to concentrate almost totally on teaching. His own decision to choose to work at Primus was due to many factors, including a well-established laboratory with an excellent staff, good funding sources, a reputation for gifted students, a good salary and good opportunities at the university hospital for his wife, a gifted researcher in clinical medicine. Martin also wants to raise his two children in a stable, yet intellectually invigorating environment. Primus University recruited him due to the passion that is clearly visible in his previous work and which he was now targeting to his teaching. Martin is naturally doing his best to encourage similar passions in his students. So what kind of a university is Martin actually working at?

Primus University was established several centuries ago and is continuously renown for its superb facilities, beautiful campus, high research and education standards, independent financial wealth and a long list of Nobel laureates. Since the university is financially independent – it has real estate, investment funds and equity in promising spin-off companies – it has created its own accountability forms and methods which do not stress the teaching and research staff. Its carefully chosen academic staff is motivated by intellectual goals rather than financial rewards, even though every member can reap the rewards of their own successful projects. Thus Martin has licensed some of his patents to start-up companies, but he is not allowed to be a board member in order not to create a conflict of interest with the university. In Primus, the policy concerning intellectual property rights is flexible, so research partners, university and the university staff agree on their division case by case. Primus acts a facilitator for its staff when discussing the terms of contract research and does not dictate rules to the involved parties. On a national level, intellectual property rights are respected in legislation, which means that domestic and international industrial partners feel safe to invest in Primus and in the whole region.

Primus is the talent magnet in its region, drawing also many gifted students worldwide to study there. As a well-known school in many fields and wanting to maintain high standards, the university selects its students with care. The aim is to keep a 50-50 balance between local students and foreign students. But more importantly, the prospective students are always tested for certain skills, depending on the field, and not just for previous success at school. The idea is to create diversity among students and to insure that people trained at Primus have the necessary skills. For instance, motoric skills of the hand, so important for surgeons, need to be practiced already at childhood to develop the neural pathways in the brain, and the same result can rarely be achieved as an adult. The tendency to favour local students has a goal the enrichment of the surrounding area, as some of the students settle there immediately after graduation or they return to their roots later in life. One of the goals of Primus is to nourish the local community intellectually and to create wealth, which in turn enables the university to prosper.

For centuries, the presence of Primus has created an active business community in the neighbouring areas, and research interests between the university and the companies are rife. Primus and the collaborative companies liaise on many levels and in fact operate in a healthy ecosystem created by cooperation and trust. For instance, students become familiar with the local companies already during their studies by preparing course assignments for them. Also during their studies, many students participate in a mentoring program where experienced professionals share their practical and hidden knowledge of real-world environments. Normally the companies are eager later on to hire graduates who are known for their practical problem-solving skills and seeing beyond the numbers. The discourse between the university staff and companies is further nourished by arranging continuous education and events, where people meet, exchange thoughts and develop ideas for common projects. Thus the collaboration is often initiated by shared fields of interest or by the need of the companies to develop their products and business models using the university's wider resources and knowledge. In practice, Primus has set up partnerships with companies to send its staff to collaborate on joint projects that might create innovations, but more importantly, motivate both parties to solve problems and learn more. Primus also benefits from the companies by gaining knowledge on the current state of industries, which is then used in teaching.

To appear attractive to prospective students and private partners, Primus jealously protects its academic standards created by centuries of tradition. Thus teaching is conducted in small classes, and the student-to-teacher ratio is purposefully kept low. However, Primus was among the first universities to start arranging virtual courses on the Internet. After years of experimenting, it was noticed that the achievements of its students were not greatly enhanced and the lack of physical human encounters sometimes even isolated people. The best results are still achieved in small groups on the campus, while using modern, technologically assisted teaching environments. Yet the larger scale virtual courses have their role in enhancing the reputation of the university worldwide and in bringing in some revenue, as the courses are not free of charge. Undeniably, they also give a chance for remote learning and are increasingly popular methods of continuous education, which Primus actively arranges.

The curriculum, even in science and technology, contains traces of the ancient liberal arts and encourages entrepreneurial skills, with the aim to raise intellectually agile citizens as well as budding professionals. For it was foreseen decades ago that is difficult to predict the needs of society where skills and knowledge are concerned, but the cultivation of intellectual learning and entrepreneurship is never misplaced. Developing the mind, the brain and the body are seen as the fundamentals for lifelong learning and innovation. Furthermore, putting the information in context in cleverly designed study programs enhances learning and activates the brain as well. In general, intellectual growth, understanding and critical thinking are encouraged instead of learning by heart.

Teaching methods at Primus include role playing and games, which enable students to practice what they have learned. The same methods are also used in teaching ethics and moral codes in every department of the university, so students become aware of the consequences of their decisions and actions on a human level. With similar practice, students also learn to experience failure and start again. Failure is also learned by keeping up high academic demands. The grades given at the university have not inflated during the years, so the students may not necessarily pass their exams on their first attempt.

As a result of the teaching methods, Primus graduates are also known for their excellent leadership skills, and they are noticeably not prone to moral corruption. Thus the Primus Business School (PBS) is particularly proud that its former students were not involved in the great financial scandals of the early 21st century financial meltdown, but were instead highly praised as people solving it. In fact, PBS concentrates on educating people to run start-ups and small and medium-sized companies instead of corporations, because the networked SMEs are seen as giving a wider foundation for wealth. First of all, they seem to do certain things better than large companies where innovations are concerned and secondly, they create diversity and inspire entrepreneurship on a macro-economic level (Carlsson et al., 2009). Thus students leave the school with experience and ideas to run their own businesses rather than aiming to be public servants or wage earners.

4.4 Discussion

There are many paths that a university can choose from in hopes of creating economic growth. However, all educational institutions are attached to a society, so they also reflect that society's values and, in a way, the society sets guidelines for the university's development in a reciprocal way. A successful educational policy or a successful higher education model in a country is not a guarantee that it can be applied and generate the required results in another country. Some of the issues that definitely require a deeper level of understanding (such as local context, capabilities, resources, culture, and available opportunities) can help shape the policies that can be successful. Today's world is a world of specialization, and to be successful one has to be an expert in his or her own domain. This stands true for educational institutes in developing nations with limited educational budgets. Developing nations, keeping in view their own context, can start by specializing in a certain niche and building on further.

The described scenarios present a very positive outcome. However, both universities might encounter problems due to unexpected changes in their operational environment. For example, the mining university is rather heavily focused on a specific industry, which exposes the whole institute to industry-specific risks. Due to technological and market developments, the prices of raw materials could fall, which would cause major problems for the mining industry. In this case, the university might lose its main funding source and research collaborators. As the university is heavily specialized in mining only, it may have difficulties in finding new focus areas. Because the university has a very applied focus, it is also an open question whether Copperland as a nation has broad enough research and education portfolios that contain basic sciences as well, in case all its universities have a similar strategy.

Primus University, on the other hand, might encounter serious challenges when new and disruptive changes take place in any field of science. Because of its long traditions, it may not be agile enough to respond to the need for changes in its research organization. For example, if there were a break-through in fusion energy technology, it might be hard for the energy and other departments connected to energy production to shift their priorities quickly and effectively. The heavy cost structure of teaching might also make the university vulnerable to recessions or other financial turmoil.

5 Conclusions

Knowledge transfer between academia and industry is an important and timely issue throughout the globe. So-called university marketization has already started driving universities towards more institutional autonomy and accountability, and this is taking place together with the global trend where universities are also expected to bring concrete profits to society in the short run. Essentially this means that universities are required to create new profitable businesses in the surrounding society mainly through commercialization of innovations. In addition, many developing nations are trying hard to become knowledge-based economies in order to get their share of the most valuable segments of international industries such as innovation and branding, which usually require educated and innovative people. This increases knowledge competition between nations and also creates differing requirements for universities in different regions of the world.

In this report we studied the link between a nation's higher education system and its innovative capability, with particular focus on governmental actions that foster useful forms of academia-industry collaboration. We presented the ongoing trend of university marketization and discussed its overall effects. Then, different frameworks for academia-industry collaboration were covered, and IPR-handling practices that would create more incentives for commercialization were suggested. We also studied how entrepreneurship could be bolstered within universities. Finally, two future storylines were sketched to serve as future scenarios for universities in two different nations facing different societal challenges.

We found that measuring the impact of universities on creating new business value is very difficult, because many knowledge transfer mechanisms are indirect and have different timescales. Therefore as a conclusion we suggest that all concrete knowledge transfer through collaboration projects and entrepreneurial activities is valuable, and in this report we presented different frameworks where collaboration between universities and industries can be made more effective. We also want to stress the importance of increasing the amount and quality of entrepreneurial education as compared with today, not only to secure the emergence of new companies in the future, but also to train educated individuals to be able to face the changing and more dynamic working life, society, and environment of the future.

One of our key findings was that IPR-handling practices and regulations are crucial for increasing the knowledge transfer between academia and industry, and that establishing effective IPR practices is challenging. There is a lot of room for improvement in developing these practices in such a way that they create a successful collaborative environment that attracts people both in industry and academia. It seems that unsatisfactory IPR practices and regulations can make other means to increase university-industry collaboration ineffective. We expect already scientifically productive nations to gain a significant competitive advantage in global competition in the future if they can find effective tools to increase their university-industry cooperation, and developing effective IPR frameworks plays a key role in this. Nations with no world-class universities may also be able to attract foreign investors and researchers better than their peers if they can offer tempting frameworks and practices for fruitful academia-industry cooperation.

We emphasized already in the introduction that developing higher education is a multi-objective task, and our approach focused mostly on one objective: how universities can contribute to innovativeness and knowledge-based economic growth. Also the scenarios were designed for this purpose, with few elaborations about universities' other tasks. However, we acknowledge that universities are also required to increase understanding of the world, contribute to well-being, respond to global and societal challenges, and civilize the society, among other things. Thus, in the future, more studies that account for the higher education system and all of its roles as a whole are needed: how universities can complete all the above-mentioned tasks and still be an active part of the economic system. As our final conclusion, we do not fear that increasing universities' economic impact through facilitating industry collaboration and educating entrepreneurship would threaten other important tasks of universities, as long as nations understand that their higher education systems have many different purposes that are all crucial to their wealth in its entirety.

Acknowledgements. We would like to thank Pirjo Kutinlahti, Torsti Loikkanen and Erkki Ormala for the interviews that made a great contribution to this paper.

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1.2 Innovative state: changing role of governments – start-ups as the core of innovations

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Abstract

Each nation seeks a higher *Gross Domestic Product* (GDP). This is most often sought through innovations, as that has been the biggest driver of success. There are several institutions measuring nations' innovation and ranking them accordingly. It is clear in all studies that there is a positive correlation between the innovation index and GDP. Our aim is to study how different nations have adopted the measures to support innovations through start-ups. Our study suggests that size matters. Small nations are using a different approach than big nations. There also seems to be a connection to best practices, depending on the economic maturity of a nation. When a nation ranks high, it is like a sports team doing well. If it is not continuously reshaped, it will lose its dominant position.

Keywords: innovation, start-ups, government role, financial instruments, innovation ecosystem

1 Introduction

The rate of development of infrastructure throughout the world is rapidly increasing. Population growth, rapid urbanization and modernization, changing climate and reduced natural resources have placed greater challenges to fulfil the demand for improved quality of systems in every field of life. Emerging markets in the sectors of energy, communication, automation, transportation, health care, agriculture and many more, have generated an environment of global competition among researchers, scientists, managers, companies and countries. As a natural phenomenon, there is always a gap between the present and the future. Nations always strive to make a successful transition from the present to the future, and innovativeness in all forms is mostly focused as a key factor in this transition around the globe.

Innovation refers to the early adoption and implementation of new or improved ideas for an existing product, system or environment. Innovative behaviour is significantly correlated with human development; and at the same time, human development and economic growth has a two-way relation (Gustav, 2004). Although an unintentional consequence of economic development is deep competition between communities, states, and nations for new economic development projects in today's globalized world, this competition is not an end in itself. It means to enhance people's lives in a certain order, starting from developing to developed nations (Selim, 2012; Cuts, 2008). This makes some nations prosper while it motivates other nations to struggle effectively for prosperity.

In this chapter, we have selected five nations to be analysed: Sweden, Finland, U.S.A., China and Pakistan. The motivation for selecting these countries from different regions (America, Europe and Asia), which cover a wide range economic and innovation indices from top to bottom, is to present an intercontinental comparison of nations' conduct for innovative growth. Nations follow their own route, depending upon cultural, political and regional circumstances. Another reason for selecting nations that are 'poles apart' is to evaluate the contribution of controlled and partially controlled factors that make them 'breakout, breaking out, and pre-breakdown' nations. The role of government is important in boosting the innovation process for the first two categories, but it is obligatory for the third category.

As nations compete on many levels and one of the generally referred levels is GDP, we have considered the Global Innovation Index (GII) and GDP per capita as a starting platform for our analysis of selected countries. Figure 1 represents GDP in terms of purchasing power parity (PPP) in USD along the horizontal line and the GII ranking of the selected countries along the vertical line, clearly reflecting a direct correlation between GII score and GDP.

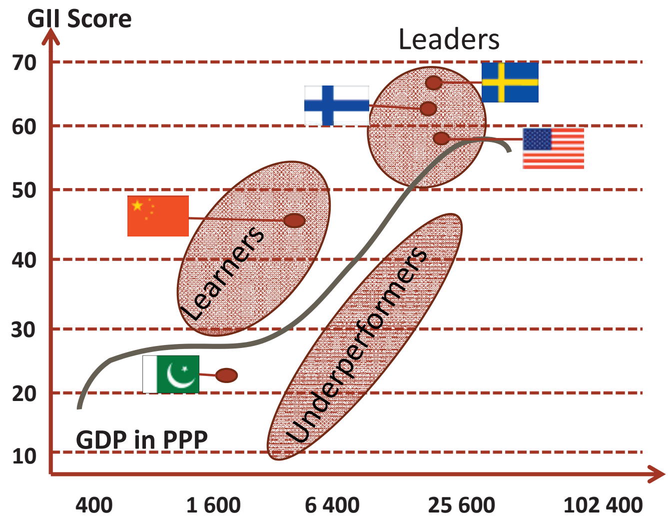

Fig. 1. GII score versus GDP per capita PPP (USD), bubbles sized by population

1.1 The role of government

In debating the role of the state in all areas of public policy, some believe that international capital flows and advancement in telecommunications have made national boundaries less meaningful or even meaningless in understanding innovative activities because the organization of research and development has increasingly been globalized. It has been studied extensively in a variety of countries that national differences in historical, cultural, political and institutional factors are crucial in understanding their innovative performance (Pankaj, 2011). There are numerous examples where the state remains an important agent, although its role has been restructured and focused on two parallel tracks: 1) providing stable political conditions and safeguarding national security; 2) promoting national economic growth, mobilizing state-oriented and autonomous agents, and exploiting opportunities for international integration. Another significant role is the implementation of continuously improved legislative policies to create a favourable playing field for business where any organization can respond without reservations.

Among the various roles, in this chapter we have analysed the role of government as a 'mobilizer' of state-oriented and autonomous agents using their financial instruments. We have found that in many cases governments have shifted from being a principal financer of innovation to communicating the important problems to solve and creating the environment for innovators and entrepreneurs to succeed. This also mean freeing up the entrepreneur and changing the incentives and tax policies, and possibly furnishing the best accounting methods to incentivize the innovation process. The effect of financial tools on the innovation process is studied on the bases of two activities: 1) upgrading the existing capabilities, and 2) bringing new ideas and their execution. These activities can be referred as 'start-ups'. When a disruptive innovation is made within a large corporation, typically there is internal entrepreneurship that is not visible to the outside world. Internal "start-ups" are very hard to identify and calculate. For example, IBM is known, even though it has gone through many complete changes in its form – no more main frames, no more laptops, but services. All this is the outcome of strategic decisions and internal entrepreneurship. In this article, we are not discussing stories of successful and failure start-ups specifically, but in general we are considering start-ups as 'cracking the code' of the innovation process, and their overall contribution is assumed to be the fuel to economic growth.

1.2 Our framework

Hautamäki (2012) presents an ecosystem of innovations as a conceptual framework to analyze the conditions of innovation (see Figure 2). The ecosystem contains the following elements:

- *entrepreneurs* and the companies they have founded,
- *structural factors*, such the institutions of research, financing, and taxation, which create conditions for innovative activity in companies, and
- *dynamic factors* that stimulate interaction, such as cooperation, mobility, recycling, social networks, and an entrepreneurial culture that supports the desire to experiment.

Hautamäki (2012) makes an interesting observation on the necessity of idea regeneration and collaboration. He thinks those are essential elements to make an area or nation adaptable to changing conditions and thus able to prosper, e.g. Silicon Valley.

As an example in Finland, in the aftermath of the changes in corporate downsizing and restructuring, there are idea spillovers to recycle with new collaborating actors. The program is called Innovation Mill, where large corporations like Nokia or Wärtsilä, called anchor firms, gives access to their innovations they have made but are not willing to develop further, as they are in the strategic centre of the firm. These innovations are given to SMEs or new start-ups to develop with or without the anchor firm's resources. Public funding is provided up to 50% or a maximum of 200 000 € per project.

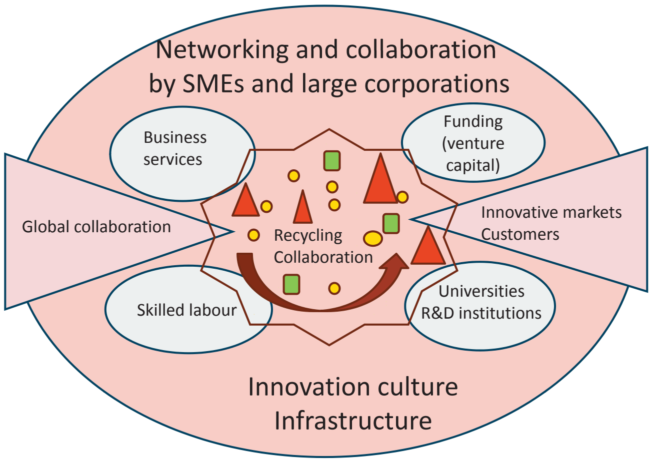

Fig. 2. Elements and dynamics of the ecosystem of innovations (A. Hautamäki).

Attention must be paid to how the funds will be targeted. This means that both funding organizations and the use of granted funds must be measured. It can be expected that there will be a shift in the funding focus to small and medium-sized, ***growth-oriented*** enterprises aiming to enter international markets. In this respect, bigger and established companies must increasingly take care of their own research and development costs. Figure 3 shows the roles of public and private funding.

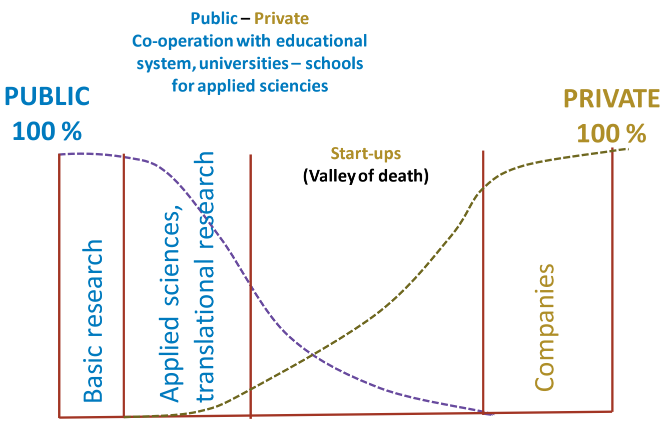

Fig. 3. Roles of public and private funding as a function of technology maturity

1.3 The significance of start-ups

Start-ups are one important factor in the innovation process. Start-ups are typically high-risk ventures and used as tools to probe ideas if they can have a commercial life. Big firms are often slow to change, as a big vessel is slow to manoeuvre. Big firms emphasize internal entrepreneurship and low organizational structure to gain agility. The benefit that a big firm offers to an SME (small and medium enterprise) or a start-up is easier access to resources. Start-ups operate with a scarcity of resources, which also calls for innovative solutions.

Jerome S. Engel from UC Berkeley has studied innovations in corporations and what can be learned from agile start-ups. His finding is that most disruptive innovations are seen to be those going beyond mere technical enhancements of a product but also involving other areas such as new media possibilities, marketing and the supply chain.

Being newly founded does not in itself make a company a start-up. The most essential characteristic is growth. Everything else we associate with start-ups follows from growth. If you get growth, everything else tends to fall into place, which means you can use growth as a compass to make almost every decision you face. The trick is how you do it, and that calls for innovations. Founding a new pizzeria should not be called a start-up, as it is most likely doing the same thing in the same way as all other pizzerias – very tough if not impossible to grow.

The U.S. government has taken a step forward to promote start-ups with Barack Obama's initiative "Startup America". Its main goals are to increase the number and scale of new high-growth "Gazelle" firms. It is believed that this is the way to create economic growth, innovation, and quality jobs. Certainly the U.S. is seeing this also as a means to enhance its global dominance as the number one superpower. This is one essential view of the importance of start-ups as the core of innovation.

1.4 Venture capital as a catalyst to innovations

Venture capital is one source to support innovative start-ups. It is fundamentally the minds behind the innovation making the start-up grow. The will to become a major player is also essential to become a so-called high-growth "Gazelle" firm.

The main finding of Samila & Sorenson (2010) is that public research funding and venture capital have a complementary relationship in fostering innovation and the creation of new firms. Consistent with perspectives that emphasize the importance of an innovation ecosystem, their results therefore point to a strong interaction between private financial intermediation and public research funding in promoting entrepreneurship and growth.

Since high technology businesses often require both inventors and entrepreneurs, venture capital allows regions to exploit a larger share of the ideas that emerge from the region and consequently to grow more rapidly (Samila, 2010). The availability of venture capital may even encourage researchers to explore more radical innovation paths, with the knowledge that an ecosystem exists to nurture the fruits of those investigations.

Researchers do not have a uniform acceptance of the catalytic power of venture capital. Research carried out by Caselli (2008) suggests that in the Italian context, venture capital is not a factor to promote continued innovation process, but firms are concentrating on managerial and economical aspects after the initial listing (IPO).

The nations we examine have different economic systems in place. Even though it is possible to look deeper on the regional level, we are not focusing on these aspects. For each county, we will make suggestions how the government should act to improve the ecosystem for innovative start-ups. Keep in mind that every country is unique and every suggestion is context-dependent, and so actions we suggest for one country might not be beneficial in another country.

2 Sweden – create a market for small companies

Most Swedes are creative, hardworking and have an excellent education. These three attributes are vital for advancement. It is essential for the Swedish government to continue placing a large share of its budget towards these elements. But these attributes are not unique to Swedes. If Sweden wants to compete successfully with the rest of the world, it will need to continue being among the top innovative countries. The best way for Sweden to get ahead and stay ahead is for it to think small. It needs to create a market for small, innovative start-ups to grow and prosper. Public projects should be broken into pieces so that smaller companies can compete for them. By increasing competition and creating a market for small companies, Sweden will see a surge in efficiency and effectiveness.

Sweden recently finalized an innovation strategy (SMEEC, 2012) and aims to stay among the top innovative countries in the world. There is a clear emphasis in the strategy that it is not the government in itself, but the individuals working together that is essential for innovation. The conclusions of this excessive study are that Sweden needs innovative individuals, research and higher education with high quality as well as good laws and infrastructure to support innovation. Sweden needs innovative companies and organizations that work systematically with innovation, and it needs to take advantage of the regional variations within Sweden. There should also be more collaboration between universities and the private sector as well as between public and private organizations.

Accessibility of capital is a cornerstone to support growth and innovation in companies. It is vital that there are good regulations and a functioning capital system for companies at different stages of development. Investments in innovation are usually correlated with a high risk, and to achieve success there is a need to combine a diversity of competences together with financial resources. Angel investors have a very important function when it comes to early investments, according to several studies (e.g. OECD, 2010) since they combine economic resources with business thinking and networks. There is a big potential to increase the contribution of capital from angel investors in Sweden.

2.1 Environment for start-ups today and in the future

Today Google has problems with employees leaving the company because they think it is old and boring (Miller, 2010). They would rather work for Facebook and Twitter, companies they see as much more modern and fun. This movement is taking place even though Google was funded as recently as 1998. It is important for the Swedish government to be aware of this increased pace and mobility when creating the environment for companies in the future.

The Swedish venture capital firms are organized through SVCA, the Swedish Venture Capital Organization. The organization consists of 126 venture capital firms, 78 firms that provide services for venture capital firms, 49 angel investors and 17 angel investor networks. Another big actor is Vinnova, the Swedish innovation agency, which aim is to increase the innovation and competitiveness of Swedish companies. Vinnova is a public organization that helps fund companies in the very early stages when the risk is very high. The agency never provides capital unless there are private venture capitalists who also invest in the company. The socioeconomic profit from investing in the earliest stages of companies' development is significant, even though a majority of the individual investments will fail.

Sweden is an attractive country for foreign capital, but the international competition for investments is growing. In an international comparison (OECD, 2010), there is a relatively good amount of private and public venture capital in Sweden. On the other hand, in comparison to other comparable countries, the amount of capital in the earliest phases is low.

2.2 Decreasing amount of venture capital for start-up companies

As can be seen in Figure 4, the amount of venture capital that goes to start-up companies in Sweden has decreased annually since 2008. This is a bad sign in an export-driven country, which relies so heavily on new companies with fresh innovative ideas. The Swedish government is well aware of the situation and has a long-term strategy on how to change the trends and have a great environment for start-ups by 2020.

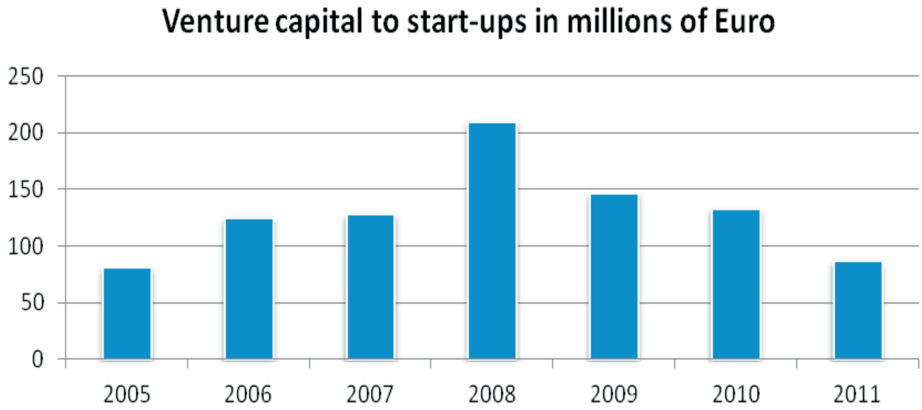

Fig. 4. Venture capital going to start-ups between 2005 and 2011. (source: SVCA, 2011).

2.3 Taxation

Swedish tax rates are in general very high, and according to the competitive index taxation, they are the biggest burden for doing business in Sweden. The current government is aware of the problem, and they are reducing some of the taxes every year. Next year they will reduce the corporate tax from 26.3% to 22% (SMF, 2012), making it lower than the average of 23.4% in the European Union.

There are no tax incentives for start-ups, but it is something that is being discussed. A suggestion from a governmental study (SOU, 2012) is that you will get reduced taxes that you will have to pay back if the company is doing well. This would reduce risk, since you would not have to pay it in case of bankruptcy. The main argument against tax incentives is that it complicates the taxation system, which can create loopholes.

2.4 Sweden needs to change drastically

Looking at the past and present, the figures are very comforting. Looking into the future, there are some tendencies that are alarming and old systems that need to change. Taxes, funding and collaborations change very slowly, and often it takes several years until it is possible to see if the changes have had a positive effect. Stability in the economy is of course essential, but things are changing rapidly all over the world, and without immediate actions, Sweden will be left behind. What the Swedish government needs to do is change their way of thinking rather than pouring money into a black hole. To summarize what has to be done in three points:

1. It is not the government's job to invest in start-ups
2. The government should create a market for start-ups
3. The government should help initiate collaborative networks between big and small companies

It is not the government's job to invest in start-ups. Private venture capitalists are better suited for this, and if an investment is too risky, it should not be realized. To compete with private venture capitalists is naïve, short-sighted and would in many cases lead to money ending up in the wrong baskets.

The government should create a market for start-ups. Many times the government is to blame for the lack of opportunities for small companies. *The government needs to think smaller.* When investing in infrastructure, divide the budget into smaller pieces so that smaller companies can compete for parts of the huge project. When investing in defence, let smaller innovative companies take part whenever possible to get more advanced solutions. When investing in health care, make sure that there is room for small private clinics so that individuals have several options.

The downside is that smaller projects come with increased administrative costs and might lead to inefficient incompatible solutions. If the most efficient alternative is that a large established company acquires all the smaller projects, this should still be an option. It is important to emphasize that the idea of splitting up projects is mainly to increase competition. Even if a project goes to a large company they will have to do a good job in order to get the next project.

The government should help initiate collaborative networks between big and small companies. If the government is going to use taxpayers' money to generate more start-ups, they cannot afford to be wasteful. To increase the number of start-ups, more public venture capital is not needed, but rather more opportunities. Whenever a big company has a big project they need to get done, they often make it easy for themselves and make a single huge investment from another big actor. *By splitting up the project into smaller pieces, more companies will be able to compete for the projects, and they would most probably end up getting a better job done.* Governments of course cannot put a limit on how big projects can be, but by creating clusters in which representatives from big and small companies discuss and collaborate, the government can change the attitude. Clusters would not only change the attitude, but would also initiate projects that would never have been realized in the first place. Small companies are more flexible and can take risks to work on open-ended innovative projects that bigger companies might be unable to do since they need to satisfy their shareholders.

3 *Finland – public funding in changing environment*

The share of research and development (R&D) of GDP in Finland is the second highest in the world, and there is an impressively strong collaboration between universities and companies. These factors have given a boost to Finnish GDP growth in the past, and continued investments will most certainly pay off also in the future. Inventions do not alone create growth, but it allows companies to develop new products and services. Who will benefit from a specific idea is not immediately clear. This is why it would be beneficial for Finland to have collaborative network platforms in which innovative ideas can be shared among several companies and universities. Collaborative platforms would be beneficial for several reasons. It would allow companies and universities to have access to a larger pool of innovative ideas; it would help researchers at universities to spread their findings; and it would let a single invention be utilized by several companies. It would also create opportunities for new start-ups when there are ideas that would be too costly for a single company to develop further. This can be described as a state-wide open-source innovation initiative.

3.1 Cooperation between industry and higher education

Finland's continued economic and social success depends highly on the Finnish institutes of higher education and research institutes. It is essential to be able to create continuous value added to the country by cooperation between R&D and the business sector in international markets. Successful recruitment of innovative individuals and turning ideas into marketable products and services is challenging. In this respect, continuous cooperation with enterprises and higher education is important. Investment in research and development (R&D) in an innovative environment and supporting development policy in general is the key for Finnish companies to prosper in the future.

It is also important to continue work where government-supported research and fund-granting organizations would increase their mutual cooperation in spite of the fact that they would operate under the control of different ministries. At present, the different forms of grants are directed mainly to turn innovations into products and services. In the future, more attention must be paid to also fund those phases where products are being brought into the marketplace. This means that start-up companies must be active by themselves, not only in developing new products but also in creating relations with customers.

3.2 Innovation cultivation in Finland

Finland adopted a knowledge-based innovation strategy in the aftermath of the financial melt-down of 90s. There was a global recession and Finland also lost huge exports to the former Soviet Union, as there was political and economic turbulence and the iron curtain, a remnant of the cold war, had vanished.

The current global financial situation is calling for measures for all to downsize public expenditure. In Finland, this means that among other measures, government funding for direct funding in the innovation sector should remain constant. Therefore new measures for making funding more effective are crucial. The government seems to be almost unanimous that direct support of innovation has to be reduced and it is not the job of government to compete with venture capitalists but rather to co-operate. For example, previously, TEKES (one of the governmental bodies supporting innovation cultivation) funded up to 70% of approved projects. Today the maximum is set at 50% and the rest has to be private equity. There are voices calling for the government to start creating supporting platforms and living labs instead of direct funding.

Globally we have to face the fact that the actual physical production of goods and some services have moved to areas where costs are lower. This is a challenge to many high GDP countries – how to maintain the welfare state when the social system is changing and producing less and with an aging population. Many European countries as well as North America have selected the path of innovation as the key driver to support exports.

Spending on research and development was 7.2 billion euros in Finland in 2011. This corresponds to 3.6 percent of the GDP. Total public research and development funding in Finland was close to 2.2 billion euros, accounting for about 1 per cent of GDP in 2011. The share of the business sector was about 5 billion euros, or 70% of this sum. Spending on research at the university level was 1.5 billion euros, and other public-sector spending on research and development was about 0.7 billion euros (Official Statistics of Finland, 2012).

3.3 Taxation

The government has made a number of decisions to support innovation policy. These included the introduction of a tax incentive for research and development and capital investment activity from the beginning of 2013. At present, there is great global competition between nations on how to tax incomes based on innovations. The Finnish Research and Innovation Council estimate that during the fiscal year 2013, the tax incentive corresponds to 150 million euros and it is estimated to grow to 300 million euros by 2016. The government decided to examine the introduction of a tax incentive related to the utilization of patents. In practice, this is to think small. It is more likely that private investors are keener on putting their investment to grow and can actively support and cultivate the process, whereas a governmental program has limited resources, knowledge and skills to promote the growth process.

3.4 Finnish innovation funding

The Finnish government grants funds for research and innovation work through several organizations, such as Tekes (the Finnish Funding Agency for Technology and Innovation), the Academy of Finland, and Sitra (the Finnish Innovation Fund). Finnvera is a specialized financing company governed by the Finnish state; it has official Export Credit Agency (ECA) status and provides businesses with loans, guarantees, venture capital investment and export credit guarantees. VTT (the Technical Research Centre of Finland) supports industrial and social renewal with research on innovation systems and innovation policy. Finnpro is a national organization boosting the internationalization of Finnish companies and their exports and promoting international investment in Finland. As for a new start-up, this is a jungle – a very fragmented system. Big corporations have had the ability to master this, but SMEs struggle with high bureaucracy. This is one possible reason that in the past, the majority of funds have been funnelled through big corporations.

Currently the government has taken action to reduce fragmentation. Many functions are going to be put under the TEKES umbrella. This is expected to intensify the utilization of limited resources as well as increase efficiency and the exchange of information and experiences. The same structural change is also taking place in the fund-granting organizations.

Tekes, Finnvera and Finpro – the principal actors of the so-called Team Finland model – will move to new premises in Otaniemi, in the heart of the ***Nordic countries' largest innovation hub***. The new building will be located in the immediate vicinity of Aalto University and VTT. This project will bring key actors participating in the new government model for the promotion of exports (dubbed 'Team Finland') under one roof. The aim of this action is to intensify cooperation between the different organizations as well as to increase the mutual exchange of information and experiences.

3.5 Ecosystems and platforms rather than money

According to Tero Kuitunen (2012), new innovations and their development into new business will be increasingly supported by creating ecosystems and living labs, platforms where experiences and information will be spread to various actors. The electric car platform is an example where different actors develop the car and its subsystems, batteries, distribution of energy as well as related forms of communication. It can be forecast that instead of using old financing instruments to support business development, an increasing share of resources will be used to create supportive platforms when turning innovations into marketable products and services.

The role of TEKES has been successful. Each euro invested in research and development has produced three euros for the national economy. It is important that start-up companies take on a larger part of the risk than previously. However, the role of public funding in the future is also to support the creation of a new business base for innovations as a risk-sharing partner (Kuitunen, 2012).

Sweden has entered a multicultural era some three decades earlier than Finland, which gives Sweden an advantage in the globalization era. In spite of the fact that a multicultural society is being supported by several public organizations, many of the rapid growth companies do not have adequate cultural competence. Rapid-growth new enterprises target their actions towards new international markets with new solutions. That is why supporting networking (for example) could be the right means to utilize public funding. It is important that support will be directed by taking into account new conditions based on international markets (Ministry of Employment and the Economy, 2008).

Funding should be able to support start-ups to survive through the valley of death. One possible solution, which should be further studied, is the role of other funding organizations such as pension insurance companies. They could, e.g., concentrate on granting funds to small new companies for marketing and the breakthrough stage to ensure a safe start-up and the generation of well-being for the enterprises themselves as well as for society.

3.6 Conclusion

Finland's public funding in research and development is generally high. In the near future, government is planning to hold expenditures at the current level of 1% of GDP. Therefore it is essential to ensure that the funds available are used effectively to reach the set targets. One concrete action is to unite state research organizations and fund-granting organizations under one roof. In the environment of rapid product and service development and globalization, new forms of support should be considered. Finland, as a cultural habit, is more pessimistic than optimistic. Therefore, measures to overcome this should be sought. As Shane points out in his work, one of the major factors in boosting willingness to innovate is low uncertainty avoidance, that is, willingness to take risk. Finnish people, enterprises and funding organizations must take this into account. A new system for quickly responding to start-ups developing innovative ideas should be put in place, and there are ongoing actions in this direction. The Finnish government has taken action to support development of networking and information exchange through new ecosystems and platforms where companies and research organizations work together and recycle the generated knowledge. Pension insurance companies should grant more funds for start-up companies.

4 The U.S: learning from the past and concentrating on the strengths

The U.S. economy is the largest in the world, possessing a highly skilled work force, world class companies and an excellent higher education system. In terms of innovation, the U.S. is doing good, ranking 10th in the Global Innovation Index (2012). And when it comes to the number of start-up companies, which is often highly associated with innovation, U.S. is doing excellent. Probably because of the strong incentives and support for entrepreneurship, more than 12% of U.S. adults reported starting a business or running new businesses in the year 2011, up from just below 8% in 2010 (Klein, 2012). And there is Silicon Valley, the world-leading technology hub where more than 30,000 companies have been created since the 1990s (Wonglimpiyarat, 2006). All components are there to indicate that the U.S. is the best place in the world to start a business.

What made this astonishing economic growth possible? There is widespread agreement about the three main factors that have contributed greatly to the economic strength of the United States during the last century: support for research, education, and infrastructure. For decades, the U.S. government and the private sector have spent more than any other nation on R&D (Markovich, 2012). As stated in the innovation report by the U.S. Department of Commerce (2012), "Federally funded R&D, which have been made with no commercial benefits in mind, have resulted in innovations and discoveries, leading to new companies and entire industries making Americans more prosperous, healthier, and safer". Today, the college and university system in the United States contains a significant share of the world's most prestigious universities. Also, throughout the last century, infrastructure investments, supported by the public sector, have been crucial for the increased standard of living and economic growth experienced in the United States.

Despite the astonishing success of the U.S. economy in the 20th century, alarms are ringing and questions have been raised whether this economy can continue to be competitive in the 21st century. During recent years, American citizens have been hit by stagnating job growth and falling incomes, as businesses have faced increasing global competition. New policies and methods, and definitely new ways of thinking, are desperately needed to ensure the continuing success of the country.

4.1 Actions taken to promote innovation

"The first step to winning the future is encouraging American innovation."
– President Barack Obama

In the United States, innovation has been seen as the backbone of economic growth for decades, and actions to increase the success of entrepreneurs have been taken by several presidents, from Roosevelt to Obama. President Obama's Strategy for American Innovation was issued in 2009, explaining how the administration, the American people, and American businesses can work together to strengthen the innovation capacity and economic growth of the country. The three critical areas that are seen as the most important areas of improvement are:

1. Invest in the building blocks of American innovation, highlighting investments in basic foundations: workforce, scientific research and infrastructure.
2. Promote market-based innovation. Promoting national environment ripe for innovation and entrepreneurship that allows U.S. companies to drive future economic growth and continue to lead on the global stage.

3. Catalyse breakthroughs for national priorities, such as supporting the development of alternative energy sources, bio- and nanotechnology, reducing costs and improving care with health IT, catalysing advances in educational technologies. (National Economic Council, 2011).

The basic foundations for creating innovation are certainly important, and, for example, basic research is an essential part of enabling new innovations. In 2009, overall R&D performed in the U.S. was about $400 million, of which development activities accounted for 63%, basic research for 19% and applied research for 18%. The business sector provided 62% and the federal government provided 31% of the funding for the total R&D in the U.S. The federal government is the most important funder for basic research, providing 53% of the funding (NSF, 2012).

Also focusing on certain fields of technology might result in fruitful outcomes. For example, in support of the Obama administration's energy strategy, $10 million will be invested in small business-led projects to speed solar energy innovation and strengthen the leadership role of the country in this growing industry, undoubtedly further increasing American jobs in this field at the same time (Nanowerk, 2012). And transferring innovations into marketable products is another crucial aspect that involves issues such as intellectual property rights and tax incentives to support entrepreneurs involved. An important step for patenting innovation was taken in 1980, when the Bayh-Dole Act gave U.S. universities, small businesses and non-profit organizations the right to pursue ownership of an invention that results from federal government funding. Protecting intellectual property rights are also presented in the new innovation strategy in the new patent reform, which aims at cutting the processing time for new patents, among other things (National Economic Council, 2011).

4.2 Entrepreneurship as the key and taxation as fuel for innovation

In the U.S., entrepreneurship plays an essential role in generating innovation and stimulating economic growth. New firms account for most net job growth, and small businesses employ 30% of the high-tech workers. Extensive measures have been taken to support start-up companies in the country. The most extensive action by president Obama was launching Startup America in January 2011, a White House initiative to accelerate high-growth entrepreneurship throughout the nation. The biggest challenge of entrepreneurship – finding funding before incomes and return on investment can be guaranteed – has been identified, and several initiatives and acts have been introduced to limit this obstacle. For example, the Small Business Administration (SBA) brings together start-ups and investors, and even if it doesn't provide loans itself, it provides a guarantee which enables start-ups to receive bank loans.

And of course, taxation is a huge issue. The U.S. is known as a country with a taxation system that highly supports entrepreneurship and venture capital funding. In

September 2010, President Obama signed the Small Business Jobs Act (SBJA), which included eight new tax cuts for small businesses, making investment and growth more affordable – for example, making investments in one million small firms eligible for zero capital gains taxes. Several states are also competing for new start-ups by providing tax benefits for new entrepreneurs. In New York, there is discussion about giving a 25% tax credit to investors who invest from $25,000 to $1 million in NYC-based start-up companies. Wisconsin offers a 25% credit and has seen angel investments increase from $30 million in 2005 to $180 million in 2010 (Kellner, 2012).

There is also an incentive regarding R&D, which is seen as the cornerstone of any competitive company or country. The Research and Experimentation (R&E) tax credit encourages private sector R&D by allowing corporations to take income tax deductions for qualified research spending, although the identified problem is that this does not benefit start-ups who invest heavily in R&D during the first years, when they do not have income tax liability yet. However, an enhancement regarding this problem has been introduced through the Startup Innovation Credit, which allows a start-up company to claim the credit in the following year by reducing its employer-side payroll taxes by an equivalent amount up to $250,000 (Coons, 2012).

When looking for remedies for enhancing innovation-related activities, taxation – with suitable tax incentives for both start-up companies and investors – is an essential means for the government. However, this alone is not enough, as inspiration for creating new ideas, leading to innovation, is not only dependent on the economic environment where the company is operating.

4.3 Collaboration and venture capital. Can other regions follow the example of Silicon Valley?

Clearly the most successful region in the U.S. is the famous Silicon Valley, the technology hub located on the San Francisco, California, peninsula. Silicon Valley is the largest concentration of VC in the world (half of VC firms in the U.S. are in Silicon Valley), whereby it receives the greatest amount of investments. The mechanisms driving the development of Silicon Valley are its dense industrial networks; knowledge intensity; community dynamics among business, governments and other sectors; high-quality labour markets; high-class universities and the supply of VC, which together encourage entrepreneurship and experimentation enabling the translation of ideas into new commercial innovations (Wonglimpiyarat, 2006).

Looking at this success inevitably leads to the question: could Regional Innovation Clusters (RICs) be the driving force of innovation in the U.S. on a larger scale? Even if Silicon Valley cannot be replicated as such, it seems that new businesses are very often generated by RICs. From the more than 150 clusters that exist around the country, RICs have resulted in increased spin-offs, creating new commercial activity. For example, the CleanTECH San Diego cluster initiative that was launched in 2007 and focused on energy efficiency, renewable energy, transportation, and water management has generated extensive start-up activity. And now San Diego hosts more than 800 clean technology companies, supported by world-class universities and a network of investors (U.S. Department of Commerce, 2012). However, even if the RICs are already seen as important for spurring innovations, no new Silicon Valleys have emerged. This implies that it is not self-evident that a pattern that has emerged once cannot be copied in another, even if very similar, environment.

Supporting RICs also raises an important question: "But what is the government role here?" As Wonglimpiyarat (2006) argues, "the government helps foster a favourable business environment while the companies and industries mainly perform business functions to achieve and sustain competitive advantage." It can be stated that the numerous government programs that are helping companies receive funding should only be a complement to, and not a replacement for, conventional equity funding. Also, Silicon Valley would not be so successful without its dense networks, and therefore fostering co-operation between different actors should be an important target of regional governments. This, as many other arguments, supports the idea that the government role in the U.S. should be kept at a minimal level, mainly providing support to create a favourable environment for the companies and not by directly interfering with business activities.

4.4 How could the U.S. do better?

The United States seems to be a perfect environment for start-up companies, and therefore the country also undoubtedly provides an outstanding base for innovation. Financing basic research, providing strong financial initiatives for entrepreneurs and support for clusters and certain technologies ensure that the risks of implementing inventions for commercial activities are not too high. And the U.S. and especially some regions are, indeed, doing extremely well when it comes to the number of start-ups. However, the fact that economic competitiveness among several countries is increasing and global competition is tightening raises important questions about the future success. The U.S. strategy to overcome challenges and maintain the excellent environment for start-ups in the country is certainly a great initiative, but in order to maintain its position as a world leader, the U.S. might have to adopt significant changes in its attitude and supporting methods.

Even though the U.S. has the highest R&D spending in the world, when considering the size of the population, the country ranks only 9th (the R&D/GDP ratio is about 2,9%). Also the federal government provides more funding for defence and there is a declining trend in basic research, which is essential for fruitful innovations in the future (Markovich, 2012). It is easy to point out the weaknesses here and suggest that for keeping the volume of innovations high, the country should invest more in R&D (by business or in basic research), instead of defence – but it is highly unlikely that the on-going trend will change.

A larger government role in financing innovation by different means can always be proposed as a solution for fuelling innovation, and typically this solution works. However, when looking for an ultimate solution for spurring innovations, it might be more useful to keep in mind the things in which the U.S. has a long tradition of doing well or excellently. Therefore it is good to understand the importance of the large share of funding for development provided by businesses. As Markovich (2012) shows, this type of funding dominates, as it provides lower risks and the outcome might be patentable innovations with direct commercial objectives. By encouraging the business sector with different incentives to extend funding for all types of R&D, basic research could also be one option for the government to fuel innovation while still keeping direct government involvement and direct funding for R&D at a low level.

It is also good to understand the role of applied sciences in the U.S. The country has a successful history of developing ideas that have already been created, and bringing them to fruition with the help of existing resources. Apple is an example of a company whose amazing success does not depend on R&D activities, as the company's funding for R&D is relatively low. Also several other inventions, such as eBay and Facebook, are not new inventions as such, but they manage to bring earlier created technologies to consumers in a new, extremely innovative manner. If the federal government does not want to continue funding basic research, which seems to be the on-going trend, no fruitful outcomes in that area can be expected either. Instead, the government can, with less direct involvement, support activities that build on earlier research outcomes. When focusing on applied science and dissemination of innovations, the government can still, at relatively low expense, enable the competitiveness of the country and ensure that the U.S. will stay on its successful path.

This is also related to the fact that many U.S.-based innovations are actually developed by non-Americans. As much as one-third of the technological companies started in the U.S. are founded by a person of Indian origin (Wadhwa et al., 2012). Continuing importing talented people to the country might be highly important for the future of the country's innovations, and tightening the immigration policies will not be favourable regarding this. Instead, the government should ensure that a skilled and educated workforce can enter the U.S. and benefit the country's economy significantly by creating new innovations.

All in all, instead of creating new innovation strategies that emphasize focusing on special issues, maybe the U.S. can continue doing great by simply learning from its past and focusing on the things which the country is already doing great. Traditionally the government role has been small in the country. The government is mainly seen as an enabler of a suitable economic environment for companies instead of an actor interfering in business activities. There are enough of evidences to indicate that this role of the government does not need to change drastically but that the country can continue being successful in terms of its innovations with minimal government involvement by highlighting the things that its people and thousands of companies are doing great.

5 China

China's drive to acquire one of the top positions in the global economy has always been criticized and admired for its hegemonic progress while lacking neoliberalism. While China's rise has been much discussed, China is often considered as having an export/investment-based state-driven economy, reliant on administrative methods for managing economic and financial activities. One of the projections of analysis based on a changing global economic environment implies that economic models like that of China's rely upon having passed their 'use by' date. Perhaps this is because, while China's success in manufacturing and building are notable, the country is far from leading the world in creation and innovation. Given its long tradition of copying others, lack of diversity and conformist culture, China still has an upward climb. In the last few years, China has had spectacular development reforms by introducing a new system of neoliberal hegemony for itself, which has dramatically improved its previous model of economic and technological growth. Today, China is named as one of the top listed innovative countries, and the discussions are on that 'Is China the next hub for innovation?' (Shapiro, 2012)

China's economy started to rise after the reforms in 1978, but the early decades in its development is not impressive at all. Economic policies in China have experienced complicated and diverse changes due to the country's economic and political transition. Policies were based on the Soviet model, which was characterized by bureaucratic rather than professional principles of organization, and the focus was on military technology. Although it was soon realized that efforts should be made to develop the natural sciences in order to serve the construction of industry, agriculture, and national defence, but still the goals were set in accordance with a centrally determined plan, which created an anti-intellectualism environment regarding a wider perspective of growth. After the Cultural Revolution (1966-1976), an effective process of rehabilitation and rethinking started and established a coordinated economic policy. The reforms started in 1978, getting in its well-refined shape in the late 1980s and early 1990s, continued in a major way by focusing on developing an efficient pricing system by implementing a dual-track pricing system and reorganizing the role of the state in the organization of economic resources in order to incentivize the innovation activities. The dual-track price system was the introduction of an intermediate price system between the state control price system and the free market price system. This simulated production, alleviated the pressure of excess demand, and encouraged energy conservation and high quality management (Liou, 1998). Incentives were initiated in two forms: 1) financial incentives – direct government funding (grants, loan, subsidies, etc) and indirect funding of state-owned and private entrepreneurship, and 2) fiscal incentives – tax relief measures that encourage firms to carry out innovation activities by reducing their cost (Ding, 2008).

5.1 Entrepreneurship and start-ups

The Chinese government is not only a regulator but an active participant in China's venture capital and entrepreneurship industry. The first international venture capital firm entered China in the early 1980s. In 1984, the National Research Centre of Science and Technology for Development established a venture capital system to promote high technology. Current Chinese entrepreneurs come from four types of companies: state-owned companies, former state-owned companies turned into stock companies, private companies, and foreign fund companies or joint-ventures except for a few highly regulated sectors such as electricity, telecommunications, oil and even the defence industry (Hu, 2005). Currently a huge number of small and large, local and international, state-owned or private enterprises are working successfully at their own levels of interests.

Some of the renown state-owned enterprises (SOE) are State-Grid in the Philippines, China mobile in Pakistan and COSCO in Greece, while private enterprises are YD Venture Capital, Capitech, Zhangiang Ventures, BJC Venture Capital, China Business Angels Network, AAMA Shanghai Angels, Xcelerate, China Founders Fund and Eastern Bell Venture Capital. There are two types of traditional financing for the companies: firstly for the running companies who want to enhance their production capabilities in their current areas using improved and efficient technology, and secondly for the companies' start-up in the domestic and global emerging areas.

There are some boring figures, but they might be needed to believe that Chinese economic reform has been an economic success and has generated rapid economic growth over two decades. The amount raised in terms of VC was USD 2.26 billion in 2004 and increased gradually to USD 4.21 billion. Opening to the outside remained essential to China's development. China continues to attract large investment inflows and VC was recorded as USD5.9 billion in 2011. This resulted in higher growth of exports, and consequently living standards in China rose. In 2004, the GDP per capita was USD 1267 and the overall ranking declared China as the sixth largest economic body in the world. GDP per capita rose to USD 5,300 in 2008 and reached USD 8,442 in 2011.

The Government of China supports VC by implementing improved policies in 2010-11 to stimulate the continued rapid growth of the VC industry, more investment in new developing (middle and western) regions of China, the emerging high-value-added and environment-friendly products. This includes seven major fields for VC investors, namely energy conservation and environmental protection, next-generation IT, biotech, advanced manufacturing, alternative energy, innovative materials and new-energy powered vehicles. However, the IT and clean-tech sectors are likely to dominate VC activity in the years to come. The VC industry in China has achieved new heights in 2011 in both amount of investment and number of investments, as shown in Figure 5. The ongoing pace predicts that China will likely surpass Europe as the second-largest venture hub globally comparing the amount of investments by the end of 2012 (Ernst, 2012).

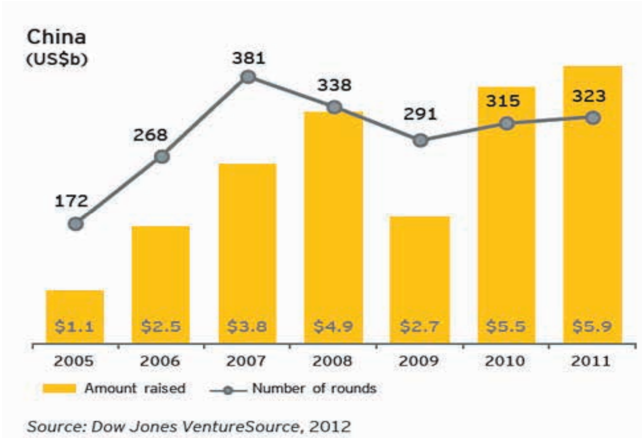

Fig. 5. VC market in China, 2005-2011

5.2 Tax incentives to boost innovations

Fiscal incentives enable the companies to reduce their tax bills as a reward for carrying out innovative activities; therefore they can reduce the total costs of such investments (Ministry of Finance). China initiated the "Medium- to Long-term Strategic Plan for the Development of Science and Technology" in 2006 that sets out the key objectives and priorities in science and technology. The overarching goal is to make China an "innovation-oriented" society by the year 2020. Chinese policy makers clearly focused on how tax incentives fit in the overall policy mix for supporting R&D and innovation. Related structural reforms of taxation system for 1985-1995 were matured to exploit S&T opportunities in 1995-2005 and kept growing development of a firm-centred innovation system (2005 onwards) (OECD). Statistics indicate the presence of over 600 items of preferential tax treatment in 20 taxes levied by China since the compound tax system was set up in the 1980s. Now there are 118 preferential policies for technological innovation, including 48 turnover tax policies, 58 income tax policies, and 12 property tax policies. The number of preferential policies for technological innovation is the second largest after the number of preferential policies for social welfare. At the same time, the amount of tax exemption and reduction allowable for science and technology is almost in the highest range (Ding, 2008).

China's tax incentives for technological innovation encompass all forms of internationally adopted tax credit, pre-tax deductions and accelerated depreciation. Therefore, China has set up a fairly comprehensive taxation regime oriented to support the development of an innovation system. A recently implemented improved fiscal policy in 2011 promotes more taxation reforms and structural tax cuts by replacing business tax with a value-added tax (VAT) to enhance the upgrading of the manufacturing sector and the development of the service sector. The aim is to add the telecommunications, railway transportation and construction sectors at an appropriate time (China Daily).

5.3 Future of China's growth

The People's Republic of China has a large population of over 1.3 billion, with over 22 provinces, five autonomous regions and four directly controlled municipalities: Beijing, Tianjin, Shanghai, and Chongqing, plus the two mostly self-governing administrative regions of Hong Kong and Macau. Although establishing a start-up in China costs far less, it also comes with a high chance of failure. Most investors try to enter the big markets such as Beijing, Tianjin, Shanghai, and Chongqing. The chances of failure or success depend upon the behaviour of an effective domestic market. Although China has a huge population, this does not mean that the market is as large as the population. The larger cities and older markets are on their way of becoming saturated. The bigger picture shows smooth growth, but the rate of growth in 2008 was 11.2%, which drastically decreased to 6.2% in early 2009. Although with some fluctuation it comes to 9.8% in 2011, but there are predictions that it may continue to slow down.

Observing this behaviour of noteworthy growth is the massive long-term potential of other growing Chinese cities (apart from above-mentioned cities), which outweigh the opportunities in other emerging markets. The probability of an efficient start-up is high, to accelerate China's economic development, promote technological innovation and upgrade existing industries. Shenzhen and Guangzhou climbed to sixth and seventh place, respectively, in last year's rankings of the top 50 cities in China, even though the two cities did not perform very well during the period. When there is a deficiency or gap, there is space for improvement. According to its fifth annual Emerging Business Cities survey conducted by Fortune China, hearing from 1,278 Chinese senior managers who ranked 50 selected cities, Suzhou, Qingdao, Shenzhen, Ningbo, Guangzhou and Dalian were selected as having the most potential new candidates for start-ups. The survey is conducted based on the overall business environment, the cost of doing business, the local talent pool, and the quality of life. Initiatives have been started. For example, a few start-ups were selected by the members of the Nordic to Global Initiative, which are the leading public investors Finnvera, Innovation Norway and Innovationsbron (Nordic Innovation 2012). Considering all fields in the mobile market, including manufacturing, Internet, technical and social services, education, technology, renewable, medical and bio, China's mobile Internet market is booming and offers the best opportunities to start an enterprise for the lowest cost in the world. During the last three years, smart phones have increased from 10 million to 200 million and are expected to increase five-fold over the next year (Want China Times, 2012).

If we look at China today, structural reforms have been implemented to strengthen the foundation for a market-based economy by redefining the role of government regarding state enterprises and developing the private sector, and deepening the reforms in the land, labour and financial markets. The economy is approaching the technological front and creating the potential for acquiring and applying innovative solutions from abroad. China needs to speed up its transition from engineered to designed and artistically based creative start-ups and China's product will have their own 'Soul'. China has to gradually reduce the cloning work, although it will slow down the time to market but will raise the innovative front of China's progress, especially like Silicon Valley which adopts built-to-acquire. A relative prediction made by XU Xiaoping is that China still has a long way to go unless it sends students overseas to become really creative and innovative (Venture, 2012).

6 Pakistan – investing in stability and the future

Since birth, Pakistan has been facing a lot of challenges in the form of internal and external conflicts in the region and natural disasters. In spite of these challenges, Pakistan's economy has grown at a steady pace but is still not sufficient for a remarkable success.

Innovation is identified as a key pillar of the country's competitiveness. Pakistan has been unable to make an influence in this area. While looking at the list of countries ranked according to the global innovation index, it has been ranked quite low. Especially in the last five years, the rank has drastically fallen from 73 out of 107 in 2007 to 131 out of 141 in 2012.

Table 1. Pakistan's rank in the Global Innovation Index from 2007 to 2012

Year	2007-08	2008-09	2009-10	2010-11	2011-12
Rank	73	93	103	105	131
Total countries	107	130	132	125	141

During the last few years, the country's major problems have been security and energy crises. The law and order situation has not been satisfactory and that plays an important role in a society's progress. The situation got worse when Pakistan got involved in the war against terror as an ally of the United States. The bombs don't have eyes to differentiate between militants and innocent civilians. The drone attacks and military operations launched in the border areas of Afghanistan killed thousands of innocent people. In reaction, suicide attacks throughout the country have disturbed the social life. Due to instability and an inadequate energy supply, the factories have started moving abroad or close to getting closed down. For the same reasons, there is no foreign investment coming into the country. Increasing oil and food prices are pushing the inhabitants below the poverty line.

The government is trying to cope with the situation that Pakistan is facing due to its geographic location and its importance. The damages caused by the war on terror are more than $70 billion, while the United States has reimbursed only $9.97 billion under the Coalition Support Fund (Tribune, 2012). The figures publicly available from the World Bank's world development indicators show that the country has been investing more in military than in education and research and development. Although the expenditures on the military have been reduced during the previous years (7% of the GDP in 1988 and currently 3%), it is still far more than the 0.46% of the GDP spent on research and development. This figure was nearly negligible before 2003 (World Bank, 2012).

Another alarming situation is the country's growing population. 68% of the current population is under the age of 30. This can be an asset, but considering the current situation, due to the unavailability of jobs it is becoming another huge problem, creating radicalization in the society making the law and order situation worse. Pakistan's current economic growth is steady at 3%, but to fulfil the needs of youth, it has to grow around 6-7%, which means it has to create 36 million jobs in the next 10 years (Dustin et al., 2012).

6.1 Venture capital in Pakistan

Venture Capital companies and funds in Pakistan originated in the 1990s, when a legal framework to found a venture capital company was set up in the same decade (Khoso, 2009). This framework was later revised in 2000 to help venture capital companies' growth by being more flexible. But still, the growth was slower than expected. Different reasons for this are mentioned. It is directly related to overall slow economic growth. There is a scarcity of professional venture capitalists who understand how to set up venture capital in the developing countries' environment. Other key factors are entrepreneurs' attitudes towards risk-taking. This can be directly related to a culture where people mostly have family-owned businesses and sharing ownership is highly discouraged. The collateral requirements of financial institutions are too high; they go up to 120–130% of the loan value, which is another cause for the limitation of start-ups (Khoso, 2009).

6.2 Taxation

Pakistan has substantially higher tax rates for enterprises. This is another huge disadvantage to the country for foreign and domestic investment. The current corporate tax rate is 35%. While other countries in the region are trying to reduce the figure every year, Pakistan's tax rate has been consistent for the past five years. There is also the problem of fairness and clarity of law regarding tax refunds, resulting in another hurdle to launch a business.

To encourage venture capitalists, the government of Pakistan exempted tax on investments for about seven years – from 2000 to 2007 (Khoso, 2009). The highest annual growth of 218% in venture capital assets occurred in the year 2005, when it was Rs. 3,200 million, compared to Rs. 1,005 million in the year 2004 (Khoso, 2009) (1 USD = 60 Rs.). Currently, no such incentives are offered.

6.3 Steps taken – government's role

In order to progress, the government and the private sector have to work together. The role of the government should be taken as a facilitator to offer policies and facilities to the private sector. There was no comprehensive policy and strategy to address the needs until the Competitiveness Support Fund (CSF) came into existence. CSF is a joint initiative of the Ministry of Finance, Pakistan and the United States Agency for International Development (USAID) to bring Pakistan's economy to a competitive level. It aims at improving the policy framework required for innovation-based competitiveness by providing input to policy decisions, improving regulatory and administrative frameworks, and support public private partnerships (Competitiveness Pakistan, 2009).

In this regard, CSF started *Pakistan Innovation Initiative (PII*) in 2009, which aimed at a national innovation strategy. The *Innovation Strategy Working Group (I-SWOG)* was formed, which had the representation of all the three necessary elements of the triple helix, i.e., government, academia and the private sector. A draft strategy was defined, which is still in the process of upgrading. This group identified 12 pillars of an innovation ecosystem. The pillars included were tax policies, government procurement policies, intellectual property protection, infrastructure for innovation, university–industry links, small business entrepreneurship, technology and business model acquisition, incubators and tech parks, education, venture capital and commercialization, attitudes towards risk, and encouragement of patents. (Competitiveness Pakistan, 2009).

6.4 Private sector

The government's role alone is not enough to bring economic success. It is more in the hands of private initiative that takes advantage of the facilities and policies provided by the government and plays its role. Current private enterprises have more of a rent-seeking culture, which results in unproductive activities. This needs to be addressed. A private equity fund could help in creating opportunities for venture capitalists and entrepreneurs for job creation and economic growth. In this context, Pakistan's Industrial Venture Fund I, backed by the Ministry of Finance, has proposed that it will focus on enterprises; the fund has $150-250 million (Competitiveness Pakistan, 2009).

6.5 Conclusion

To bring stability, the first and foremost requirement is to have peace. War has never been a solution to any problem. Pakistan has to get rid of the U.S.-imposed war on terror in the northwest Khyber Pakhtunkhwa's border areas with Afghanistan. The war should be resolved through dialogue and negotiation. There is a need to differentiate between civilians and militants and to win the local people's heart back by providing education, creating job opportunities and building infrastructure. Pakistan has to say no to aid for becoming America's gun.

Gilbert Keith Chesterton said, "*We make our friends; we make our enemies; but God makes our next door neighbours*". There needs to be a lot of learning from two big neighbouring countries – China and India. Pakistan enjoys a healthy relationship with China, but with India the trade is halted. Pakistan and India both should learn from the past and agree on solutions to have open trade and a better future. Both neighbours' economic growth is quite impressive, which can serve as a learning model for Pakistan.

Policy frameworks are very important and should not be limited to only papers and documents, but there needs to be proper implementation. It has been a major dilemma where policies are only confined to papers and nothing is done in practice. Measures should be taken to reduce the corporate tax, which is currently on the higher end in the region. Government should continue giving incentives to the start-ups and venture capitalists and continue practices such as exempting taxes for venture capitalists, which has already shown a huge growth. The government should just act as a facilitator and should not interfere in the business operations. Strict measures should be taken to avoid a rent-seeking culture.

An entrepreneurial environment must be promoted. Investors should be educated and informed about the benefits of start-ups and entrepreneurship. The media can play its role by bringing forward success stories to encourage investors to take risks. Private initiative can create jobs for the growing youth and fulfil the needs, and hence avoiding radicalization. Investing in a private initiative can be key to bring stability and a prosperous future.

7 Discussion

As pointed out, there are two general levels that form the space for innovation development and changing them into marketable products and services. These general levels include first the basic level, which comprises the cultural aspects as well as monetary aspects such as the welfare of the country. Secondly, the ecosystem of innovation consists of elements such as the university and research sector, a functioning finance sector, the availability of a skilled labour force, and the possibility for cooperation and networking.

The basic level has to exist in order to make it possible for an ecosystem of innovations function. The government should pay attention that both of the mentioned levels function and support each other. Countries are different, which is why the role and task of governments vary considerably depending on the conditions of the general levels.

Pakistan is a good example of a country where the basic level is disturbed. If law and order does not exist and great amounts of funding are directed to military spending, people must direct their innovativeness into surviving and an ecosystem of innovation cannot function. Additionally, in the field of innovation, the educational system should be more democratic, enabling the utilization of the country's potential of human brain capacity. More attention should also be placed to grant funds for R&D outside the military sector.

Finland represents a country where the ecosystem of innovations functions rather well, more or less. For example, high-quality higher education is available. The business environment functions and the level of funding for research and development are more or less in order. Also the recycling of experiences, meaning the distribution of information, is quite open. This is, in fact, stressed at the government level. To be further able to increase well-being through commercialization of innovations, the only possibility is to change the structure of the basic level. While the amount of money put into R&D is at a high level (one of the highest in the world, in fact), the only possibility is to try to change the cultural aspect. This means that instead of increasing monetary funding in general, the government should pay increasing attention to cultural issues such as supporting the creation of eco-labs, platform thinking, and risk-taking. This development should be directed to all players, including state organizations, the educational system, companies, and also to individuals. Naturally, the functioning of the innovation ecosystem can be intensified by increasing cooperation between ministries in supporting R&D and free exchange of information.

Sweden, like Finland, has an innovative climate. To prosper in the future in the increasingly competitive global market, the focus on innovation will increase further. To have an innovative environment in Sweden, small companies are essential, especially start-ups. To get an increasing number of start-ups, the government should find ways to create a market. This should be done by splitting up the larger public projects into pieces and by working for increased collaboration between large established corporations and small start-ups.

The U.S. also represents a country where the ecosystem for innovation is very good. The U.S. has extremely talented labour, top universities, and the business environment and support provided for entrepreneurs are excellent. The American culture is also highly supportive of innovation. What perhaps characterizes the innovation environment the most is the strong willingness to take risks. This is undoubtedly one of the main factors that contribute to the high number of start-up companies as well as the good ranking in the GII index. As both the innovation ecosystem and the basic level are functioning well, it is difficult to give suggestions on how the country could do even better. However, one issue clearly stands out when looking at the government's willingness to fund R&D activities, which are usually seen as highly related to innovation. Even if the government is the largest funder of basic research and strongly supports development of some specific technologies, such as clean energy, it is evident that the main focus is on the defence sector and defence-related research and activities. If the U.S. wants to continue being competitive and innovative at the same pace as other highly competitive countries, it should change its attitude and start channelling more funds from the defence sector to other R&D, such as basic research. This would ensure that the ecosystem for innovation would function even better and the country could achieve an even higher level as an innovative state. As long as the U.S. does not want to change the trend when it comes to funding R&D, it will have to look for other solutions for spurring innovation.

The evaluation of China's progress reflects that financial policies have undoubtedly played an important role in supporting science and technology development. It is well known that governments of developed countries (mostly) have accumulated many successful experiences with reference to China in uplifting the pace of technological and economic development. For China, there is room for doing much more. Considering the real pulse of the large educated young population and the low labour cost compared to western countries, China can follow the example of Turkey, where opportunities of growth are being distributed all over the country instead of in conventional business centres . The local potential is being explored to develop innovative ideas in every category of life, such as tourism, business, agriculture, and multimedia. The Chinese market is indeed fascinating, challenging and interesting, but within it are some hidden flaws. Reservations have been cited about organizational processes regarding various bureaucratic approvals and certifications before start-ups. The lack of many foreigner's ability to adapt to the very different Chinese culture is an obstacle to many foreigners. Its general culture (hence its business culture) is very different from what we know in the West. "The Chinese market is very difficult to penetrate and to succeed in. But on the other hand, it is very hard to ignore it due to its potential". China needs to exploit its objectionables to sweep in the horizons of growth.

8 Conclusion

Countries are different by nature. All the studied countries are, at least to some extent, focusing on innovation at the government level, and innovation strategies have been launched presenting ideas how the countries could compete better. However, the methods presented in the innovation strategies, as well as our own suggestions for how the country could do better, are very different in each country. Therefore our case studies support the idea that as all countries are operating within their own cultural context, there is not only one specific model that can be created for enhancing the innovation environment. In the world of tightening competition, it is not possible for countries to copy what has worked successfully somewhere else. All countries should have a model of their own for how to combine the rotation between education, the work force, financial support, business services and the exchange of experiences.

Our country analyses strongly suggest that bringing innovations into successful and marketable products, creating welfare to the society, means that both the basic level and the environment of innovations have to be in balance. In this respect, the governments have a central role of guaranteeing and supporting the functioning of the basic level. If the basic level has not been achieved (which includes, e.g., peaceful, stable, and democratic social development in the society), it is not possible to develop and utilize a well-functioning environment for innovation. In Finland, Sweden and the U.S., which all rank high on the GII index, both the basic level and the innovation ecosystem are functioning rather well. In these countries, it is challenging but still necessary to create new methods and to change the way of thinking in order to continue performing well and maintain their high ranking. China is also doing considerably well in terms of innovation, but here it is easier to point out what should be changed in order to enhance the innovation environment. Pakistan is a rather different case because of the safety issues. Even if the innovation ecosystem were improved, it would still not ensure a successful innovation environment.

An underlying assumption of our study was that start-ups are essential for innovations and for a country's success in global competition. In start-up companies, new ideas are created, or existing ideas recreated, and these are developed further and brought to potential customers in a marketable form. Even if the government role might be changing, it can be stated that the government still has an important role in providing a stable and socially and economically suitable environment for innovation. This is very important even in countries where the government is not willing to directly interfere with innovation. Supporting the formation of start-up companies by spurring venture capital financing or by allowing tax relief, for example, is one way in which the government can promote innovations. In most of our case countries, the governments have taken measures to improve the environment for start-ups, probably most successfully in the U.S. Money, however, is not the only important element to support innovations, but the amount of money available in the society and the level of GDP do have a significant effect on innovation. Therefore, how the money is distributed in order to support the development of an innovation environment is an issue that the government should address.

However, some things are out of reach of a country's government, and changing them is extremely problematic. Based on the results from our country analyses, we suggest that risk-taking is one of the cultural characteristics that should be pointed out. For example, in the U.S., risk-taking is an essential part of the business environment, whereas in the Nordic countries, people are so used to a peaceful way of living that avoiding risk is one of those things that may have a negative effect on developing ideas into profits. Changing the risk-taking culture might be essential for the further economic success of some countries, but this cannot happen only on the government's initiative. Instead, it is an extensive process that would include re-thinking, changing attitudes, and creating a totally new "try it out" atmosphere.

It is highly important that the governments, the business world and individual citizens realize that social and cultural issues related to the innovation environment cannot be changed in the short run. In some cases, they should not (or cannot) even be changed at all. In many cases, it is not possible for other countries to copy those that are ranking high in GII. On the other hand, some innovations can work extremely well in countries with a lower GII ranking, where the innovation ecosystem is not supportive. This can be proven by the amazingly high number of innovative and successful foreign entrepreneurs in some countries that are performing well according to GII. In these cases, the innovation culture of individuals might be extremely high. This supports the argument that it is not only the innovation culture of the country that matters, but that different goals can also be pursued by businesses or individuals.

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1.3 Deviant Davids and greying Goliaths: micro-initiatives to induce growth

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Abstract

The traditional national industrial fields have weakened in Finland. Renewing the industries and finding new strongholds for global competence requires new ways of thinking and new initiatives. The general perception based on the existing scientific literature and government reports proposes a variety of micro- and macro-level approaches. We propose three alternatives for cooperation between universities and companies: transfer of tacit knowledge, lifelong learning and creating an entrepreneurial mindset. In this chapter, we argue that the innovation process has been institutionalised to support macro-level structures and that more micro-level approaches are actually needed to encourage a more entrepreneurial mindset. We suggest incentivising micro-level activities as a means of shifting current mindsets and the working culture, building informal regional networks and encouraging this type of behaviour. The Pessa model serves as an encouraging benchmark for making these changes.

Keywords: entrepreneurial mindset, innovation, Pessa model, regionality, research collaboration, strongholds

1 Introduction

While acknowledging historical developments and accounting for future trends, the future wealth of nations is actually being created today. In an ever-changing environment, the ability to reinvent oneself is a systemic advantage for persons and companies operating in places like Silicon Valley. For more than a decade now, nations have been allocating efforts and resources to develop this ability. With the current downturn in developed economies, the primary aim is to increase the number of jobs by encouraging the birth of new companies. In particular, it is increasingly important that highly educated people with university degrees become entrepreneurs and contribute more directly to economic growth through the commercialisation of new technologies, ideas and innovations developed at the universities. Yet success stories are rare, and the complexity of building an ecosystem is difficult to translate into executable and measurable steps. One shared element of most initiatives is an appreciation of past success factors; this element is epitomised by the concept of 'national strongholds'.

As countries climb the development ladder, regional industrial clusters emerge that become the dominant contributors to a country's gross domestic product (GDP). The significance of such industries can be assessed in terms of the percentage of a country's population that they employ, their gross business activities, or in abstract terms, as national strongholds. A national stronghold can be understood as the backbone of a nation's development, since they attract talent and have succeeded in competing over a sustained period of time. Through these regional and industrial strongholds, knowledge can be conserved and systematically reinvented. In the Finnish case, governmental institutions, universities and research institutions are exploring new ways to create growth because traditional industries are losing their competitiveness globally. Thus, these old, industrial strongholds, which still have plenty of know-how, are in need of a burst of innovativeness to renew and grow again. At the same time, all companies need to capture more of the value chain of products and services in the globally changing environment. To help Finland meet these challenges, the Ministry of Employment and the Economy is currently participating in the Massachusetts Institute of Technology's Regional Entrepreneurship Acceleration Program (MIT-REAP), which brings together diverse regional teams committed to accelerating their region's innovation-driven entrepreneurial ecosystems (MIT REAP, 2012). The working group has set the vision that 'Finland is the best place in Europe for innovation based startups and growth entrepreneurship by 2025' and its practical task is to create a strategy for making this happen.

For a regional innovation programme to be effective, it has to make the change more concrete in the regional environment by acknowledging existing players and structures. Finland already ranks high in several statistics: for instance, it is regarded as a business-friendly environment (IFC, 2013) and as a highly innovative country (Dutta, 2011), and per capita it has the most researchers globally (World Bank, 2013). Thus, it is baffling to understand why the country does not create more growth-oriented SMEs. In part, an explanation can be found in the entrepreneurial culture, in industrial traditions and in the systemic experiences of growth enterprises (Autio, 2009). In other words, the original factors that helped create Finnish economic wealth are partly the reason why innovative growth-oriented enterprises are rare in number. Yet, in stark contrast, a strong educational system provides solid bedrock for innovative practices on a regional or even a national level. While being sensitive to the historical developments in Finland, we emphasise the need for including educational institutions in the regional innovation model. From a university point of view, R&D activities often occur based on a company requesting research support (depicted in Figure 1, line 1). Another possibility is for university research staff to actively engage with companies to investigate collaboration and joint, applied research efforts (depicted in line 2). As a third option, new inventions can be introduced to companies that support the commercialisation process (depicted in line 3). Together, the three options span a range of possibilities for incubating new enterprises or disseminating innovations via incumbent firms.

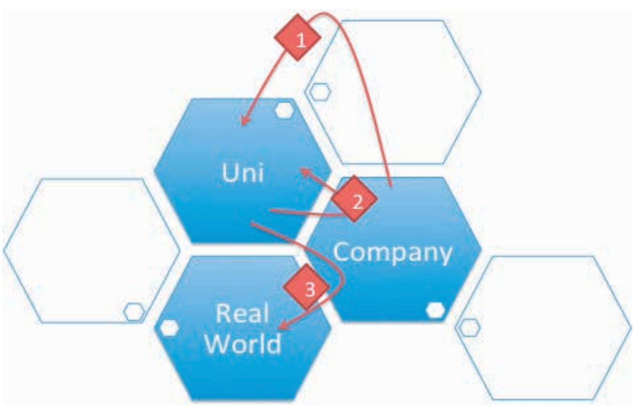

Fig. 1. Three modes of research collaboration

Our chapter, Deviant Davids vs. greying Goliaths, studies the possibilities to transfer tacit knowledge from experienced experts to energised students, and vice versa, as a means of triggering new ways of thinking about standard practices. The question we pose is the following: ***What kinds of micro-level initiatives support the renewal of strongholds in Finland?*** Since entrepreneurial activities are being strongly encouraged and since, in particular, governments are looking for new entrepreneurs, we will explore the extent to which it is possible to create an entrepreneurial mindset and an entrepreneur-friendly environment via governmental actions and policies. As the Finnish government is renewing its policies and regulations to induce the birth of new companies, we ask the following questions: Can real entrepreneurship be born in this type of 'safety net' provided by the government? Or, is the government instead institutionalising the birth of start-up companies by creating an extensive framework to incubate companies? Normally, entrepreneurs are a dynamic reflection of the business situation. Entrepreneurs react to challenges and opportunities creatively and quickly, and thus they develop a heightened awareness of their fields of operation. As a result, entrepreneurship education has received vast degree of interest at universities. Yet, entrepreneurship education is a process of learning to do things by practice. Mentors who transfer their experience to newcomers facilitate the learning process. It was previously thought that all knowledge could be made explicit and taught in an institutional setting. Now, as the world enters the digital age, old habits are sometimes becoming obsolete while tacit knowledge is becoming more valuable. This tacit knowledge is part of the stronghold of a region. It includes the idea that networks share information and offer advice; it includes a specific language and the hidden structures of industries. It is our objective to discover how micro-level initiatives can encourage researchers to be innovative in the traditional stronghold sectors. In this section, we begin by defining what strongholds and an entrepreneurial mindset entail. In section two, we present the traditional mode of collaboration by applying an innovation system perspective. Our case focus is Finland. In the third section we explain recent types of researcher-industry collaboration, emphasising the successful Pessa model, and in section four we study universities as the new hubs of collaborative innovation practices between students and industry. Finally, we provide three suggestions for change based on the lessons learned.

1.1 Definitions

What is a stronghold? National stronghold is a vague concept that describes a sustained job engine and knowledge filter for a particular region or nation. For this study, we define it as a geographical area or industry that possesses the human capital and tacit knowledge to successfully compete for a sustained period of time. If 'X' is a national stronghold of country 'Y', then 'X' can withstand the changing global dynamics (in terms of demand and growth) and will be able to compete on a global level even in hard times. Compared with previous definitions, we add the human capital element due to the fact that competition is more and more influenced by intangible factors. We assume that in a beneficial environment, strongholds by definition will prosper.

The importance of a stronghold for a nation or a region is that traditionally industrial know-how is accumulated over a period of approximately 30 years. These long cycles tend to convey the message that the best investment in terms of innovation is to build upon existing industrial knowledge. While strongholds have created wealth for centuries, it is dangerous to assume that the same development can be projected ex-ante. In the last decade, innovation and growth companies have primarily emerged in non-traditional industries. Yet, strongholds have the capacity to adapt to the newly introduced technologies and resulting competition.

Start-up companies run by nascent entrepreneurs represent the flipside of strongholds. They have no liability in terms of past practices, which makes them ideal candidates for innovative solutions. Their innovation drive, risk-taking behaviour, motivation and creativity are perceived as promising contributors to wealth creation. However, only a small number of them achieve this goal, while most disappear. They lack a vital ingredient for sustained success, which is experience, mainly industry-specific know-how. This can be compensated for much better in newly emerging industries than in traditional ones. Nonetheless, due to their entrepreneurial mindset, they are important innovators driving market development.

What is an entrepreneurial mindset? An entrepreneurial mindset is not a personality trait; it is a state of mind, an approach to addressing uncertainty and new situations. Hence, it can be trained, applied and learned; entrepreneurs are made, not born (Kruger, 2007). Over time, a person develops a different approach to how they perceive opportunities, for instance external change, which is a pre-requisite for actively engaging with opportunities. From cognitive psychology, we can learn that a person's actions, intentions and mindset are all interconnected, which, as Kruger (2007, p. 124) has discovered, also applies to entrepreneurship:

- Behind entrepreneurial actions are entrepreneurial intentions;
- Behind entrepreneurial intentions are known entrepreneurial attitudes;
- Behind entrepreneurial attitudes are deep cognitive structures;
- Behind deep cognitive structures are deep beliefs.

Therefore, the main reason that politicians are pushing for its citizens to adopt an entrepreneurial mindset is that only a change in deep beliefs will enable entrepreneurial action. It is further assumed that an entrepreneurial mindset will generate pro-active behaviour or active citizenship, a necessity for a healthy functioning democratic society. The categorisation presented here far exceeds the more popular narrow view on venture creation. In times of great uncertainty, an entrepreneurial mindset is desirable because it increases the probability of each individual working in an open and proactive manner and not shying away from new challenges. Currently, researchers link the following elements to an entrepreneurial mindset: role identity, strategic thinking, pattern recognition, effectual thinking (bricolage, improvisation), optimism, meta-cognition, counterfactual thinking, a bias towards action and value creation as sine qua non. While this list is by no means exhaustive, interestingly it shows attributes of ordinary people, yet the combination is what creates this particular mindset.

On a macro-theoretical level, several frameworks exist for creating an entrepreneurial mindset. The frameworks provide a fertile environment but not sufficient conditions, since an entrepreneurial mindset is a social and psychological phenomenon. To aid national growth, the mindset has to be coupled with technological developments and innovations, so that opportunity-based enterprises emerge. As a result, technological developments support value-based growth for those entrepreneurs and the nation. However, combining an entrepreneurial mindset with the aspirations of national growth is a challenging process. System theory advocates taking a bottom-up investigative approach to better interpret the complex reality of entrepreneurship. This prompted us to look for micro-level initiatives across Finland that will help foster an entrepreneurial mindset and revive the global competence of Finnish strongholds.

2 An innovation system perspective on regional renewal

The underlying economic reason for emphasising entrepreneurship as a means of economic development is evolutionary economics and an 'innovation systems perspective'. Evolutionary economics provides the motivation that neoclassical growth theory does not hold (Nelson & Winter, 1982). It emphasises technological progress much more strongly and assigns it a central role in growth; winning technologies are determined through an ex-post competition (Nelson & Nelson, 2002). According to Nelson and Nelson, 'For evolutionary theorists, a country's level of technological competence is seen as the basic factor constraining its productivity, with technological advance the central driving force behind economic growth. [...] increasingly evolutionary economists are coming to see "institutions" as molding the technologies used by a society, and technological change itself' (Nelson & Nelson, 2002, p. 267). While an innovation system is an institutional conception par excellence, institutions are perceived of as social processes (Ibid.). According to the innovation system perspective, human action and interaction need to be understood as a result of shared habits of action and thought, and there is a deep rejection of 'maximisation' as a process characteristic of human action (Ibid.). 'Routines' is the key unifying concept. Business practices are seen as routines when it comes to setting prices, ordering new inventory, hiring new workers or deciding whether or not to promote them. Whether we are talking about social or physical technologies, the concept of routines holds equally true. The basic logic for the existence of widely used routines is that, 'widely used routines are widely used because they are effective, and they are effective because over the years they have been widely used' (Nelson & Nelson, 2002, p. 268). Yet the major obstacle is that it is risky for actors to learn new routines, as well as costly and time-consuming. In this chapter, we argue that, nonetheless, following this 'risky path' can actually help minimise risk, as strongholds possess key competences for renewal.

In this section, we present the typical university-industry collaborative practices of strongholds and their aims for renewal and discuss them within the Finnish context.

2.1 Strongholds – from a Finnish perspective

Despite being a small country, Finland has received a top ranking in various measured indexes for growth and prosperity during the last few decades, for instance when it comes to its level of global competitiveness (Schwab, 2012) and industrial competitiveness (Hausmann et al., 2011). Since 1917, industrial production has been a substantial factor for economic growth in the country. Joining the European Union in 1995 has provided substantial opportunities for funding, investment and closer collaboration. This trend will likely continue due to the regular renewal of a favourable environment at all levels.

Until the 1990s, a common saying was that '*Finland lives on its forests*'. Therefore, paper and the wood industries associated with paper and the machine industry are considered national strongholds of Finland that date back to the 19th century. A century later, electronics became an important sector for exports. Nokia and the companies associated with it are now the crown jewels of Finnish industry and also considered a national stronghold.

Finland is exploiting its opportunities to grow through traditional infrastructure development and modern knowledge-based technological advancement. During the Cold War era, Finland was heavily biased towards growth in 'heavy industry', with no significant international capital. Today, the imminent liberalisation of services has triggered new opportunities in a wide array of industries and technologies. Its high-quality services, arts and science capabilities, creativity and adaptability help promote the prosperity of its citizens and bring benefits to all of Finland.

Yet, Finland is already undergoing the next transformation into a service-dominated economy. This transition is visible in the numerous initiatives started by the government and even by the European Union. One advertised toolkit coming out of Brussels' Pandora's box is the strategic Centres for Science, Technology and Innovation (knows as SHOKs). It is a policy instrument being implemented in Finland to renew industrial clusters in order to create new competencies and induce radical innovations at a system's level, in addition to accelerating the innovation process. It is a flagship programme of Finnish innovation policy, which is organised around public-private partnerships. At present, six SHOKs are in operation (energy and the environment, metals and engineering, health and well-being, ICT and digital services, the built environment and the bioeconomy). However, the use and effectiveness of the mechanisms have been widely questioned, as it seems that they support existing industrial structures, which inhibits innovation.

If we consider 'innovation' the key determinant for competitiveness, then knowledge-based capital needs to be strengthened to achieve an increased level of national innovation capacity. Centres of expertise, science parks and innovation centres are being established in the larger urban regions, which are becoming increasingly international through strong collaboration between the public and private sectors. Finland ranked 1st in the World Economic Forum's Global Information Technology Report 2013! Finland is the best country in the world when measuring how prepared an economy is to use ICT to boost its competitiveness and well-being.

Despite the general approach of viewing countries as part of a single homogeneous system, which is what those rankings do, strongholds are more of a regional phenomenon. During an interview with Prof. Matti Pohjola (after an article was published in the Helsingin Sanomat on 8.3.2013 — 'Increased services exports compensate for the decline in physical goods exports'), we received confirmation that strongholds in Finland should be viewed more as 'local strongholds' based on traditional industry inherent to a particular region. Figure 2 shows the national strongholds in Finland, which include the paper industry, wood, ICT, mining (metals), construction, oil refineries, business services, machinery, electrical equipment and transport equipment (*European Competitiveness Report*, 2012).

	Finland	Estonia	Sweden	Denmark	Russia	Germany
Paper Industry	9,43	0,82	5,50	0,69	1,01	1,23
Wood	5,11	8,96	3,79	1,13	3,51	0,83
ICT (services)	3,81	0,74	1,87	0,48	0,49	1,11
Mining (metals)	1,82	0,52	1,14	0,33	3,28	0,79
Construction (Service)	1,71	1,83	0,34	0,24	2,26	1,91
Oil refinery	1,57	2,60	1,25	0,71	8,90	0,23
Business services (Service)	1,44	0,76	1,55	0,65	1,11	1,27
Machinery	1,43	0,64	1,28	1,63	0,17	1,57
Electrical equipment - electric motors, frequency converters for example	1,30	1,45	0,98	0,98	0,20	1,20
Other transport equipment - tractors, ships for example	1,07	0,57	0,39	0,51	0,67	1,30
Sum	**28,69**	**18,89**	**18,09**	**7,35**	**21,60**	**11,44**

Fig. 2. Comparative advantage index of selected industries

These industries are not evenly distributed throughout Finland; for example, the machine building industry is concentrated in the vicinity of Tampere. Professor Pohjola was of the opinion that a nation (or a region) cannot transform its path dependence. In other words, it will take decades to acquire the required knowledge. Establishing a university may expedite the process of transforming a region, though it is more fruitful to emphasise its historical development, for example the role of ICT in Oulu and life sciences in Kuopio. Thus, it is necessary to discuss Finland's regional character in the next section. The University in Oulu was established in 1959 in Oulu and the University of Kuopio in 1966 (name changed to University of Eastern Finland in 2010), whereas the University of Helsinki dates back to 1640.

2.2 Regionality and national growth

In the journey of continuous progress in today's rapidly developing world, companies, regions and nations are feeling the same competitive pressure. The competitiveness of an urban region can be defined as its ability to attract flows of information, technology, capital, culture, people and organisations that are important to the region, and based on this, its ability to maintain and develop the quality of life and standards of living of the local residents and also create an innovative environment in which companies can develop their competitiveness.

On a small scale, Finland has been a melting pot of different cultures and languages. This is the main underlying factor for why the different regions in Finland have created different types of strongholds. The second major contributor is geography: the country's low population density and the long distances between regions.

Outside the Helsinki Metropolitan Area, which has 1.2 million inhabitants, the regions with higher educational institutions are relatively small municipalities of between 150,000 and 250,000 inhabitants and their surrounding suburbs. This enables the local community to have stronger ties between business, education and governance, the so-called triple helix system. This is one of the distinct differences between the Helsinki Metropolitan Area and the smaller municipalities, and therefore the metropolitan area behaves quite differently than the other regions of Finland. Each region is also building its own capabilities based on local strongholds and embedded tacit knowledge. On the basis of historical, economic and business evidence, the Helsinki Metropolitan Area, Tampere, Turku and Oulu are considered the main urban regions of Finland. More than half of the Finnish population and approximately 70% of all higher education graduates live in these areas, which provide almost 60% of the jobs and produce more than 60% of Finland's GDP.

The Finnish government has now taken swift strategic action to reorganise the scattered research institutes, public funding organisations and universities. There is ample evidence that the subsidies for and direct investments in research and innovation in strategically well-selected areas have yielded a threefold return for the national economy. Therefore, it is a good strategy to streamline the institutional structures in such a way that they can adapt to new realities even more quickly. Given the new economic reality, this is particularly important in innovation areas, where start-ups and an entrepreneurial mindset are key success factors. Thus, we discuss the university-industry nexus for national growth in the next section.

2.3 University-industry nexus for national growth

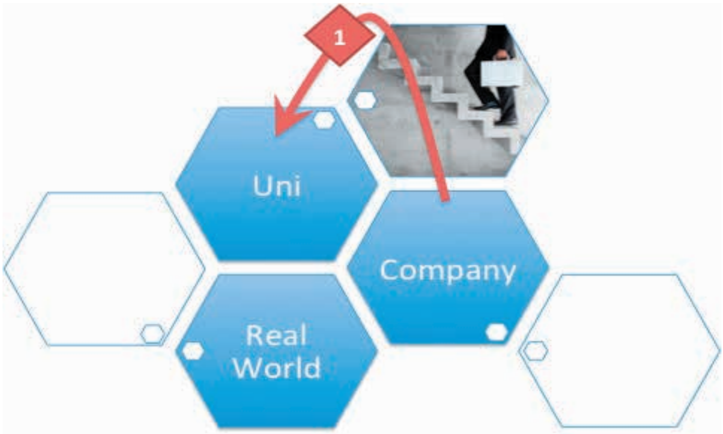

Fig. 3. Traditional contract-research conducted by universities for companies

National growth very much depends on innovation, (all forms of) capital and labour. Of these three factors, innovation precedes the other two in the current era of digitalisation and globalisation. Innovations often result from distributed inter-organisational networks rather than from single institutions (Coombs et al., 2003). The university-industry nexus is one such inter-organisational network that plays an important role in innovation; it is necessary for ensuring national growth either through new innovations or through renewing existing strongholds. Table 1 shows the different types of links between universities and industries.

Table 1. University-industry links (Perkmann and Walsh, 2007)

Research partnerships	Inter-organisational arrangements for pursuing collaborative R&D
Research services	Activities commissioned by industrial clients, including contract research and consulting
Academic entrepreneurship	Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own
Human resource transfer	Multi-context learning mechanisms, such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty
Informal interaction	Formation of social relationships and networks at conferences, etc.
Commercialisation of property rights	Transfer of university-generated IP (such as patents) to firms, e.g. via licensing
Scientific publications	Use of codified scientific knowledge within industry

Nations need to strengthen the university-industry nexus to be more competitive. In the case of Finland, strengthening this link is vital for reviving the economy, especially considering the emphasis on innovation through research both in industries and at universities (see Figure 4). Among the different links tabulated in Table 1, we consider academic entrepreneurship and informal relationships as important in the present economic context, since more than 25,000 people are participating in research activities at higher education institutions. The traditional industry-university link has been contract research, which is sketched out in Figure 3. In this article, we focus on these two types of university-industry links. Successful academic entrepreneurship requires a high level of mobility between industries and universities (Perkmann and Walsh, 2007). The mobility facilitates continuous interaction, which enables the commercialisation of university research and the ability to capitalise on market opportunities foreseen by industries due to their close proximity to the market environment. On the other hand, informal interactions allow for network-building opportunities based on the respective needs of researchers and industrial experts. These need-based networks help create new enterprises or new innovations. In other words, informal interactions provide enough synergies for innovations and enterprise creation (Cockayne, 2004; Rothschild and Darr, 2005).

There are several ideas for how to strengthen the industries and support knowledge transfer and we will introduce a couple of examples in support of these ideas in the next section.

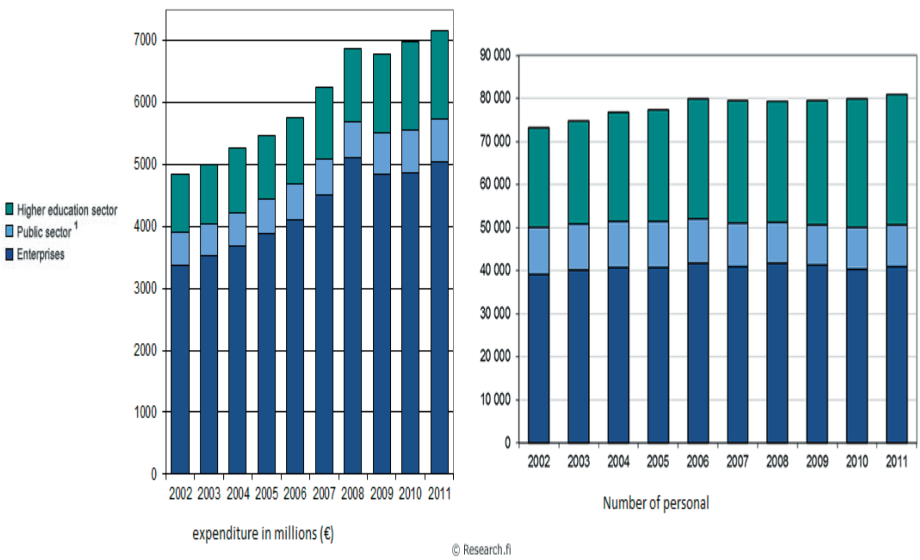

Fig. 4 Research landscape in Finland (Source: http://www.research.fi/)

2.4 Alternative: lifelong learning, a passion for knowledge

Old age is measured neither in years, nor in grey hairs; a person is old when they have lost their sense of humor and are no longer interested in anything
– Hoffmann von Fallersleben

Standing still is going backwards. In the modern world of work, this applies now more than ever before. Entrepreneurs who neglect to keep themselves and their staff up to date will rapidly cease to be competent and competitive.

The first idea we would like to introduce is a lifelong learning model, that is, an incentive-based, return-to-university approach. Lifelong learning in this case refers to a payback to society for governmental subsidies that simultaneously help update companies via university research findings and student initiatives. Let's assume that a company receives tax incentives for R&D activities or grants from the national research funding institutions. The money is a direct burden for the taxpayers, but the value created as a result of the research results is mainly captured by the company and returned to society in the form of additional taxes. While it would be detrimental to adjust the tax level and reduce the competitive position of the firm, the motivation should be to improve it and, at the same time, to pay back society. This can be achieved through incentivising education at universities, for instance every 5-7 years for a limited period of several months, during which time the company's personnel returns to the university on a weekly basis for several hours. The extra incentive for this return could be implemented via any governmental or semi-governmental funding allocation in such a way that an additional sum could be gained if the company's researchers would seek out university collaboration on an educational level. Their mission would be to disseminate their practices (industry experience) and introduce related technological areas, while at the same time learning from the student projects and the latest research findings. On the one hand, they would act as mentors for students, while on the other hand they would become familiar with the practices of other, related industries.

In what ways would a company and its employees benefit from lifelong learning?

- Knowledge is kept up-to-date
- Competitiveness is enhanced
- The performance of the staff is maintained
- The motivation of the staff is increased.

Our interviews and investigation showed that older employees often fail to take advantage of training opportunities, for example because they are no longer used to learning anything new. The training measures should therefore be adjusted to fit the changes in the learning behaviour of older people: the employees should be able to decide for themselves at what pace they want to learn and the knowledge should be imparted practically, i.e. at the workplace itself. We are aware of the number of 'professional' education courses available to employees as well as the 2-3 days per year that employees have the right to pursue further education. The educational approach we suggest is linked to researchers and the type of action-oriented, experimental education that can be integrated with a public university's activities.

The experienced personnel would be able to get in touch with the vibrant student community and their entrepreneurial spirit. They would learn about related technologies that are of interest to their work but often not achieved due to current priorities and time constraints. The university would further provide a venue for them to work on ideas that they have created over time but not been allowed to work on because of company interests or the disruptive potential of the ideas. The courses offered would be hands-on courses with an action-based learning philosophy.

What's in it for the students / nascent entrepreneurs? Exploiting the knowledge of others is the main factor. For young entrepreneurs and entrepreneurial-minded people, the great benefit would be to have access to industry know-how. Their main disadvantage would be a lack of the type of experience that would equip them with the unwritten rules of the game. This intrinsic knowledge cannot be obtained in the normal university setting, but it can be bridged in honest voluntary (or incentivised) cooperation with experienced industry insiders, mainly researchers and decision makers. As a direct result, we can assume that errors and false assumptions would be detected at a much earlier stage, thereby increasing the success potential of the student initiative.

Even the university would greatly benefit from the pool of mentors because the mentors would in part be compensating for their time spent at the university by becoming involved in student projects. Moreover, the university would be able to offer a greater number of student projects. The incentivised return-to-university model for senior industry staff would further build stronger informal networks. This additional benefit should not be disregarded or undervalued.

3 Dancing tango at work — transferring passion and desire from start-ups to established firms

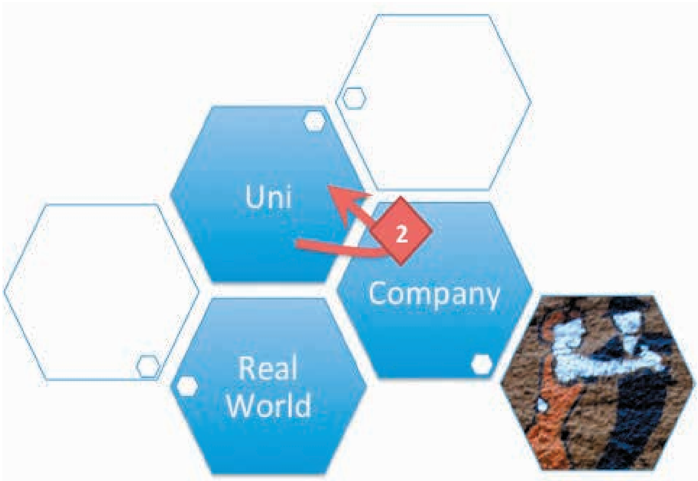

Fig. 5. A university researcher-driven collaboration with industries

Dancing tango is a manifestation of passion and desire, in which two parties intimately share a valuable moment of their time. In working life, we assume that a symbiotic relationship between young-spirited individuals and wisdom-laden greyhounds can lead to a similar climax. Both groups share a passion for what they do, as well as a desire to create something new and of value. Young start-ups are lacking a vital ingredient in their magical mixture, the sense of an innate understanding of industry rules, the unwritten and unspoken parts of work that are only acquired after years of practice. The opposite holds true for established firms: they have developed a proven business model that is being challenged on a daily basis by competitors and need new ideas. Both parties demonstrate opposite strategies and behaviours: in this instance, could a liaison be bigger than the sum of its parts?

3.1 Tango in Tampere: the 'Pessa' model

So how does one dance the tango in Tampere? While doing background research for this article, we encountered several references to the 'Pessa model' for how to commercialise university research and turn researchers into entrepreneurs. To find out more about this model and its practical manifestations, we interviewed Professor Pessa briefly at Tampere University. Markus Pessa is a professor emeritus of semiconductor technology at Tampere Technical University and he also founded the Optoelectronics Research Centre (ORC) in 1999. Through his lifelong work, he has helped convert Tampere into a laser, or rather, photonics research hub and aided in creating five spinoff companies based on university research.

First, Pessa emphasises that the road from research to commercial product is a long one — it also requires money and facilities when high-tech manufacturing industries are concerned. Thus, the economic viability of the project and the need for possible products need to be assessed carefully. The evaluation of real-world possibilities is integrated within the research projects and discussed on a regular basis among the researchers. We find such continuous considerations to be one of the key issues in successful commercialisation because it also tunes people to actively look for and recognise solutions to known problems. This is also an approach that the authors have not often encountered in their own respective fields.

Second, there is a great need to have industrial connections when commercialising research. Such links are not born immediately; they require active work globally among the different actors. Pessa's group did not have these contacts initially, but over the years they have managed to network with the most important industrial actors in the field.

The third significant problem is the personal financial security of a new entrepreneur. In Tampere, one of the solutions has been part-time employment at the university, which lessens the risk and financial burden on families. As with the manufacturing facilities, the aim is only to provide support during the initial stages of a new company and in time the companies should become fully independent. As the earning possibilities in the private sector are substantially higher than in public sector universities, motivated people normally have no problems in becoming independent.

According to Pessa's experience, many researchers are willing to become entrepreneurs, but they need support when taking the initial steps to start a new company. For instance, in optoelectronics there is a need for expensive equipment, which small companies have difficulties in accessing financially. Therefore, it is possible to engage in developing and prototyping activities using the university's facilities, including two laser manufacturing lines and equipment, which are worth more than 30 million euros; this can be done by contract. In the long run, new companies will need of course to have access to their own manufacturing facilities to ensure their competitiveness. So far, the new companies are not competing against each other, since they also work in a specific niche within the industry.

After the birth of a company, the cooperation between the university and the companies does not need to stop; a continuous circular process exists. As Figure 5 shows, in time these companies are able to participate in new research projects as industrial partners. As the people are already connected even on a personal level, informal information sharing may also have a substantial effect on the success of these companies, as has been shown in the knowledge transfer activities of Swiss high-tech companies (Arvanitis and Woerter 2009). The possibility of recruiting highly skilled personnel from among the university graduates can also be seen as an advantage and a reason for the companies to stay in the Tampere region.

Due to the success of the photonics cluster, the university and ORC now attract a great number of potential students. As few as 10% of applicants can be accepted, which means that the university can choose the best potential candidates and thus raise its quality. The personnel working on ORC projects has grown from approximately 20 to some 90 people

According to Pessa, the funding for the university projects has never been a significant issue at ORC. The Finnish funding bodies, including TEKES and the Academy of Finland, have met the requirements of the ORC quite well, and industrial partners have participated in the funding as well. Only at the very beginning did Pessa have to convince the university of the significance of his aims and work, but since then there has been constant support. Also, the City of Tampere has aided the birth of the new industry considerably. Tampere has a very long industrial background starting from the early 19th century, and by the turn of the 20th century it was the most important industrial city in Finland. By the 21st century, it has had a long history of changing industries and thus the transition and support to yet another, completely new field, optoelectronics, fits the traditions of the city well. It also seems that the size of Tampere and the low level of regional hierarchy are favourable for cooperation because the key actors know and trust one another. Thus, Pessa's entrepreneurial approach has been welcomed with open arms.

3.2 Alternative: creating the mindset

The Pessa model seems to work well in Tampere, where the ground is fertile for entrepreneurial activities. What if the ecosystem is lacking from the beginning and the actors do not see themselves as entrepreneurs? This might be a more typical situation at Finnish universities, even though the general framework for entrepreneurship is among the best in the world (Nordic Entrepreneurship Monitor, 2010). In many disciplines, the university graduates have been trained to become researchers who will become civil servants or other wage earners once they leave the university. Where the graduates find employment has traditionally not been the burden of universities because their main task is to engage in scientific research and provide teaching in their specific fields. Thus, a whole ecosystem where graduates might transform themselves into entrepreneurs or people with an enterprising behaviour seems to be rare today and can be better found at applied universities.

The next question has to do with how the existing ecosystem can be changed when the majority of the active staff might not have any entrepreneurial aspirations or experience. Furthermore, the university staff members might not be willing to add any unpaid task to their existing curriculum, which means that encouraging entrepreneurial activities needs to be rewarded at the universities. Since many universities depend on public funding, the funding bodies should also develop methods for encouraging entrepreneurial activities. In fact, the recently developed European Union university ranking system, U-Multirank, clearly emphasises the societal impact on entrepreneurship by measuring 'success in knowledge transfer (such as partnerships with business and start-ups), and contribution to regional growth' (European Commission, 2013).

While the attitudes and experience of the staff may be a more difficult problem to tackle, it may not even be necessary to worry about all personnel: universities also need research-oriented people. As in the case of Tampere, it might be important to discuss and reflect upon the impact of the research on a daily basis and its effects on their daily surroundings and the field at large. The actual training of the students should take place in multidisciplinary teams, which can be guided by experienced personnel. As Collins and Robertson (2003) suggest, an effective entrepreneurial learning process may consist of learning from another person, learning by doing, learning by discovery, learning through mistakes and learning through problem solving.

4 Universities, the hubs for innovation

Fig. 6. University spin-offs

With the higher education sector now adopting more competitive practices, universities are being encouraged to profile research and education and engage in stronger outreach activities. Hence, universities have become hubs for innovation, places where industry and students start collaborating. The surge in the number of student entrepreneurship clubs or societies indicates that the students welcome this development and no longer intend to wait for company offers. Instead, they use the university as a low-risk environment to try out and sometimes fail with risky ideas. Hence, we are currently experiencing the 'age of university spin-offs' at higher education institutions. While this might not have an immediate economic impact, it helps create and develop a much desired entrepreneurial mindset. It is worthwhile considering options about how to connect these initiatives to established industry practices to create somewhat more sustainable efforts.

4.1 Professional incubation services at universities

In this section, we briefly introduce a small number of incubation services that feed upon one another and also construct a framework for understanding the process. They are merely exemplary case studies and can be found in similar form at various research universities around the globe. Yet, the example will show us the kind of incubation services that are worth considering.

Demola is an open innovation platform where companies can bring in their ideas and develop them further together with students. Thus, the companies may benefit from fresh thoughts and approaches and the students can use such assignments as part of their studies. The students may also profit by practising their entrepreneurial skills and gaining experience with the entrepreneurial atmosphere. The idea is also to use multidisciplinary teams consisting of students from all of the universities in a particular region, which may create totally new ideas for existing fields. The students will also get hands-on experience with collaborating on projects. Demola was developed in Tampere and the concept has now spread to Oulu and outside Finland to Lithuania, Hungary and Sweden. In Finland, Demola is coordinated by Hermia Oy and funded by universities and public sources.

Protomo is the equivalent of Demola for university graduates, where highly trained people can explore the possibilities for entrepreneurship by playing on their own ideas or ideas that companies have rejected. As a true modern start-up incubator, Protomo also offers possibilities to network and encourages creating scalable products that can be marketed globally from the start. Similar to Demola, the Protomo network is coordinated by Hermia Oy and funded by universities and public sources.

The third platform within the same incubation system is Suuntaamo, which could be translated as 'Direction' or 'Guidance'. This organisation is part of the Tampere region innovation pool. Its main target is to help a new idea meet the requirements of users regardless of whether it is a product or a service. Fiskars scissors design (see Figure 7) is a good example of integrating a user interface with a very ordinary product. This type of direction or guidance is essential at the very early stage of design; it just cannot be built at the last minute prior to product launch, as many still think today. IDEO, a well-known design and innovation-consulting firm, has used an example of the classic telephone handset. If you want to try and find out about the functionality and user-friendliness of the handset, the important thing is not that it functions but that it can be built rapidly and with a shape that best fits its use. Today, additive manufacturing tools are of great help in this process. Suuntamo in the Tampere region has played an essential role in the early development of ideas that have led to the commercialisation of products and it fits well into the framework created by Demola and Protomo.

Fig. 7. User-centric design

The Vigo Accelerator programme is aimed at existing start-ups and its aim is to bring together new beginners and experienced entrepreneurs. The experienced entrepreneurs not only help the selected start-ups to grow safely and globally, but they also invest their funds in these companies. As such, the programme is limited to certain fields, which are seen as growth-oriented fields and where experienced people and venture capital are available. One of the aims is also invigorate the Finnish venture capital markets and bring more venture capital to Finland. The programme was launched by the Finnish Ministry of Employment and Economy and is being coordinated by PPOFict Oy.

Just to mention an example from our home university, Aalto Startup Sauna is a business incubator working within Aalto University. It aims to create an ecosystem suitable for start-ups in Northern Europe, so the activity is not only aimed at budding companies. According to its website, Aalto Startup Sauna also finds internships for students to work at high-growth companies in Helsinki and the Silicon Valley. The Aalto Startup Sauna is a non-profit organisation and is funded by its own foundation, Aalto University, and by public sources.

4.2 Alternative: a student-driven TTO model

Technology commercialisation is an important activity at universities; it provides a source of revenue and supports applied research at a public university. The existing models are uncountable, but still dependent upon the general university structure.

Traditionally, and still evident at the majority of universities today, education, innovation and research are separated from one another and different actors are responsible for one single area. One example is that professors are researchers and only assistants and doctoral students are educators; this is a typical model in many countries, but not so much in Finland. The discourse on the evolution of the university model is currently centred on the entrepreneurial university concept. The entrepreneurial university provides new opportunities for different public-private collaboration (compare Figure 8).

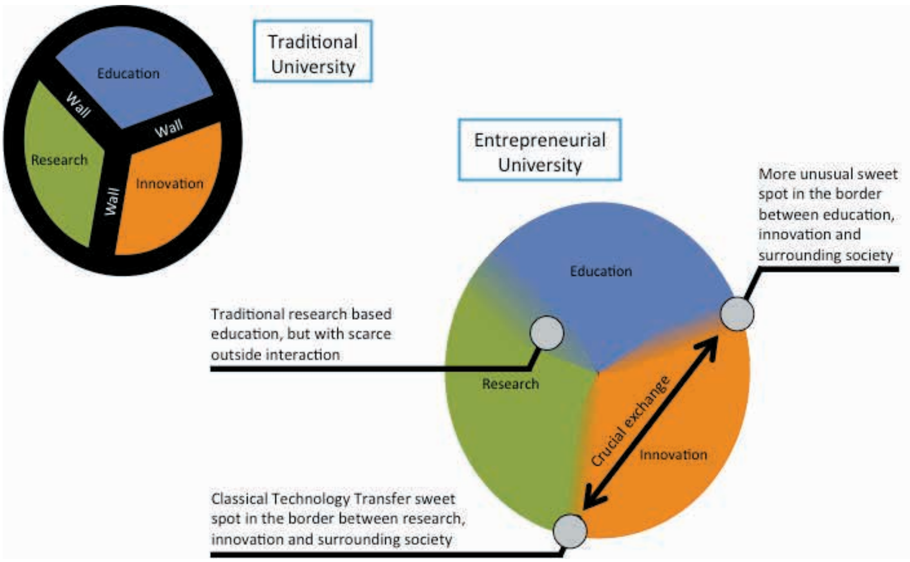

Fig. 8. Traditional versus entrepreneurial university (adapted from Lackeus, 2012)

One model we would like to introduce is that of a student-driven technology dissemination process, which complements the technology-transfer model operated by Finnish TTOs. The simple reason that it complements the current model is that it does not provide much support for student innovations and that the commercialisation potential is difficult to predict at an early stage. Therefore, potential inventions are not monetised. The going argument is that a TTO is a functional model, a certain formula that fits a specific type, regardless of whether the R&D activities are occurring in private companies on a regional or a national level. With the current staff and model, this problem is difficult to overcome, though a complementary model could provide part of the solution.

A complementary model for university-based inventions would be based on crowd-evaluation from the private sector. Let's assume that a student or researcher has an idea he/she would like to test, so they present their idea at the TTO for evaluation. In cases when it rejected and does not enter the standard support model, the process would often then be stopped. However, the idea has not yet failed or been proven wrong as such; it is just that the people in charge of the TTO simply do not recognise the current potential of the idea as being valuable enough. A private company involved in similar R&D activities might disagree. One possible reason is that they have more up-to-date industry knowledge; another is that they wanted to explore this idea but have not had the resources available to do so thus far. The TTO could open up its decision process and provide the filing description of the idea to regional or national companies. If the companies find this idea worth exploring, a match-making process could start, and after mutual agreement between the inventor and private company, a first proof-of-concept phase could be started irrespective of any resources provided by the TTO. In this way, the evaluation process is crowd-sourced and the chances are greater that it will be a promising fit for an invention and commercialisation partner.

In such a model, it can be expected that the entrepreneurial university will become stronger in its aims to be a regional hub between the public and private sector, educating and innovating at the same time.

5 Conclusions and recommendations

The purpose of this study was to assess different micro-level initiatives supporting the renewal of strongholds in Finland. Strongholds are a country's backbone of economic activity; they possess the tacit knowledge required to achieve systemic change. To renew the strongholds in Finland, we chose to focus on the importance of an entrepreneurial mindset in an academic environment as the basic paradigm for making it work. This is important because of the strong emphasis on research and innovation in Finnish universities; this can help turn innovations into value-added products to revive national growth.

Our analysis of traditional collaboration practices revealed that an innovation system perspective is still quite relevant these days and that the regional aspect must be stressed. From an evolutionary growth perspective, routines limit economic action. Technological advances are assigned the leading role for progress, and social technologies (related to mindset) enable this to occur. **The lesson learned is that strongholds are a regional phenomena and that collaboration has to be fostered on a local university-industry level.** In order to achieve this, we propose that a life-long philosophy on collaboration become an institutionalised practice (routine), one that connects and integrates the innovation practices of industry to the novel ideas of students (depicted in Figure 9, line 1). In other words, instead of institutionalising the solution, we propose an incentive-based system that leads to institutionalising practices on a micro level. The additional value added by students is that they are unbiased by industry assumptions; thus, it is more likely that they will facilitate out-of-the-box thinking.

Our endeavour further reveals that a strong level of co-operation between university researchers and industries at the micro level seems to be one of the key elements for renewing strongholds. Based on the 'Pessa model', we propose adopting different strategies to supplement existing mechanisms. As such, life-long learning will facilitate a more active environment for researchers and the greying Goliaths of industry in particular. Yet, we feel comfortable to claim that these strategies cannot reach their full potential without the active perseverance of a mindset shift at the institutional level. **The lesson learned is that an entrepreneurial mindset is a pre-requisite for changing the collaborative innovation practices of strongholds.** In our opinion, existing frameworks do sound perfect at a theoretical level. However, on a practical level they do not support creating an entrepreneurial mindset, since such a mindset is a social and psychological phenomenon. Therefore, dancing the tango, i.e. engaging in joint research efforts instead of protectionism, is one alternative that we propose (depicted in Figure 9, line 2). Engaging in application-oriented research from the early stages of doctoral research in emerging fields will be one interesting alternative. A beneficial side effect is that stronger informal networks will emerge that will further strengthen the dissemination of innovations.

Taken together, the previous suggestions raise the role of universities and make them even more vital components of regional innovation activities. Currently, students are hungry for more support services that can help them realise their ideas beyond classroom settings. This desire can be matched quite well with newly created incubator and accelerator services. Whereas in the past prominent companies were quite certain that graduates would apply for jobs with them after graduation, students are increasingly active in project-based or venture-creation activities during their studies. **The lesson learned is that universities are the new hubs for innovation because student enthusiasm is nurtured and exploited there, which increases companies' interest to engage with them.** In addition to the ongoing efforts to build an infrastructure (facilities and services) for such innovations, we propose an alternative approach for technology transfers, one that is embedded in a general transformation towards becoming an entrepreneurial university. In other words, a student-driven TTO approach to product innovations in industry lowers the perceived risk during the initial phases of enterprise creation. One reason for this is that opening up the TTO process to regional strongholds enhances the chance of finding the best angle for the commercialisation process (depicted in Figure 9, line 3). Another reason is that students are an extra resource through which a greater number of early phase innovations can test their go-to-market performance. The change in research commercialisation practices best occurs when connected to the process of universities becoming more entrepreneurial in nature, an idea that needs to be studied further.

Fig. 9. Comparison of three collaboration models for university-industry collaboration

The very concept of innovation and the role of universities in growth significantly differ in different countries, institutions and organisations. In our opinion, innovation has become an institutional phenomenon in Finland, which has created complex networks of innovation institutes and organisations. We do agree with the need for macro-level initiatives, however, considering the individualistic attributes of entrepreneurship and enterprises; we advocate for micro-level initiatives with minimal macro-level supervision, which will enable a fertile environment for informal, yet fruitful, relationships between university and industry. We encourage symbiotic relationships on a regional and informal level between university research activities and related industries. Therefore, a mindset and working culture shift is needed to achieve new routines. An incentivised system is one possible alternative for narrowing the current gap.

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1.4 Breaking governmental silos – using best practices from open innovation platforms

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Abstract

New policies are needed for a changing world. Globalisation and digitalisation have changed the world significantly during the past decades. Even though governments are also subject to changes, governmental structures have barely changed at all. How can governmental silos be broken? We have studied five open innovation platforms and put these contemporary organisational structures into a governmental context. We provide concrete suggestions for how governments can tackle the collaboration

difficulties. We discuss how governments can attack bureaucracy, cross borders and become more accountable and agile. We also present three different concepts by implementing the best practices found from the open innovation platforms. Our suggestion is that governmental silos can be broken by thinking differently, by having agents of change and by giving more power to the people.

Keywords: governmental silos, open innovation platform, collaboration, co-creation

1 Introduction

In this chapter, we present a framework based on the best practices from open innovation platforms for how governments can tackle the difficulties with collaborating across borders. By open innovation platform, we mean an organisation that is using ideas and knowledge originating both from the organisation itself and also from outside of it. The basic idea is that the flow of knowledge is accelerating innovation (Chesbrough, 2003). The chapter does not target any specific country and our suggestions are applicable to governments in many small European countries. To emphasise the need for new policies, we start the chapter by highlighting three particular problems related to government collaboration. We provide suggestions for how governments can solve these problems in Section 4.5.

1.1 The deteriorating education system in Sweden

Sweden used to be famous for having a strong education system with competent teachers and highly performing students, but things have changed. Between 2000 and 2009, Sweden dropped from above the OECD average to below the OECD average in reading literacy, mathematical literacy and scientific literacy (OECD, 2003, 2010). Things need to change quickly in order to avoid creating an entire generation that lacks a proper education. We believe that much of the responsibility rests with government, which needs to change the current trends and propose new ideas for the future (discussed in subsection 4.5.1).

1.2 The healthcare ICT infrastructure in Finland

The Finnish ICT infrastructure is slowly moving from being a decentralised infrastructure to a centralised infrastructure, and ensuring that the transformation is handled smoothly will constitute a tremendous challenge in the next years. At the same time, technology is advancing more quickly than ever, which means that if you do not implement your solutions quickly enough, they will be outdated as soon as they are released. Some suggestions on how to handle the problems have been made in the Finnish Ministry of Employment and the Economy's study, *21 Paths to a Frictionless*

Finland (*21 polkua Kitkattomaan Suomeen*, 2013), and the health service solution, 'Taltioni', has already been implemented. Our framework supports solutions like Taltioni and we encourage governments to push for more centralised IT solutions. However, a new infrastructure is by no means sufficient. (Hämäläinen and Saranto, 2009) point out that the majority of doctors rate their ICT know-how as poor, which is unacceptable when they daily have to spend hours at their computers. We continue this discussion and give concrete suggestions in subsection 4.5.2.

1.3 Government's interventions in business in Finland

In Finland, there are numerous different support channels for developing businesses. The organisation Team Finland is gathering together different governmental organizations (e.g. Tekes, the Ministry of Industry and Employment, Finpro) in an international arena. Many studies and companies acknowledge the importance of these organisations, claiming that they have helped make start-ups profitable and also helped build knowledge and competence as a means of increasing the competitiveness of Finnish industries (see, for example, Kuusela, 2013; van Der Veen et al., 2012). Also, it has been found that in Finland (and many other European countries) government venture capital has been able to add value to a business just as effectively as independent venture capital (Luukkonen, Deschryvere & Bertoni, 2013).

However, there are also studies and vocal opinions that the government funding system for new businesses and innovations is not nearly as effective and functional as it should be, that the system is too complex and bureaucratic, and that, for example, more strategic agility and funding for high-risk projects is greatly needed (Koski & Tuuli, 2010; Tahvanainen & Seppälä, 2013; Hämäläinen & Saranto, 2012). Some experts have criticised the fact that in some cases, government funding depends too much on using pre-selected consultancy services that do not necessarily have any notable advantage for a specific company (Ekman, 2013).

Providing effective public support for businesses is very challenging, and it is perhaps even more challenging to accurately measure the results because there are many secondary effects, for example when a company that is being supported stimulates the business of SMEs through subcontracting. Also, the differing and often very long time frames for supporting innovation make it difficult to measure the success of the policy. However, even though government support for growing businesses seems to be effective in many cases, we claim that to respond to challenges in the global business environment, collaboration between the different governmental actors and businesses should still be made much more agile and effective. We also provide some concrete suggestions for this based on our study in subsection 4.5.3.

1.4 Why should you care?

Traditionally companies, universities and governments have had very hierarchical structures and well-defined areas of responsibility. With the advent of new technology and an ever-changing work environment, significant changes in organisational structures are occurring. The structure of individual organisations has changed, but not as dramatically as the network within which organisations collaborate. It is essential for most companies to collaborate with a wide variety of other companies with different fields of expertise. At the same time, multidisciplinary collaboration has become increasingly important at universities, and we have also seen a huge increase in collaboration between universities and companies. Even though governments have also been subject to changes in technology and responsibilities, governmental structures have barely changed at all, as pointed out in several studies (e.g. Finnish Ministry of Education and Finnish Ministry of Employment and the Economy, 2009; Hjelt, den Hertog, te Velde, Syrjänen & Ahonen, 2008). Many current issues, such as regulation and policies regarding ICT infrastructure (Finnish Ministry of Employment and the Economy, 2013), are complex problems that do not fit into a single traditional ministry. Because of the nature of the current issues, it is not always clear what department or minister should be responsible for a particular issue, which in many cases leads to an inefficient process.

New technological advances lead to huge challenges for governments. The ministerial structure is not ideal for dealing with many of the current challenges, such as Internet policies, an aging population, the sustainable use of resources and the ICT infrastructure, to name just a few. In Section 2, we will discuss current governmental challenges within the context of small European countries, and in Section 3 we will study different contemporary organisational structures. In Section 4, we will put the contemporary organisational structures into a governmental context and give concrete suggestions for how governments can tackle collaboration difficulties. We will finish the chapter by offering some conclusions and suggesting future courses of action in Section 5.

2 *Key issues for government collaboration*

In this section, we will discuss some key issues for governmental collaboration. They are challenges that are currently occurring in the world, where the changes seem to be fundamental and deep. Governments are subject to changes as well and we will review the issues particularly from a governmental point of view.

2.1 Complexity and uncertainty

There are a huge number of factors that influence competitiveness and productivity, ranging from infrastructure and education to policies and regulations. The system is very complicated and it can be a challenge to improve it through innovation, but collaboration is one way to stimulate institutional innovations (Harvard Magazine, 2012). Many innovative solutions require collaboration between several different actors who contribute a diverse set of competences and cutting-edge knowledge (Rothaermel, Hitt & Jobe, 2006). We may find new solutions by combining and re-configuring different disciplines and expertise in new types of flexible organisations (Lam, 2000).

Another potential driver of collaboration is uncertainty. New technologies such as nanotechnology and biotechnology have the potential to completely change the technological frontier, which may transform complete value chains (Herstad, Bloch, Ebersberger & van de Velde, 2008). Since it is impossible to know who will capture the value in question, it is important that the government should act to enhance collaboration and risk sharing in uncertain high technology sectors through policies and regulation.

2.2 Globalisation

Globalisation can be seen as increasing interaction as well as the mobility of people, money, goods and knowledge. Globalisation has to do with a transition from internal knowledge to global knowledge networks where companies, regional innovation systems and sectoral innovation systems become more open (Herstad et al., 2008). There are specialised knowledge development nodes that are linked together. Not only markets, but also many policy issues are global. According to an evaluation report by the Finnish Ministry of Education and Finnish Ministry of Employment and the Economy (2009), it is more difficult to justify old innovation policies, like subsidies, in the globalised world because most of the benefits extend beyond national borders. Traditionally, national innovation systems have focused on companies, but in this era of globalisation the focus may have to shift from companies to creative individuals says the evaluation report. National innovation systems and governmental perspectives must open up to a more global world.

For high-income countries, globalisation means renewal and more emphasis should be put on quality rather than competing over price (Finnish Ministry of Education and Finnish Ministry of Employment and the Economy, 2009). According to the study 'The Role of Innovation Policy in Fostering Open Innovation Activities among Companies', small European countries share some similarities and yet also have different weaknesses when it comes to the level of openness of their innovation policies (Lemola, 2008). There is weak cooperation between innovative organisations in the Netherlands, Sweden and Norway. The small number of start-up companies seems to be the problem in all of the studied countries (the Netherlands, Sweden, Finland and Norway). Norway has weak performance in innovation output and Finland has weak performance in commercialising its research results. In the Netherlands, Sweden and Finland, multinational companies may reduce R&D expenditures in their home market and increase R&D outsourcing from abroad. According to the review the 'Major challenges for the governance of national research and innovation policies in small European countries', an increased level of awareness about the consequences of globalisation has been the major driver for governance changes (Hjelt et al., 2008).

In many countries, analyses have been done on how to deal with globalisation. The report 'Policies for Open Innovation' anticipates that open innovation policies should increasingly be offered at the international level rather than at the national level (de Jong, Vanhaverbeke, Kalvet & Chesbrough, 2008). The decisions made in one country also affect other countries in the globalised world.

2.3 Networking

Networking is a source of innovations both in a company and a governmental context. Innovation has to do not only with technological innovations, but also with service, social, institutional and systemic innovations. Business — as well as government — ecosystems need to be enriched in order to work in an effective and competitive way: the strength of the different pieces within a system and their interaction with one another determine prosperity and economic growth. The principle idea of an ecosystem is that the different pieces of the system come together. According to Professor Rosabeth Moss Kanter, cross-sector collaboration is one important issue that makes the ecosystem work better (Harvard Magazine, 2012). Money is not enough: the pieces must talk to each other.

The report '21 Paths to a Frictionless Finland' also emphasises that more cooperation is needed both within particular fields and also between different fields (Finnish Ministry of Employment and the Economy, 2013). It seems that multidisciplinary collaboration is the key to new innovations. Ecosystems are necessary for solving global challenges. National, regional and local parts of an ecosystem must be able to network globally, and the level of know-how must be relevant and of a high quality in matters of global competition.

Innovation results from many different sources; however, the most important source of innovation is the linkages between the different sources says Professor Melissa A. Schilling in her book *Strategic Management of Technological Innovation* (Schilling, 2005). Networks are powerful and they constitute a complex ecosystem within which innovations occur. The ability and willingness to exchange knowledge can be easier if there is a certain degree of proximity and interaction. Networking complements the older sectoral and centralised innovation policies in many countries (Hjelt et al., 2008). There seems to be a need to create new operations and structures that go beyond the old hierarchical modes of governance.

2.4 The role of the government in collaborative innovation networks

A government can affect the business world through policy making; hence, it is important for a government to have policies and regulations that facilitate collaboration between companies both on a national and on an international level. According to the report 'Policies for Open Innovation (de Jong et al., 2008), open innovation makes it possible to utilise knowledge and ideas in a broader array of business models and network configurations in order to increase value creation in society. It is credible to assume that including the government in the network configurations would help boost value creation.

There is growing evidence that governments themselves should act as open innovators (de Jong et al., 2008). Governments are in many cases an essential part of research projects ranging from defence to space programmes. Since they help fund such projects, they own the IP, which could have a huge economic potential if applied to other industries.

2.5 Politics

Although politics surely influences companies and open innovation practices, it plays a much bigger role in a governmental context. Political parties have their own interests and worldviews. In companies, the bottom line, money, can ultimately be used to justify decisions, but with government policy making there is no single metric that can be used to decide on the best option.

By politics, we mean on the one hand the justification of decisions based on the values held by the policy makers, while on the other hand we are referring to the political play that takes place in government. Ideally, different political parties represent the different values that are present in society. These values may be conflicting, and therefore they may introduce more complexity into the policy-making process. In practice, this can also mean political play, where different agreements are made between the parties on non-related issues. These 'if you support us on this, we will support you on that' agreements are the result of the fact that political decision making takes place within a complex environment. The decision on one issue affects all other decisions.

There is a need to find a balance between policy planning and political plans (Hjelt et al., 2008). If there is too much emphasis on political plans, the environment for innovations will become too turbulent and unpredictable. On the other hand, if rational policy making is emphasised too much, it may become challenging to find support among the different political parties or societal actors. Politics is required to create the necessary commitment to particular plans of action.

One example of the importance of commitment is the Finnish innovation policy. Finland is trying to adopt a broad-based innovation strategy, which is vague and challenging to implement (Finnish Ministry of Education and Finnish Ministry of Employment and the Economy, 2009). A broad plan based on 'rational' analysis may not be enough; the involvement of different stakeholders across governmental and political borders is needed.

2.6 Experimentation

Experimentation makes it possible to create and test many new ideas, insights and concepts. Many of the experiments may fail, but that is perfectly acceptable. The failed experiments are essential learning and unlearning experiences.

Also, the public sector needs more agility, more willingness to unlearn and address difficult matters in a solution-oriented way. Most of the product and service innovations arise in firms. However, the competitiveness of the public sector affects the firms' possibilities for development. Both active and passive choices within the public sector affect how diverse the economic structure will be in the future (Finnish Ministry of Employment and the Economy, 2013).

However, experimentation, and especially failure, is not unproblematic in a governmental context. There are two main reasons for why this is the case:

1. There is a need for financial accountability when experimenting with public money;
2. There is a need to provide a stable policy environment for companies.

In other words, the challenge is to find the right balance between experimentation and financial accountability as well as between agility and stability (Hjelt et al., 2008).

There is an increasing trend to provide 'value-for-money' evidence when it comes to policy experiments (Hjelt et al., 2008). This may restrict radical experimentation. Failed policies are not seen as learning opportunities, but rather as proof of the incompetence of policy makers. A company can more easily invest money in high-risk experiments because they do not have to worry that much about political play.

Experimentation requires agility from the governance system (Hjelt et al., 2008). Agility means the ability to quickly adapt to changes and be flexible when needed. However, agility also means that the policy environment may become too turbulent and unpredictable. This may lead to, for example, company being unwilling to invest in a certain new technology because they interpret the situation as still being open to changes.

Because of globalisation, there is a need to increase the tolerance for policy experiments and possible policy failures (Finnish Ministry of Education and Finnish Ministry of Employment and the Economy, 2009). This is also linked to politics because the failures need to be seen as learning opportunities and not as proof of incompetence by the rival parties. A policy experiment thus may benefit from broad-based cross-governmental commitment.

3 *Best practices in new open innovation platforms*

In order to find ways to overcome the challenges presented in the previous section, we will explore five examples of open innovation platforms. We will discuss their experiences with practices that are working and find common factors that can be applied within a governmental context. The cases we have chosen are the Multidisciplinary Institute of Digitalization and Energy (MIDE), the Design Factory Network (DF Network), the Tampere New Factory, the Oulu Business Kitchen and W. L. Gore & Associates. The best practices are summarised in Table 1 at the end of the section.

3.1 Multidisciplinary Institute of Digitalization and Energy (MIDE)

MIDE is a research programme on digitalization and energy technology at Aalto University. It takes advantage of bringing together different disciplines and carries out research to strengthen the competitiveness of Finnish business, industry and training. It combines expertise from various fields of science, engineering, business and design to perform research along with its applications. The programme started in 2008 when funding for the research was collected under the umbrella of the 'Technology for life' campaign. Approximately € 20 million was collected from different donors, including companies and communities. Currently, 11 research projects are in progress (mide.aalto.fi).

Elina Karvonen, MIDE's project coordinator, explained the structure of the programme and the measures that are taken to make the collaboration successful. She mentioned that the programme has a small administrative staff and a low level of bureaucracy. It has a steering group that consists of members from Aalto University and a follow-up group that consists of representatives of the largest donors. In order to achieve successful collaboration, the administration tries to facilitate intra-project communication by having frequent breakfast meetings and annual research seminars. Annual external research seminars are also organised where both the researchers from MIDE and the donor representatives can discuss the research that has been carried out.

Since the programme functions within Aalto University, academic output, which includes research, publications, dissertations and other theses, is one of the most important measures of success. One of the underlying objectives of the programme is to support new avenues of research that strengthen the competitiveness of Finnish industry. In this sense, programme-enabled spin-offs, patent applications, follow-up projects and novel kinds of multidisciplinary cooperation should also be considered as ways of measuring success.

In response to a question posed to him, Sami Ylönen, MIDE's project manager, mentioned that, 'co-creation never succeeds without hard work. All of the partners have to be active and make a strong effort at co-creating. Only in that way is it possible to achieve good results. Another important remark is that it is not possible to start collaborating at a deeper level if the partners have not collaborated beforehand. In that case, it will take time to deepen the level of collaboration.'

3.2 Design Factory Network (DF Network)

The Global Design Factory Network consists of design factories that operate using the philosophy and principles developed at Aalto Design Factory and adapted to fit the local environment; it employs three different collaboration schemas, as shown in Figure 1.

Fig. 1 The different collaboration models of the Design Factory Network

As of today, March 2013, the DF Network consists of five members: Aalto Design Factory in Finland, a founding member that started in 2008; Aalto-Tongji Design Factory in China, which has been a member since 2010 under the In Partnership model; Swinburne Design Factory in Australia, which has been a member since 2011, and Duoc Design Factory in Chile, which has been a member since 2012, both under the Powered By model; and, finally, Design Factory India in Delhi, India, which has been a member since 2012 under the Inspired By model. A design factory at CERN, in Switzerland, is currently being developed.

What is a 'design factory'? A design factory is a multidisciplinary co-creation platform that started at Aalto University in 2008 with the mission of bringing together three universities (Business, Technology and Arts) to form Aalto University and help create a new culture and identity for it. Some of the things that have made the design factory a game changer are not necessarily the things that are a part of it, but rather, the things that are not a part of it: bureaucracy, strict rules, closed doors and hierarchies. In a design factory, people are encouraged to change the status quo by doing things differently in an ever-changing environment where the workspaces are re-designed in new and innovative ways in order to prototype spaces that improve communication and co-creation. These spaces exist with the sole purpose of allowing 'planned coincidences to happen', since all members are able to use the spaces to host their lectures, workshops, courses, seminars and all sorts of educational events and to also work on their own projects with the 'risk' of bumping into someone with similar interests that might take the project to a whole new level.

3.3 Tampere New Factory

The 'New Factory' is a fast-growing innovation and business incubation centre in downtown Tampere. The idea behind the Tampere New Factory is to combine know-how in one physical and mental space in order to produce technical, commercial, social and service innovations. The goal is to speed up the renewal of the Tampere region by creating new businesses, jobs and overall welfare, which may then also benefit the rest of the world. The Tampere New factory has approximately 2500 members and 70 collaborating companies, and it raised 13 million euros in funding for innovators and start-ups in the year 2012 alone. The industries represented include ICT, machine building and automation, media, wellbeing and energy (www.uusitehdas.fi).

The Tampere New factory is divided into four parts: Demola, Protomo, Accelerator and Suuntaamo. At Demola, multidisciplinary student teams develop demo concepts together with companies. The immaterial rights for the demos stay with the students, but the companies can buy the rights. So far, 95% of the demo concepts have been claimed for business use. The Demola model has also been adapted in Oulu, Vilnius and Budapest. Protomo provides facilities and a support network for developing prototypes of products, services and companies. Accelerator is the newest part of the Tampere New Factory and it aims to support the internationalisation of growth businesses. At Suuntaamo, new products and prototypes are tested and refined. It is an open society compiling ideas from citizens, researchers and service providers (Matikainen, 2012).

The mains characteristics of the Tampere New Factory related to our governmental context are the emphasis on bringing together talent, on minimising bureaucracy, on testing and developing new services in an open society and on focusing on action. The dynamic nature is also reflected in the aesthetics and the language used. The Tampere New Factory emphasises not only bringing people from different backgrounds together to the same physical space, but also creating a new and shared mental model: the sense that we are working towards a common goal — the increased welfare of the world (www.uusitehdas.fi).

3.4 Oulu Business Kitchen

Oulu Business Kitchen is an open innovation environment and business-oriented network providing support, networking possibilities and information to local entrepreneurs, entrepreneurs-to-be and students. The Oulu Business Kitchen is located in the city centre and it provides premises for several start-ups and support for small and medium-sized growth enterprises and organisations. Approximately 25 companies have been steered onto the growth track and about 30 new companies have been started within one year (www.businesskitchen.fi).

The Oulu Business Kitchen was created as a result of co-operation between Oulu University of Applied Sciences, the University of Oulu and the Oulu Innovation Alliance. The Oulu Innovation Alliance is a strategic alliance aiming to foster the long-standing local tradition of cooperation between the universities, research institutes, companies and the public sector. The members of the alliance include — in addition to the two local universities — the city of Oulu, the Technical Research Centre of Finland (VTT) and TECHNOPOLIS.

Doctor Johanna Bluemink, who works in the Oulu Business Kitchen, says that the level of cooperation between the different entities has been very good. The Oulu Business Kitchen has succeeded in creating and strengthening start-up culture in the city of Oulu and also at the University of Oulu. However, the project's organisational structure has been quite bureaucratic, says Doctor Bluemink. Instead of the current inflexible organisational structure, she would prefer a financing system that would be more suitable to flexible and quick actions. She feels that it has been challenging to work in the Oulu Business Kitchen with so many different entities; having only a single administrative unit would probably improve the situation.

3.5 W. L. Gore & Associates

W. L. Gore & Associates was founded by Wilbert (Bill) Lee Gore and his wife, Genevieve Walton Gore, in 1958 in Newark, New Jersey. W. L. Gore & Associates is a uniquely inventive, technology-driven enterprise with more than 10,000 employees that is focused on discovery and product innovation. The company produces innovative products in four main areas: electronics, fabrics, industrial and medical products (www.gore.com). W. L. Gore & Associates has been among the top five workplaces to work for on *Fortune* magazine's list of the '100 Best Companies to Work For'; it has earned a position on that list several times since the rankings started three decades ago. The company has also earned similar honours for its operations in Europe (Fortune, 2010).

Bill Gore first presented the concept of a 'lattice' organisation to the company's employees in 1967. Unlike the traditional management structure, Bill Gore proposed a flat, lattice-like organisational structure in which everyone shares the same title of 'associate'. There are neither chains of command nor predetermined channels of communication. Leaders replace the idea of 'bosses' and associates choose to follow leaders rather than having bosses assigned to them. Associate contribution reviews are based on a peer-level rating system (www.gore.com).

Within the lattice-like organisational structure, associates are encouraged to communicate directly with each other and are accountable to fellow members of their teams. Hands-on product innovation and prototyping are encouraged. Teams typically form around opportunities, new product concepts or businesses. As teams evolve, leaders frequently emerge as they gain more followers. This unusual organisational structure and culture has been shown to be a significant contributor to associate satisfaction and retention (Hamel & Breen, 2007).

'Not only does our company culture contribute to associate satisfaction, it also drives innovation,' says CEO Terri Kelly, who joined the company as an engineer more than 25 years ago. 'We resist narrowly-defined titles, bureaucracy and formal chains of command. Instead, our culture is built on teamwork and direct communication, creating an environment ideal for creative collaboration' (www.gore.com).

Table 1. Summary of the best practices in new open innovation platforms

Open innovation platform	Best practices / key learnings
Multidisciplinary Institute of Digitalization and Energy (MIDE)	Light bureaucracy supports new research openings Strengthen the competitiveness of Finnish industry Co-creation needs active partners and a great deal of effort in order to succeed
Design Factory	Creating a new multidisciplinary culture No bureaucracy, no strict rules, no hierarchies Doing things differently
Tampere New Factory	Bringing talent together and minimising bureaucracy Creating a new mental model: working together to increase the welfare of the world
Oulu Business Kitchen	Fostering cooperation between universities, entrepreneurs and the public sector Strengthening the start-up culture Inflexible project organisation
W. L. Gore & Associates	Very flat organisational structure Reviews based on peer-level ratings The structure drives innovation and creative collaboration

4 Breaking the governmental silos

We have studied five cases: the Design Factory Network, the Multidisciplinary Institute of Digitalization and Energy, the Oulu Business Kitchen, Tampere New Factory and W. L. Gore & Associates. All of these cases emphasise the significance of open innovation, external sources of knowledge and multidisciplinary institute cooperation. Each case that we studied has its own way of arranging its organisation, structures, operations and decision making to promote collaboration. Based on the case studies, we propose some solutions to enhance collaboration within a governmental context.

4.1 Attack bureaucracy

One of the most common points raised in our case studies is the level of bureaucracy in the organisations. At Aalto Design Factory, MIDE, Tampere New factory and W. L. Gore & Associates, a small administrative staff and minimum level of bureaucracy are keys to successful and innovative collaboration. On the other hand, the Oulu Business Kitchen mentioned that complex bureaucracy is a drawback in their organisation, one that leads to inflexibility and a slow capacity to take actions.

Hierarchical, multi-layered and complex structures result in a slow decision-making process and a great deal of repetitive paperwork. Having this kind of structure discourages innovation and creativity. Individuals are not able to generate strategic ideas in a large interdisciplinary group. New ideas fade away or lose their importance when transferred from one layer of an organisation to another. This destroys the ability to take risks.

In order to minimise complex bureaucratic structures, several measures can be taken. Based on the case studies, we recommend the following:

- **Reorganisation:** The first and foremost step is to reorganise in such a way that it minimises the layered and hierarchical structure of an organisation. This can mean blurring the department lines, increasing the independence of departments or dividing the complex layered structure into horizontal working units. The latter, flat, lattice-like structure is also defined in our case study of W.L. Gore Associates.
- **Simplify procedures:** Reducing the size of an organisation, downsizing some agencies and reorganising others can be a way to simplify the procedures.
- **Privatisation:** Certain responsibilities can be outsourced to private enterprises. This can help in carrying out programmes at less cost and increased levels of efficiency.
- **Introduce ICT:** By introducing ICT into the system, paperwork can be avoided. This helps make the decision-making process swift. Another advantage is that it can help an organisation avoid corruption within the system since ICT makes things easy to trace. An important issue is to keep the ICT systems transparent, open and compatible with each other in order to avoid the situation described in the introduction. ICT should be enabling and simple to use, i.e. it should not get in the way or be a reason in and of itself for needing to make changes.

4.2 Break the borders

Government is like a slow-paced career in which the players who have been there the longest tend to have the power and influence over the ones with less experience. This leads to a static organisation in which young dynamic people are unable to express new ideas. This is a big obstacle to innovation.

Our case studies have used the following mechanisms to encourage members of organisations to break the boundaries between disciplines, mentalities and hierarchies:

- **Empower members**, prepare them to believe in themselves so they can excel and take the stage. MIDE and its Bit Bang course, W.L. Gore Associates and the Design Factory Network all empower people from different disciplines and cultures to work together towards a common goal. W.L. Gore Associates has a 'hierarchy-free' structure in which everyone has the same position within the organisation and everyone has a voice since day one. To empower people, it is also crucial to train them to be multidisciplinary and to know other areas outside their own areas of expertise, as MIDE is doing with its Bit Bang course. Likewise, the Design Factory Network encourages companies and students from different countries to work together to create new products.
- **Force interaction / encourage communication**. If people already know each other, it is easier to start understanding and sharing information, which in turn might lead to co-creation. Aalto Design Factory, Oulu Innovation Kitchen and Tampere New Factory all put emphasis on getting people together. For example, at the Aalto Design Factory the kitchen is the only place to get coffee in the building. Since everyone has to eat and (almost) everyone needs to drink coffee, this is a way of forcing everyone in the building to come to the same place to meet and interact with other people.
- **Lead by example**, not by status. The lattice-like structure of W.L. Gore Associates works because it does not force a single person to become a leader. Rather, groups are created and a natural leader emerges from it, usually one that has taken the leadership role by inspiring the rest of the group and gaining their trust. At Aalto Design Factory, although there is a hierarchy, it is not rare to find the factory director emptying the dishwasher or sweeping the entrance hall.
- **Open Doors** to see what is happening. Tampere New Factory works around the clock and the door can be unlocked with a mobile phone. The members of Aalto Design Factory can apply for access cards. But opening doors means more than just having round the clock access; it is also about sharing information about what is happening. In order to showcase its newest developments, MIDE holds an annual research seminar. Aalto Design Factory has weekly breakfast sessions to attract talent to come and share ideas in order for 'planned coincidences' to happen.

4.3 Finance experimentation

Experimentation is an important part of the organisations in our case studies. At Aalto Design Factory and Tampere New Factory, companies can ask students to come up with fresh ideas for their products or solve a problem in a new way. This is relatively low-risk experimentation for the companies and a good learning opportunity for the students.

Government is not the best example of radical experimentation, as politics and financial accountability tend to water down the more radical ideas. A good option would therefore be to 'outsource' the experimentation closer to the end user, be it companies or the public. We describe one possible structure for accomplishing this in the next section, but first we offer some recommendations based on the case studies and an analysis of the Finnish innovation system:

- **Inverted subsidy decision making**: W. L. Gore & Associates has a 'bottom-up' type of decision-making process rather than a 'top-down' process. We suggest the same for government subsidies. When government offers subsidies, the decision can be made about how to use them by the actual subsidy applicants who know their own business. This new decision-making format can be realised by, for example, voting among the subsidy applicants. Whatever format is chosen, this will increase the involvement of subsidy applicants and bring in their expertise.
- **User empowered consulting:** it is important that the customers (e.g. the SMEs) have the power to decide what kind of consulting they want to buy and from whom they want to buy it. For example, instead of arranging most export consulting work through one semi-governmental organisation, Finpro, a better choice would be to, for example, offer a service voucher to the SMEs. The SMEs could freely choose where they want to buy the consulting services that best fit their needs. This would increase the competition in consulting, resulting in tangible quality improvements. It would also increase the number of international consulting services available to the SMEs.
- **Direct tax incentives**: an effective way of supporting certain technologies or business areas is to offer direct tax incentives instead of subsidies. For example, if the government chooses to support solar power companies, a traditional way in Finland is to establish a programme to subsidise solar power projects. This requires a great deal of administrative work in preparing the subsidy processes, and many times the companies do not even want to take the trouble to apply. In many cases, less than half of the money really goes to the anticipated purpose, while the other half is wasted on internal costs between the different government organisations. To minimise the internal costs of the government organisation and give the companies more direct financial benefits, direct tax incentives should be considered. Continuing our example, the government could give all solar power equipment 0% value added tax guaranteed for at least 10 years. In Finland, this would be a direct 24% incentive with minimal implementation costs, and it would send a clear message to companies that the government is committed to creating a market for solar energy. By using direct tax incentives, companies get direct financial support from the government while keeping administrative work at a minimum.

4.4 Three different structures for government collaboration

The best practices mentioned above can be implemented in different ways. We present three concepts, which differ mainly in their structure:

1. Separate government unit
2. Internal network
3. Open network

Separate government unit: think different. Perhaps the easiest solution is to put together a separate think tank or a satellite unit, which independent from any one ministry but ready to solve any problem. This satellite unit could be kind of an intra-government consultancy service, aiming to think differently and keep the whole picture always in mind. Any ministry or even companies and the general public could bring problems for the unit to solve.

In order to avoid adding just more complexity to government bureaucracy, the culture of the unit should be open, dynamic and action-oriented. Here, the lessons from encouraging communication, empowering members and facilitating open doors are essential. Also, the procedures should be simple and the hierarchy kept at a minimum. All of the members of the unit should be equal and ready to take the lead in problem solving. The members could be from ministries, but the unit should also attract top international researchers and experts from industry. Competition should be encouraged, but in a way that does not hinder collaboration; the unit should have a common goal and a positive work culture.

Internal network: agents of change. Building a network across different ministries requires a shared willingness to tackle problems together. This network could consist of selected persons from each ministry, preferably those that are not too busy or too alienated from the day-to-day life of the ministry. These persons could act as 'agents' diffusing information across borders and putting together projects that cross the governmental silos. The network would be a shortcut through the bureaucracy and hierarchy. The agents would also be examples of a different and more dynamic way of working, and by their example, they would also change the culture inside the ministries.

The network would focus on short-term applied research and search for temporary funding from the industry and non-governmental organisations. Although the structure would be that of an internal network, it would also collaborate with companies and the general public. The agents would be empowered to start and organise projects with as little bureaucracy as possible.

Open network: power to the people. The third and most radical concept would be to blur the line between government, industry and the public. This would mean shifting decision making closer to the people. Some examples mentioned above include inverted subsidy decision making or offering service vouchers to SMEs. This decentralised and self-organising structure would be highly dependent on ICT solutions to enable voting, topic preparation and networking.

The role of the government would be to take care of the bigger picture, for example guiding IPR policy in the collaborations between different companies. The government would also be obliged to take part in the projects and the collaborations started by the project to ensure that they would be connected to political decision making and policy processes.

The open network would be a place for radical policy experimentation. Both the policy failures and the successful experiments would be celebrated as learning opportunities. None of the policy experiments would usually be implemented in a broader context as such; rather, both the failures and successes would guide the way for the best solutions. (Soliman, Kivisaari, Warma, Looga, Saarikko, Deng & Buda, 2012.)

4.5 Applying the best practices

In Section 1, we introduced some real-life problems regarding governmental collaboration. In the following subsections, we will apply what we have learnt from open innovation platforms to these problems and then propose concrete solutions.

Swedish educational system. After being on top for many years, the Swedish educational system is now decaying quite rapidly and the only way to stop that decay and improve the system is to react quickly, to avoid vicious bureaucratic circles and to think outside the box. There has been an ongoing debate in Sweden about how to fix the problem; Maciej Zarembas sparked the debate in 2011 through a series of articles published in the Swedish newspaper *Dagens Nyheter*, which later ended up in a booklet (Zarembas, 2011). In the ongoing debate, the Swedish Minister of Education, Jan Björklund, has been pushing for well-educated teachers and suggests increasing salaries significantly for the top 10% of teachers (Örstadius, 2013). Another hot topic in the debate is how higher education can survive the competition from the online courses offered by the best institutions in the United States (Jardenberg, Lidne, Sturmark, 2013; Karlsson et al., 2013). There are also a growing number of online courses at the elementary school level, which are increasingly being utilised in the United States; in fact, all elementary schools in Idaho are adopting them quite rapidly at the moment (Ash 2013). Based on our open network idea, we suggest that the government should not only allow, but also encourage, increased experimentation in a few pilot schools by changing the regulations. These would be, for example, schools with a strong emphasis on Internet-based learning or schools in which there are more requirements regarding the teachers' academic degrees. The degree to which the new regulations for the pilot school were successful can be identified and refined in order to produce better nationwide regulations and policies. Furthermore, we believe that the constantly changing political environment should not jeopardise the children's education. We welcome the opposition leader Stefan Löfven's ambitions for collaborations across political boundaries (Linder, 2013), and we believe that this is a problem that should be tackled by a politically neutral expert group. We believe that our proposed separate governmental unit would be well suited for challenges of this nature.

Finnish healthcare ICT infrastructure. In Section 1.2, we presented some challenges with the healthcare ICT infrastructure in Finland. To improve the infrastructure, collaboration across borders is of utmost importance. Because the high-tech sector changes too quickly for the government to successfully manage it, we suggest new policies and increased financial flexibility so that expert groups like ICT-2015 can take action without having to go through the slow political processes. Whenever there are new technologies available, we also suggest that experimenting more with the ICT infrastructure can help pilot projects in smaller cities get a head start. An excellent example that governments can learn from is the successful Estonian primary healthcare system. Numerous changes have recently been made, including changes in the organisational structure, policies and regulations, financing and resource allocation. A strong level of collaboration between ministers, deputies and a technical team resulted in a link between policies and the operational level (Atun, 2006). Furthermore, the eHealth strategy was defined and has evolved over the years with the introduction of ICT (Doupi, 2010). Since the foundation is already in place, only fine-tuning is now required without changing the basic structure (Doupi, 2010). Returning to the Finnish healthcare system, the ICT infrastructure that we observed needs increased levels of collaboration between politicians, IT specialists and doctors; an ICT solution needs to be successfully implemented in the hospitals that functions well in the long run. After the ICT infrastructure is in place, it still needs a strong level of collaboration between doctors and IT specialists to keep it updated and so that it can meet the changing requirements.

Finnish government intervention in business. In Section 1.3, we briefly discussed the way the government intervenes in business operations in Finland. Based on our framework, we suggest that the policies for offering financial support for innovation in Finland should be changed significantly. Government involvement should be better organised to reduce bureaucracy; in particular, Team Finland should be streamlined and restructured more according to companies' needs. The current way of evaluating innovative business ideas is done by different funding agencies acting in isolation. In accordance with our open network suggestion, we propose that the process should be more open in order to select the best ideas to fund. Furthermore, it is likely that a voting system similar to the peer-level voting system at W. L. Gore & Associates would be beneficial for the process since it would make it easier for the inventors to see how competitive their own ideas are compared to those of others.

5 Conclusions and future directions

One of the main sources of institutional innovation is collaboration and co-creation. Our study covered the issues hindering government from successfully collaborating with both organisations and among its internal ministries, and how those issues can be tackled. This was addressed by discussing the key issues that can help the government in achieving collaboration and hence, strengthen the innovative process. There is already a huge amount of collaboration between educational institutions and companies, but when it comes to government a silo effect has been noticed among different departments and ministries.

Government acts as a facilitator to the business world by offering policies and regulations. These policies and regulations should encourage collaboration between companies to share and develop R&D, to improve product development and to access new markets. Government itself should act like an open innovator in which some of the sources of innovation can be identified as collaboration, experimentation and networking at the national and international level. Collaboration excites innovation by sharing risk where uncertainty is involved in policy making. Linkages and networking between different sources in a globalised world also empowers innovation through interaction and knowledge sharing. Experimentation makes it possible to create and test many new ideas, insights and concepts. It requires agility with respect to having the ability to quickly adapt to changes and be flexible when needed.

We identified the best practices from five different open innovation platforms and offered suggestions about how governments can learn from and adopt their best practices. Some of the main challenges for governments today have to do with reducing bureaucracy, adopting a multidisciplinary co-creation approach, bringing talent together, strengthening start-up culture in the public sector and encouraging cooperation between universities, entrepreneurs and the public sector as well as being able to present flexible financial solutions without losing liability. Based on the challenges, we have identified three main objectives. First, **attack bureaucracy** by simplifying the procedures, by privatising certain sectors, by introducing ICT and by reorganising the hierarchical structures; second, **cross the borders** by empowering members, reinforcing communication and having an open door policy as well as by leading by example; third, allow for **financial experimentation** by providing access to resources via the use of fast mechanisms, such as inverted subsidies, user-empowered consulting subsidies, tax incentives and pre-commercial procurement. To succeed in tackling the objectives, we have furthermore suggested three concrete actions: **create a separate government unit,** which should work on a project-by-project basis with projects from all different ministries, **improve the internal network** inside the government by having select employees that help spread information and **create an open network** between the government, companies and the public that allows for policy experimentation.

We provide a few concrete suggestions on how to break governmental silos. There is room for many more innovative and radical ideas and we encourage further research in the same direction.

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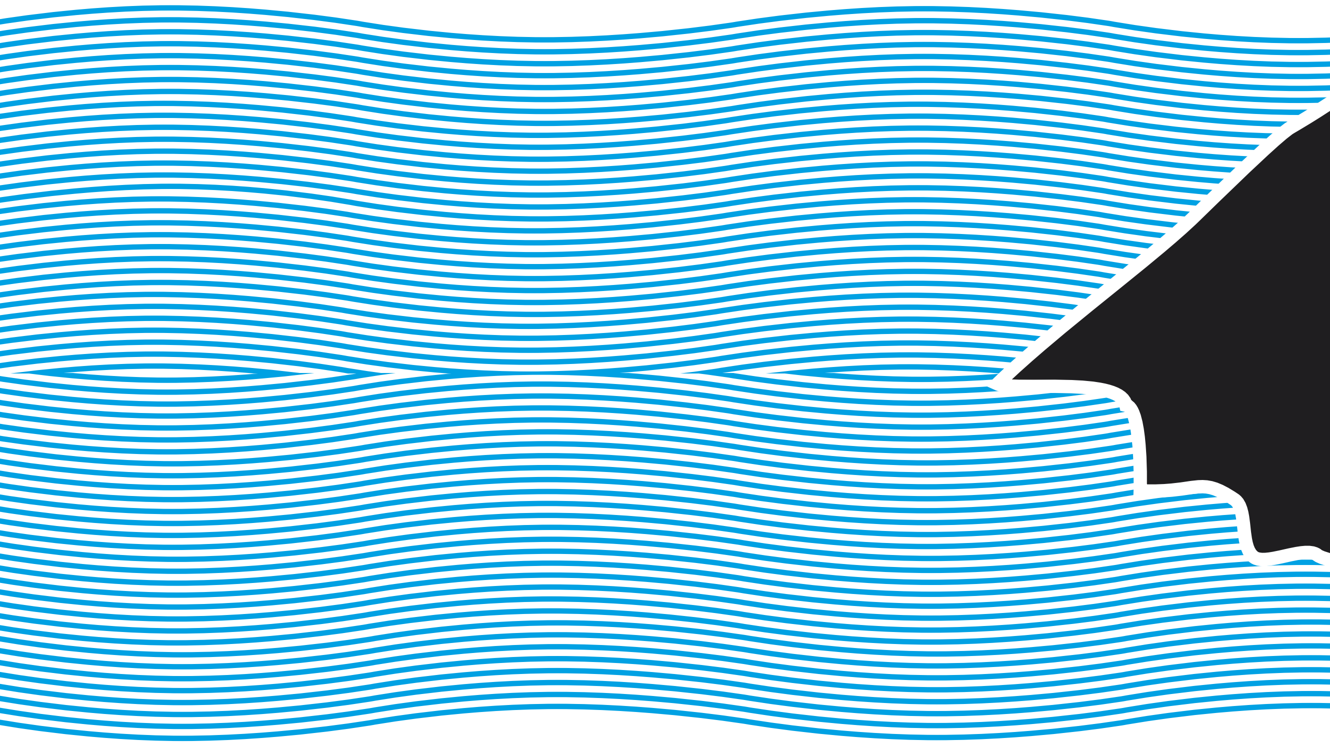

2

Industries in transition

2.1 Additive manufacturing – printing the future

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Abstract

Additive manufacturing (AM) has attracted lots of publicity in recent years and is expected to become a disruptive innovation. The attractiveness of additive manufacturing is easy to see, considering its theoretical potential and the possibility to bring manufacturing industries back to high-income countries. However, considering the

current technological, economical and legal questions, the expectations aimed towards additive manufacturing may be overly optimistic. Through this article, we take a critical look at the potential of additive manufacturing and the possible effects its widespread adoption could have on the economic, societal and global levels. A special concern is the policymaker viewpoint: what can be done to capitalize on the possible rise of additive manufacturing? Does it have the potential to bring manufacturing industries back to the West?

Keywords: additive manufacturing, business models, IPR, future scenarios

Preface

What to do if a part in your dishwasher breaks down and you are unable to find a replacement? This was the situation a Hackerlab in Finland faced when the lock mechanism holding the dishwasher closed broke. They couldn't find a replacement part so they decided to model it with 3D design software and print it using their 3D printer. It took them about two hours to produce a part that is actually superior to the original (Hacklab, 2012). They uploaded the part to Thingiverse, a popular printing design site, which already has around 3,000 design files just for replacement parts freely available.

A man fractured his pelvis in a car accident. He had to get surgery to reposition and fixate the fractured pelvis in its natural position to ensure that it grew back to its normal state. To help plan the surgical procedure, a 3D model of the fractured pelvis was printed using additive manufacturing technology. The model helped the doctors to visualize all possible fractures and was also used as a means of communication between the surgical team members. As a result, the surgical procedure turned out to be fairly simple and relatively short. The surgeons were pleasantly surprised by the smooth flow of the procedure as well as the little amount of fatigue after the procedure. They said that the model helped them to re-align and restore the fracture with a simple "jerk" of the patient's leg, instead of a difficult and slow repositioning procedure (Honiball, 2010).

The Texan law student Cody Wilson initiated a collaborative effort to print handguns using the AM technique. The mission of DefenseDist[1] is to create the 'Wiki Weapon' – freely available designs to print your weapon at home. The American producer of 3D printers, Stratasys, first delivered to them their latest device, but after discovering Wilson's project, they refused the offer and demanded their product back (Wired, 2012a). Surprised by this action, Wilson went to the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) to claim his rights, because the legal regulatory frame is still undefined. Because of the uniqueness and ethical problems attributed

1 **http://defensedistributed.com/**

to the WikiWeapon project, the news spread quickly and the manufacturer had a chance to react. However, it raises a more fundamental problem. How are we going to legally protect ourselves as well as the device-producer from abuse of copyrights, designs and even illegal production?

1 Introduction

As a new manufacturing method, additive manufacturing (AM) is providing solutions to three challenges of manufacturing: How to bring manufacturing closer to the consumer and away from overseas? By a disruptive technology, we mean a technology that creates a new market and value network, disrupting an earlier market and displacing earlier technologies (Christensen, 1997). How to minimize the production costs of customized low volume objects? How to manufacture complex designs feasibly? It could potentially change design and manufacturing with profound implications on geopolitics, commerce, socio-demographic conditions and the environment. In the manufacturing and logistical sectors, a growing interest exists in additive manufacturing. Practical applications of this technology are already penetrating the market in industries ranging from aerospace to medical sciences. The business community is investigating further opportunities to capitalize on the potential of additive manufacturing. With an increased number of applications, AM has created a buzz in the general media (see, for example, The Economist, 2012; Forbes, 2012; Wired, 2012b). They expect that wide-spread adoption of additive manufacturing could spur a game-changing, disruptive shift for the manufacturing and logistical industries.

In this chapter we explore why additive manufacturing could be a disruptive technology in manufacturing, what factors could limit this disruption, and what the implications are for national policies and business. First, we briefly describe what additive manufacturing is and provide the main reasons why it is thought to be disruptive. We then describe the current situation in technology, patents, legal rights and business models, followed by the main limitations of additive manufacturing. At the end, we explore the future of additive manufacturing with four different scenarios and conclude with the implications for policy and business. Before proceeding further, it would be important to get to know what Additive Manufacturing is.

1.1 What is additive manufacturing?

Additive manufacturing, also known as three-dimensional (3D) printing, is a manufacturing technique using 3D digital models to produce the object in successive layers, each one adhering to the previous layer. As portrayed in Figure 1, the additive manufacturing process begins with a 3D model of the object, usually created by CAD software or a scan of an existing artefact. Specialized software creates a cross-sectional layer model of the object, which is then sent to an AM machine. The object is created from the bottom-up, adding one layer at a time. There are different techniques to adding these layers.

Fig. 1. The generalized AM process (Campbell et al, 2011)

2 Why additive manufacturing could be disruptive

If additive manufacturing becomes a disruptive innovation, the fundamental roles of machines, labour, materials, and distribution networks change. Additive manufacturing could lead to a "fabrication cloud" manufacturing approach (Scot et al., 2012). A fabrication cloud uses additive manufacturing and no longer the conventional machine tools. The role of designers is emphasized and manufacturing is done on demand and on-site (compare Table 1) from a production line and manufacturing web. Following the concept of the fabrication cloud, additive manufacturing is the enabling technology for a new manufacturing system that shifts the value-adding activities to different groups in the production chain. Therefore, it can be considered a disruptive technology.

Table 1. Three manufacturing approaches (Anthony et al., 2011).

	Production line	Manufacturing web	Fabrication cloud
Machinery	Manually-operated machine tools	Computerized numerical control machine tools	Rapid prototyping/ Additive manufacturing
Labour's added value	Skilled machine operators	Programmers	Designers
Materials	Metal, wood, rubber	Metal, wood, plastic, foam	Plastic, low melting-point metals, powdered materials, cells, blinders
Distribution	Wholesalers	Retailers, direct to consumers	Fabrication on demand, fabricate on-site

To support the claim that additive manufacturing can be considered a disruptive technology, the impact of the fabrication cloud from an engineering, economic, design and social perspective will be presented in greater detail. In brief, the engineering perspective focuses on control of the manufacturing process from a process-engineering standpoint, whereas marginal cost is used to understand the economic implications of the fabrication cloud. The design perspective focuses on the digitalization and the rising role of designers as opposed to programmers. From a social perspective, the localization of manufacturing is the key changing element. Next we consider these factors in depth.

Control of the manufacturing process. Conventional manufacturing processes mainly use subtractive techniques in which objects are created through the subtraction of material from a work piece. This fundamentally limits the quality of manufacturing in the case of objects with complex geometric shapes and composite materials from a process-engineering[2] perspective. This also limits exploiting the potential of geometrical freedom offered by digital design using CAD software. Additive manufacturing creates objects from the bottom-up by adding material one cross-sectional layer at a time and can thus produce objects of complex geometric shapes with great precision. From a process-engineering standpoint, this adds more freedom and better control in shaping the object.

In conventional manufacturing, parts made of different materials are assembled together into a single object. In the case of objects with geometrical complexities, micro-scale precisions and desired structural behaviour may be difficult to be achieved this way. In additive manufacturing, it is possible to add different materials layer by layer and thus produce complex and precise components impossible or unfeasible to produce with other methods.

2 Process engineering focuses on the design, operation, control, and optimization of chemical, physical, and biological processes through the aid of systematic computer-based methods.

Freedom in designing complex objects and the ability to embed composite materials offer enormous opportunities in applications like medical prosthesis, where extreme customization is essential. For example, hearing aids need to be comfortably fit in the aural canal. The comfort depends on mechanical properties of hearing aids, such as elasticity and shape. To summarize, theoretically speaking, it is possible to make any object with complex geometrical shapes using composite materials with precision.

Near-zero marginal cost[3]. In the era of mass production, economies of scale have driven the industrial revolution and the manufacturing sector. Firms have competed on price relative to the added value of different product features. To achieve a low price, it is usually necessary to have large volumes of the same product. Because consumers' preferences are changing more rapidly, the competition has shifted to the design space. Existing manufacturing methods hinder firms' competitiveness to differentiate by design due to high marginal cost with changes in design of the product. In the case of AM, a marginal cost of production with different designs is at least theoretically near zero, in stark contrast to conventional manufacturing, as objects with different designs can be produced without intermediate tooling. This eliminates costs and delays associated with changes in design. This is especially useful in industries like aerospace and defence, where it is impossible to achieve economies of scale due to low-volume demand (Ruffo et al., 2006). Brett Lyons (2012) predicts that aerospace and defence industries will provide essential critical mass for the diffusion of additive manufacturing technologies as an innovation in the manufacturing sector. In recent years, new business models are also emerging due to zero marginal cost propositions, such as the print-on-demand model in the book/publishing industry, or online flea markets such as eBay.

Digitalization of manufacturing. CAD tools have played a significant role in product design in the last four decades. However, their role is not integrated into the manufacturing process as a whole. The designs play a passive role in manufacturing. Additive manufacturing integrates the CAD process into manufacturing. This integration opens abundant opportunities in the manufacturing sector in terms of design, fast response to changes in customer preferences, and extreme customization. Most importantly, considering the number of available CAD experts and the digital age we all live in, additive manufacturing unravels new frontiers with the digitalization of manufacturing. The impacts of additive manufacturing and digitalization can be compared to the two historical industrial revolutions brought forward by the introduction of mechanization and the assembly line. Mechanization replaced manual workers by purpose-built machinery and assembly-line production allowed

3 In economics and finance, a marginal cost is the change in total costs that arises when the quantity produced changes by one unit.

for unprecedented volumes of production. They dramatically changed conceptions of what is possible or economically feasible to manufacture. Simultaneously, both changed the role of labourers in manufacturing and were the driving forces behind societal upheavals. Additive manufacturing is not constrained by many of the physical and economic limitations of earlier manufacturing methods due to the digitalization of the manufacturing process. This digitalization could cause unprecedented consequences on existing value chains[4] of products and business models.

Revival of local manufacturing. Manufacturing has evolved from small workshops in the early 20th century to complex networks of global supply chains. During this development, workshops were gradually replaced by production lines, which required less manual supervision and offered economies of scale. A global manufacturing web was gradually established with the growing use of computers and an increase in global trade. The roles of machines, labour, materials, and distribution have changed in this process. The manufacturing sector in developed countries has lost competitive advantages to countries with low production costs during this transition. As a result, employment opportunities significantly decreased in the manufacturing sector in the West and created an import-export trade imbalance in national economies. In the last few years, there has been a growing concern in the minds of policymakers and politicians to revive local manufacturing as a competitive advantage in the West. With the ability to efficiently manufacture customized goods using digital design with lower inventory costs, additive manufacturing offers a potential alternative to a global manufacturing web and can revive local manufacturing. In the future, widespread use of additive manufacturing could restore the trade balance in many economies.

As our analysis shows, mainly four factors will provide necessary leverage to additive manufacturing over conventional manufacturing approaches, and it will emerge as a new manufacturing trend in the future. Possible implications of these four factors are tabulated in Table 2. Yet, we have to understand how this evolution in the manufacturing sector is most likely to occur. Therefore, we look at the status quo of additive manufacturing from a technological, an IPR and a business viewpoint in the next section.

4 Value is created when producing, distributing, and servicing a product in successive stages. This is called the value chain. Identifying the value chain allows a firm to refine its operations in an effort to improve quality, add efficiencies, and increase profits.

Table 2. Possible implications of additive manufacturing

Offering of AM	Implications
Precise process control	Utmost design freedom Complexity is free Waste reduction
Zero marginal cost	Economic feasibility of low-volume production Extreme customization Transformation of global supply chain
Digitalization	New business models Open fabrication Disruption in product value chain Consequent effects on IPR
Localization	Production on demand Extreme customization Revival of manufacturing in the West Restoration of trade balance New industries Fundamental shift in global wealth creation and geopolitics

3 The current state and trends of additive manufacturing

3.1 Technology of additive manufacturing

Additive manufacturing had its first application in rapid prototyping, where it was able to drastically reduce the time and cost needed to make a product thereby reducing the product development cycle (Figure 2). At present, not just the prototypes, but ready-to-use end products can be made using additive manufacturing, leading to the era of rapid manufacturing.

The major technologies that have helped to start the additive manufacturing revolution are computer-aided design (CAD), computer-aided manufacturing (CAM) and computer numerical control (CNC). CAD software like AutoCAD, Autodesk and Google SketchUP help to create the digital models of objects to be manufactured. CAM refers to various techniques, at the heart of which lies CNC, which are used to control different aspects of automated manufacturing.

The first stage in the process of additive manufacturing is the process of creating a digital representation of the object being manufactured. It can be created with the help of specialized CAD software by a skilled designer. Another method of creating the digital representation of an object is to scan the existing ones using 3D scanners. Due to the development in 3D imaging technologies, a wide variety of 3D scanners with various degrees of precision are already available. On the other hand, there are software tools that enable devices like Microsoft's Kinect controller to function as a 3D scanner and be used to scan objects for 3D printers.

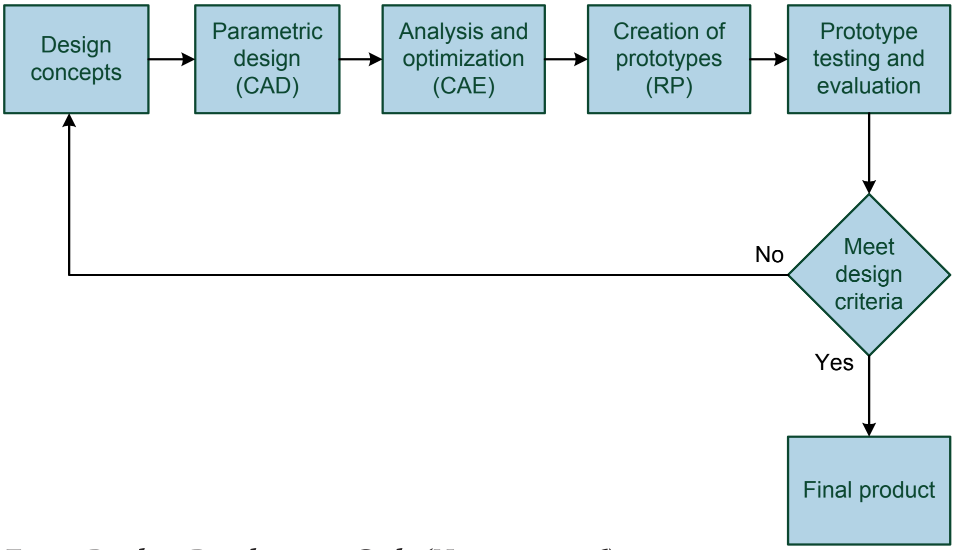

Fig. 2. Product Development Cycle (Noorani, 2006).

This 3D representation of the object is then converted to Standard Tessellation Language (STL) format where the continuous geometry of the object is approximated by triangular pieces with smaller triangles producing a closer approximation. This is a crucial step in additive manufacturing, and the vertical resolution of the 3D printer should be taken into account while creating such representations. There are also newer formats like SLC, SLI, CLI, HPGL, which overcome the limitations of the STL format (e.g. they also provide the colour information).

Additive manufacturing technology can be divided into various categories. The main categorizations are based on the state of the raw materials they use (Figure 3) or the process of manufacturing (Table 3).

Stereolithography is the oldest AM technique in which a photosensitive polymer is solidified, layer by layer (as specified in the STL file), using ultraviolet laser. After a layer is completely traced, the table containing the layer is lowered a distance equal to the thickness of one layer into the vat containing the resin. This process continues until the whole object is built.

3D Printing (3DP) is a powder-based technique in which a liquid binder is sprayed onto a thin layer of the material. The binder glues together the powder to form a solid object wherever specified by the STL file. After a layer is complete, the next layer of powder is deposited and the process is continued. Prometal is similar to 3DP but is mainly used to make dies and injection tools and the material is stainless steel powder. Fully functional parts can be made after a sintering, infiltration or other finishing process. **Selective laser sintering (SLS)** is again a powder-based technique in which a metal powder on a manufacturing bed is sintered by carbon dioxide laser at a location specified by the design. After a layer is formed, the bed is lowered and a new layer of powder is spread on top, which is then sintered. **Electron beam melt-**

ing (EBM) is **similar** to SLS, but a beam of electrons rather than a laser is used for melting the metal powder.

Table 3. Additive manufacturing processes (Scott et al., 2012).

Process	Example companies	Materials	Market
Vat Photopolymerization	3D Systems (US) Envisiontec (Germany)	Photopolymers	Prototyping
Material jetting	Object (Israel) 3D Systems (US) Solidscape (US)	Polymers, waxes	Prototyping, casting patterns
Binder jetting	3D Systems (US) ExOne (US) Voxeljet (Germany)	Polymers, metals, foundry sand	Prototyping, casting moulds, direct part
Material extrusion	Starsys (US) Bits from Bytes RepRap	Polymers	Prototyping
Power bed fusion	EOS (Germany) 3D Systems (US) Arcam (Sweden)	Polymers, metals	Prototyping, direct part
Sheet lamination	Fabrisonic (US) Mcor (Ireland)	Paper, metals	Prototyping, direct part
Directed energy decomposition	Optomec (US) POM (US)	Metals	Repair, direct part

In **Fused decomposition modelling (FDM)**, the material is in the form of a filament that is melted and deposited to make the object which is then cooled so that the plastic can set. It is a cost-effective technique and thus suitable for hobbyists. Good quality can be achieved using a professional machine. On the downside, FDM requires support materials, is slow, and may not make watertight objects due to poor layer-to-layer adhesion. In **Laser engineered net shaping (LENS)**, parts are built by depositing small quantities of powdered materials at specific locations, which are then molten by applying a high-powered laser. A wide variety of materials, which include metals and different kinds of proprietary polymers, may be used in both processes.

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Laminated object manufacturing (LOM) uses a combination of the additive and subtractive manufacturing techniques, in which the sheets of materials are bonded together by using heat and pressure. The excess material is then cut out by a powerful carbon dioxide laser and removed. **Polyjet** uses inkjet technology in which the inkjet head moves horizontally depositing photopolymer, which is then cured by ultraviolet light after each layer is finished. Very thin layers can be produced using this technique and the end products can be of different colours.

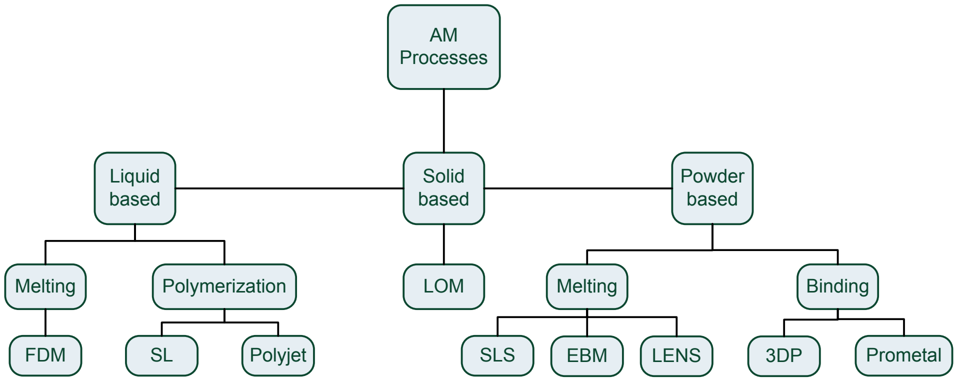

Fig. 3. Additive manufacturing techniques classified by the material used (Wong and Hernandez, 2012).

From the above description, it is clear that all the processes have associated strengths and weaknesses. Most of the techniques use only one type of material, while some (Polyjet and LENS) can use different kinds of materials as well. Similarly, the quality of the manufactured product is also different in these different techniques. While Polyjet can produce a very high resolution object quickly, FDM (which is mainly used by hobbyists) has poor resolution and the manufactured objects may need post-processing. In the next section, we will discuss IPR and business models, and in Section 4 the various limitations of current additive manufacturing techniques.

3.2 Intellectual property rights in digitalization of manufacturing

Additive manufacturing technology is novel and seems to develop rapidly and change a lot in the world of manufacturing. Intellectual property rights (IPR) are affecting AM technology itself on the one hand and digital models and the final objects created by the new technology on the other. In this section, we discuss some basic views of IPR that are most relevant in the field of AM.

Additive manufacturing is based on digital models that are easy to copy and replicate with just a few mouse clicks. The global nature inherent in digital contents, together with manufacturing spreading around the world into smaller units, makes it very difficult for design right holders to control their rights. It is also difficult for a potential right user to find a way to use the design legally. Digital technology is strongly affecting designs: AM will have a huge impact on the use of designs. Professor Ian Hargreaves has written a review in 2011 “Digital Opportunity - A Review of Intellectual Property and Growth” (Hargreaves, 2011) in which he is answering

British Prime Minister David Cameron's question related to the intellectual property framework: "Could it be true that laws designed more than three centuries ago with the express purpose of creating economic incentives for innovation by protecting creators' rights are today obstructing innovation and economic growth?" There is a strong message in the Review: IP laws must adapt.

Technological development has also put pressure on patents; there are some technology areas that are suffering from patent thickets. Patent offices are overloaded by the high patenting activity and it is difficult to get new products on the market in patent thicket fields. The situation impedes innovation rather than encourages it, which contradicts the original philosophy of patenting. Professor Hargreaves suggests international co-operation to get rid of the backlogs and thickets by cutting down low-value patents. Patent thickets are not necessarily a concern for AM; the patent term of the first patents protecting the 3D printing devices are ending. This might mean that the price of the devices come down because the technology is available for anyone without licensing fees. On the other hand, the new technological features of the printing devices may be protected by patents and those are still valid. Patents may also cover products manufactured by 3D printers. Non-commercial private use is not infringing patents in most legislation, but as soon as the manufacturing is commercial, patent infringements are possible.

Copyrights were originally important particularly for authors and their publishers, but now they seem to be barriers for emerging businesses because of the digital revolution in society. The Review by Professor Hargreaves (Hargreaves, 2011) is proposing a new Digital Copyright Exchange, bringing together the rights owners and those willing to license, and thus responding to the need of speedy licensing. IP law should enable rather than inhibit the technology's potential to contribute to growth, says Professor Hargreaves, but at the moment, knowledge of the relationship between design rights and innovation and growth is inadequate. The interaction between copyright law and design law also needs to be reconsidered.

Several sources point out current trends in the world of IP. Digitalization and globalization are shaping the world at a faster pace, and there is a need for IP to adapt to the modern world. AM represents the changes extremely well; it is digital and global by nature. Non-commercial private use has conventionally been free in most legislations and thus does not infringe on IP rights, but as soon as the use is commercial, there is the possibility of infringement. Because AM is spreading the manufacturing into smaller units all over the world, it is more difficult to control possible infringement and to litigate. Protection can work only if there is some barrier to entry to using the protected material and if the infringement can be identified, says Neil Gershenfeld in his article "How to Make Almost Anything" (Gershenfeld, 2012). Instead of restrictions, new forms of access to designs are needed – for example, something like the Digital Copyright Exchange proposed in the Digital Opportunity Review. Bringing rights holders and buyers smoothly together, the system would respond both to the need for protection and for speedy legal licensing. That kind of forum would also serve small rights holders who do not have resources for marketing and controlling their rights as big rights holders do. The trends in innovation models and practices are the increasingly international nature of the innovation process, the more central role of IP in business strategies, and the rise of IP-based knowledge markets. On the other hand, IP is pushing the changes and at the same time it is targeted by the changes.

3.3 Opportunities for new business models

As manufacturing evolves from mass-production to mass-customization, current business models are being challenged. The main impact is that small volumes become economically viable, hence the long tail business models become interesting in the manufacturing area. These business models offer larger quantities of niche products of infrequent demand (Anderson, 2006). The most prominent examples – Netflix, eBay, YouTube, and Facebook – share that the aggregate sale of a large number of niche items can be as lucrative as any traditional business model focusing on a small number of bestsellers (Osterwalder & Pigneur, 2010). Due to high inventory and adjustment costs of the production line in traditional manufacturing, long tail business models have not been lucrative up to this point of technological development. Assuming economically rational decision-making and business practices, it is of interest for policymakers to understand the most affected elements of a business model in order to capture significant parts of the created value for the local economy. For this purpose we apply the visualization of Osterwalder's Business Model Canvas – a tool that captures all major elements of a business model and presents it on one canvas.

In the centre of the Business Model Canvas is the value proposition. This refers to the need that the product or service satisfies or the problem it solves. Put simply, it is the value or argument provided to the customer. On the right-hand side are all the front-end activities, meaning the elements that connect the product or service with the customer: customer segment, channels, and customer relationship. Combined with the value proposition, they produce revenue streams for the company, presented by the box in the bottom-right corner. On the left-hand side, the back-end activities complement the entire operational spectrum of the business: key activities, key partners and key resources. Those elements combined are the input needed to produce the value proposition and hence is connected through the cost structure as presented on the bottom-left corner. The Business Model Canvas is a useful tool to visualize changes in the competitive landscape, as general trends can be drawn through the connection of the nine boxes.

As an example, let us look how Shapeways – the Amazon of 3D printing – has a different business model from traditional manufacturers (Figure 4). Looking at the input side, key partners are not generally affected, but rather differ on a case basis, depending on the kind of product manufactured. However, the key activities and key resources are influenced significantly. The key activities move towards developing the Internet platform and excellence in logistical distribution, as the quality of the manufactured goods will converge. As seen in other industries that became digital (for instance, book publishing), the platform becomes a key resource. The main value created is the self-printing service and bringing together supply and demand. On the front-end side, it is most interesting that the customer segment changes towards more non-professionals and independent developers or designers. Overall, this example shows that a liberalization or even democratization of the manufacturing sector begins. The new forces determining the success of a manufactured design (a 3D design) are the direct final customer and the social media success factors affecting the choice.

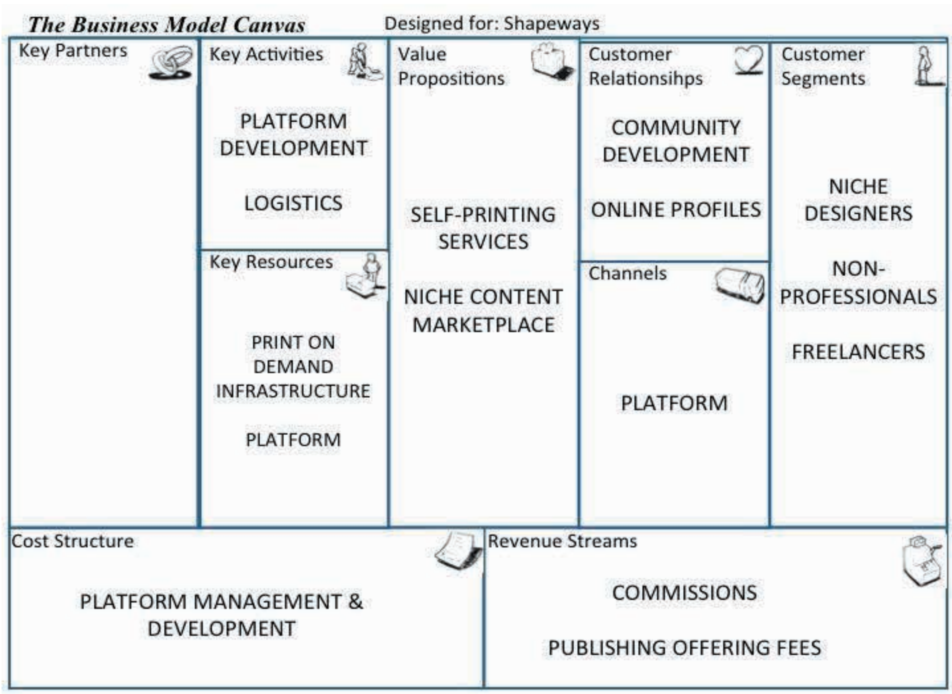

Fig. 4. Business model canvas for Shapeways

4 *Current limitations of additive manufacturing*

While their promises are impressive, it could be said that additive manufacturing techniques are not currently ready for widespread adoption for mass production due to both engineering-related and economic issues.

The most fundamental of these issues are related to materials: only a narrow selection of materials can be used in additive manufacturing, and practically all techniques have their own limited rosters of materials. Even in cases where these materials are readily available in bulk (such as ABS plastic, nylon, and metals), they need to be delivered as special powders, resins and filaments that can be processed in AM, with prices often dramatically above bulk prices. For instance, material costs for injection-moulded ABS can typically be 1.80 USD/kg, whereas ABS that has been prepared for material extrusion can cost $180/kg (prices based from Hopkinson (2006)). From the viewpoint of material properties, currently available plastics like ABS and nylon are durable enough for prototyping designs and shapes but not for functional prototypes or tools that have to endure mechanical stress. This problem is not shared by metal-based AM methods, in which the structural properties of the final product are comparable to traditionally manufactured products, but the equipment and material costs for metals are often prohibitively high for small-scale production and prototyping, with unit costs for equipment on the scale of $100,000 and materials costs in the upper $10s/kg (for comparison, screw-machine steel for traditional machining costs around $1/kg).

If and when AM gets more widely adopted, materials and equipment costs can be reasonably expected to go down due to economies of scale. From the viewpoint of sustainability, it should also be noted that the majority of the materials available for AM are petroleum-based plastics, which because of increasing oil prices, could prevent their future price decreases and foreseeably make them even more expensive than they are now. Some sustainable materials options such as bio-plastics and recycled materials can already be used in AM, most notably recycled ABS and existing bioplastics such as PLA and starch-based polymers, as exemplified by MakerBot (MakerBot, 2012).

Due to the layer-by-layer structure of objects made with AM, surfaces that are vertical inside the AM machine often have jagged or stepped finishes that need to be polished or otherwise finished after production. In the case of sintering and powder-bed techniques, the basic principle means that even horizontal and slanted surfaces need to be finished by hand if a non-grainy finish is desired. Especially relevant surface finishes that are hard if not impossible to achieve straight out of manufacturing are transparent or polished-looking surfaces. In addition to surface roughness, objects often endure mechanical stresses during manufacturing that require "sacrificial" support structures which need to be removed afterwards. The supports complicate object design, are often made using another material than the manufactured object itself and need separate equipment or manual work to be removed. Currently, there is a drive to alleviate this problem by using easily soluble, automatically removable plastics as supports (exemplified by recent releases from MakerBot (2011) and Stratasys (2011)). The need for surface finishes is more problematic: first, it is related to the fundamental working principle of AM, and second, it makes it more labour intensive, since the finishing needs to be done or supervised by hand. Typical manual finishing times for AM objects are in the range of a few minutes (Hopkinson et al., 2006). While soluble supports and higher vertical resolution can decrease the need for manual finishing, it is likely fundamentally impossible to eliminate altogether. The need for manual finishing also somewhat undermines the selling points of AM, since it is not additive and brings labour-intensive steps into methods that are supposed to make manufacturing less labour-intensive. Since AM is hoped to increase the competitiveness of high labor cost markets, the need for non-additive manual finishing could, despite sounding trivial, be a problem for its widespread adoption.

While one of the advantages of AM is that production can start virtually immediately when a design is finished, the manufacturing itself is very time-consuming. Typical production times for simple plastic objects are in the order of hours. This is in contrast with traditional moulding or machining, where the crafting of moulds and equipment can be very time-consuming, but the production time per unit is short. In AM, the production time is directly related to the number of layers and thus the size of an object, which together with the time consumption, high material costs and the physical limitations posed by equipment size, currently keeps AM confined to the making of relatively small objects. Currently, production speed is being rapidly increased by improved mechanical and software design, but in several AM methods it is ultimately limited by the physical processes involved, such as the time required for an extruded plastic to harden or a sintered metal to melt. These physical limitations will likely keep many AM techniques always slower than methods that process the same materials non-additively.

To construct parts and an object additively, digital schematics are needed. While such schematics can be produced semi-automatically using 3D scanning techniques, their creation is still very much an engineering task and requires expertise especially in optimizing the structural integrity of the printed structure both during printing and in its final use. There exists academic research on methods for automated optimization of structures (e.g. a recent work by Adobe Systems and Purdue University) (Stava et al., 2012), and the possibility for structural modelling is built in to many CAD tools, but their use still requires specialist knowledge. At the moment of writing, there exists no single standard file format for schematics that would be supported by all vendors and AM methods. The STL format, developed by 3D Systems for stereolithography in the 1980s, is popular, as are the open OBJ format and the 3DS format used by Autodesk, which are widely supported. In the foreseeable future, the fact that the production or finishing of schematics still requires expert knowledge and that software mainly aimed at professional users is needed is likely to keep 3D printing away from non-experts. Since the need for digital schematics can be expected to increase, causing demand for easier, more automatic creation, it can be expected that software aimed at casual users, equipped with algorithms that suggest structural solutions and fixes, could become available at some point.

On the purely economic side, the somewhat opaque costs of operating an AM production line are a central issue. While AM has low starting and reconfiguration costs, consisting mainly of the initial equipment and schematic purchases, the actual operating costs of an AM production line are more opaque and can quickly make it economically unfeasible, even when not taking into account possible technical limitations. Examples of what could be called hidden costs in operating an AM line are supporting equipment such as heaters for raw materials, finishing equipment, and compressed air. As noted above, several AM methods also need support materials that support the structure during manufacturing and are removed afterwards, which further increase and complicate the material costs and have to be accounted for separately for each design. An interesting comparison, pointed out by Hopkinson, Hague & Dickens (2006), is that from the economic viewpoint, what is called rapid prototyping has a clear advantage over traditional manufacturing methods, since the production of single parts or objects can be remarkably faster with additive than with traditional manufacturing. However, in the case of larger-scale manufacturing, the economies of scale involved in traditional manufacturing often make unit costs fall relatively quickly below the constant unit cost of AM, making it economically unfeasible to use additive methods beyond the prototyping phase, or the production of moulds, jigs and other tools for traditional manufacturing.

The complicated cost structures, and the fact that few single-package solutions with clear operating and supporting equipment and materials costs (Stratasys' Mojo (2012) being the most notable example at the moment of writing) are available, reflect the immaturity of the AM market and could be expected to be solved as the field matures. From the viewpoint of a hypothetical small or medium-sized company wishing to adopt AM, they remain, however, obstructions that need to be solved before wider adoption is realistic.

Table 4. Limitations of additive manufacturing

Limitation	Problems
Materials	Narrow selection Cost Strength
Layer-by-layer structure	Rough edges and grainy surfaces Need for support structures Need for manual finishing
Time consumption	Slow process Speed depends on object size and precision
Software	Hard to use Different formats
Economics	Hidden costs Constant unit cost

5 *How could additive manufacturing shape the future?*

The general consensus in many articles and in expert views seems to be that additive manufacturing will disrupt existing value chains and business models and will indeed change our whole society. However, opinions vary on what these disruptions will be. In this section we explore what these disruptions could be by presenting four different future scenarios. We made the scenarios based on two variables: the "centralization" vs. "decentralization" of manufacturing and the consumption vs. recycling of raw materials (Figure 5). We chose these variables because the use of raw materials and manufacturing are central elements of product value chains. Because of this, these scenarios allow us to look at different disruptions in the value chains. We now describe the scenarios in more detail and illustrate their implications for policy and regulation, and how they change existing business models and value chains. (See Table 5 for a quick summary of these scenarios.)

5.1 Scenario 1 – Instant hedonism

"When you see it, you can have it" is the promise that additive manufacturing has fulfilled. Because of the cheap price and ease of use, most households have their own 3D printer and are not afraid to use it. Businesses have seized the opportunity to satisfy consumers' need to have an advertised product right away. You can click or scan a commercial to download a "recipe" for 3D printers for a nominal fee, and the recipe is sent to your printer right away. Within minutes of seeing the ad for a product, you have it in your hands – and it did not cost that much.

To enable this type of instant consumerism, the 3D printers have evolved to print faster and be easier to use. No need to use 3D modelling or slicing software. Just download a "recipe" from an online repository for a small fee, or just tap on an advertisement and click 'Print'. This development has come hand-in-hand with on-demand video and TV services. People have even shorter attention spans and are constantly looking for the next fad.

Manufacturing at home has led to a decline in transportation, since basically only raw material and food have to be supplied. Everything else travels electronically. Despite the reduced need for transportation, the overall effect of this new type of manufacturing is bad for the environment. Houses and landfills are full of "crapjects", low quality products used only one time, which seemed to be fun to produce. The energy use is greater, and although additive manufacturing does not waste raw material, unsuccessful prints produce waste in addition to the "crapjects".

Manufacturers of small products have either gone bankrupt or survive in producing large batches of standard products. However, large scale manufacturing has not been that much affected, as the final customer has not learnt to assemble more complex products. New companies have emerged who specialize in making and supplying product "recipes", raw material for the printers or the printers themselves. Of the newly created value, most can be captured by the ecosystem providers, as they charge fees for designers to use their channels to sell to the customers. Similar to successful app producers, a selected number of designers will be able to capture much of the value, as ecosystem providers have hundreds of million users in their network.

Because manufacturing has spread all over the world, also the former trilateral power of USA, Europe and Japan in the IPR world has scattered. There are new strong national and regional patent offices and the focus has moved to East. Business is using IPR as a tool, but IPR is managed and enforced differently in different geographical areas. IPR protection – and particularly the global protection – is not easy (EPO, 2007).

The whole global landscape is scattered too. The world is more divided into rich countries with "global" consumerism and poor countries that are left out of the global markets. There are regional blocks and alliances in different parts of the world, trying to promote the issues essential for them. Business competition is aggressive.

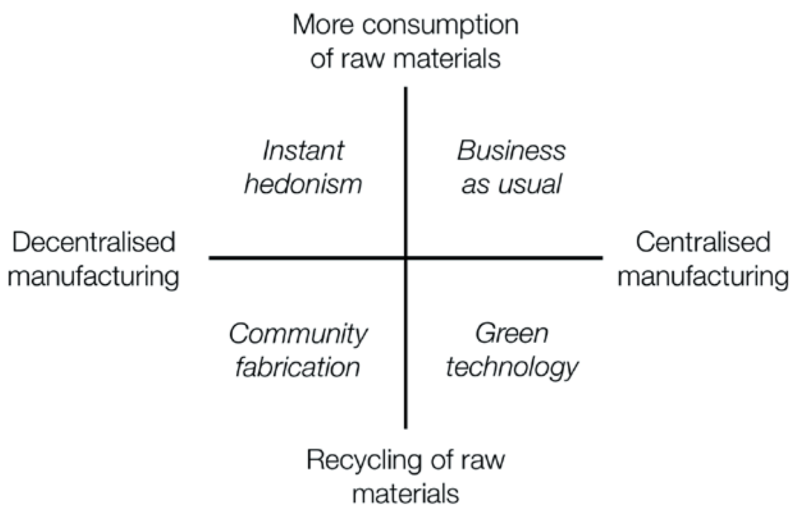

Fig. 5. Scenario axis and four scenarios

5.2 Scenario 2 – Community fabrication

The 3D printing community has expanded and produced an alternative to centralized manufacturing. Inexpensive 3D printers are available, and there are schematics for many of them freely available. The same goes for 3D modelling software, which is mainly open source and maintained by a dedicated community. This openness has resulted in many different 3D printers and software versions.

Additive manufacturing has enabled a nearly closed cycle of material flow. As plastics and other materials have gone up in price, the recycling of existing, out-of-use products as raw material for 3D printers has become common practice. New material entering the cycle is locally produced and often biodegradable. The focus on recycling of resources has made trash almost non-existent.

The closed cycle of material flows and many different, sometimes incompatible versions of 3D printers favour a small closed community. This, along with the trend to be more self-sustaining regarding food and energy, has led to de-urbanization and the emergence and flourishing of small village communities. However, these villages are connected together by information networks creating a global network of self-sustaining nodes. This global network also enables the sharing of different product designs. There are many "Thingiverse"-like design file repositories covering most objects. The designs are shared freely, and the design repositories operate on ad revenues or small donations. Patents and other legal issues are disregarded. The decentralized structure of the system hinders any attempt in centralized control of what is manufactured.

As the technological development has become faster and faster, patenting is seen more as hindering development because patenting processes are slow and there are better and faster ways to share information. Patents are no longer considered as enhancing innovation and creativity. The public image of patents and other IP is negative. Patent enforcement has also lost its significance, and there is not much litigation seen in the patent world. Copyrights have lost most of their importance too, because they were seen as limiting access to information. Peer recognition and networking give value for the creators. Companies are either using secrecy to protect their innovation or involving their customers in the development of new products. The whole IPR system is eroded and the new standard is information-sharing, not protecting (EPO, 2007).

In this open-community world, some designers have gained pop-star status, but the value is captured by companies that bundle the freely available designs and offer packages around tastes or themes. A new kind of manufacturing service business will become prominent, one that identifies and cooperates with traditional manufacturers to allow extreme customization by replacing only small parts of a complex assembled product, for instance a car. In this world of mass customization and closed material cycles, amateur products will flood the market, but most will not be able to monetize them. Another industry that will develop new business models close to the customer is the recycling industry. As recycling of these materials becomes cheaper and the amount of these objects increases sharply, they will be able to create great revenues as they become the new 'mining' companies – the resource providers.

Overall, the world consists of strong communities across national boundaries: people interested in same issues are easily connected via the Internet. These civil societies are questioning old ways of doing things, old laws and businesses. They work together with each other and with companies that have similar values of sharing information.

5.3 Scenario 3 – Green technology

As humans enter the "bio age", industrial ecology has become the new norm in production and manufacturing. The waste produced by one factory is used as raw material by another factory. Additive manufacturing has become one of the enabling technologies. Because the additive manufacturing process does not create any waste, it is often the "sink" in the industrial ecological system. Advances in material science and developments in 3D printers have enabled the use of many materials as input to the additive manufacturing process.

Environmental concerns and regulations have increased the price of polluting and producing waste. Partly because of that, additive manufacturing has become a competitive technology compared to more traditional manufacturing methods, although it is still not as fast as mass production. Many companies have changed their production to rely more on additive manufacturing.

Another way additive manufacturing is seen as "green" technology is that it enables the production of enhanced products. Shapes that have been impossible or costly to produce with traditional manufacturing methods are now possible, and this has led to "super machines" – very light jumbo jets, light and ultra-safe cars, more efficient motors, etc. The use of these "super machines" has cut down emissions from transport and industry.

New forms of intellectual property rights appear. A faster and lighter form of patent is available for all technologies that solve environmental problems. Patent offices have new ICT systems that help the workload situation in patent offices and at the same time make the patenting process quicker for customers. Secrecy and open source are both relevant alternatives for patenting (EPO, 2007).

Countries try to combat climate change and resource scarcity together. Politicians all over the world think that because the problems are shared, they can only be solved together. Governments are supporting R&D activities, particularly in the areas of clean technology and material technology. New technology is developed to tackle problems, and technological progress is more rapid than ever before. New technologies are seen as a key to solve problems but also as a huge business opportunity globally.

5.4 Scenario 4 – Business as usual

Additive manufacturing has become a widely used technology by companies, and it coexists with other forms of manufacturing. The technology is more advanced than at present. The process is quicker, the results are more precise and the range of available materials is wider. The major changes compared to the present are in logistics, customization and enhanced products. However, the basic model of manufacturing remains unchallenged: companies manufacture products and ship them to retailers where consumers buy them.

The manufacturing of products has moved closer to consumption and there are halls of different sizes full of 3D printers close to the consumer. The easy scalability of manufacturing capacity, the demand for mass customization and the electrical transfer of designs are the main drivers pushing this new type of factory forward. This has also enabled multinational companies to easily expand to new territories, including the developing world.

Consumers want products that match their style, and therefore they want highly customized products. Manufacturers serve this demand by providing easy Web tools allowing and encouraging changes to be made to their designs before sending them to be printed near the consumer. Customization is also one factor driving consumption, since most objects have now become fashion statements. Different customization fads or memes come and go.

The whole IPR system has been simplified and modernized to meet the requirements of the digital world. Global patents have superseded national and regional patents and they cover most of the geographical areas of the world. And companies are using patents as competitive weapons. Disputes are handled in global IP courts. Trading in IP is sophisticated and licensing is a huge business. The role of IP has become dynamic and proactive. Patents are effectively utilized and traded and the former role of patents as part of a defensive strategy is not the norm anymore (EPO, 2007). The main disruption to existing businesses is the reduced need for logistics. However, since production still takes place in large facilities, the reduction is mainly in overseas transportation.

5.5 Expert views

Risto Linturi, a visionary with long experience in the IT business, is Change Manager at the IT training company, Sovelto. He is seemingly a true believer in AM technology. In an article in the Finnish Tietokone magazine, he forecasts that in five years 3D printers will be as common as photocopying machines are today; and in ten years they will be as common as ordinary 2D printers are today. He believes that as 3D printing quality gets better, simple needs such as broken parts of domestic appliances will be printed by everyone's own printers – not ordered from China anymore. The patented technology of high-quality 3D printers is becoming available for all due to the end of patent terms. Thus the cheaper printers will improve, and as the quality is better and prices come down, demand increases. Linturi says that at the moment, one problem is the availability of printers. From his view, it can be concluded that the emergence of AM will be a reality in the future, depending on decreasing costs and a greater availability of 3D printers.

Research Director Jukka Tuomi works at Aalto University's BIT Research Center. He agrees with Linturi on the rapid and revolutionary nature of AM but does not believe that 3D printers will be in every garage. Cheap printers are suitable for models but not for high-quality articles. It is an environmental issue (people would print low-quality objects that are not really needed) and a security issue (quality is not good enough for objects needing security, such as helmets and security locks). Instead, Tuomi believes that 3D printers will be in every village and in every hospital, for example. One future scenario is that you can buy a design via the Internet (e.g. from Amazon) and pick up the object from a gas station or a market, for example ("good quality device in every village"). The gaming and entertainment industry will most probably develop applications around 3D printing. It is an enabling technology, says Tuomi – anything you can imagine, you can produce; this has not been possible by traditional manufacturing methods.

Table 5. Summary of the scenarios

	Instant hedonism	**Open fabrication**	**Green technology**	**Business as usual**
Materials	New materials used only once	Recycled, closed material flow, use what you've got	Recycled, closed material flow, industrial ecology	New materials, different types, specialized materials
Repositories of designs	Corporate-owned and free ad-based	Distributed, open, collaborative	Government run repositories of environmentally friendly solutions	Corporate-owned and customization wizards
Design software	Mostly professional, consumers have no need for it	Free software, not easy to use, support on forums	Mostly professional	Customization wizards, Web-based, easy to use, central support
IPR	IPR system more scattered; different rules in different areas	IPR system has eroded; patents are seen as hindering development	New lighter forms of IPR arise for environmental technologies	IPR system smooth and simplified; global patent
Value chain	Straight from designer/company to consumer	Consumer as designer, manufacturer and end user	Manufacturer - retailer - consumer	Manufacturer - retailer - consumer
Business models	Sell "recipes" for products	Sell printing service	Sell green tech solutions	Sell products
Global landscape	World is more divided into rich countries with "global" consumerism and poor countries that are left out of the global markets	World consists of strong communities across national boundaries	Countries try to combat climate change and resource scarcity together	As is today
Competition	Competition depends on having the best designers and marketers	Competition depends on collaboration with others and sharing know-how	Competition depends on eco-efficiency: minimum energy use and optimized use of raw material	Competition depends on the ability to add value to a product using AM: Is mass customization needed?

Harri Kulmala, the CEO of the Finnish metals and engineering competence cluster, highlighted five changes during a management seminar on 3D printing. Firstly, AM will change value networks, bringing different customer-supplier relations and new business models. Secondly, new business ecosystems built around a specific AM technology will bind the technical possibilities of a community in much the same way as smartphone ecosystems influence consumer behaviour. Thirdly, AM will enable the manufacturing of objects that were difficult or impossible before. Fourthly, consumers gain more power over manufacturers as producing and customizing products becomes easier. And finally, environmental damage becomes more expensive as AM enables more precise monitoring of material flows.

6 Implications for policy in the four scenarios

The biggest policy implication for the instant hedonism scenario is the management of 'crapjects'. This requires that more effort be focused on inventing materials that are biodegradable. As there are no factory jobs anymore, people should be trained to use the software tools of AM right from school and be prepared for the service economy. Moreover, industries will have to manufacture more modular devices, as the spare parts are easily printable. One of the fundamental advantages of this scenario could be the software design tools that are used for designing these 3D objects. If these tools do not require very specialized knowledge to operate, are intuitive and easy-to-use, and favour collaboration with others, then the design of high quality objects can even be crowdsourced. A manufacturer, for example, may provide the basic design of certain objects, which may be tinkered with by ordinary users, which may lead to an altogether different kind of innovation. Moreover, competitions similar to the 'Netflix Prize' can be initiated where awards can be offered to the general public to solve some design challenges. Since the objects are being printed by almost everyone, the existing IPR and patent laws should be overhauled. The Copyright Exchange could be one way to simplify IPR issues, where the rights of all stakeholders are preserved without stifling innovation. Moreover, the printing of weapons and firearms along with the proliferation of instant hedonism may have adverse security implications.

The open fabrication scenario relies on an educated workforce sharing and co-operating in the production process. Therefore, a common voice able to compete with major manufacturers will not emerge. The number of available designs will be uncountable, and the current IPR system will have become redundant. The risk for society and policymakers is that corporations will capture most of the value that is created by the communities. Nonetheless, the nations most engaged in education in this technology will become the hot spots of innovations in the field. Environments like Silicon Valley are required where expertise and open sharing of ideas is a key characteristic if a nation would benefit from this technology. Teenagers and young adults who grew up using this technology as a tool in daily situations are needed.

At the same time, early awareness and ethical debates are needed because abuse is a major threat. Pirated products and the manufacturing of weapons are already an obstacle nowadays. A new system has to evolve, far beyond the slow and inflexible IPR system.

Another trend that has to be acknowledged in this scenario is the role that manufacturing at home plays. Due to the high number of printers at home, fewer goods require transportation and fewer ordinary factory jobs are needed. Overall it becomes easier to work from home as the economy develops further into a service economy. Even alternative currency models that circulate inside those networks (for instance, Bitcoins) become popular. Regions inhibiting this development will quickly fall behind. Technological literacy, access and openness in the environment are the key enablers for a prosperous community in this scenario.

The major global emphasis has been placed on recycling and environmental technology solutions. The recycling processes are sophisticated and efficient locally and globally. Additive manufacturing is used as one important tool to enable industrial ecology: the material flows are closed cycles. There is a global need to manage and accelerate the adoption of green technologies through open designs. There are incentives for all innovations and enhancements related to recycling and environmental technologies and processes. At the same time, there are heavy sanctions for polluting industries. Governments rely on high technology as enabling high living standards and a clean environment. Business is growing strongly in the recycling and clean technology areas. Western countries want to see clean technology diffusion all over the world. On the one hand, it provides more business opportunities; and on the other hand, they see environmental issues that need to be solved globally.

For Western policymakers, additive manufacturing has not been the magic bullet it was hoped to be. While additive manufacturing has enabled production to be closer to consumption, the new generation of consumers, ever more eager to stand out through their purchases, are mostly not in the West, and manufacturing is located to readily serve their needs. Instead of attracting manufacturing, successful economies have been able to capitalize on the engineering and design underlying additive manufacturing. While manufacturing itself moves to where the consumption is, the inherently digital nature of additive manufacturing means that designs can be made anywhere around the globe and easily distributed. Since additive manufacturing enables more designs to be turned into physical products, the increasing demand for skilled designers and engineers empowers urban areas with strong industrial design communities, such as Helsinki, Copenhagen, Eindhoven, and Milan in Europe. For policymakers to benefit from additive manufacturing, they need to keep their communities thriving through incentives and access to high-quality education. Simultaneously, a dangerous fixation on attracting the "lost" manufacturing sector may cost policymakers the opportunity to capitalize on other parts of the changing value chain.

A major issue in all the scenarios is product safety and reliability. Before the industrial revolution, a craftsman would personally guarantee the product with his reputation. Because bad reputation meant no business, he had to make sure that the materials he used were of good quality and the end result was durable. Since a craftsman's tools played a minor role compared to AM, he could not blame the tools for defects in the product. Likewise, in modern legislation, the manufacturers and distributors are held responsible for injuries or other damage that a faulty or dangerous product may cause. In the case of AM, an unsatisfied end user could blame the design, the material or the machine. A fault in any of them can lead to failure in any product no matter how it is manufactured, but in AM, they are completely decoupled. One person may do the design and never see it as a physical object, the producer of the material has no knowledge of how it ends up being used, and finally, the person manufacturing (or operating) the printer may be not aware of restrictions implicit in the design or material. Standardization may help the situation, but from the viewpoint of the end user, it is ultimately a problem of missing information. It may be possible that a of fame or reputation system emerges that promotes people who are good at system integration, that is, who know what materials are suitable for which products, what the machines can do, and who understand the structural properties of the designs. Designers or system integrators could also tie in their design with some specific technology or material and offer guarantees if and only if these criteria are met, or make the design available only if a liability waiver is agreed on.

7 Discussion and conclusion

Following the scenarios developed, the current tendency is that the 'business-as-usual' will not continue for long. Reasons are found in the current media-hype, expert opinions, steadily decreasing material and device costs and human traits that drive our consumer behaviour. The cumulated effect makes the 'instant hedonism' scenario the probable scenario. AM would not be a disrupting technology but driving the development of products in the consumer industry. With regard to an economic system built around growth partly from increased consumption, companies and governments will feel tempted by the technological developments to exploit this opportunity. Yet, it will eventually lead to an environment characterized by 'crapjects'. Policy-makers ability to interfere with this trend is limited, and requires educational efforts and building up a more sustainable mindset.

This mindset development, though, is already starting in various fields such as responsible eating habits or climate conscious behaviour. In particular environmental drivers are emphasized stronger, which leads to our preferred scenario the 'green technology'. It is achievable due to the low disruption effect of the technology in this scenario. The value chain will not be disrupted at the core; the major value remains in the R&D, design, service and branding activities. Production and consumption patterns follow similar models existing at the moment, yet, we will see developments in the services provided. Technological innovations related to material cycled can be best implemented and support our societal evolution towards more sustainable behaviour including consumption.

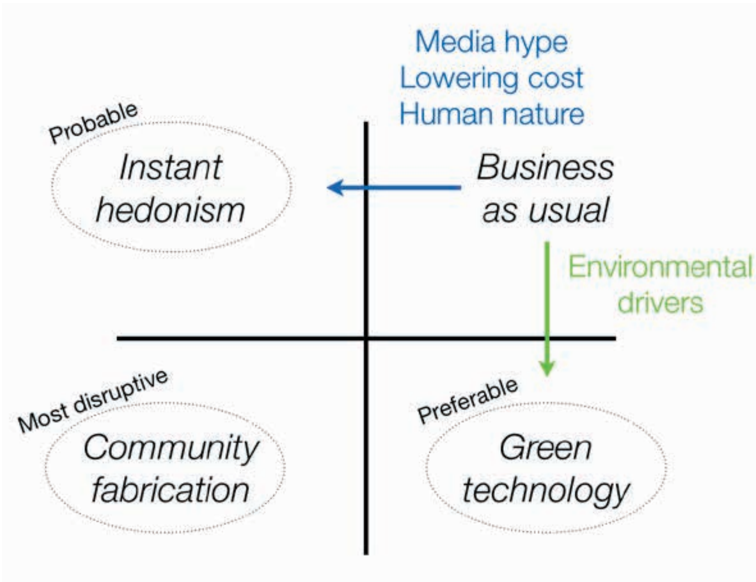

Fig. 6. Scenarios analysis

The open fabrication scenario is most disruptive to the existing value chain. It requires a new perception of the value on design, and even more will the service and branding activities be discussed. The conflict arises as major ecosystem-providers would capture most of the value, which contradicts the fundamentals of the open-knowledge and open-fabrication movement currently in place.

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2.2 Drivers behind CleanTech: separating fact from fiction

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Abstract

This chapter explores three cases of clean technologies in order to identify the type of drivers behind current developments. CleanTech has been suggested as the next socio-economic paradigm that will have a pervasive effect on all sectors of the economy. In this chapter it has been argued that in order to realize the transition to CleanTech,

special attention must be paid to the drivers behind the change. Through examining and comparing the cases, it seems that regulatory and political drivers are still dominant over economic and social drivers. Although political support and regulatory action may help in the initial stages of the transition, economic and social drivers must strengthen for CleanTech to become a significant self-sustaining force.

Keywords: CleanTech, sulphur directive, solar energy, hydro-wind power, environmental policy

1 *Introduction*

Throughout history there have been eras when new innovations have fundamentally changed the way of life for entire populations – consider the industrial revolution for example. These transitions are sometimes referred to as waves of innovation or changes in the socio-economic paradigm. Five of the most recent waves running up to the beginning of the 21st century are depicted in Figure 1. It has been said that we now live in the age of information and communications technology, but what will the next wave be? One relevant candidate – and the topic of this chapter – is CleanTech, the so-called green revolution.

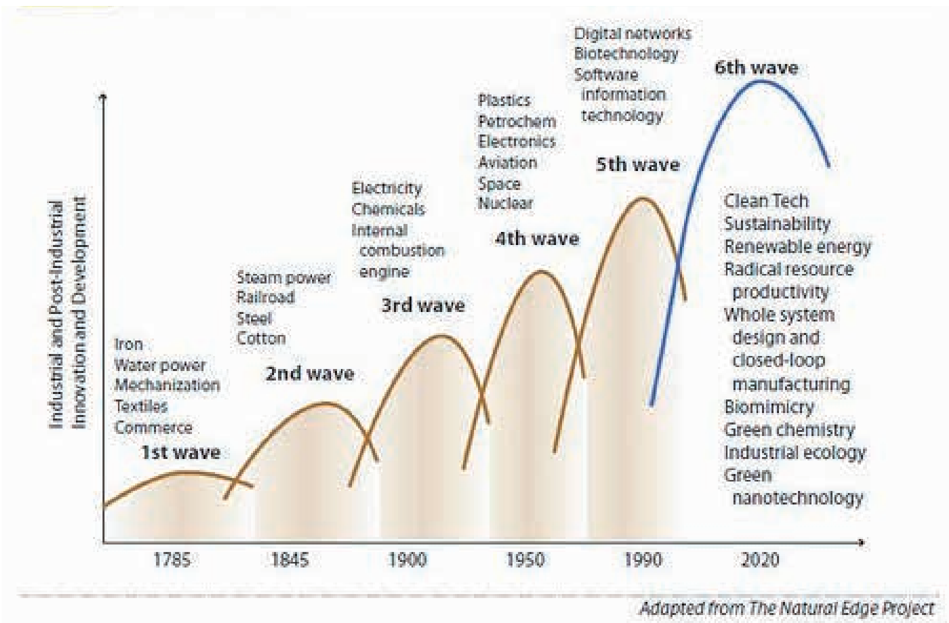

Fig. 1. History of waves of innovation (The Natural Edge Project, 2012).

CleanTech is a means to improve performance, productivity and efficiency with a smaller environmental footprint and minimal pollution, though it is commonly used to refer to any environmentally oriented technology. The core areas of CleanTech include green chemistry, recycling, green energy, green ICT, green house and transportation, and waste treatment (although in the course of a CleanTech revolution, all economic sectors would be affected). Recently, increasing oil prices and climate change policies have especially encouraged investment in renewable energy technologies including solar, wind and biofuels.

Over the past decade, CleanTech has been moving rapidly through a hype cycle. The movement began with the technological advances, growing environmental awareness and rising energy prices of the early 2000s (known as the technology trigger). CleanTech then sped through the boom times of 2006 and 2007 (known as the peak of inflated expectations) when, for example, large government alternative energy grants were widely available. Nowadays CleanTech is hitting tough times (known as the trough of disillusionment) with, for instance, the collapse of prominent companies (such as Solyndra and ABC123) and gridlock over global environmental regulation reform.

Politicians are particularly interested in whether CleanTech can provide competitive advantages that can help create a plethora of so-called 'green jobs'. These 'green jobs' could have the potential to replace jobs being lost due to increased automation. For instance, in the U.S., about 2.3% of all jobs are connected to companies involved in creating green goods and services, while 0.7% of all jobs are directly related to green technologies and processes (US Department of Labor, 2012). The political interest towards CleanTech is easy to understand since it is widely considered as a means of combining economic growth with solving environmental problems (ILO, 2012).

Interestingly, the future of CleanTech over the next decade remains an open question. CleanTech could help jump-start a green revolution and become the next dominant techno-economic paradigm. Or CleanTech could remain a marginal force that fails to become a real viable alternative to existing methods. To predict the future of CleanTech, we examine the critical drivers behind several real CleanTech projects while simultaneously investigating the theory regarding those drivers.

A major assumption of the investigation is that the drivers of CleanTech must be primarily economic and social rather than regulatory or political for CleanTech to become a significant self-sustaining force. Thus while regulatory or political drivers can help in the initial stages of development, these must eventually be replaced by economic and social ones. This assumption is based on studies of previous socio-economic paradigm shifts and the drivers behind them (Perez, 2010).

Furthermore, the investigation's main hypothesis is that *despite the hype surrounding CleanTech, the drivers remain mainly regulatory and political and thus CleanTech will not become a significant force in the short to medium term.*

The examined case studies cover a range of different initiatives under a broad definition of CleanTech. The cases include the use of sulphur scrubbers on ships, the solar energy industries in Germany, the U.S. and China, and a hybrid hydro-wind power plant on a remote Spanish island. The first case concentrates on the effects of having environmental regulation as the main driver of CleanTech, the second case concentrates on the timely subject of government subsidies in promoting cleaner energy production, and the third case highlights the interlinked nature of the different drivers.

2 *Scrubbers and the sulphur directive*

In September 2012 a directive was passed in the European Commission to limit sulphur emissions from ships. Coined simply as the "sulphur directive" by the Finnish media, it has raised lively debate for both pro and con. The directive will first come into force in designated sulphur emission control areas (SECAs) in 2015, and then in other European sea areas in 2020. The new limits for the maximum sulphur content of fuels are 0.1% in SECAs and 0.5% in other areas; a notable decrease compared to the current limits of 1.5% and 4.5%, respectively. The supporters of the directive argue that this will lead to cost savings through improved health and reduced mortality and that without it, sea-based sources of sulphur emissions will exceed those from land-based sources within the next decade (CEEH, 2011).

The business concerns regarding the sulphur directive were voiced extensively in 2011 at an informal meeting between the federations of Finnish Technology, Forest and Chemical Industries. Based on a report by the Finnish Ministry of Transport and Communications (Kalli et al., 2009), the industry interest groups argue that the directive could impose annual costs of up to €1.2 billion, equivalent to the cost pressure of 24,000 man-years of work. It would cripple the competitiveness of Finnish export industries and lessen the attractiveness of Finland for foreign investors. And the cost is only the icing on the cake, which is the groups' opposition to the directive's unequal treatment of countries. First, 80% of Finland's foreign trade is transported by sea, and the country's island-like geographical position makes it impossible to use other means. Second, because the Baltic Sea has been designated as a SECA, all sea traffic in and out of Finland will have to comply with much stricter sulphur emission norms than other areas. Also, the new limits for emissions come in force in SECAs five years before other areas, especially giving Mediterranean countries more time to prepare. In short, the sulphur directive puts Finland in an unfair competitive disadvantage (Teknologiateollisuus, 2011).

However, the report the industries base their worst case scenario numbers on does not take into account a backdoor built into the directive that enables the use of technological means to achieve a reduction in emissions equivalent to that gained through switching to low-sulphur fuel. The Finnish technology company Wärtsilä's open and closed loop sulphur scrubber systems are examples of such solutions (Wärtsilä, 2012). The open loop system utilizes seawater to remove sulphur oxide (SOx) from the exhaust. The exhaust gas enters the scrubber and is sprayed with seawater in three different stages. As the SOx in the exhaust reacts with water, it forms sulphuric acid. There is no need for chemicals since the natural alkalinity of seawater neutralizes the acid. For fresh and brackish water areas with low natural alkalinity, the closed loop system is more suitable. In it, the wash water is being circulated within the scrubber. Exhaust gas enters the scrubber and is sprayed with fresh water that has been mixed with caustic soda (NaOH). The SOx in the exhaust reacts with this mixture and is thereby neutralized. A hybrid system has also been developed that combines both techniques. An illustration of the system components is provided in Figure 2.

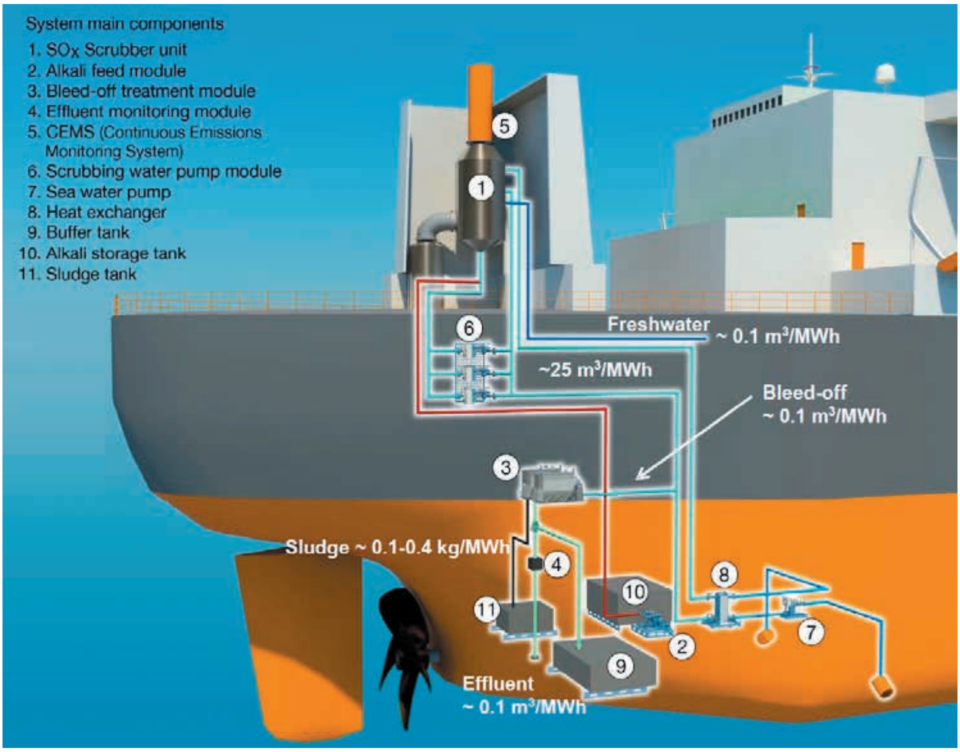

Fig. 2. Wärtsilä's scrubber system can also be retrofitted in existing ships (Wärtsilä, 2012).

According to Wärtsilä, there are significant economic benefits to retrofitting existing ships with scrubbers and installing them into new ones (Filancia, 2009). The savings accrue from the ability to continue using fuel with high sulphur content, which is cheaper due to smaller demand and lower processing degree. Especially in SECAs, where the emission limits will be the strictest, the payback period is calculated to be less than a year. From this it seems that if all ships operating in the Baltic Sea were to implement scrubbers, the requirements of the sulphur directive could be met without the industry-killing consequences that the interest groups envision. Because it has been estimated that the price of low sulphur fuel will increase in the future with increased demand, and that the limits for sea-based sulphur emissions will further tighten globally (e.g. Kalli et al., 2009), the scrubber business looks promising not only for Wärtsilä but also for the current Finnish government regarding their aspirations to expand the CleanTech sector (Finnish Government, 2011).

As was mentioned in the introduction, CleanTech is sometimes seen as the next Kondratiev wave or the next large cycle in economic development that simultaneously drives forward all sectors of the economy. However, what is common to all previous grand cycles of innovation is that they are based around some general technologies that have a vast number of transformative applications across the board: steel, electricity and the microprocessor, to name a few of the more cliché ones. Although it is justifiable to call scrubbers CleanTech on the grounds of environmental benefits, they do not seem to possess qualities applicable to many other uses. It's quite the opposite, actually. According to Wärtsilä's (2012) product brochure, it is the open loop scrubber that is based on technology that has been in use for over 50 years. So even if it is an innovative application, the sulphur scrubber seems to be just an addition to a mature technological trajectory, not the start of a new one. This becomes more apparent when examining the driver.

To understand the driver behind Wärtsilä's scrubbers, it is important to note that the sulphur directive is actually not a stand-alone piece of legislation but an amendment to European Commission's earlier directive 1999/32/EC relating to a reduction in the sulphur content of certain liquid fuels. More specifically, it is an action to incorporate the latest amendment to the International Convention for the Prevention of Pollution from Ships (MARPOL) of the International Maritime Organization (IMO) into the legislation of the European Union. As can be seen from the timeline in Figure 3, the actions of the EU and IMO against sulphur emissions from fuels have their roots at least in the 1970s. At first, EU regulation has concentrated mainly on reducing sulphur emissions from land-based sources such as vehicle fuels. After the MARPOL convention (and especially its Annex VI concerning greenhouse gas emissions from ships) came into force, the EU has also been active in regulating sulphur from sea-based sources. Looking at the timeline, it can be said that EU decision-making has for more than a decade followed that of IMO very closely and predictably in its actions.

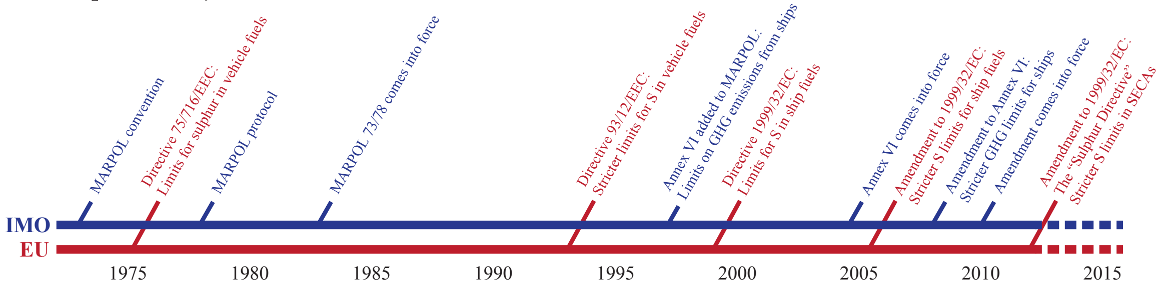

Fig. 3. Timeline of key decisions by the EU and IMO leading up to the sulphur directive

The actions of IMO and the EU are in line with scientific studies that imply a decoupling of sulphur emissions and economic growth in developed countries (e.g. McConnell, 1997; Panayotou, 1997; Stern, 2004). By decoupling, it is meant that economies in developed countries have become much less sulphur-intensive since the 1980s. In the studies, this development has been accredited to a variety of factors: availability of novel technological solutions, public health concerns, regulatory efforts, and increased environmental awareness. The change has been so profound it seems almost as if decreasing sulphur emissions has become an end in itself. In this much wider context, it seems unsurprising that the control of sea-based sources of sulphur emissions is also strengthening. So even if the sulphur directive is behind the demand for Wärtsilä's scrubbers, it is fair to argue that both the driver and the technology are a part of a trajectory whose roots run much deeper than the current CleanTech boom.

Another reason, and perhaps a more central one, why scrubbers have only a minor role (if any) in the birth of the CleanTech paradigm is that they are a prime example of end-of-pipe technology, i.e. "an approach to pollution control which concentrates upon effluent treatment or filtration prior to discharge into the environment, as opposed to making changes in the process giving into rise to the wastes" (GEMET, 2012). Removing sulphur from the exhaust does not make the ship travel faster or more reliably, nor does it decrease the fuel consumption of the ship. The only added value that the scrubbers provide the shipping companies, in addition to compliance with environmental regulation, is the ability to use fuel with high sulphur content, which means, in most cases, no change to the pre-sulphur-directive situation. Thus this case is in line with previous literature highlighting the link between environmental regulation and end-of-pipe technology, questioning the feasibility of environmental regulation as a driver of clean technologies (Frondel et al., 2004; Hammar and Löfgren, 2010).

Decreasing sulphur emissions from land and sea-based sources is important because of health and environmental issues. The intention of the sulphur directive, and the IMO regulation before it, is widely considered good. The method of execution, however, does not score many points from the industry because of the unequal treatment of countries within Europe, not to mention globally. Although it is easy to morally argue that health concerns should precede economic ones, it is not necessarily smart politics even from the point of view of advancing ecological and social sustainability to squander political legitimacy on forcing the change, especially since the CleanTech solutions the directive indirectly led to are not value adding without the environmental regulation.

3 Solar power in Germany, the U.S. and China

Solar Energy is the fastest growing clean technology around the world in the last decades and, in many experts' opinions, is the one that could really become a viable option for clean, sustainable and pollution-free energy. Government subsidies, economic capacity from ventures and continual innovation are the main drivers for the fast growth of the solar energy industry. In this chapter we will talk about solar energy's standing point and how much more it could be developed, followed by how subsidies have allowed it to grow, and if the solar industry could survive without these subsidies, after that a case study of solar energy industry in Germany, the U.S. and China will be used to illustrate some real-life scenarios.

3.1 Where is solar energy now?

Photovoltaic power systems, which are comprised of solar cells, have been around since the late 1880s and have since been under constant development: from being able to convert around 1% of incident light coming into them to electricity in 1931, to today's state of the art cells being able to convert around 24% of the energy they get from the sun. Note that this last figure is the known record for single cells, not solar panels, which means that while single cells can get up to that number, some efficiency is lost when putting cells together to form panels that could be installed and actually used to harvest the power of the sun. The technologies that can achieve numbers as high as 24% run into problems when manufactured into actual panels. At that point, the final product efficiency would be around 16 to 18 percent. And taking into account that the theoretical efficiency level that can be achieved from a cell is around 29% (Levitan, 2012), the real challenge might lie with the ability to manufacture those record-breaking cells into actual panels that can be made into usable power systems. And by that, it would mean that those individual cells would need to be assembled together without any connectors or assembly parts blocking any of the light coming in. And that's where the big losses are made today.

Besides their performance referring to how much energy can actually be harnessed from the sun, there is a very important factor to be taken into account: the return on investment. In this particular case, economic resources might not be the ones to look into, but energy resources. For this purpose, Energy Return on Investment or EROI can give us another perspective (Fairley, 2012b). As efficiency rises, the EROI continues to rise along with it, already coming close to be a match for the Oil and Gas EROI, which continues to drop due to more and more energy needed to extract these materials from very deep water offshore wells. Still it's not the end of dirty energy supremacy on EROI, there is still big R&D conducted to improve efficiency of, for example, coal-based power plants such as GreenGen (the Chinese integrated gasification combined cycle (IGCC) generator that brings the promise of smarter conversion of coal into electricity to cut down on greenhouse gas emissions cuts). Still, these kinds of power plants have one thing in common: their construction tends to delay a few years and cost a lot more than was originally planned (Fairley, 2012a). This might slow down their progress, but this industry has a solid foot in the market and can fund itself. But this was not so in the beginning, as they were at one time heavily subsidized. One question to ask is how long will solar energy be dependent on subsidies?

Recently, there have been hot debates on solar energy around the world about how to benefit as first movers. Here, we will look at it broadly in the whole value chain in solar energy including downstream manufacturers and upstream array planners.

It is well known that Germany and the U.S. are leading in research and development of solar energy. We will focus on Germany's cases in this work. Before 2007, expertise in engineering was needed in solar production lines to combine chemical baths, singulation machines, and flashers, etc. In 2007, turnkey production lines were commercialized combining these together. Some firms from Germany started to sell solar production lines that required less expertise in engineering. Q-Cells and SolarWorld from Germany bought lines as well as Trina and Suntech in China. The manufacturing value started to shift to China, probably due to lower labour costs. In 2010, a rooftop solar array cost ca. €2,900 per kW, while panels now imported from China cost ca. €700 per kW (Morris, 2012). People start to worry about the competitive advantages of solar industries in Germany and the U.S. It is true that some solar manufacturers in Germany and the U.S. are in a difficult situation. Q-Cells from Germany and Evergreen Solar, which were the top solar manufacturers, announced bankruptcy. On the 6th of September 2012 in Brussels, the European Union began a broad anti-dumping investigation of Chinese solar power equipment. The case covers imports from China worth €21 billion. Germany and China are seeking to negotiate this case. Later, on 10th October 2012, the U.S. announced a 35.97% tariff for Suntech and a 23.75% tariff for Trina.

Let's move to the whole value chain of solar power to think more deeply about Germany's role in the value chain and get a clue how solar industries in Germany continue to benefit as first movers.

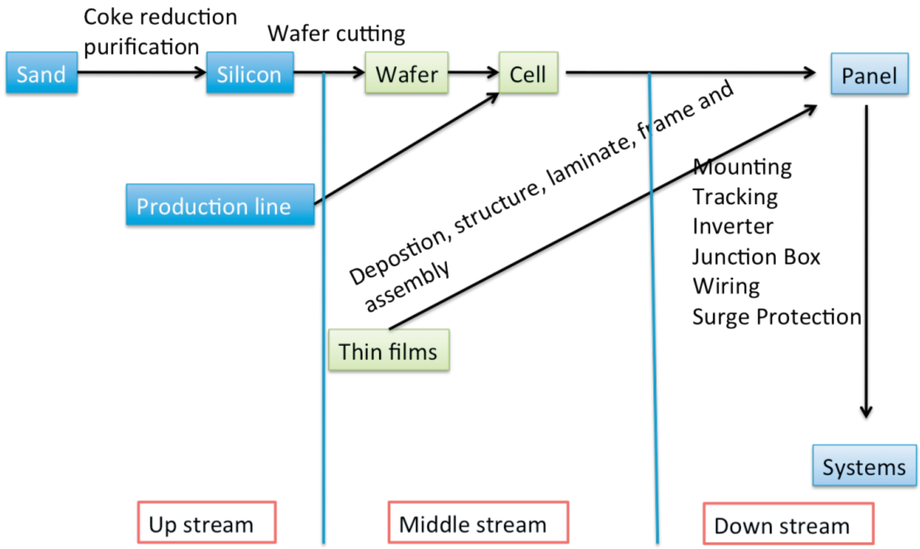

Fig. 4. Value chain of solar energy from upstream to downstream

From the value chain, China benefits mainly from the wafer, the cell and sometimes the panel in the middle of the value chain. However, silicon is imported either from Germany or the U.S. The German solar silicon manufacturer Wacker reaches its full production and plans to increase 50% this year. It is said that all of its silicon is sold up to the end of 2015. Furthermore, Germany does benefit from selling production lines from upstream in the value chain, and at the same time the panels are affordable for installation. The drop in solar panels is beneficial to local players in downstream, because other prices do not drop much and therefore the share of manufacturing in the value chain decreases. For Germany, even using imported solar panels, 50 % value is domestic in Germany (Morris, 2012).

Let's move to a real case of installation of solar panels. In the U.S., a family of four paid around $2,500 per year for electricity. They installed a 9.43 kW solar cell system in November 2011. The cost was $51,865 with a tax credit of $15,560 from the federal government and a rebate of $7,100 from the state. The net cost after subsidies was $29,205. From November 2011 to October 2012, the solar system created 13,803 kWh of electricity and the family used 7,596 kWh. The surplus is 6,207 kWh in one year. It is said that the added value of the solar panels to the family was around $30,000 (Tofel, 2012).

3.2 How to drive solar energy industry without subsidies?

In the past, heavy subsidies were needed in order to overcome the losses in EROI in the Photovoltaics case and to keep the technology evolving to where it is now. But is it mature enough to run without these subsidies? The solar energy industry, as a

CleanTech industry, has benefited from subsidies for a long time globally based on encouraging policies (Tyler, 2012). However, this becomes the most contentious issue in global trade, in spite of subsidies having been cut in recent years (Beatie and Chaffin, 2012). For long-term strategy, it is time for companies to think about how to survive without subsidies (Aanesen et al., 2012). Competition between manufacturers will intensify, especially facing the challenges from China with low-price products. Therefore, the downstream of the value chain will become more attractive.

a. Solar companies need to seek innovations in system integration to improve the overall efficiency from cells to panels and the whole system.
b. A grid that allows storage of excess solar power and stabilization
c. Inverter technology allows a solar power plant to stabilize the grid at night or in cloudy weather when there is not much sunshine.
d. A solar distributor has great growth potential in providing simpler installation and longer warranties.
e. Customized application system

On 7 December 2012, the U.S. Department of Energy announced a $29 million investment in improving grid connections and reducing installation costs through innovative technologies and reliable solar power forecasts. Solar systems have to be designed to make the process of buying, installing, and connecting faster and less expensive for applications. Technologies are developing for easy selection of solar systems for installation, wiring and connecting to the grid. Standard solar components will be designed to be simply adaptable to any residential roof and installed and connected to the grid quickly and efficiently.

The key success factor for downstream players is to satisfy customers' needs (especially high-value customers) at low cost. Companies need to make a greater effort to investigate and specify customers' needs when developing targeted customer offerings. Companies have to develop solar applications combining direct-current water pumps, mobile charging units, and LED lighting. For off-grid applications, simpler installation and construction are required. Furthermore, companies can collaborate with local stakeholders to gain access to reliable distribution channels and deliver products and services. The U.S. and Germany have been major innovators and engineering developers in the downstream solar sector, and there will be strong solar system integrators (Morris, 2012). The downstream strategies do not only apply to EU or U.S. companies, but also to Chinese companies. China is a big potential market, and Chinese solar manufacturers have lowered the price. However, more expertise is needed to capture downstream value for local customers in China.

Very recently, SunPower from the U.S. announced a joint venture with solar-based companies from China to sell solar tech for efficient premium solar panels and trackers. The joint venture is focused on SunPower's new tracker and concentrator technology with rows of parabolic mirrors and 22.8% efficient solar cells. SunPower is going to put $15 million toward the $60 million joint venture (Fehrenbacher, 2012).

Considering the development in solar energy industry, policy and economic investment are the main drivers in the beginning. However, significant progress occurs after an important invention in technology. Technology or design plays a most important role in developing solar energy. Still, even when having the technology, it is very important not to make decisions based on the hype and the availability of subsidies, as happened in some rural areas of Bavaria in Germany, where in 2004 the world's largest solar power based power plant was built without taking into consideration that in that area, clear skies might only occur a few times each summer (Smil, 2012). The solar industry is facing critical challenges with decreasing subsidies. However, those players who strategically focus more on the downstream value and develop valuable propositions to target the needs of high-value customers will win.

4 El Hierro: confluence of factors

Islands are considered as paradises around the world, but they are facing considerable challenges in meeting their energy needs in a sustainable way. EURELECTRIC (2012) identifies five main characteristics of island energy production: small sized market, inconsistent regulation adopted from mainland regulations, low security of supply, difficulty to comply with future emissions requirements, and a total dependency on oil imports from the mainland.

For these reasons, islands are facing difficulties complying with emissions directives, such as the Large Combustion Plant Directive (LCPD), thus placing them on an unsustainable path (EURELECTRIC, 2012). The Industrial Emissions Directive (IED) allows an extension for small isolated systems obtaining less than 5% of their energy through the European grid, thus substantially benefiting islands. The extension requires them to fulfil the emission limit values by 31 December 2019, instead of 1 January 2016, the deadline for other areas (EURELECTRIC, 2012). Additionally an average increase in the energy demand of 24% is expected until 2020 (EURELECTRIC, 2012). Thus, alternative energy production methods will be needed in order to accomplish sustainable growth.

In the group of Canary Islands, it is located El Hierro, the first island in Europe to become 100% energy-sustainable only from clean energy resources (Marín et al., 2005). It is the smallest island in the group of Canary Islands, and it has an area of 278 km^2 and a population of 10,995 inhabitants[1]. The island's economic sectors in the past were sugar and wine exports; but from the beginning of the 20th century, the economy has been based on four main pillars: cattle raising, agriculture, fisheries and tourism. The tourism sector is showing a slow but continuous increase, and it is focused on attracting quality tourism that values the discovery of natural spaces, as opposed to mass tourism (Cabildo de El Hierro, 2006). The project is planned to

1 INE. Instituto Nacional de Estadística de España. National Statistics Institute of Spain

start a testing period in 2013, and afterwards, in the same year, to start working with normality connected to the network (Gorona del Viento, 2012).

This 100% sustainability will be possible because electricity will be produced by a hybrid system based on the combination of a windmill farm and a pumped-storage hydroelectric plant, using wind as the main source of electricity and the pumped-storage hydroelectric as an energy storage system. When the demand increases the production capacity, water is thrown down from the top deposit, enabling the production of energy from the turbines (Marín et al., 2005).

4.1 Drivers behind the change

Social drivers. The origins of this change go back 25 years, when the local population convinced the authorities to move towards a 100% sustainable island model (Guardian, 2011). In 1997, the local island government devised a sustainability plan and then revised the plan in 2006 (Cabildo de El Hierro, 2006). Between these years, UNESCO declared El Hierro as a world biosphere reserve (UNESCO, 2007), thus reinforcing the importance placed on the environment and accelerating the El Hierro Island Planning Regulations (Marín et al., 2005) (although also obligating the wind farm to meet stricter environmental requirements (Guardian, 2011)). Furthermore, environmental benefits became an important issue in the case of islands because in 2019 they will have to fulfil the requirements of the LCPD, as was introduced before. In the case of the hydro-wind system, the environmental benefits will be substantial and are summarized in Table 1.

Table 1. Environmental benefits of hydro-wind system (Marín et al., 2005; ABB, 2011)

Product	Saving (units/year)
Oil	6,000 tonnes – €1.8 million
CO2	18,200–19,000 tonnes
SO2	100 tonnes
NOx	400 tonnes
Particles	7 tonnes

Besides the social conviction that this sustainable development investing in clean technologies could be implemented in the island, another driver was the commitment to the primary sector as the main contribution to conserving the identity of the island, as stated by Padrón (2005).

Political drivers. Political drivers behind the change were focused on the potential market that islands represent for clean technologies, as areas where they can be successful, as well as the opportunity to use El Hierro case as a model and pilot test to export the idea to other islands. Concerning the potential market, it is good to consider that Europe has 659 islands, with a total population of 16.8 million people, varying from 50 inhabitants on the smallest island to 5 million inhabitants in Sicily; and the total world market is 100,000 islands with a population of 500 million people (Marín et al., 2005).

Focused on the future, another driver that facilitated moving towards clean technologies was the possibility of becoming a model for other regions with similar situations. Already when the execution of the project had not ended (it is planned to fully start in the current year 2013 (Gorona del Viento, 2012)), the European Union launched programmes to study the possibility of expanding this model (INRES[2] and DIREKT[3], for example). And recently it has already been included in the Spanish Programme of Special Actuations (2012), in which one aim is to promote internationally the island as a model for sustainable tourism and energy production.

Economic drivers. Economic drivers also played a large role in the push for El Hierro to build the hydro-wind system. However the economic drivers were not primarily related to energy, as would be expected. Instead a main economic driver was the need to increase tourism on the island. The island of El Hierro is more isolated and less developed than the main group of Canary Islands (including Gran Canaria) and thus draws less tourists. The hydro-wind system would both increase the brand image of the island and attract an estimated 1,000 new visitors a year. A tourist in the Canary Islands spends about €1,000 during a single trip (which averages 9 days in length). Thus the hydro-wind system could bring in an additional €1 million annually in tourism revenues to El Hierro.

The pure energy related economics of the system are also favourable (as shown in the economic analysis section of the case). However, a levelized cost of energy study was not performed until after construction had already begun and was performed independently by the University of Texas (Hallam et al., 2012). In other words, the planners did not initially study whether the system would be more economically efficient over its lifetime than the current diesel system. Furthermore, electricity generation on the island was already subsided by the Spanish government. Residents paid a tariff of last resort significantly less than the cost of generation, and the government reimbursed the energy company Endesa for losses. Thus, the pure energy economics was likely only a secondary consideration.

Another important economic driver was the low economic risk of the project. While a large initial capital investment of about €65 million for construction was required, about half of this investment was provided as subsidies by the EU and Spanish governments. Furthermore, since the operating cost of the system is not dependent on the price of oil, the future oil price volatility risk is mitigated.

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2 http://www.inresproject.eu/
3 http://www.direkt-project.eu/

This volatility risk is very problematic for El Hierro, and remote islands in general, because about half of their electricity is used for water desalinization. Thus a sudden price spike or oil shortage could also result in a serious water shortage.

Technological drivers. The technology implemented in this system is based on a wind farm and a hydro-pumping generating plant working together (Marín et al., 2005), and both technologies were already well-known and developed. This was reducing the risk in the technological innovation, and it focused the work on developing the system controlling all the involved sub-systems, with the aim to maintain stable the electricity provided to the network (ABB, 2011).

Parallel to this, other clean technologies were possible to adopt, such as desalination plants or clean transportation. Regarding water supply, it is reported by The Guardian (2011) that the whole system will power three desalinations plants and provide drinkable water for the population as well as water for irrigation, while also considering the 60,000 tourists that annually visit the island. Regarding the transport, the aim will be concentrated on replacing the 6,000 cars already existing on the island with electric vehicles (Guardian, 2011).

Economics of the total system. The economics of the hydro-wind system can be compared to the economics of the current diesel generation based system on El Hierro. Unsurprisingly, the two systems vary greatly in their initial capital investment and operational cost structures (as seen in Figures 5 and 6). The diesel system cost is highly dependent on the price of oil, which accounts for about 70% of its operational costs. The hydro-wind system is highly dependent on the cost of the initial construction work and electronic/mechanical components.

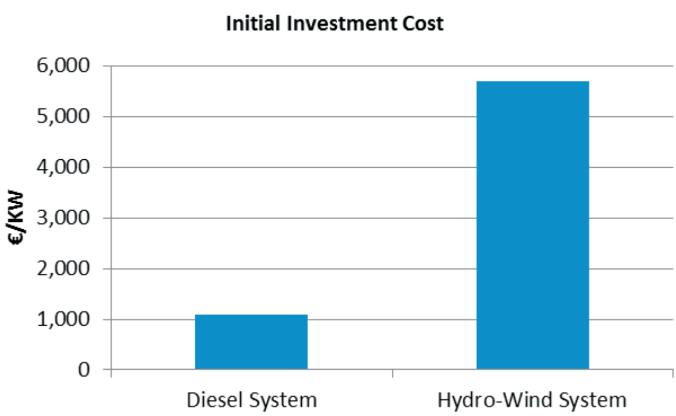

Fig. 5. Initial investment costs comparison (Hallam et al., 2012).

Hallam et al. (2012) studied the levelized cost of energy of the two systems and concluded that the hydro-wind system is more economical as long as the price of oil is greater than €30 a barrel. In other words, the economic crossover point between the two systems is €30 a barrel of oil. Historically, oil prices have been greater than €30 a barrel for almost the entirety of the last seven years, and prices are predicted to continue rising over the next decade. If the estimated emission costs of the CO_2 and nitrous oxide from the diesel system are also included in the analysis, then the cross-over point drops to €15 a barrel.

The purely economic advantage of the hydro-wind system is an important milestone for CleanTech systems in general. In fact, recent US Department of Energy levelized cost estimates provide a broader example. The estimates predict that an American on-shore wind plant entering service in 2017 will have a lower total levelized system cost per MWh than a similar conventional coal plant entering service in 2017 (US Energy Information Administration, 2012). (Although photovoltaic solar energy is still about 56% more expensive than conventional coal, the conventional coal plant cost also includes an assumed tax of about $15 per metric ton of CO_2 emissions).

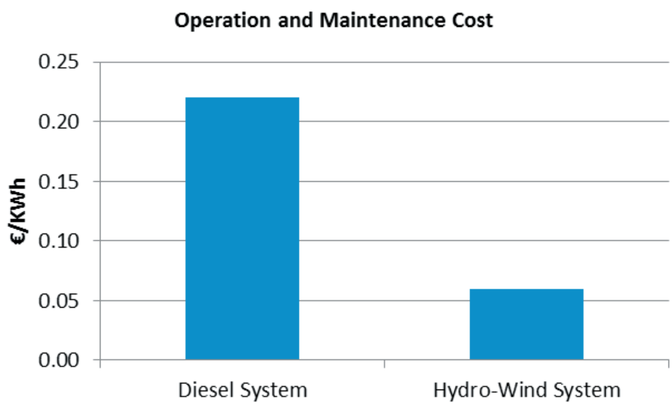

Fig. 6. Operation and maintenance costs comparison (Hallam et al., 2012).

5 Discussion

A brief comparison of the drivers of these different cases emphasizes that political and regulatory drivers remain integral to CleanTech. (Table 2 summarizes the most important drivers of each case.) Furthermore, the economic and social drivers that influenced the cases tended to be weak and dominated by the political and regulatory considerations. For example, the economic driver of the El Hierro hydro-wind plant was related to tourism rather than the economics of the system itself.

Table 2. Most important drivers of the CleanTech cases

Case	Economic	Social	Regulatory	Political
Sulphur Scrubbers	--	(Environmental and health concerns)	EU and IMO decisions	--
Solar Energy	--	--	--	Government Subsidies
Hydro-wind	(mainly for tourism value)	--	EU emissions directives	EU and Spanish funding

As hypothesized, in our view, these regulatory and political drivers and the lack of major economic and social drivers indicate that CleanTech is still in an early development stage and will not become a revolution in the next few years. In the future, significant social and economic drivers will need to become part of the equation.

These future economic drivers of CleanTech will likely be enabled through technological advances that make clean technologies cheaper and more competitive. The solar case showed how such technological advances are progressing rapidly in the area of photovoltaic efficiency. However, as mentioned, in purely economic terms, the total cost of energy of solar still lags behind other sources such as natural gas and wind. Although CleanTech has not yet replaced traditional means in energy production, rising energy prices are already giving birth to viable CleanTech solutions related to energy conservation.

The future social drivers of CleanTech will likely be more difficult to activate. For example, a major future social driver could be consumers buying higher priced environmentally friendly products in the open market. However, corporate managers currently see a significant disconnect between consumer attitudes toward environmentally friendly products and consumer buying behaviour. In the words of one manager, "There is a gap; there is a dissonance between what consumers say and what they do" (Sandhu et al., 2010).

Furthermore, instead of spending political legitimacy on regulation, governments could place more effort on raising environmental awareness through education, which could have a self-enforcing effect. This is already happening, as environmental studies are taking a larger part of the curriculum on all levels of the education system. Also the media has really taken up the agenda of sustainability in the last decade. Societal values change slowly, however, and social drivers will likely lose to economic drivers in importance in the short-term.

The individual cases also helped emphasize smaller targeted lessons that can help shape the discussion. The sulfur scrubber case emphasized that regulatory drivers still have an important place in targeted environmental areas. However, these regulatory drivers tend to create only end-of-pipe innovations that won't spur a significant CleanTech revolution. Furthermore, these regulations have to be crafted carefully or they can create national (or regional) competitive disadvantages that can spark political tensions. For example, as mentioned, the sulfur directive limits will take effect in the Baltic Sea five years before the Mediterranean Sea, thus creating a regional competitive disadvantage for countries that export through the Baltic.

The hydro-wind case emphasized that in certain areas the economics of CleanTech are even more favourable than current technologies. However, the economics of clean technologies in terms of capital and operational expenditures can be significantly different than currently used technologies. These economic differences can become a barrier to large-scale projects.

The solar energy case emphasized that significant technological progress had been made in some CleanTech areas (specifically photovoltaic). As mentioned, the progress can be seen in greatly increased efficiency rates. However the case also described the short-term political disputes (over subsidies, in this case) that can cause artificially higher prices.

6 Conclusions

Facing climate change, loss of biodiversity and other serious environmental concerns, it is easy to say that developing, adapting and diffusing CleanTech globally in the near future is a necessity. In addition to solving challenges related to ecological sustainability, CleanTech is seen especially by politicians in developed nations to provide a means to sustain economic growth. In this paper, it has been argued that in order to realize the desired transition from business as usual to CleanTech, attention must be paid to the drivers behind the change. Through examining and comparing three cases, it seems that regulatory and political drivers are still dominant over economic and social drivers. Although political support and regulatory action may help in the initial stages of the transition, economic and social drivers must strengthen in order for CleanTech to become a significant self-sustaining force.

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2.3 Creative industries and bit bang – how value is created in the digital age

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Abstract

Creative industries are based on individual creativity and skill, as opposed to traditional manufacturing and service industries, which are technology and process driven. Examples of high-impact creative industries include music, advertising and computer gaming. These industries play an increasingly important role in national economies worldwide. In this paper, we discuss how creative industries are structured, how they differ from more traditional industries and how digitalisation is changing the business models for these industries. In particular, the discussion explores several salient examples, including the music, computer gaming, newspaper and fashion industries. Based on the examples, we draw general conclusions about the future of creative industries. For example, we discuss how the traditional linear value chain is being transformed into a value network due to novel business models for the information age. Similar studies concentrate primarily on traditional products and their supply chains. Thus, there is a lack of information about creative industries available to support policy-making decisions in such areas as higher education or national investment planning. This paper helps fill in this information gap.

Keywords: creative industries, value chain, digital transition, music, fashion, newspaper, gaming

1 *Introduction*

Creativity is hard to define, but creative enterprises are as old as human civilisation itself. However, grouping together a broad class of activities under the rubric of creative industries, and treating them as producers of economic value, is a fairly recent innovation (DCMS, 1998). These industries generate tremendous value (UN, 2010), especially in the developed economies, and they possess some unique attributes that are different from those of the more traditional manufacturing or service sectors. For instance, their output relies on an individual or a group's creativity rather than on technology or business processes.

Creative industries are no exception to the fact that the proliferation of high technology, especially of the digital variety, is transforming almost all areas of human life. These technologies have changed the way products are made (e.g. the usage of CAD/CAM), the way services are provided (e.g. the use of the Internet to book hotels) and the way business is done in general (e.g. the use of email). Since the value generated by the creative industries is all about transforming already existing knowledge or information into novel forms, information technology is quite a natural tool to use in this sector and it is gradually (and in some cases, quite abruptly) transforming the dynamics of creative industries. For instance, until a few years ago the main focus of the advertising industry was on print or broadcast media. Now, due of the widespread adoption of the Internet and smart mobile phones, approximately 20% of global advertising spending goes to online businesses (Groupm, 2013).

In this paper, we study the disruption caused by digital technology in the creative industries. The most apparent implication of this disruption is in the way creative content is being distributed: the Internet has replaced traditional broadcast media like radio and TV to become the medium of choice for delivering entertainment and advertisements to consumers. We study a wide range of creative industries and try to predict the future changes. We also examine how the relationship between the different actors in the value chain is being transformed and the way in which the distribution of power among them is shifting. This shift may force traditional players to change their old roles and even open up avenues for the arrival of new players. Finally, we also discuss the implications of these changes with respect to national policy makers.

We begin by offering a definition of and explaining the characteristics of creative industries in Section 2. Then in Sections 3-6, we present case studies of different creative industries with a focus on the traditional business focus of such industries and the transformative effects of digitalisation. Based on these case studies, we summarise the trends going on in the creative sector in Section 7. Then we conclude by discussing the implications for policy makers in Section 8.

2 Creative industries

The UK Department of Culture Media and Sports (DCMS) defines creative industries as 'those industries which have their origin in individual creativity, skill and talent and which have a potential for wealth and job creation through the generation and exploitation of intellectual property' (DCMS, 1998). The UK is a representative case of a typical developed economy that has a large and vibrant creative sector and good historical data concerning the industry.

The DCMS includes advertising, architecture, art and antiques, computer games, crafts, design, designer fashion, film and video, music, performing arts, publishing, software, TV and radio as creative industries. According to a report published by the DCMS (2009), creative industries contributed 6.4% of gross value added (GVA) to the economy and have grown by 4% annually between 1997 and 2006 (while the whole economy grew by just 3%). The recession after the banking crises of 2008 had significantly less impact in many of these sectors compared to the rest of the economy. The success of creative industries is due to, among other things, a highly educated workforce, the large number of reputable educational institutions, the historic strength of copyright and intellectual property laws, and the proliferation of English as a global language. Almost all advanced economies have many of these characteristics, and therefore, could potentially emulate the success of the UK.

Creative products falling under the DCMS definition require some form of human ingenuity and involve the transformation and transmission of symbolic messages (information) that may have some utilitarian or aesthetic value. The artists create new products that the wider population is interested in consuming. This product is then produced on a large scale by some producer, which then goes through the distribution and retail phases before it reaches the end consumer. So a four-stage value chain can be proposed (Figure 1), which models the path through which a creative product successively acquires value. In real-life situations, though, the different parts of the value chain may not be as clearly separated from one another, as we will see in the various cases presented in the next sections.

Fig. 1. Creative industry value chain

Traditional products, such as manufactured goods (cars, mobile phones) or services (legal counselling, a cup of coffee) often have a somewhat similar value chain. For those products, the early part of the chain consists of R&D, product design and other intangible value-adding activities. Obviously, these activities do not lack creativity; lots of creativity is needed when, for example, new products are designed. The difference is that successful organisations can complete such tasks independent of a particular creative individual due to advanced processes and the nature of the product or service. Creative industry products, on the other hand, are crucially dependent on the individual; such an individual might be a music composer or book author. Yet, the value chain for a creative product could resemble a straight line or an inverse U: traditionally, the producer captured the most value and not the product (in contrast to, for example, manufacturing, where the value chain is more of a U shape) (Figure 2). Another key difference between traditional and creative industries is in the product itself: a traditional product has specifications or drawings, and it can be incrementally improved and reverse-engineered; creative products are much more 'blurry' in this sense.

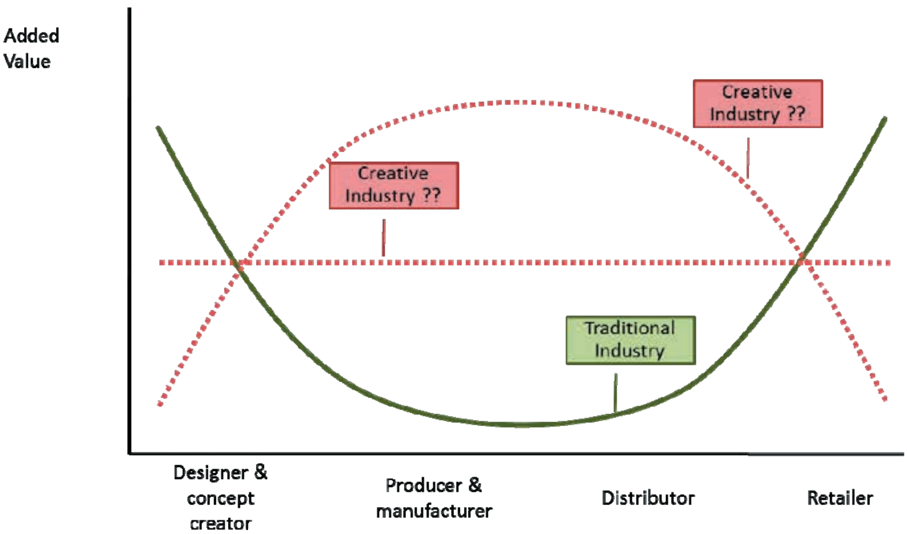

Fig. 2. Value chains for a traditional industry and a creative industry (Deng, 2011)

Due to the rapid developments in digital and ICT technologies, the linear value chain no longer captures the essence of the working dynamics of creative industries. To get a more complete picture, a more complicated 'ecology' of creative industries (Figure 3) may be considered, which is more representative of the complex and dynamic relationship between creators, distributors, service providers and consumers. The free flow of digital data makes immediate feedback possible from each stage to the previous stage, leading to the cross-fertilisation of ideas and co-creation of content by the creators and the consumers. We can take the example of the music industry, where creators and artists in the music industry who traditionally relied on the producers (who had the market information) to get their products to the consumers (and, therefore, followed the linear model) are now increasingly using digital and social media to test the market themselves and interact with different market players; this makes it possible for them to distribute musical content without the need for a traditional 'middle man'.

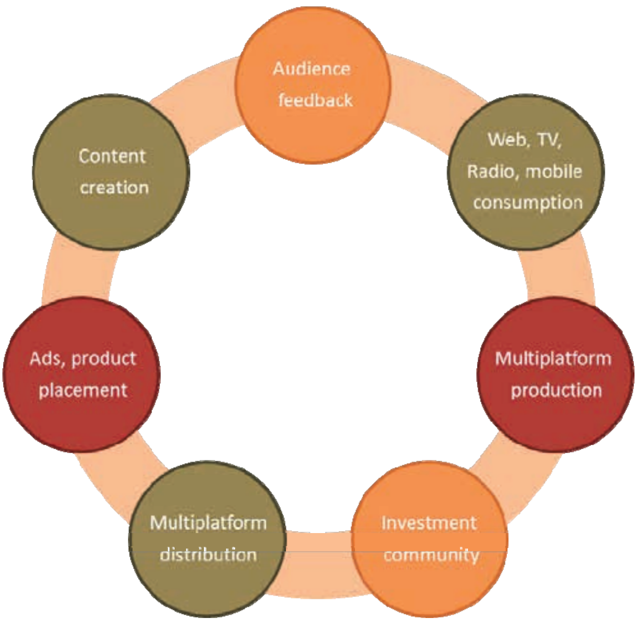

Fig. 3. Creative industry ecology

We utilised a classification system proposed by the Technology Strategy Board, UK (TSB 2009), which divides creative contents in three groups — services, content and artefacts — as shown in Figure 4. They can be further classified based on whether they generate digital output and whether modern technology helps with the production. The economic value of a creative product increases depending on the extent to which digital technology is used to produce the product, since products then become easy to reproduce (massively scalable) and distribute to a wider audience (compare the DVD sales of movies to ticket sales for theatre musicals). Moreover, the extent to which high technology is used when creating the product also increases the value of the product (radio and TV shows generate more revenue than arts and crafts). A clear implication is that the more digital a creative product is, and the more dependent it is on high technology, the more technology-driven disruptions it will face in the future. Therefore, such industries need to modify their business model by taking into the account the effect of digitalisation.

We selected industries with varying degrees of digitalisation in order to observe the impact of technology. Music and newspapers (or the publishing industry in general) existed long before the advent of the digital age, but they have already faced abrupt changes due to technological innovations and are now facing further disruptions. The use of technology in the fashion industry is a recent phenomenon and the observations from other industries may help us predict where it may be headed in the next few years. The computer games industry is the child of the digital age; it relies entirely upon digital technology for production and distribution, and therefore, it provides a good case study for the industry, which may go 'all digital' in the future.

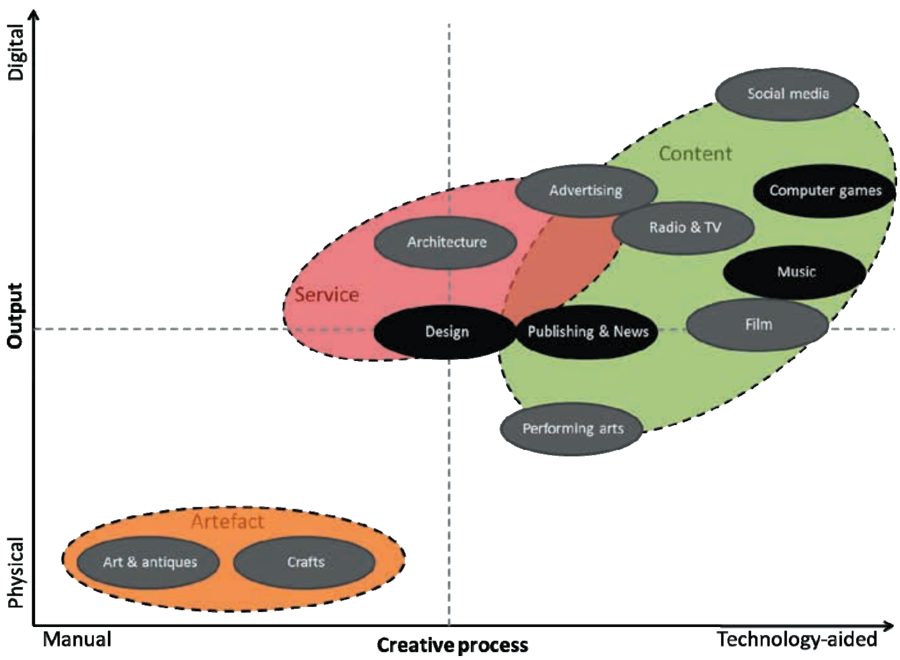

Fig. 4. Classification of creative industries

3 Music industry

Music products are known to virtually everyone throughout the world, and most consumers above the poverty line consume musical products annually — if not directly by buying records or live performance tickets, then by purchasing products that somehow support the music industry (e.g. a new cellular phone). The music industry is difficult to define accurately: Williamson and Cloonan (2007) promote the idea of plural music industries and present different ways to categorise different sectors within the music industry. For example, they have identified eight relevant sectors in a study from Scotland: artists, composers and orchestras, live music, recording, media, other creative services, ancillary services, education and retail.

3.1 Traditional value chain

We focus on four key players: authors (including composers and publishers, who are often the same person or company), performing artists, producers (record labels, concert promoters) and retailers (both physical and online retailers). According to various studies and the experts we interviewed (see acknowledgements section), three revenue streams dominate the industry:

- Live performances
- Recorded music (CDs, online music)
- Copyrighted and broadcasted music (radio stations, the Internet, events)

How the key players in the industry take advantage of these different forms of revenue is discussed by Meisel and Sullivan (2002) and illustrated in Figure 5.

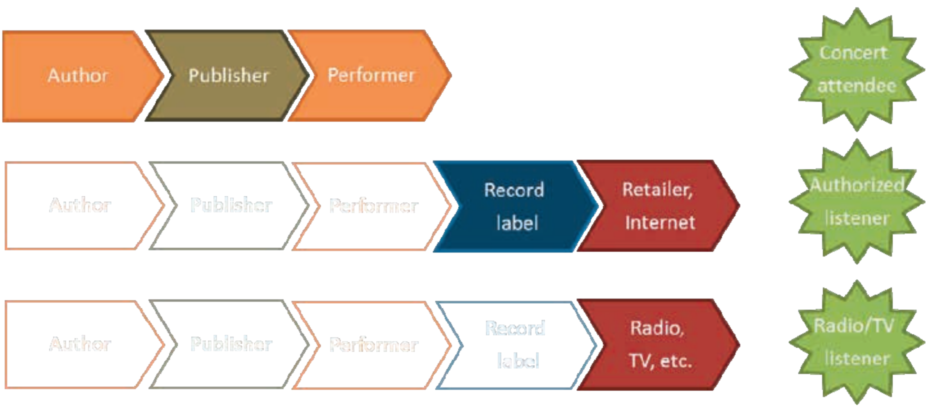

Fig. 5. Simplified value chain for the music industry (modified from Meisel and Sullivan, 2002)

Consumer markets vary globally and, in general, it is difficult to obtain accurate data from the music industry. Thus, we restrict our analysis to illustrative examples. A breakdown of industry revenues in France (Brousseau, 2008) and Finland (Tolppanen and Tuomainen, 2012) is presented in Figure 6. The Finnish artists that we interviewed confirmed that these figures look reasonable, albeit their personal income included a significant number of copyrights, since they also compose music. According to all of our sources, the general trend is that, a) the music industry is growing, or at least it is not shrinking, and that b) increasingly more revenue is being generated by live performances (and also merchandise sales in the case of big artists) and less by record sales.

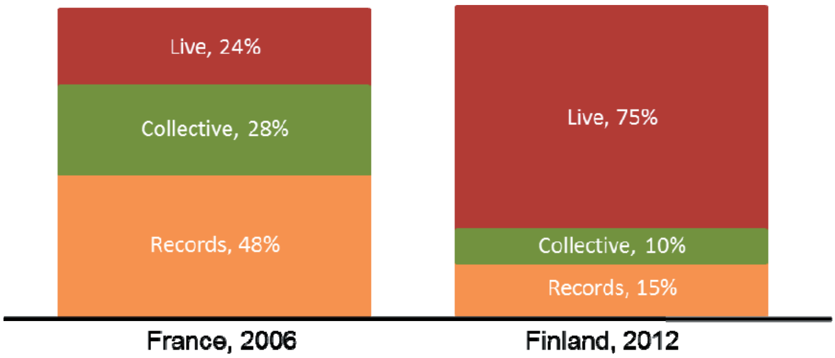

Fig. 6. Breakdown of revenue in the music industry

The trend of diminishing record sales has had a large impact on the traditional music value chain because different players are dependent on different revenue streams. For example, Brousseau (2008) calculated that 94% of record companies' revenue comes from record sales, so they are justifiably worried about the decreasing number of CD sales. Artists on the other hand get 75% of their revenue from live performances. One of our interviewees noted that for many artists, state support is also a critical source of revenue. Another interviewee pointed out that even though records do not play a major role in revenue generation, they are nevertheless key products for marketing purposes. In any case, artists' revenue does not depend so much on record sales (at least directly). And authors get a lion's share of their revenues from the collective management system (copyrights) and a mere 17% from record sales. In summary, whereas record labels and retailers had previously been able to capture some 60%-80% of the value of every CD sold, now they are losing ground as CD sales are declining.

3.2 Digital transformation and the new role of record labels

Previously, record labels were the most powerful players in the industry because they were able to make risky investments in new artists and finance their business with the sales of hit records. The investments were needed because producing a master record, manufacturing CDs (cassettes, LPs), distributing, marketing and communicating with concert promoters are very costly for individual artists or publishers. New technologies, the Internet and the digitalisation of music in particular are changing this business model rapidly.

Meisel and Sullivan (2002) list the potential causes of the disruptions in the music industry as a result of digitalisation: a) it revolutionises manufacturing and the distribution of music, b) it lowers the threshold for illegal distribution (piracy), c) it disrupts traditional radio broadcasts (Internet radio, streaming services), and d) it orients artists more towards live performances due to the revenue sharing logic explained before. Despite these threats, our interviewees argue that record labels are still needed: while creating and distributing music has become significantly easier for publishers and performers, they are increasingly dependent upon the promotion and marketing channels of record labels. Also, the expertise of record labels in the international music business is unique, and it cannot be readily replaced by any other player. It seems that record labels with their vast digital eco-systems are still the best way for mainstream artists to promote their music. Lately, according to one interviewee, record companies have enhanced their role as live performance promoters.

Brousseau (2008) also points out that even though very large digital-age companies, such as device manufacturers (Apple, Nokia), ISPs (Sonera, Vodafone) or on-line retailers (Amazon, Apple), are increasingly interested in the music industry, they use music as a 'loss leader' to accelerate the sales of products in their core areas. Thus, they probably will not have an interest in mastering the music industry, but rather they might be the potential customers of record labels, since they can sell their knowledge to these giant companies.

The role of online sales systems is rather twofold: according to an estimate by one website called 'The Cynical Musician' (http://thecynicalmusician.com/2010/01/the-paradise-that-should-have-been/), the sale of a traditional (full-album) CD is equivalent to 1.08 full-album sales in an online CD store (physical product), 12.7 single-track downloads in Amazon or iTunes and approximately 2000 plays in Spotify. This means that an artist living on a minimum monthly wage of $1160 would need to sell either 1800 single-track downloads in iTunes or Amazon or reach the level of more than a million monthly plays in Spotify. While these figures seem somewhat disappointing — and were confirmed by the artists that we interviewed — one needs to remember that artists' revenue comes mostly from live performances (and possibly copyrights). In addition, many positive developments can be seen in music digitalisation: according to the recording industry IFPI (2012), 'The music industry has grasped the opportunities of the digital world in a way few, if any, other businesses can claim to have done. Our digital revenues, at one third of industry income (and now more than 50 per cent in the US), substantially surpass those of other creative industries, such as films, books and newspapers.' For example, there are encouraging developments in Asia, where the digital music market in South Korea has more than 3 million active users, or in China, where the Internet search giant Baidu has established a new digital music offering with three major record companies.

All in all, the music industry is facing a transformation where the balance of power in market transactions is shifting towards consumers, artists and new entrants into the digital age and away from the record companies. Still, as our interviewees consistently brought up, record companies are essential for the industry, for all of the reasons specified above.

3.3 Future of the music industry

As Meisel and Sullivan noted in 2002, 'business as usual in the music industry is over'. In saying this, they were referring to the rise of MP3s and new distribution channels and some fundamental changes in the industry, such as the change of the typical sales unit from a full album (LP) to a single track. This development is sometimes called Music 2.0, and it still is, as became apparent in our interviews, highly topical and relevant for people in the industry. However, one of our interviewees also brought up the point of how the 'business as usual' idea is changing again: this time it is being called Music 3.0, which represents a more disruptive development.

Music 3.0 refers to an industry model where anyone can become a content creator. This development is strongly driven by various Internet-based services where consumers, artists, song writers and creative people in general can create and share content online (see, for example, soundation.com), for the most part without the traditional 'middle man', the record label. In this environment, the content might be free for the consumer, and the revenues can come from, for example, advertising. YouTube represents this kind of a channel. A recent article in the *Guardian* (Lindvall, 2013) explains how songwriters and artists can claim rights to cover songs and other YouTube videos that make use of their copyrighted music. They can also dictate what kinds of ads are displayed during the videos, which can impact their revenue stream significantly. There are even publishers who have hired a person to promote their songs to cover bands and other potential content producers. This kind of revenue sharing ecosystem is clearly very different from the traditional one.

In conclusion, the digitalisation wave is bringing new revenue streams to the industry, and the value chain in these cases is very different from the traditional value chain. Some features of this development include: i) treating music as a service instead of a product (e.g. subscription-based web platforms, live music as a service), ii) providing free content to promote another product (mobile phones, websites), iii) the increasing number of new production platforms and co-creation of music (soundation.com), and iv) the presence of an increasingly scattered market, where finding a new niche can represent a big opportunity for profits (e.g. Muve Music, which is a subscription service for consumers without computers and credit cards).

4 Fashion industry

The fashion industry is a modern industry, which emerged as part of the new technologies and factory system of the late 19th century. Before the mid-19th century, most clothing was either custom made at home or ordered from tailors; by the 20th century, clothing had become a mass-produced, standard-sized and fixed-priced product. Today, the fashion industry is significantly important: for example, the fashion industry in the UK is the largest employer out of all the creative industries, directly employing 816,000 people (Fox, 2010). In Finland, textile and clothing production employs approximately 5,000 people and the industry accounts for 293 mil. € (Tilastokeskus, 2011).

The fashion industry is characterised by short product life cycles, volatile and unpredictable demand with a high level of impulse buying, tremendous product variety, long and inflexible supply processes, high initial capital dependency and strong value chain interdependency (Sen, 2008; Diges, 2010). The globalisation of trade and industry, new technologies and changing values and attitudes are accelerating the continuous changes within the fashion industry. As a result of the tightening competition in the clothing industry, the number of collections offered each year to consumers has increased significantly, and the design process has changed to continuously and flexibly adapt to the needs and tastes of customers (Abecassis-Moedas, 2006). Companies are encouraged to increase their flexibility, invest in new technologies, adopt new production methods, renew their organisational structures and specialise (Kauppinen, 2006; Gereffi, 1999).

In Finland, the number of fashion industry actors has been decreasing since the recession in the 1990s, and meanwhile the importation of clothes has increased drastically (from 800 million euros in 1998 to 1300 million euros in 2008). However, small innovative companies have been founded during the last decade, especially in southern Finland. Entrepreneurship is supported on the strategy level, but the general attitude towards the fashion industry is still rather sceptical (Diges, 2010). It has also been suggested that future consumer values, such as individuality, eco-friendliness, locality, ethicality, durability, safety and recycling, might change the fashion industry; individuality and higher prices will be valued more as a counterweight to mass consumption. Also, the importance of surveying production will become more important as consumers increasingly want to know about the background of the product, and therefore the transparency and ethicality of the production chain will be a competitive advantage for companies (Tissari, 2008; Diges, 2010).

4.1 Traditional fashion industry

The clothing value chain is a buyer-driven commodity chain, which means that retailers and brand-name merchandisers are the key players, with design and marketing being the key activities that deliver profit (Diges, 2010). According to Godart (2009), the main producer in the fashion is the fashion house, which is typically composed of a team of fashion designers. Producers in fashion combine inputs from suppliers to create fashion designs and items. The suppliers are textile and clothing manufacturers who use raw materials to produce clothing items. Fashion design teams and related professionals working for fashion houses select and combine clothing items, cultural symbols and the identities of the fashion models to create the fashion designs that are displayed in fashion shows and magazines. These fashion designs are in turn incorporated within fashion items that are diffused to customers through retailers, and feedback is provided by customers to producers. This process is illustrated in Figure 7.

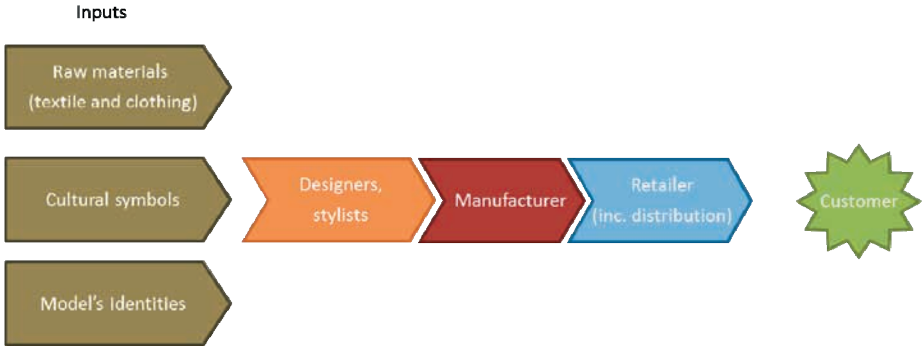

Fig. 7. The production process in the fashion system (Adapted from Godart, 2009)

The feedback gained from the sales of similar products is important, and this requires collaboration between retailers and manufacturers (for cases in which the designer does not have their own stores). Sen (2008) highlights the on-going vertical integration taking place in the fashion industry, which makes it more difficult to distinguish between retailers and manufacturers. Retailers have internalised the design process, while designers (ex-manufacturers) have kept the design in-house, outsourced the manufacturing process and internalised retail. Retailers have access to sales feedback, and removing one of the intermediaries makes it possible for retailers to save on lead time.

4.2 Digital transition

With the emergence of the Internet and the advances in information technologies, many companies in the apparel supply chain have begun to conduct their business online. Electronic commerce is divided into two categories: business-to-consumer commerce and business-to-business commerce. Online sales of apparel began in the mid-1990s (for example Amazon.com in 2002). The importance of multi-channel retailing is increasing: the three retailing channels are stores, websites and catalogues. In 2006, online apparel sales accounted for only 4.3% of sales, but they have been growing significantly each year. B2B applications are not only limited to trading online; companies are also looking for ways to collaborate with their supply chain partners over the Internet (Sen, 2008).

Coordination between retailers and manufacturers is required for product orders and for replenishing the stock of clothing, and this can be facilitated by electronic data interchange. Also, product lifecycle management technologies aim to improve communications throughout the supply chain during the product development process. The new product design process in the clothing industry needs to be flexible and take into account the latest fashion trends and sales feedback. The use of computer-aided design tools, which internalise a large part of the technical skills, increases the flexibility of the process, reducing the time needed to make patterns and enabling electronic storage of the design, which makes later modifications and transmissions easy (Abecassis-Moedas, 2006; Sen, 2008).

There is also an increasing need to engage customers during the design process, which can be seen in the mass-customisation phenomenon ranging from made-to-measure shirts to the online mass customisation of all products. The idea to integrate users into the design and production process is a promising strategy for companies that are being forced to react to the growing individualisation of demand. It is about by-passing retailers and making the final customer the designer (Piller et al., 2003).

4.3 Future trends

The increase in the amount of electronic communication has raised customer's expectations about the availability of fast and easy customer service. Small and flexible companies might have better possibilities to provide services to customers because they can more easily change their practices according to customer and market needs (Salonen, 2009). Products that need to be fitted will, however, impose challenges for electronic commerce, but with help of new technologies, such as virtual fitting applications, these challenges can be overcome. For example, the Estonian start-up Fits.me charts information about the user's physiques and then shows how the clothing would look on the user's body type (Kauppalehti, 2010).

While mass customisation is not a new phenomenon, the increasing number of digitalised experiences provided by, for example, Facebook and the development of digital tools might have reached an inflection point. Several brands are inviting their customers to participate in the design process by adding personal letters or colours (e.g. Louis Vuitton, Prada, Rickshaw, Denim Refinery), while some brands, for example Burberry, are going even further, letting the consumer order customised clothes by choosing the styles, fabrics, colours, buttons, studs and other parameters (The Business of Fashion, 2011). An innovative service is also being provided by Nomo Jeans: the customer is able to choose the cut, colour, effects and numerous other details for the jeans in the store, after which precise measurements are taken of the customer with a 3D body scanner. The price always remains the same and the customer can choose how much he/she is willing to participate in the design process (NOMO).

In the fashion industry, information about customer behaviour is power, and this power has been increasingly accumulating among retailers who can directly observe customer tastes and preferences. However, because of the rise of electronic commerce, information about a customer's taste is no longer only in the hands of the retailers; instead, it can be received by the brands/designers themselves. In the future, this might lead to significant changes in the value chain and the distribution of power, decreasing the importance of or even eliminating the need for retailers. However, some customer preferences and habits might change only slowly (for example, customers might still want to see the products and try them on before buying them), and it remains to be seen what kinds of changes will occur in the future distribution channels and to what extent digitalisation will revolutionise the fashion industry.

5 Newspaper industry

The newspaper is a storied medium that remains widespread throughout the world and that has shaped public opinion for centuries. However, the newspaper industry itself is in a significant period of transition with an uncertain future due in part to the effects of digitalisation.

5.1 Traditional newspaper value capture

The value chain for the traditional physical newspaper model has been well documented (OECD, 2010; Vogel, 2010). In essence, traditional newspapers deliver value to consumers through their collection and aggregation of highly relevant news into a coherent package. Traditional newspaper activities include editorial work (content creation and editing), advertising, printing and distribution. Some of these activities, such as printing and distribution, are typically outsourced to other companies. For example, printing in the US has become increasingly concentrated in larger regional factories that print several different newspapers daily (Callaghan, 2011). In terms of cost, Figure 8 displays the cost structure of a typical UK newspaper.

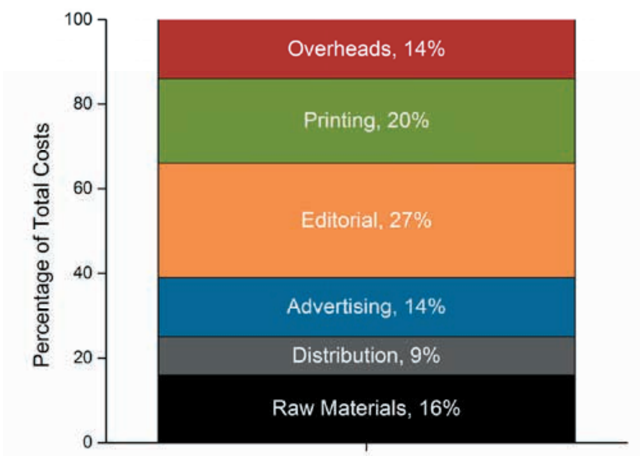

Fig. 8. Cost structure of a typical UK newspaper (Enders, 2011)

The costs associated exclusively with physical newspaper production include raw materials (newsprint and ink), printing and distribution. Interestingly, these costs make up about 45% of total newspaper costs. Thus, the transition to digital distribution could result in significant cost savings for traditional newspapers.

In terms of revenues, traditional newspapers derive their revenues from both advertising and circulation (the selling of newspaper subscriptions or newsstand issues). The revenue split between advertising and circulation is highly country dependent and varies from between 85% (advertising) and 15% (circulation) to a 50%-50% split for each (OECD, 2010).

5.2 Digital transition

Advances in ICT technologies and widespread Internet penetration have had widespread consequences for the industry (Picard, 2011). The two largest effects have been the rise of digital distribution and the rise of targeted Internet-based advertising.

Digital distribution means that newspapers can now be consumed on many different devices and in almost any location, thus broadening the potential reach of papers. Furthermore, as mentioned previously, digital distribution could significantly reduce physical production costs. However, the increase in targeted Internet-based advertising has more than offset any gains resulting from digital distribution methods. Targeted Internet advertising means that advertisers can focus on a specific audience that they want to reach (with, for instance, Google AdWords), which was difficult to do with advertising in general newspapers. Ominously, in H1 2012 Google's advertising revenues for the first time surpassed the print advertising revenues of the entire US print media industry (all newspaper and magazines combined) (Richter, 2012).

Consequently, the fundamental revenue model of many newspapers is changing. For example, the revenue mix of US newspapers has shifted from being historically about 80% advertising and 20% circulation to (in some cases) being 50% for each source. Again, this shift has occurred primarily because of large revenue losses in print advertising and the failure of digital advertising revenues to make up for these losses. Figure 9 shows the aggregate print and online advertising revenues of American newspapers for the last several years.

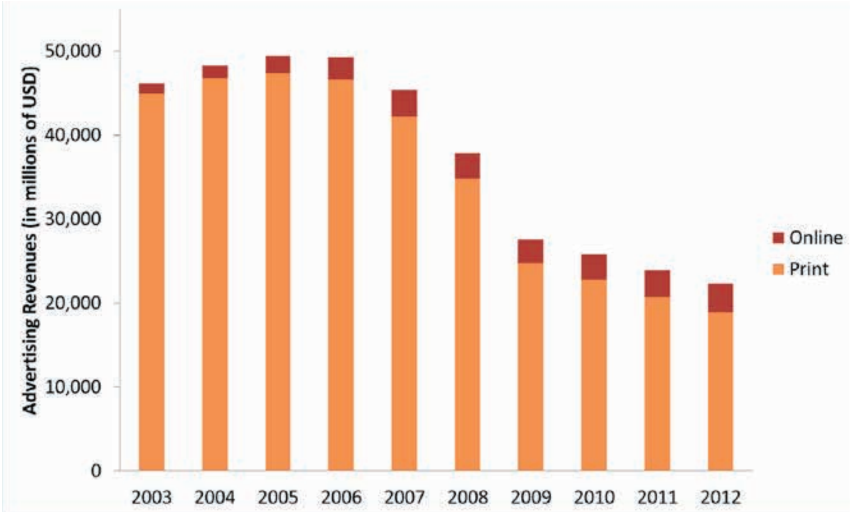

Fig. 9. Print and online advertising revenues for US newspapers, 2003–2012 (Pew Research Center, 2013)

The Pew Research Center (2013) estimates a ratio of 16-to-1 for print advertising losses in relation to digital advertising gains in 2012. Furthermore, print circulation revenues have only managed to remain stable because newspapers have significantly raised their prices in the face of falling print circulation volumes. Figure 10 depicts the national weekday print circulation and newsstand price of *The New York Times*, which serves as a salient example.

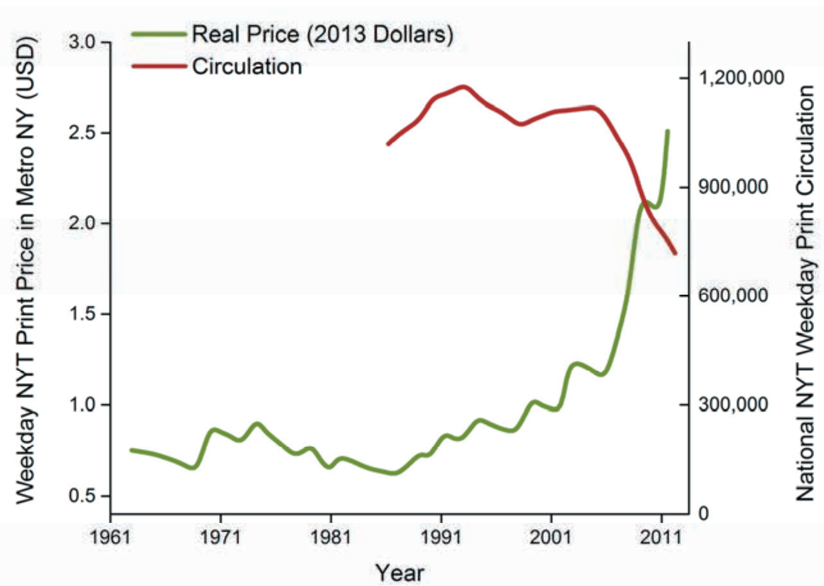

Fig. 10. Weekday NYT Real Price (in Metro NY) and Circulation (NY Times, 1961-2013)

As print advertising losses mount, newspapers are turning to digital paywalls to help monetise online content (Pew Research Center, 2013). The most popular type of paywall, the metered paywall, allows access to a fixed number of articles in a month and then requires a paid digital subscription to read more. Interestingly, about 20% of total US newspaper circulation is now digital (Haughney, 2013). In effect, newspapers are relying more on selling their actual edited content rather than selling the attention of their readers.

Newspapers are also looking to boost online reader engagement since online readers tend to spend much less time reading news than readers of physical newspapers, and engagement metrics are very important for driving digital advertising revenues. Varian (2010) reports that an average physical newspaper reader spends about 25 minutes a day with a newspaper, whereas a typical online visit only lasts for about 4.5 minutes. The fastest-growing engagement features include self-produced video, which is now being used by 95% of the top 100 newspapers in the US, and reader comment sections for articles, which is being used by 96% of the top 100 newspapers (Heater et al., 2013). Table 1 summarises the largest ICT-enabled changes, the effect of the changes and the current estimated magnitude of the impact on the traditional newspaper industry in general.

Table 1. ICT-enabled changes, effects and current impact magnitude on the traditional newspaper industry

ICT-enabled change	Effect	Impact on industry (+ or -)
Digital distribution	Production cost savings	+
Digital distribution	Potential to expand geographic reach	+
Rise of targeted Internet advertising	Loss of advertising revenue	----
Internet-enabled mass content production	Loss of content differentiation	--
Internet-enabled mass content production	Low willingness to pay for Internet-based content (free model)	---

5.3 Future trends

The types of trends affecting the newspaper industry (especially falling revenue and the loss of differentiation) will likely cause simultaneous consolidation and specialisation. Newspapers with the strongest global brands will look to expand into other mediums and become more like general media companies with strong reader engagement and loyalty. In contrast, small newspapers will look to specialise by concentrating more on local news and decreasing their national and international coverage.

Media companies with a significant stake in the newspaper business will look to merge or divest in order to realise cost savings.

In summary, the confluence of all these factors will result in a significantly different news landscape in which more people than ever will have access to news, but arguably the quality and reliability of news will decrease. A key future question is whether governments will expand their support for newspapers that engage in hard news reporting given the role of an impartial press and informed citizenry in modern democratic societies. Citizens will have to pressure their governments to increase support, though this seems unlikely given the current level of government cost consciousness.

6 Gaming industry

Next, we will analyse the gaming industry and concentrate on computer and video games; other related industries, such gambling and board or card games, will be excluded from the analysis. Compared to the other industries that we discuss in this paper, this industrial sector is peculiar in that it is the only media sector that has been using a digital format since the beginning (Hiltunen and Latva, 2011).

Laird (2005) situates the beginning of the gaming industry in the 1950s if we are also taking into account simple games such as 'Tennis for Two' or 'TicTacToe'. In the 1970s, arcade games were born and Atari was introduced to the market, which led to an expansion of the gaming industry in the late 1970s. In 1980s, Nintendo was founded and the boom in computers started with brands such as Macintosh, Amiga, Commodore and IBM. In the 1990s, PC and console gaming increased dramatically. Also in the late 1990's, mobile gaming experienced a boom.

Considering this background, two value chains will be discussed next: the traditional value chain and the evolutionary value chain. The first chain will consider the pre-Internet period, while the second one will analyse how the computer and video game value chain has changed with the rise of Internet-based technologies.

6.1 Traditional publisher-driven model

Four principal actors can be identified in the traditional value chain: the game developer, the publisher, the distributor and the retailer. The game developer was in charge of creating the game, and the main actor in this model was the publisher, who was in charge of marketing the game and assuming more risks. For this reason, Hiltunen and Latva (2011) refer to it as a publisher-driven model. A typical example of this kind of model is the Super Mario Bros game, which was published and developed by Nintendo and sold more than 40 million copies (The Telegraph, 2008)

When looking to the value chain, Hiltunen and Latva (2011) situate the revenue share in the range of 8-15% for Finnish game developers and in the range of 85-92%

for publishers, distributors and retailers. Ferrara (2009) reports the share distribution among the actors as 37.3% for the developer, 49.3% for the publisher and 13.4% for the retailing companies, based on total revenues of $67 million. Vogel (2011) reports a revenue share of 15% for the developer, 47.5% for the publisher and 12.5% for the distributor, but also mentions a 20% share for the retailer and a 5% share for the licensor, an actor not considered in any of the other sources. Each of the studies makes the point that the main role of publishers in capturing the value of a product. Figure 11 provides a graphic illustration of a publisher-driven value chain and also shows how the authors mentioned above conceive of the distribution of value along the chain.

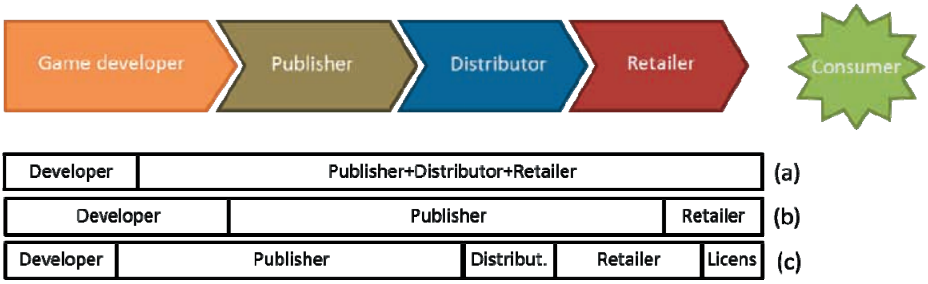

Fig. 11. Traditional value chain for the gaming industry (Hiltunen and Latva, 2010; Ferrara, 2009; Vogel, 2011)

6.2 Digital transition

Digital distribution began with the music industry when the mp3 format was launched in 1997 (Robertson, 2012). After this, digital distribution became more and more important, including the distribution of video games in 2004 with Direct2Drive, the first digital retail store (Robertson, 2012). To this day, according to Perry (2008), 29 different business models can be identified in the gaming industry. Digital distribution has changed the business dramatically: in the US, one third of all games were purchased online in 2011 (Entertainment Software Association, 2011), whereas in Finland half of the game consumers used online tools to purchase a video game in 2010 (34% from an online store and 16% downloaded from the Internet) (Sotamaa and Karppi, 2010).

Digital distribution has had a large impact on many parts of the value chain. In particular, it has led to collaborations between developers and distributors that are not at all transparent, as Johns (2006) mentions. Johns (2006) continues by saying that even though this opacity makes it more difficult to find individual figures, the collective revenue share of developers and publishers is 40%. Hiltunen and Latva (2011) report a value of 70% for the collective revenue share of Finnish developers and publishers. Figure 12 shows how Hiltunen and Latva (2011) conceive of the value chain; the transition colour between the game developer and the publisher indicates the level of collaboration, based on the information presented by Johns (2006).

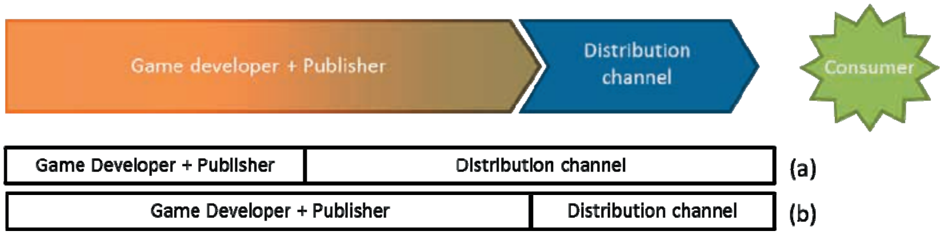

Fig. 12. Digital distribution value chain for the gaming industry (Johns, 2011; Hiltunen and Latva, 2010)

Another factor impacting the video gaming industry has been the evolution of 'Massive Multi-Player Online Games' (MMOGs) (Johns, 2006). MMOGs have grown into platforms that can support many players at one time and that also offer the possibility for game developers to access a wider audience and distribute at low cost. In 2006, more than half a million players took part in MMGO games such Everquest and Dark Age of Camelot (Johns, 2006). Everquest is a good example of this impact, since in 2006 it had more than 430,000 players; it integrated the developer, publisher, distributor and retailer into the same platform, where they could interact and make it possible to open new distribution opportunities for developers and publishers (Johns, 2006).

According to the International Telecommunication Union (2011), almost 40% of the world's population uses the Internet and the penetration of mobile phones is almost 100%. Thus, the future of the gaming industry is bright.

6.3 Future trends

One clear impact of digitalisation on the gaming industry is that it has connected the developer and the end user without the need for any intermediary. In this way, a new opportunity called 'Game as a Service' has been identified by, for example, Sotamaa and Karppi (2010) and Bagga (2011). This development refers to the establishment of a permanent relationship between the developer and the end user (Sotamaa and Karppi, 2010), and it makes it possible for the end user and developer to co-produce a game by creating the storyline, the rules, the patterns, the visuals, and so forth (Huotari and Hamari, 2012).

Related to the previous trend, developers and end users have recently begun using the games in other environments and to find solutions across disciplines; this trend is called 'gamification' (Huotari and Hamari, 2012) or 'serious games' (Annetta, 2008). Recently, the Finnish Funding Agency for Technology and Innovation identified it as a clear future trend (TEKES, 2011). Originating in 2003 (Annetta, 2008), this approach nowadays ranges from simple ideas, such as integrating the progress bar at LinkedIn in order to measure people's progress when filling in personal details (Huotari and Hamari, 2012), to much broader aspects, such as learning in schools, corporate training, military training or for medical purposes (Annetta, 2008; TEKES, 2011).

In the area of corporate training, Havenstein (2008) mentions a report from Forrester Research Inc, which mentions the importance that many companies such as Volvo or Hilton Hotels give to video games when training their employees to carry out certain tasks. Examples in the field of education range from simple applications, such the game *10 monkeys,* which was designed to teach mathematics to 6-10 year old kids (Anderson, 2013), to more complex applications, such *Immune Attack*, which is used to teach complex biology and immunology to students, or Food Force, a game created by the United Nations World Food Program with the objective of being able to better distribute food in a country affected by scarcity.

7 Summary of the cases

As illustrated by the cases, while creative industries differ quite a bit from one another, they do share some common features. We summarise the finding from our case studies in Table 2. Unsurprisingly, digitalisation has already impacted the traditional business models of all the industries (except perhaps that of gaming). Furthermore, digital technology has aided in creating and distributing the new digital content. Finally, in most of the cases, the widespread adoption of the Internet has allowed for a smooth flow of information from the consumers to the creators, thereby creating new business opportunities.

Table 2. A summary of the different creative industries

Industry	Current state	Impact of digitalisation	Future opportunities
Music	Sources of income are changing; record labels are losing power	Sinking CD sales; rise of e-distribution; cheaper to produce	Music as co-product; collaborative online composition sites; music as a service
Fashion	Globalisation and new technologies are increasing the amount of competition; short life-cycles of products require flexibility	Increase of e-commerce; use of computer-aided design, integrating the user into the design	Good opportunities for small and flexible companies; new methods for mass-customisation and e-commerce,(e.g. online fitting, direct feedback connection with customers)
Newspaper	Falling revenues; increasing competition from the Internet and TV; shrinking and consolidating industry	Huge loss of advertising revenues; eventual physical production cost savings	Potential to broaden audience and circulation revenues through digital subscriptions
Gaming	Increasing synergies between developer and publisher	E-distribution; direct connection between developer and end user	Game as a service — long-term relationship; gamification and serious games; cross-disciplinary use of games

As a general trend, there is a shift of value from the middle actors (publishers and retailers) to the creators (those designing the clothes, composing the music, developing the game or writing the news). This is supported by the changes in the value chains analysed in this article: as an example, record labels used to be the dominant players in the music value chain, even though they are not responsible for the creative content in music. Through digitisation, they are losing this power and thus they need to develop new value-adding activities to remain vital in the value chain.

In a recently published analysis, Künstner et al. (2013) argue that in the creative sector, the established business models for middle players (publishers and distributors) have become obsolete, and value has shifted to the creation, marketing and consumption steps. Figure 13 illustrates this shift.

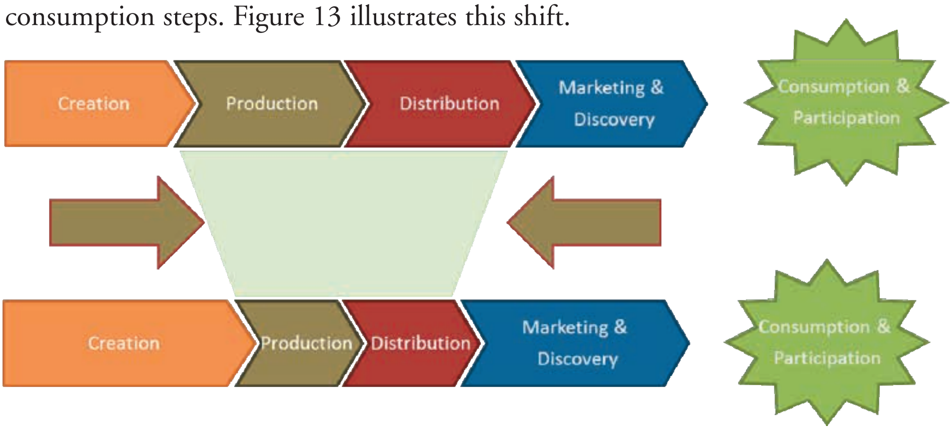

Fig. 13. Shift of power in the creative industries (shrinking role of intermediaries)

Künstner et al. (2013) also identify another future shift that we witnessed in our cases. Namely, until quite recently the value chain has been largely organised horizontally. Due to digitalisation, this structure is becoming obsolete, and in many industries the value chain of the future resembles more a network-based model, as illustrated in Figure 14. In this way, collaboration between all of the actors involved in the creative ecosystem will increase and new ways of creating value will emerge. As an example, the gaming industry has witnessed an increasing dialogue between game developers and end customers where customers (players) can also participate in the actual development process by providing content and suggesting new ideas ('user innovation'). Indeed, Künstner et al. (2013) predict that crowdsourcing will contribute to this shift from a linear value chain to a network value chain, which nowadays is still in its early stages, and it will blur the distinction between creators and consumers.

Another major trend across the creative industries is the increasing role of content discovery, classification and selection services (content aggregation). As digitalisation is making it easier to generate content, the amount of creative content (music, games, news, etc.) is increasing rapidly. Thus, consumers are increasingly dependent on content aggregators that filter this content for their purposes. In the music industry, this role used to be managed by radio stations or record stores. Now, there are plenty of Internet sites, Spotify applications and user-generated YouTube playlists that are being used for the same purpose. Furthermore, specialised news aggregators are replacing newspaper editorial work by using complex algorithms to predict news relevance for users. Another relevant phenomenon is the blogosphere, which serves as a fashion content classifier in the fashion industry.

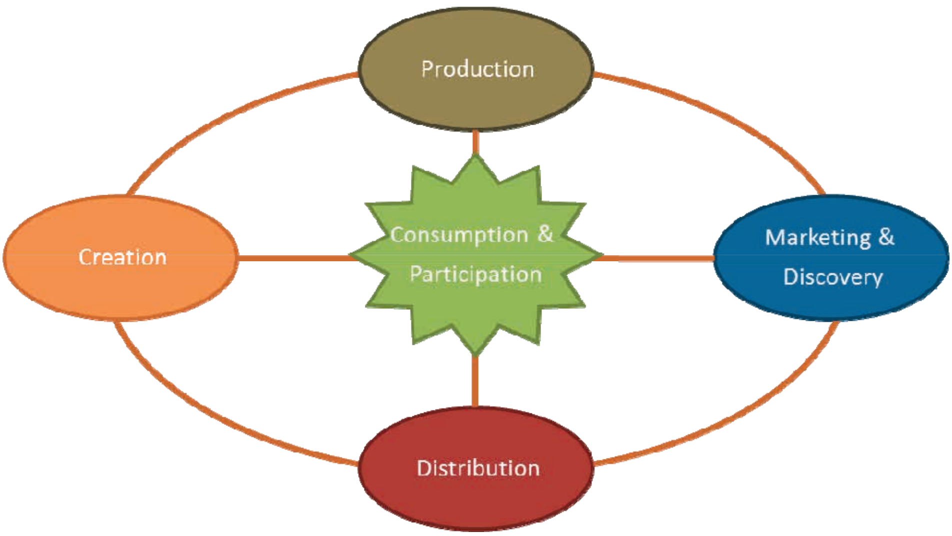

Fig. 14. Network-based ecology of creative industry's components

In some of our sample industries, new business models have shown that the way in which copyrights are managed is in many ways obsolete. Examples include the already mentioned news portals that collect content from other content providers and the utilisation of copyrighted material in YouTube videos. These have led to discussions about the extent to which copyrights apply and what should be free on the Internet, as well as how the original artist can earn his share of, for example, Internet advertisement revenues. It seems that there is a need for systemic and global copyright reform that better fits needs of the digital world.

8 Conclusions

The aim of this paper was to shed light on the dynamics of creative industries and to help the reader understand the future outlook of these industries. Creative industries are not economically very significant. For instance, the UK is a music superpower but the music industry there accounts for a mere 0.2% of the total GDP (PRS, 2011). Other industries, such as traditional services and manufacturing, are and will remain dominant (in an economic sense). However, the importance of creative content is expected to grow in the digital age, and traditional industries are increasingly benefiting from this creative content. As an example, design and architecture are vital to the traditional construction business, music content is extensively bundled with consumer electronics and the hit game Angry Birds is used to promote soft drinks, detergents and coffee mugs. This multiplicative use of creative products and knowledge makes these industries particularly interesting for a wide audience. Arguably, a nation with lots of creative buzz can utilise the output of creative industries to promote more traditional products, and thus understanding creative industries should be on the agenda for national-level policy makers and a wide array of industrial players, too.

Another factor that speaks for the importance of these industries is their position on the digitalisation frontier. New ideas, trends and technologies diffuse very quickly in industries such as music or gaming. If homemade hip-hop beats can be developed into commercial hits with the help of experts through an online portal, why wouldn't the same be possible in the case of new design for an everyday tool or an idea for a new type of elderly treatment? Creative industries can provide a way to follow and learn for those in more traditional and slower-moving industries.

As mentioned above, creative industries are not the prime motors for economic growth. However, they do have potential for job creation in the form of entrepreneurship. Establishing a company in the areas of food services, gadget manufacturing or financial services is impossible for most people due to the capital requirements. In the creative industries of the digital era, the cost of founding a company is typically small: to produce film, one only needs a modern digital camera, a microphone and a laptop (at the cost of a few thousand euros), whereas a laptop is the only necessity for becoming a freelance designer. Of course, these will not in most cases become growth companies, but there is potential in creative industries when it comes to employment policy. Something can also be learned from the business models in creative industries when considering ways to employ citizens for other industries, such as construction or elderly care.

Also, we would like to emphasise the large cultural impact of creative industries on society. Many industries do a great job of contributing to a nation's economy, but for the ordinary citizen they offer nothing more than tax money. Many creative industries, on the other hand, play an important recreational role. They are also building blocks for national identity. In this sense, it is an imperative that political decision makers keep creative industries vital. We argue that this is possible and that they can also have a greater economic impact than they currently do.

Finally, we would like to mention some future research topics. First, there seems to only be a limited amount of industry data available for creative industries compared to many other industries. It would be extremely helpful if industry statistics would be collected in a systematic manner and stored in an open database. The creative industries in different countries could then be compared and the geographical differences between them better understood. Second, it is not clear whether creative industries should be supported by governments. On the one hand, they are companies just like any other company, but on the other hand, they have special roles related to, for example, recreation or being a watchdog of democracy (newspapers, literature). Third, in the digital age controlling piracy is a must for many creative industries. Thus, the role of copyrights should be studied in detail and new models should be developed to manage copyrights. Related to this topic, there is emerging research in the area of automating creative content. While this seems to go against the very definition of creativity, it merits further study.

Acknowledgments. We would like to thank Sami Huhtinen (music industry allrounder), Ilari Kivelä (songwriter/artist, Pariisin Kevät), Torsti Mäkinen (songwriter/artist, Lovex) and Kirsi Snellman (researcher with a great deal of experience in collaborative creative processes and entrepreneurial processes in the music industry) for their valuable responses to e-mail interviews conducted in March, 2013. We also would like to thank Suvi Latva from NeoGames and Harri Kuusela from Hermia for their contribution in providing the report on The Finnish Games Industry (2010-2011).

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2.4 The stuff that dreams are made of – REEs and other strategic minerals as a national asset

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Abstract

Rare earth elements (REEs) are needed for numerous critical applications from energy production and storage to defence and telecommunications. The demand of some of the elements already exceeds their supply. China is practically the sole supplier of REEs globally, but other countries are looking for ways to gain a foothold in the value chain. This paper discusses the changes that are happening in the traditional REE value chain, focusing especially on recycling, replacement and new sources. The

implications of these changes are discussed in the form of REE strategies that have been formulated for Europe and emerging nations.

Keywords: rare earth elements, rare earth minerals, metals recycling, replacement, asteroid mining, deep sea mining

1 Introduction

In the course of human history, technological progress has created a demand for previously uninteresting materials. For example, with the rise of the semiconductor industry, silicon, previously used industrially only as a building material in its unrefined forms, became significantly important and was suddenly needed in unprecedented levels of purity. In recent years, technological innovations have resulted in a great number of applications that need rare earth elements (REEs), leading to a great increase in their demand. Partly due to their rapid miniaturisation, modern electronic devices and their components require materials with very specific physical properties, such as high electric polarisability or capacitance, or a combination of transparency and high electric conductivity. Many of these properties are found in a group of elements collectively called REEs.[1] While not technically REEs, certain other metals with a limited and geographically uneven supply, such as indium and rarer noble metals such as palladium, share their strategic importance.

The first REEs were discovered in rare oxide minerals from the Swedish village of Ytterby in 1787. The first mineral was called ytterbite, but in 1800 it was renamed *gadolinite* after the Finnish Academy professor Johan Gadolin. Within a century, all 16 REEs had been discovered, but there were no applications for them and they were not important outside of scientific curiosity. The first technological applications for REEs were identified in the 1950s, and they began to be industrially mined and produced immediately afterwards. REEs have critical uses in energy production and storage as, for example, permanent magnets or in biomedical engineering and optics, underlining their importance for modern society. A great amount of the growing demand is from so-called 'green technologies', which aim to lower energy consumption, provide renewable sources of energy and prevent and control air pollution. An exemplary list of applications is presented in Table 1. Without a stable supply of REEs, the existing defence, aviation, telecommunications, consumer electronics and clean technology industries that are an essential of our information-age society would simply not be able to function.

1 When defined strictly, the following elements are counted in REEs: scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Outside of the scientific literature, it is not uncommon to refer to certain other metals, such as indium, as 'rare earths' or 'rare earth metals'.

Table 1. End use applications of REEs

Rare earths' applications	REEs	Growth drivers
Magnets	Nd, Pr, Dy, Tb, Sm	Hybrid vehicle electric motors Electronic power steering Other small electric motors Air conditioners Generators Hard disc drives
NiMH Batteries	La, Ce, Pr, Nd	Hybrid vehicle batteries Rechargeable batteries
Auto Catalysis	Ce, La, Nd	Gasoline and hybrids, diesel fuel additive Tightening of automotive emission standards globally
Fluid Cracking Catalysis	La, Ce, Pr, Nd	Oil production Increased use of sour oils
Phosphors	Eu, Y, Tb, La, Dy, Ce, Pr, Gd	LCD TVs and monitors Plasma TVs and displays Energy-efficient compact fluorescent lights
Polishing Powders	Ce, La, Pr, mixed	LCD TVs and monitors Plasma TVs and displays Silicon wafers and chips
Glass additives	Ce, La, Nd, Er, Gd, Yb	Optical glass for digital camera Fibre optics

The demand for REEs results in a combination of different metals. The demand for each individual metal is related to its end uses and to the demand for specific products. Some elements are being used for several end uses and some for one end use only. The profitability of mining and production of REEs depends on the total demand for the element group, not the demand for individual element.

The known supply of global REE resources is approximately 110 million tons, and China by far has the largest share of these resources (Table 2). There are concerns that the demand for some individual REEs, such as neodymium, praseodymium, dysprosium, terbium, lanthanum, yttrium and europium, will exceed their supply within only a few years. This has made it necessary to open new mines and explore new places, such as the ocean floor, as well as increase the amount of materials that are recycled. The combined rapid growth in global demand and supply shortages, triggered by Chinese export restrictions, has led, and is expected to further lead to, a significant increase in REE prices.

Table 2. Distribution of REE resources (Source: U.S. Geological Survey, 2013)

Country / region	**Share (%)**
China	> 50
Russia (CIS)	17
United States	12
India	3
Australia	2
Rest of the world	16
Total world	100

The aim of this chapter is to shed some light on the current supply chain for REEs and to discuss the implications of some of the changes taking place. In the next section we describe the current value chain and its economic and political meaning. We also take a look at the historical development of REEs, that is, how China gained its central position in the market. In the third section we describe the changes that are taking place in the value chain. We focus especially on the recycling of REEs as a necessity, on substituting or replacing REEs as a possibility and on asteroid and deep sea mining as alternatives. Based on these future trends, we draft REE strategies for Europe and emerging nations. We chose to focus on Europe and emerging nations because they do not seem to have elaborate plans for securing their supply of REEs in the future. We predict that recycling in particular will grow in importance in the coming decades and open up new possibilities for numerous countries and regions. We then present our conclusions in the fifth and final section.

2 The past and present

Rare earth elements are moderately abundant in the Earth's crust, however they are not concentrated enough to make them easily exploitable economically. Although both economic and marginally economic reserves in China account for approximately half of the world's total supply, 97% of the world's supply of rare earth elements can be found in China (Humphries, 2012).The supply chain for these strategic elements is highly concentrated in one nation, and, more importantly, the nation itself is a huge consumer of the same elements. Today, the shortage of supply and the uncontrollability of the supply chain are becoming major headaches for developed countries.

In this section, we explore the background to the current situation, starting with a brief historical survey in Section 2.1. In the first section, the trade policies and regulations of the major REE stakeholders, such as China, will be discussed. Then in Section 2.2, the current value chain for REEs is explained and the impacts of environmental regulations on mining and processing are discussed briefly. Various implications of the current value chain from a policymaker's perspective are discussed in Section 2.3. Section 2.4 discusses the geographical distributions of past, present and future mining fields. The current geopolitical situation and its implications will also be explored in Section 2.5.

2.1 The historical development

India and Brazil were the world's major exporters of REMs[2] (rare earth metals) until the 1940s. From the 1960s to the 1980s, the United States was the dominant world producer, with the majority of the US's production being extracted from Mountain Pass, California (U.S. Geological Survey, 2013). China's production of rare earths took off in the early 1980s, and by 1988 it had moved past the US to become the world's leading REM producer, as can be seen in Figure 1. In addition to owning approximately 30% of the world's reserves, China's rise to the position of top producer was partly due to its early investments in R&D for mining, selecting, dressing and separating techniques (Information Office of the State Council P.R.C., 2012). It was also partly the result of its cheap labour supply and lax environmental laws. As China has further solidified its top position, the world's REM prices have drastically decreased, while at the same time the mining of REM has significantly increased (Blakely et al., 2012). As of 2010, only China, Russia, India, Brazil and Malaysia were known to be actively mining earth metals. China remains the world's leading producer, and in 2009 the country extracted 97.4 per cent of the world's REMs. Russia currently ranks second with only 2,500 tons of REMs or two per cent of the world's rare earth production. India, Brazil and Malaysia combined produced only 0.56 per cent of the world's supply of REMs. The trade policy in China has meant that the price of REMs is typically 20-40% lower in its domestic markets than on the international market. In addition to other barriers related to mining techniques, a sharp fall in world prices due to changes in Chinese policies made investing in the rare earth's industry outside China non-competitive. Since 2007, China has been imposing export taxes and restrictions on REE exports to guarantee a supply for its domestic market and also as a result of environmental issues (Korinek, 2010). There is significant concern, especially in the West, that China is using its monopoly power to influence international affairs (Blakely et al., 2012).

2 The terms rare earth elements (REEs) and rare earth metals (REMs) are used interchangeably in this report.

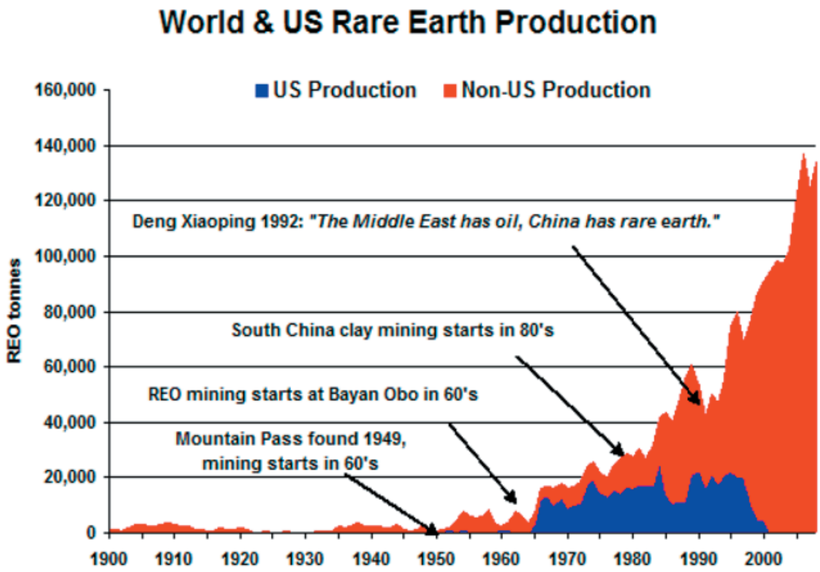

Fig. 1. Historical production of rare earth oxides (REOs) (ca. 1900-2010) (Source: U.S. Geological Survey, 2011)

2.2 The current REE value chain

Despite the name, there is no shortage of REE deposits, even though they are valuable because they fill a niche in the market (Christmann, 2013). Most of the added value in the REE value chain is concentrated downstream from its supply chain. Merely discovering a deposit and mining the minerals does not add value to the elements. Even just producing concentrates of bastnasite and monazite does not provide much added value to the elements, since the market is not interested in the particular form of the REE. Most REEs around the globe are in the form of bastnasite and monazite. They are minerals with the formula (Ce, La) CO3 (F,OH) and (Ce, La, Nd, Th) PO4, respectively (Humphries, 2012). The market cannot use REEs as monazite and bastnasite concentrates; they need to be converted into phosphor powders that can be used for producing final products such as video screens, energy-saving light bulbs and permanent magnets (Christmann, 2013). Therefore, the majority of the added value goes to those producers that can produce what is in high demand on the market, which is phosphorus powder. To produce phosphorus powder from the ores, producers need access to cutting-edge technology; the REEs need to be separated from the ore and purified, and the ore can sometime contain more than sixteen mixed elements (GWMG, 2013). Therefore, only those producers that own the most advanced hydro- or pyrometallurgy techniques can perform the separation and purification processes and actually gain the most out of the value chain.

The main activities that currently add value to REEs on a global scale can be categorised as exploration, mining, mineral processing, separation, metal making and alloy making (GWMG, 2013). The added value of REEs increases when it moves from upstream to downstream (Figure 2). Logistical activities are not considered in the above value chain, and thus they will not be analysed further. However, it should be kept in mind that due to the geographical scattering of the production and consumption, a certain amount of value is added by transportation and logistical activities, even though it is still negligible compared with the added value in the rest of the chain. As already mentioned, the current value chain revolves around the mining of REEs. We argue, however, that recycling and component reuse will have a tremendous impact on the entire structure of the value chain in the future. This will be discussed further in Section 3.

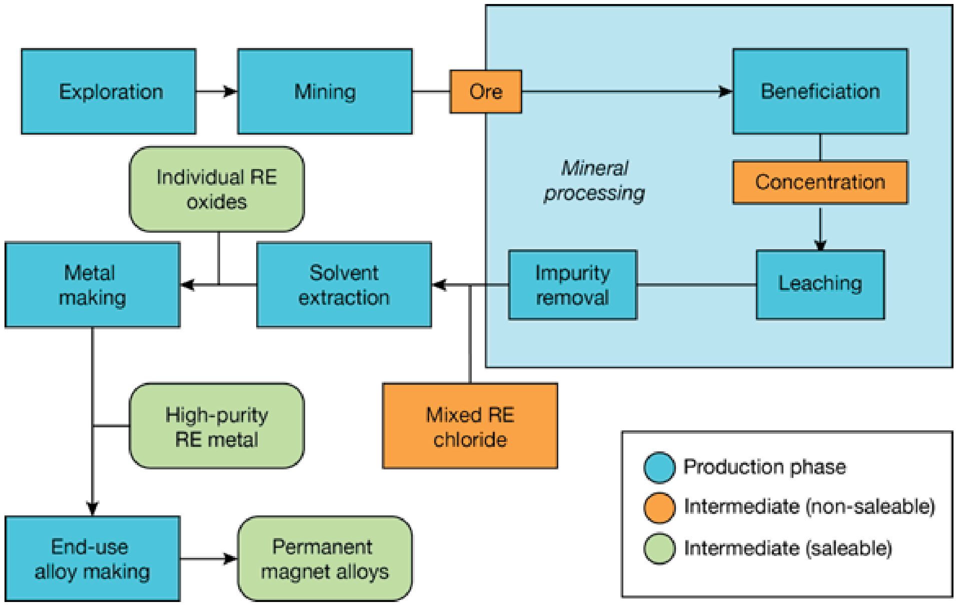

Fig. 2. The current value chain for REEs (Source: GWMG, 2013)

Exploration and mining. Globally, more than 250 companies are currently exploring the sites that contain REEs (GWMG, 2013). In this case, mining has to do with either extracting the ores from the surface or from underground mines using different methods. After the exploration phase, sites that contain economically justifiable amounts of REE will be mined. However, REEs often occur as a by-product when mining for other elements, such as copper, gold, uranium, phosphates and iron (Humphries, 2012). The sites are considered economical to mine based on the current demand and price of REEs on the market, the available and required technology for mining the REEs, and the amount of remaining deposits at the site. Most of China's REE deposits are low in radiation, and therefore, have advantage of being safer to extract than in other countries, which may have ores with REEs that are extremely radioactive.

Processing. Processing has to do with extracting the minerals from the ores and increasing the REE concentration using physical and chemical techniques. The chemicals used in this process contain acids or bases that make the processing phase the most detrimental part for the environment. Producing one ton of REEs creates on average 60 000 m3 of gases mixed with sulphuric and hydrofluoric acid, 200 m3 of acid water and 1.4 tons of radioactive waste (Blakely et al., 2012). Usually, processing consists of two phases known as the beneficiation and leaching phases. The beneficiation phase consists of three other phases: crushing, milling and concentration. At the end of the beneficiation phase, a concentrated mineral that is produced using different techniques, such as gravity, magnetic and flotation techniques, is delivered for leaching. In the leaching phase, the mineral concentrate will be transferred to a liquid sulphate, nitrate or chloride containing mixed REEs in the same proportions as in the ore. The markets for such mixed REEs are rare since most end consumers use separate oxides of individual elements. Therefore, the product produced during this phase needs to be more purified by separating the REEs (GWMG, 2013).

Separation. The product produced during the mineral process, which contains mixed REEs, will go to a separation phase to be purified via a so-called solvent extraction process. At this stage, the REEs are separated from each other. The products from this and further stages can be sold on the market (Blakely et al., 2012; GWMG, 2013).

Metal and alloy making. Using methods such as electrolysis or metallothermic reduction, the separated REEs are converted into high purity metals (e.g. Nd metal) or rare earth alloys (e.g. mischmetal or ferro-alloys) (GWMG, 2013). At this stage, the metal alloys from REEs are combined with other metals like iron or aluminium to create alloys that can be used in different industries, like ‘super alloys’ of aluminium that can be used in the aerospace industry, or permanent magnet alloys such as neodymium-iron-boron (NdFeB) or samarium-cobalt (SmCo), which are used to produced permanent magnets (GWMG, 2013).

2.3 Implications of the current REE value chain

As explained earlier, the high-tech processes in the last stages of the value chain contribute the most added value to REEs. Thus, countries like China that own most of the REE deposits (Humphries, 2012) will not benefit much from the REE value chain unless they get involved in the last stages of the value chain, namely separation and metal and alloy making. Nowadays, China has put restrictions on the export of such REEs as ore or mixed concentrates in order to encourage investments in the technology required for the latest links of the value chain and to improve the downstream value chain segments inside the country (Christmann, 2013). This is because, in the future, no matter how many deposits a company owns, the added value will belong to those who possess the technology to produce or recycle the high-demand, near-final or final REE products. Even though environmental reasoning has always been used by governments all over the world as a means for justifying the restriction on trade at different points in time, and even though China has already been able to place restrictions on the export of REEs for environmental reasons (Moreland, 2012), when cleaner processes and technologies emerge in connection with new and advanced mining and metallurgical practices China will not be able to continue restricting the export of REEs. Thus, China needs to develop the required technology in due time, before Western countries overtake it.

Currently, the patent for separating and processing REEs is in the hands of two corporate giants: GM and Hitachi (Christmann, 2013). Nevertheless, with the recent level of investments in mining and metallurgical sciences in Asia, and more specifically in China, it is expected that more efficient and cleaner processes will be introduced in the near future for separating and processing REEs, which may then take the patenting advantage out of the hands of the West. Even if Europe and the US increase their research funding for related topics, and even though they currently possess the knowledge for REE production, this still raises a vital question: What will happen if China does not let the main "artery" of the REEs go? It can be argued that the REE industry is heavily oriented towards mining, which means that China as the biggest supplier of REEs has the control of the primary supply of REEs and thus is able to dictate who can produce products utilising REEs and where they can be produced. If this is true, then even the countries that have the required technology cannot gain from the REE's value chain without China's approval. Nonetheless, China cannot restrict the export of REEs for environmental reasons forever. As mentioned previously, upcoming cleaner mining and processing technologies are in sight. If those technologies become applicable, then maintaining the restriction on the export of REEs will not be politically cheap for China. Besides, maintaining restrictions on the exports of REEs, together with increase in demand (Humphries, 2012), will increase the price of REEs. Thus, given future cleaner mining and processing technologies, it will becomes economically viable and environmentally reasonable to mine the less rich deposits around the globe and not just those located in China. Moreover, if the price of REEs keeps increasing due to China's restrictions on exports, alternatives will soon be found for products that use REEs, which may make the possession of REE deposits strategically less important.

All in all, given the current situation, countries that own some REE deposits are looking to gain most of the added value at the last stages of the REE value chain. Nevertheless, there are significant barriers to enter the rare earths market as a new producer (Korinek, 2010):

- The processing technology is specific to each ore body,
- A new mining operation typically takes ten years or more to establish,

- There is aggressive competition (especially price dumping) on the market,
- High capital cost: typically more than USD 30,000 per ton of annual separated capacity,
- Marketing is customer specific — rare earths are not traded on any recognised exchange,
- Limited operational expertise outside China,
- The industry is dominated by China, where input costs are low.

2.4 Geographical distribution of REEs

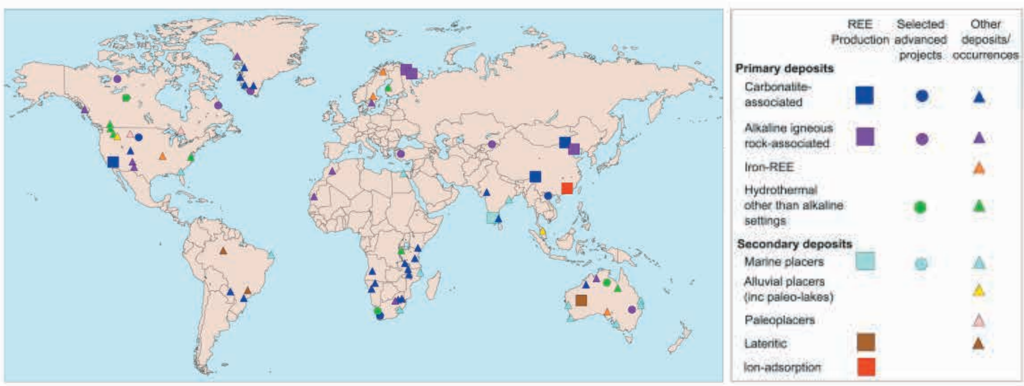

Fig. 3. Global distribution of REMs (British Geological Survey, 2011a)

Because of their geochemical properties, REEs are typically dispersed in the Earth's crust and not found in concentrated deposits. REEs are found in concentrations high enough for production to be economically viable in placer sands, lateritic clays and certain minerals. All of these sources are geologically common and found around the globe; for instance, lateritic and ion-adsorption clays cover most of the land area between the tropics and are also found in Central and Western Europe. The global distribution of REEs is illustrated in Figure 3.

The principal rare-earth-containing minerals currently being mined include bastnasite (Mountain Pass in the USA and multiple locations in China), monazite (Kerala and Orissa in India) and loparite (the Kola Peninsula in Russia). Xenotime, an yttrium-rich mineral, is also being mined in conjunction with tin in Malaysia. Because they can be processed using straightforward aqueous solution techniques, rare-earth-bearing clays are an especially attractive source of REEs. For geological reasons, their distribution is restricted to interior and marginal regions of the continents or related to large-scale rift structures. Global areas with this specific geology include South China, where all of the current production of clays takes place, but also the East African rift zones, northern Scandinavia and the Kola Peninsula, and eastern Canada and southern Brazil.

China dominates the entire supply chain and is the only exporter of commercial quantities of REEs. It also possesses a large share of the manufacturing business, where it, for example, produces 75% of the world's neodymium magnets, a crucial component in hybrid and electric cars. Also, Chinese companies have started to invest abroad in REM production, particularly in Australia.

2.5 On the politics of REEs

In a recent overview paper on the politics of REEs, Dobransky (2012) touches on an important issue: the lack of social scientific studies on the subject of REEs. Whereas there have been plenty of technical studies describing, for example, the mining of REEs, the policy implications of the rising demand and narrowing supply have not received similar academic attention. This can be seen as problematic for two interrelated reasons: first, the political impact of China's domination of the REE market remains vague, and second, the debate on the subject in the popular media of developed countries revolves around a speculative threat discourse.

In terms of the latter problem, REEs have become a hot topic among journalists in recent years, which, given their importance, is a good thing. But the discussion is heavily concentrated on pointing out looming dangers. In just the last year, typical examples of this perspective include the social (The Guardian, 07.08.2012) and environmental (*The Guardian*, 31.7.2012) un-sustainability of mining, REE availability constituting a bottleneck for the growth of renewable industries (*The Economist*, 17.03.2012) and the threat of REEs to free trade (*The New York Times*, 13.03.2012). Although the discourse shares many features with topics such as oil and sweet water, there are unique features in the discussion surrounding REEs.

China dominates 50% of the global resources but 97% of the world trade. This dominance by China in the REE supply chain is worrying many countries, especially in the West. The concerns, however, are not without justification. It is not uncommon that countries use their position of dominance in terms of natural resources as a political instrument in their foreign policies. OPEC countries, for example, fixed the price of oil behind closed doors, sometimes for political reasons, such as the 1973 energy crisis. China has started to noticeably limit its production and export of REMs using quotas and export tariffs. The reasons given by the government are the conservation of rare earth resources and environmental protection. Those reasons are within the legitimate rights of a sovereign country and are also reasonable.

Nevertheless, China's September 2010 restriction on exporting REMs to Japan as leverage in a bilateral conflict with the Japanese government raised concern for the national security of developed countries. In the East China Sea, there is an uninhabited chain of islands called the Senkaku Islands in Japanese and the Diaoyu Islands in Chinese. These islands are controlled by Japan, even though both the People's Republic of China and the Republic of China (Taiwan) also claim ownership. On the morning of 7 September 2010, a Chinese trawler operating in disputed waters collided with a Japanese coast guard's patrol boat, which resulted in a major diplomatic dispute between China and Japan. After refusing to release the Chinese skipper, who was detained by Japan for ten days after the collision, China halted the export of rare earth minerals to Japan. Although the government of China denies that there was any official decision on restricting exports to Japan, the whole incident scared foreign companies and governments. It also brought the discussion of the strategic importance of REEs to center stage.

In the global supply chain interaction, aside from politics, companies and nations are interested in whether or not the raw material provider is reliable enough. There are two different raw material supplier scenarios: the competitive advantage and the stronghold. Competitive advantage means owning economically affordable mining technology and having the experience and technology at the right time in terms of demand. However, a stronghold in natural resources means having the upper hand in terms of deposits. With respect to REEs, China does not have a stronghold as such. The government of China also seems to know this, as their stockpiling of materials for domestic consumption shows. The issue should not be about who owns the resources, as REEs are, in principle, available everywhere on the globe. The issue should be about how to develop effective and environmentally friendly mining techniques, as well as better recycling and alternative solutions as a means of preparing for the inevitable depletion in mines. Currently, there is only one green field rare earths project outside China that has all the necessary environmental and commercial approvals in place and that is currently under construction: the Mt. Weld Project in Australia (mining and beneficiation) and Malaysia (processing and separation of the rare earths) (Korinek, 2010).

The fact remains that the commercial viability and spillover political-environmental costs make REMs too expensive to produce in developed countries. China supplies approximately 97% of global demand and consumes approximately 60% of the global supply, but its reserves of rare earths are finite. The Chinese government has indicated that if the exploitation of these resources is not controlled, they could be exhausted in 20-30 years (Information Office of the State Council P.R.C., 2012).

3 The future

While the current REE value chain is heavily oriented towards mining, we argue that in the future recycling and replacing will gain a more central role. While mining will most likely retain its dominant position, recycling REEs and replacing them with other materials will open new avenues and strategic choices for developed and developing countries. These are changes that may disrupt China's position in the future, especially at the end of the REE value chain. The changes to the REE value chain are depicted in Figure 4.

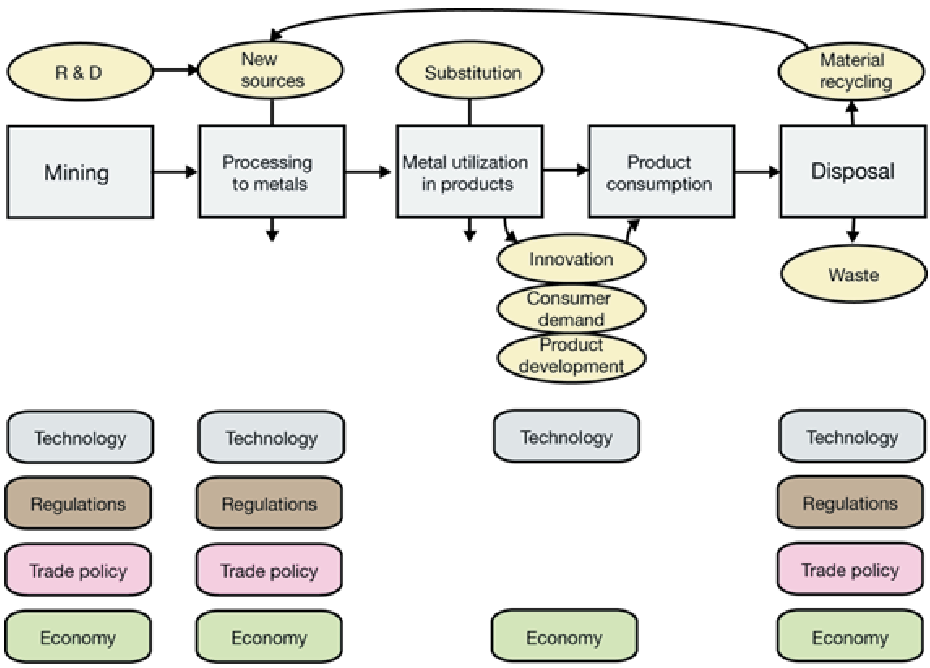

Fig. 4. Changes to the REE value chain

The framework includes all stages of the chain starting from the basic sources, namely mines. After mining, ore is processed into metals and utilised in several different end uses and applications. These include, but are not limited to, permanent magnets, which are being used for wind turbines and electrical drives, vehicle batteries, micro-electronics components and magnetic storage media, such as hard drives, specialty glasses and laser sources. When observing the figure, it has to be remembered that there are several different levels, namely technological, legislative, economical and organizational levels. The technological level includes technical issues, which are essential in developing mining practices and in metal processing, when utilising new applications, when substituting new materials and when technically separating materials from the waste streams. The legislative level includes different laws and regulations that have to be obeyed in all stages of the supply chain. Additionally, political trade policy practices have to be discussed when analysing the global availability of REMs and their trade. The economical level includes such issues as financial analysis of the supply chain starting from the global price level and comparing them to costs at different stages of the supply chain. Cost comparison between mining and recycling is essential. In recycling, the collection chain separation and process costs also have to be included. Finally, the organisational level includes such considerations as the collection of recyclables is organised and how studies for different issues should be organised.

In this section, we will concentrate on the changes to the value chain. We begin by discussing the necessity of recycling, move on to the possibility of replacing, and finish by exploring new sources and blue sky ideas.

3.1 A disruption in the current value chain: recycling and replacing

Products are being consumed by consumers and then disposed of once they wear out. They can either create a waste problem, or else the materials that they contain can be recycled and reprocessed into metals that can be used to produce new products. This means that more research work needs to be done in the field of material recycling. This includes organisational studies, studies on how the collection and sorting of products will be organised and also technical studies on how the metal can be separated from the products. Additionally, due to the high level of demand for REEs, the means to substitute them with other materials needs to be studied, too. Due to the ever-increasing demand for REEs, all possible means to increase supplies must be identified and evaluated.

The recycling of REEs is quite important so that REEs that are increasingly in demand can be supplied more independently. The recycling of the noble metal palladium can be considered as one example: currently, more than 60% of the world's palladium is used for automotive catalytic converters to convert harmful gases from auto exhaust into less harmful substances (UNEP, 2011). The recycling rate of palladium from automotive applications is 50-55%. Other applications for palladium, including electronics, fuel cells and other energy storage devices, have a greater than 16% share of the supply. The recycling rate for REEs is rather low, especially for electronic applications. In contrast to the high recycling rate in automotive applications, the recycling rate for electronic applications is 5-10% (UNEP, 2011). The expected new high prices might act as a catalyst to start building new recycling systems for REEs.

If, for instance, the European Union increases its demand for REEs by pushing for an expansion of its green technology sector, it needs to secure a stable supply of REEs, too. The contradiction between the 'green' applications of REEs and the high environmental load of their production means that the largest consumers of REEs, namely Europe, America and Japan as well as China need to take more action in resolving these tensions (Schüler et al., 2011). Formative actions for REE recycling should be carried out now, without further delay, as it will take a minimum of five to ten years for the first large-sized implementation measures to take place (T. Siren, mining engineer, Posiva Oy, personal communication, 2013). Research for substitute materials and increased efficiency of use should also be reinforced by policymakers as soon as possible, as it takes several years to move from successful research to industrial implementation (Schüler et al., 2011).

To shed some light on the different ways recycling is being done at the moment, we present two examples. First, we discuss the recycling of photovoltaic modules, electronic vehicles and electronic devices, and second, we discuss how to recycle metals from wastewater.

Recycling of PV, EV and electronic devices. When the use of REEs in cleantech applications increases, so does the importance of developing effective methods for reusing recyclable materials. Currently, the recycling rate for REEs and critical metals is low in electric and hybrid cars. Usually it not profitable to recycle REEs because the substances are found in small quantities and embedded in complex systems. Increasing the metal recycling rates, however, is a key part of the path to sustainable metal use (Pathan et al., 2013). In the future, the recycling of photovoltaic (PV) modules and materials will become a mandatory part of European Union's Waste Electrical and Electronic Equipment Directive (WEEE Directive). The collection of REEs used in electric vehicles, for example, will be increased through a producer's responsibility to guarantee a certain level of recyclability for the whole vehicle. Technically it is already possible, and in fact it has already been done by Tesla Motors, which has demonstrated a closed-loop recycling programme for recycling and reusing lithium and other materials in batteries and motors (Kelty, 2013). It is a good example for other electric vehicle (EV) and PV companies to follow.

The Umicore battery recycling technology that Tesla is using produces an alloy that is then refined into cobalt, nickel and other metals. The alloy can be used to make lithium cobalt oxide, and therefore, it can be resold to battery manufacturers. This is beneficial for Tesla not only from an environmental standpoint, but also from an economic standpoint. The recycling of Roadster battery packs is profitable without needing to further invest in recycling, which is in contrast to the lithium manganese or lithium iron phosphate chemistries typically found in EVs. The next step that Umicore and Tesla are hoping to achieve in battery recycling technology is to recycle batteries back into raw materials; this would be highly valuable considering the metals used in them (Kelty, 2013).

Another factor that affects the recycling rate is the collection and pre-treatment of electronic devices before the metals are separated from them. The U.S. Geological survey (U.S. Geological Survey, 2013) estimates that the 200 million cell phones that are retired every year contain 50 metric tons of silver, 4 metric tons of gold and 2 metric tons of palladium. Increasing amounts of REEs are being used in smartphones; as the demand for them is growing, there will be a huge end-of-life loss if more interest is not taken in recycling and recyclability. More effort is needed from the entire society, including policymakers, producers and consumers, to boost the collection of electronic waste. Even though some producers and retailers are making an effort to collect retired electronic devices, this is far from enough. More and better regulation is needed, and at the same time, the infrastructure for collecting electronic waste has to be constructed so that the waste can be stored and transported better. Producers and designers can also take more responsibility for the final disassembly and recycling process already during the design stage so that fewer alloys will be used, for example, in printed circuits and the disassembly will be much easier. Manual disassembly will also help increase the recycling rate for REEs from printed circuits compared to automatic shredding. This is because a shredder will dilute the REE concentration, which makes it more challenging to separate. As the collection rate improves and the scale of recycling goes up, the recycling cost will come down (Chatterjee and Kumar, 2009). It has to be noted that the recycling of electronic devices is not only an economic issue ,but also has a great impact on the environment and health and foreign policy.

Recycling metal from wastewater. The heavy metals in water are considered pollutants. They have a negative influence on the quality of the water body and therefore on the quality of agricultural products, threatening the health and life of animals and human beings throughout the food chain. CrisolteQ Oy in Finland develops processes to separate and recycle industrial metals that are usually difficult to recycle from the by-product flows. Cobalt, rhenium, nickel and precious metals can be recycled and reused in computer and smartphone batteries, for example, and for the catalysts used to produce chemicals. CrisolteQ Oy is cooperating with Kemira to refine materials into end products at Kemira Corporation's aluminium sulphate plant in Harjavalta. Wastewater containing small amounts of metals is considered to be interesting for the recycling of metals. It has to be noted, though, that this applies not only to the recycling of metals, but also to the cleaning of water.

3.2 Replacement: a disruption in the balance of power

The industrial applications for REEs often rely on their unique physical properties, making finding exact replacements often impossible. Nevertheless, their unstable supply has recently motivated research on both replacement materials for existing applications and alternative technical solutions in which REEs are not required. So far, such research has been particularly active within the automotive and energy production industries, both of which utilise rare earths in the high-performance, permanent magnets used in fixed-magnet generators. Finding replacements for lighting applications, in particular light-emitting diodes (LEDs) (Reddall and Gordon, 2012), has also been a very active branch of research.

One notable example of publicly funded research on REE replacements is the $156 million REACT (Rare Earth Alternatives in Critical Technologies) initiative by the United States Department of Energy (U.S. Department of Energy, 2011), which concentrates on replacing the rare earth element-based permanent magnets used in electric vehicles and wind turbines.

In the European Union, it could be argued that a key motivator behind the one billion euro 'flagship' research programme on graphene is the possibility to replace the REEs and related elements used in some applications with graphene; since it is a carbon allotrope, there are practically unlimited (although at the moment still relatively expensive) supplies of it. Applications where graphene and other novel allotropes of carbon could be particularly useful as replacements for REEs include thin film displays, light-emitting devices and fast laser sources (EU Graphene Flagship, 2013). It is also worth noting that the commercialisation of grapheme is one of the main stated goals of the research programme, which can as a whole be seen as a reaction to the major research efforts already being carried out in the field of nanocarbons by non-European companies such as IBM and Samsung.

One end use where rare earth elements are particularly hard to replace is that of permanent magnets. This is because of their fundamental physical properties: their crystalline structure results in a high level of magnetic anisotropy (i.e. that their magnetisability is highly direction-dependent) and their atomic structure means that the REEs can retain high magnetic moments. These factors, when combined, means that REE permanent magnets can produce a high field strength. (Cullity and Graham, 2008) The challenge of finding suitable replacement materials for permanent magnets has motivated the manufacturers of, for example, EVs and wind generators to search for alternative engineering solutions that do not need permanent magnets: one example of this kind of development is the joint development of an REE-free , induction-based electric car motor by Renault and Continental (Continental, 2011). Developments such as this are likely to become more commonplace should the instability in the supply of REEs continue; in many cases, they are not any less effective or economical than the solutions they aim to replace. It remains an open question whether or not companies will also be willing to adapt technically inferior or more wasteful solutions if it enables them to operate without needing to have access to REEs.

3.3 Looking further into the future: deep-sea and asteroid mining

The seabed has become very topical in discussions about finding new sources of REEs. While it is not news that the ocean floor contains REEs, a certain amount of buzz was recently stirred up by a Japanese group's study locating numerous sites with rich REE concentrations around the world (Kato et al., 2011). The group studied more than 2000 samples from 78 locations, one third of which contained REE concentrations of approximately 0.2 percent. It may not sound like much, but the scientists claim that just one square kilometre of such mud could satisfy the world's annual REE demand. An obvious benefit of most of the sites is that they are located in international waters, meaning that they are available for any actor to claim.

But locating the minerals, or even the highest concentrations of them, is not the most difficult task. In fact, some of the deposits have been known about for decades. The main problem still lies in extracting the minerals, which are beneath four to five kilometres of water. The start-up costs of a large-scale mining operation have been estimated at $1 to $2 billion, and the risks are high since it has never been done before (Goodier, 2011). Because the operation would require developing and producing new kinds of vessels, it could take more than a decade before deep-sea mining becomes a reality. As such, the timeframe is comparable to green field mining projects on land.

Another approach to utilising the minerals on the seabed is being realised at such a pace that it cannot be called a blue sky idea anymore. Harvesting so-called polymetallic nodules from the seafloor has been a recurring topic among entrepreneurs for a long time, but only now, with the rising price of REEs, that it seems economically viable. Polymetallic or manganese nodules are roughly potato-sized rock concentrations that contain mostly manganese, nickel, cobalt and copper, but also rare earth elements (Broad, 2010). Many entrepreneurs have tried and failed to benefit from them economically, but technological developments, combined with rising commodity prices, are giving rise to a new wave of fortune-hunters. Harvesting them for REEs alone would not cover the costs, so the success of any operation is also tied to the prices of more traditional minerals, especially copper.

For example, Lockheed Martin UK, an affiliate of the US defence contractor, is preparing to vacuum the seabed for these nodules in the Pacific Ocean (Schrope, 2013). Although the nodule concentrations are richest on the ocean floor, they can be found at all depths. They are also easier to extract than mud when using the currently available technologies, so it is likely that deep sea mining will start with the nodules and gradually move on to other sources.

Whereas the large-scale utilisation of seabed REE deposits will surely be a reality in the near future, the same cannot necessarily be said about asteroid mining, which is still classified as a true blue sky idea. More often than not, the future is based on an old idea. This applies to asteroid mining, too. In his 1898 novel, *Edison's Conquest of Mars*, science fiction writer Garrett P. Serviss envisions an asteroid composed of gold, mined by an adventurous group of scientists on their way to avenge an earlier attack by Martians on Earth. Recovering valuable minerals from space has long been a recurring theme in works of fiction, but in recent decades non-fiction writing has also increasingly explored this theme.

One of the more serious ventures is being set up by Planetary Resources, an American company claiming to bring 'the natural resources of space within humanity's economic sphere of influence' (Planetary Resources, 2013). Their multidisciplinary team encompasses commercial spaceflight industry pioneers, NASA veterans, astronomers, legal experts, experienced business executives and even a film director. The composition of the team is one indicator that the project is not a utopian sci-fi daydream, but actually aims to become a profitable business from an early stage. The thought put into the business side of things is also reflected in the schedule of the project, which is built in such a way that income will already be generated before the mining stage.

The plan of Planetary Resources is to first set up a network of low-cost (approximately $1 million apiece) satellites in the lower orbit of the Earth's atmosphere. The main task of the satellites is to detect and track asteroids; however, to generate early revenue, the satellites' high-resolution cameras will also be made commercially available for the wider public. The second step after detection is data gathering. For this purpose, special interceptor satellites will be used. They will be sent to orbit potential asteroids near Earth and scan them to reveal their composition. Some of the interceptor satellites will be used to gather more data by ramming them into selected asteroids, which in fact has been done before by NASA. In the third phase, interceptor satellites will be launched in the direction of asteroids far away from Earth. Although the main rationale behind it is to gather more data on asteroids, Planetary Resources is also aiming to license out their technologies to other organisations interested in low-cost interplanetary spacecraft and deep space exploration.

Only after these three preliminary steps have been taken will actual asteroid mining be attempted. Instead of going for the gold, as they do in Serviss' novel, or in REEs, as one could assume by reading this chapter, the initial focus will be on water. First of all, water is abundant on asteroids. It is also the key to many useful life-support applications, such as breathable air and hydration, and it can even be used to manufacture rocket fuel. Access to minerals is thus dependent on access to water.

When and how Planetary Resources, or any other venture, is eventually going to execute the mining activities and bring minerals to Earth can of course only be a source of speculation. Water on the asteroids could be utilised to bring the asteroids closer to Earth, for example the Moon's orbit, to make them more accessible. The extraction part is most likely going to be performed by automated robots, and some mineral processing will likely take place on the asteroids. The timeframe for transferring large-scale asteroid mining from sci-fi into reality needs to be measured in decades. Many of the technologies that will be developed, however, will likely to have useful and profitable on-planet applications long before that.

4 Regional strategies to disrupt the Chinese dominance of the REE supply chain

While asteroid mining and other blue sky ideas remain economically unfeasible, many countries are taking actions to secure their strategic supply of REEs and to gain a foothold in the REE value chain. We have observed tremendous variation in different nation's capabilities and efforts to achieve these goals. For example, the US is reopening its old mines, it is very active in researching alternative and replacement materials, and it is keeping an eye open for new blue sky sources. It also seems likely that American companies will be active in establishing mining operations in foreign countries, such as Greenland. China, on the other hand, currently dominates the global REE market, but it is still actively seeking new opportunities for the future. It wants to maintain its position in the current, mining-oriented value chain, but it seems that China is also aiming to establish a strong foothold in the recycling-oriented value chain. For example, Finnish mobile phones are being recycled in the Kuusakoski recycling facility, where lithium batteries are being separated and sent to the Nivala mill to be ground up and pulverised. This material is then treated at the OMG Chemical facility in Kokkola and sent to China to produce new batteries.

While there is relatively little we could add to the discussion on the strategies of the US or China, we have identified emerging nations and European countries as groups that would benefit from more rigid strategies. It is an interesting issue for emerging nations in particular because, without a secure supply of REEs, they will not be able to develop their high-tech industries. That is why we have drafted strategies for Europe and emerging nations that are presented in the following sections.

4.1 European Union unified around a joint REE recycling and research programme

Europe is globally one of the largest consumers of REEs. It is important for the region to secure the availability of these raw materials in the future. This means that its heavy dependence on Chinese sources of REE will have to be reduced.

Europe has already taken some actions in the political arena. The EU has complained to the World Trade Organization about China's dominant role, but in the long term these issues have to be solved economically and financially. The EU Waste Directive sets material recycling targets for recyclable materials like metals, glass, plastics, wood and paper. A recycling rate of 50% for municipal waste has to be achieved by 2020 (EU, 2008). This is a good reason to also increase the collection and recycling of such products as REEs. However, according to experiences from the paper industry, special attention has to be paid not only to collection but also to how the collected material is utilised within the EU. At present, great volumes of recovered paper is being exported to outside the EU to be utilised by China.

In the future, Europe can satisfy the increasing domestic demand by a combination of better utilising its own REE resources as well as imports from outside the region. This offers possibilities to develop the mining industry in some EU regions such as the Nordic countries. It will also be possible to increase the supply of REEs by paying increasing attention to recycling. Collection, separation and material separation from end products like mobile phones, electronics and other products containing REEs is also a means of utilising local sources.

The recycling of REEs has several advantages in comparison to using primary resources. First, Europe produces increasing amounts of waste from manufactured products containing rare earths. Increasing recycling would decrease the volume of household waste. Second, these valuable resources could be returned to the industrial recycling process. In fact, dependency on foreign resources can be reduced by using regional supplies with secondary rare earth materials. Additionally, more research has to be done on the optimal use of REEs, on how to substitute them with other materials, on how to utilise current and new resources and on how to develop collection and recycling systems. Also, material separation techniques for products should be studied. Special attention should be paid to minimising negative environmental effects and developing collection and separation systems together with other recyclables, too.

The EU has strict legislation on environmental protection. The EU Waste Directive (EU, 2008) has set clear targets for material recycling. By 2020, half of all municipal waste has to be recycled. Minimising the process hazards and waste when creating a new recycling supply chain, especially in relation to collection, sorting, and material separation, would offer Europe both environmental advantages as well as a new source of REEs. However, these targets could only be achieved if the whole supply chain, including REE separation, can be controlled by European companies. A European material separation facility for REEs that could use the collected products would make this possible. Additionally, cooperation with other regions like Africa and Australia would be essential for securing supplies of REEs for Europe. In combination with such political support, European companies could develop their know-how and environmentally sound means for utilising their resources.

4.2 Strategy for emerging nations

It is a civilised approach to constructively participate and enrich global norms through international entities such as the World Trade Organization (WTO). However, in the competitive global economic environment every nation or block of nations must strive to protect its long-term interests by conserving or regulating natural resources, especially the strategic ones. For example, the US has the 13th largest oil reserves in the world, yet it is the world's largest oil importer, purchasing more oil than all of the European Union, which rates only 23rd in reserves. Emerging nations, and especially those countries operating at a loss compared to their growth potential, have to learn to adopt such wise and long-sighted strategies. We believe that the global distribution of natural resources represent economic opportunities to increase standards of living worldwide. The ownership of deposits should not be taken as an additional weapon of enmity and division. We also believe that global organisations such as the WTO can help create a level and fair market environment, turning potential conflicts into opportunities.

Generally, the obvious priority for emerging nations is to keep their political climate stable, secure and reliable and also to maintain a predictable economic environment. Concerning REEs, we suggest two strategies: one for those nations that have economically mineable deposits and one for those nations that do not have them. Let's start with those nations that have economically viable deposits; according to Jepson (2012), there are about twenty ongoing rare earth-related development projects in south and east Africa. The following well-known strategies could be reiterated for nations:

- Having fair and beneficial deals with the mining companies is a priority. The deals should favour skill and knowledge transfers;
- Use natural resources such as REEs to attract high-tech industries and keep much of the value of the end product within the country;
- Invest the earned money in improving living standards and education. Build a knowledge-based economy and stop relying on commodities as quickly as possible;

- Any natural deposit will not last long. It will either be depleted or lose its value on the global market. Seize opportunities and keep looking to the next potential developments, such as recycling and alternative materials.

For those emerging nations that do not have economically mineable deposits, there are ways to participate in the REE bonanza in the immediate neighbourhood:

- Position themselves as a regional or global hub for REE recycling;
- Encourage and support domestic mining companies to acquire rights to REE mines elsewhere;
- Those countries that have deposits do not necessarily have the resources to separate ores. Seek such cooperation and become a regional processing hub.

5 Conclusions

REEs will increasingly be needed for different new applications, such as cleantech products. Some sources estimate that the growth in demand will be roughly 6.5% per annum [calculated based on China Minmetals Non-ferrous Metals Co. Ltd. (2009)] in coming years. At present, and in the foreseeable future, the supply of REEs will not be able to satisfy the increasing demand. The reasons for this are both technical and political in nature. The technical reasons include the geographical distribution of rare earths, the difficulty of separating them from ores and especially the so-called techno-economic reasons: opening new mining enterprises is time-consuming and the time frame for starting a new operation is approximately a decade.

From the policymakers' standpoint, REEs are critical because various critical industries such as defence and sustainable energy are highly dependent on a stable supply of rare earths. Because of the political importance of such industries, it is easy to see why policymakers would be open to even radical measures to secure a supply, or conversely, to use an available supply for political leverage. At present, China not only controls 95% of the global sources and mines, but also has been notably active in using it to defend the position of their domestic industries and as leverage in international disputes. The willingness of nations to establish new mining operations has been increasing in recent years: in the US, political pressure is mounting to lessen environmental restrictions in order to restart and expand mining at the Mountain Pass site and in Japan there is growing interest in utilising unorthodox sources on the Pacific seafloor. In can be predicted that similar changes in attitudes will also happen in other regions where previously unused resources would be available. Unfortunately, there is also a large risk that disagreements about mining rights, the environmental effects of mining and similar issues could grow into international conflicts.

As a general trend, the tightening supply-to-demand ratio of REEs will result in increasing prices, which will make the utilisation of new sources more economical. In addition to traditional mining and blue sky ideas, new sources of REE mining, such as the seafloor or even space, the importance of material recycling is definitely going to grow. At present, recycling is still very limited, so we predict that its economic importance will grow, possibly even making the collecting and refining of REEs containing waste a viable independent industry in its own right. Even if recycling is not able to support business on its own, the automotive and electronics industries in particular will likely adapt new systems for waste recollection as material prices increase. It should also be stressed that recycling can reduce the notable, although geographically quite limited, environmental impact of rare earth mining and processing.

Based on the historical developments and the future prospects concerning REEs, we have formulated strategies for the European Union and emerging nations to secure their strategic supply of REEs and gain a solid foothold in the REE value chain. We argue that the European Union should aim at taking a dominant position in the recycling value chain. For emerging nations, we discuss two separate strategies, depending on whether or not they have their own REE deposits.

Europe, together with other global regions, will be dependent on the availability of REEs in the future. Europe has two main options: to secure and support current mining-based sourcing of REE or to increase recycling. The mining-based sourcing option includes both effectively utilising Europe's mining sources and securing REEs from international markets.

An increase in recycling means actively developing the collection of products that utilise REEs. The effective utilisation of this supply chain means that all stages of the chain should be taken into account. According to experiences in the paper industry, much of the recovered paper collected within the EU is being exported outside the region, mainly to China, and utilised there as raw material in paper manufacturing. It would be essential that the collected products, which include REEs, could be recycled in Europe. This means that Europe has to invest in both collection systems and technology to separate rare metals from the collected products. This would ensure that this valuable raw material source could be utilised domestically.

Emerging nations with economically viable REE deposits have to first and foremost create a favourable economic environment for foreign companies to invest in. The long-term bilateral contracts with mining companies should help with knowledge transfer and also secure national economic strategies through flexible contractual agreements. Emerging from a commodity-price-dependent economy into a knowledge-based economy by controlling much of the value chain could also be taken as a background running strategy. Emerging nations without economically viable REE deposits could encourage national investors to go out and acquire REE mining rights. These countries could also position themselves either as regional hubs for REE recycling or as regional processing hubs by separating ores imported from their geographical neighbourhood.

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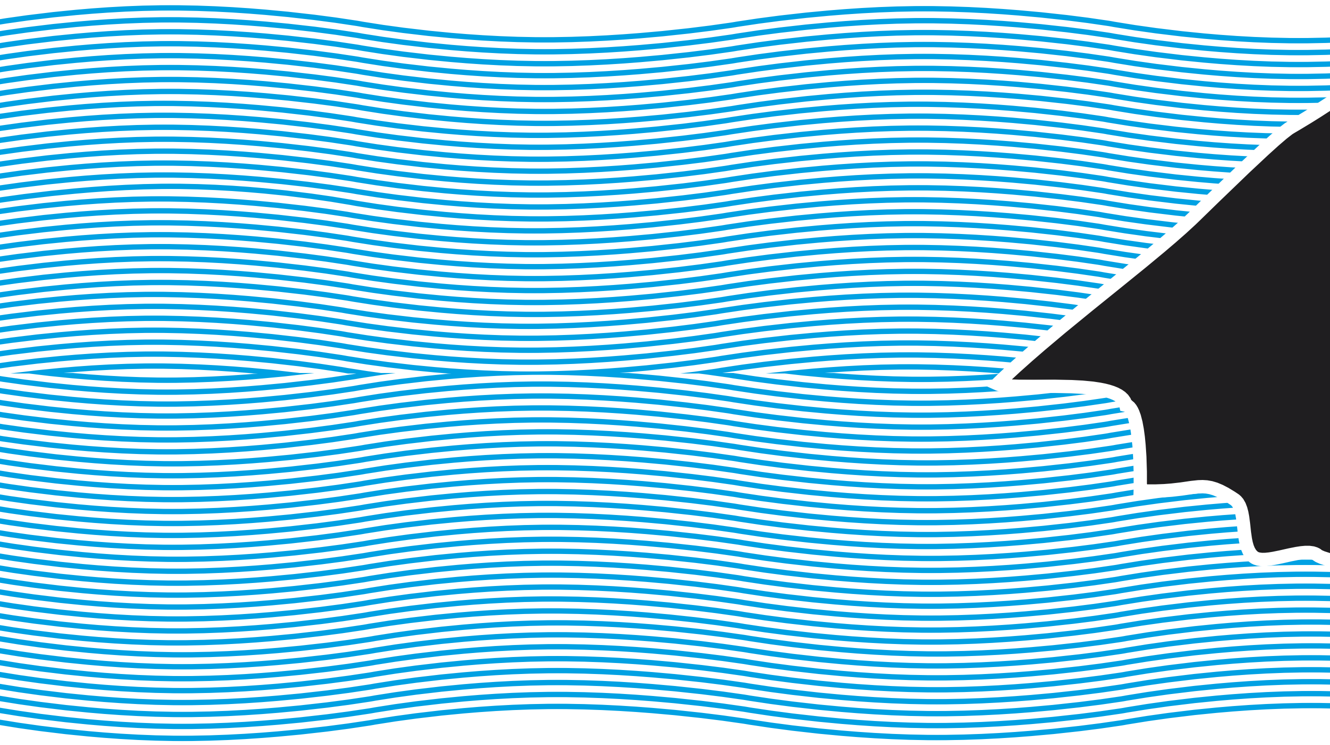

Appendices

1 The Bit Bang people

Facilitators

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MSocSc from University of Jyväskylä. Major in Political Science. She also studied in University of Latvia and in Aleksanteri Institute's Master's School in Russian and Eastern European Studies. She has worked with export promotion, foreign policy and in the civic sector in the Baltic countries.

Tutors

Arianfar, Somaya – A PhD candidate in Aalto University, Department of Communication and Networking. She works in the area of future Internet, more specifically on data-centric networks. Master's degree in Telematics and Information Security from NTNU, Norway. Hobbies include swimming, long nature walks and reading.

Kivisaari, Pyry – A PhD candidate and researcher at Aalto School of Science, Department of Biomedical Engineering and Computational Science. Currently he works on computational modelling and characterization of high-efficiency optoelectronics. Other interests include music, especially singing in vocal groups and solo.

Litvinova, Evgenia – A doctoral candidate at Department of Media Technology, School of Science. She received her M.Sc. in Computer Science from University of Eastern Finland in 2011. Her current research topic lies at the intersection of human computer interaction and ubiquitous computing. More precisely, she focuses on user interfaces and user interaction with smart spaces. Her other interests, to name a few, are user experience research, developing presentation skills, travelling, and jogging.

Lyytinen, Tatu – Research Scientist in VTT Innovation and Knowledge Economy unit and PhD candidate in Aalto University School of Business. Currently he works with innovation management of Research and Technology Organizations in early stages of industrialization in emerging countries. He has MSc (Econ) from University of Jyväskylä and has worked with foreign politics in Argentina, foreign trade in Brazil and outsourcing in Hungary.

Participants

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Dufva, Mikko – Finnish, MSc. A PhD candidate at the Systems Analysis Laboratory of Aalto School of Science. Research topic: Knowledge Creation in Foresight: How Experts Create Knowledge about the Future in Foresight Workshops. Other interests: data visualisation, foresight methods, multi-criteria decision analysis.

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Finley, Benjamin – American, MSc in Communications Ecosystem. Research topic: Effect of ICT on Social Relationships and Evolutionary Limits. Other interests: tennis, writing, news.

Ghani, Adnan Hassan – Pakistani, MSc in Radio Communications Engineering. A PhD candidate at the Department of Computer Science and Engineering. Research topic: Energy Efficiency in Mobile Computing. Other interests: travelling, sports - volleyball, cricket.

Heiska, Nina – Finnish, MA, Bachelor of Culture and Arts. A PhD candidate at the Department of Real Estate, Planning and Geoinformatics. Research topic: 3D Laser Scanning. Other interests: literature, economics, science, technology.

Hernandez Estrada, Albert – Spanish, MSc (Tech) in Forest Products Technology. A PhD candidate at the Department of Forest Products Technology. Research interest: biomaterials, forest products and natural fibres. Other interests: project viability and industrialization, business, product development, innovation strategies.

Huuhtanen, Kaija – Finnish, MSc (Tech). A PhD candidate at Aalto School of Engineering. Research topic: Geographical Patenting Strategies in Global Industry. Other interests: handicrafts, cross country skiing, deep water running.

Jin, Helena – Chinese, MSc. A PhD candidate at the Department of Industrial Engineering and Management. Research topic: Innovations in Industrial Supply-demand Networks. Other interests: swimming, basketball, yoga.

Jin, Hua – Chinese, MSc. A PhD candidate at the Department of Applied Physics. Research interest: engineering physics. Other interests: travelling, cultures, hiking.

Käki, Anssi – Finnish, Lic. Tech. A PhD candidate at the Systems Analysis Laboratory of Aalto School of Science. Research interests: risk management in supply networks, mathematical optimization and decision making under uncertainty. Other interests: snowboarding, badminton, boating, photography.

Laiho, Patrik – Finnish, BSc (Tech), MSc (Tech) in October 2012. Research interest: applied physics and carbon nanotube based thin film electronics. Other interests: music in general and vocal music in particular.

Leal, David – Mexican, MSc in Space Science and Technology. A PhD candidate at the Department of Automation and Systems Technology. Research topic: Optimization of Multi Robot Map Making taking into account Power Constraints. Other interests: all sorts of outdoor sports, fishing, robotics, AI, space technologies.

Malik, Aqdas – Finnish, MSc (Eco.), MBA (IT). Project researcher and a PhD candidate at the Department of Computer Science and Engineering. Research topic: User Experience of Cloud Based Services. Other interests: travelling, social activities.

Mazaheri, Arsham – Iranian, MSc (Management). A PhD candidate at the Department of Applied Mechanics, Marine Technology Unit. Research topic: Maritime Safety in Probability Modelling of Ship Grounding Accidents. Other interests: travelling, alpine skiing, scuba diving, watching movies, playing chess, hanging out with friends and family.

Osti, Prajwal – Nepalese, MSc (Tech) in Communications Engineering. A PhD candidate at the Department of Communications and Networking. Research topic: Resource Allocation in Wireless Networks. Other interests: hiking, cycling, travelling, reading.

Pohjalainen, Tapio – Finnish, MSc in Aeronautical Engineering. A PhD candidate at Aalto School of Engineering. Research interest: combining creativity, organizations, innovation and entrepreneurship. Other interests: flying, boating, downhill skiing, golf, reading, cooking.

Pulkka, Lauri – Finnish, MSocSc. Research topic: Innovation and Innovation Policy in the Real Estate and Construction Sector. Other interests: football.

Shafiq, Muhammad – Pakistani, MSc in Electrical Engineering. A PhD candidate at the Department of Electrical Engineering. Research topic: Design and Implementation of Induction Sensors for On-line Insulation Condition Monitoring of Power Distribution System Components Based on Partial Discharge Measurements.

Sjöland, Erik – Swedish, MSc in Mathematics. A PhD candidate at the Department of Mathematics and Systems Analysis. Research topic: Symmetries in Semidefinite Optimization. Other interests: golf, soccer and running.

2 Bit Bang guest lecturers

Autumn 2012 – Spring 2013

Aaltonen, Petri, Partner, Perfecto Ltd
Orientation to team work

Aho, Esko, Senior Fellow, John F. Kennedy School of Government, Harvard University
Convergence of Digital and Physical

Ala-Pietilä, Pekka, Chairman of the Board, Solidium Ltd
ICT 2015 Expert Group – A brief story of a nationwide change initiative of systemic nature

Breznitz, Dan, Associate Professor, Georgia Institute of Technology
Run of the Red Queen? Innovation, Growth, and Policy in China under Globalization

Ehrnrooth, Henrik, CFO, KONE Corporation
Development of competitiveness in a challenging market environment

Ekman, Kenneth, CEO and CTO, Crisolteq Ltd

Forsén, Kjell, President and CEO, Vaisala Group

Kivinen, Lauri, Director General, Finland's national public service broadcasting company, YLE
Welcome to the anything world: Any content, anywhere, anytime

Korhonen, Pertti, President and CEO, Outotec Plc
Outotec – A sustainable technology company

Kutinlahti, Pirjo, Special adviser, Ministry of Employment and the Economy and
Lehtovuori, Lauri, Board member, Aalto Entrepreneurship Society
MIT REAP Finland

Liikanen, Erkki, Governor, Bank of Finland
Monetary policy during the crisis

Ojanperä, Tero, Co-founder and Managing Partner, Vision+ Fund
Digitalization enables product investments

Reponen, Kalle, Senior Vice President, Strategy and M&A, Kone Plc
Kone – Our role in the changing world

Soini, Pekka, Director General, Tekes – The Finnish Funding Agency for Technology and Innovation
Tekes as the R&D and innovation funder

Vesterbacka, Peter, Chief Marketing Officer, Rovio Entertainment Ltd

Ylä-Anttila, Pekka, Research Director, ETLA – The Research Institute of the Finnish Economy
Global Economy in Transition – Causes and Consequences

3 Course literature

Bit Bang I. Rays to the Future. Yrjö Neuvo & Sami Ylönen (eds.) 2009. Helsinki University of Technology.

Bit Bang II. Energising Innovation, Innovating Energy. Yrjö Neuvo & Sami Ylönen (eds.) 2010. Aalto University.

Bit Bang III. Entrepreneurship and Services. Yrjö Neuvo & Sami Ylönen (eds.) 2011. Aalto University.

Bit Bang IV: Future or Internet. Yrjö Neuvo & Elina Karvonen (eds.) 2012. Aalto University.

MacKay, David (2009) Sustainable Energy without the Hot Air. Cambridge: UIT Cambridge Ltd.

Sharma, Ruchir (2012) Breakout Nations: In Pursuit of the Next Economic Miracles. New York: W. W. Norton & Company Ltd.

Vietor, Richard H. K. (2007) How Countries Compete. Strategy, Structure and government in the global economy. Harvard Business Review Press.

4 Study programme in Beijing

January 12th–19th, 2013

Saturday, January 12th

15:30 Meeting at the Helsinki-Vantaa airport
18:00 Finnair flight AY051 Helsinki – Beijing

Sunday, January 13th

07:55 Arrival in Beijing Capital International Airport
10:30 Arrival in Hotel Grand Millennium
No. 7 Mid East 3rd Ring Road, Tel: 85876888

17:00 Welcome dinner
Madam Zhu's Kitchen, B1, Building D, Wan Tong Plaza
http://www.dianping.com/shop/3500047
Invited guests: Dr. Tong Sun and Mr. Samppa Ruohtula

Monday, January 14th

07:30 Departure from the hotel
09:00 Tsinghua University day
Haidian District
http://www.tsinghua.edu.cn/publish/then/index.html
09:00 General presentation of Tsinghua University, Department of Foreign Affairs
Introduction of graduate education in Tsinghua University, Department of Graduate Education
General presentation of Aalto University and Bit Bang Doctoral Course, Prof. Yrjö Neuvo
10:15 Group discussions with professors and PhD students of Tsinghua University, incl.
Academy of Arts and Design, Department of Information Art and Design
School of Information Science and Technology, Department of Computer Science and Technology, Computer Vision & Media Computing
Department of Electrical Engineering

12:00 Lunch in Tsignhua campus

14:00 Visits in Prof. Shi's lab of ubiquitous computing and HCI and Prof. Ding's lab of multimedia processing and pattern recognition

18:00 Arrival at the hotel

Tuesday, January 15th

08:30 Departure from the hotel
09:30 Nokia day
No. 5 Mid Donghuan Road, BDA, Tel: 8711888
http://www.nokia.com/global/
09: 30 Presentation by Mr. Peng Jing, GM of Nokia Telecom Ltd, Nokia's business in China
10:30 Presentation by Mr. Zhu Yi, Senior Policy Analyst, Post 18th Party Congress Economic and Policy Outlook in China

12:00 Lunch at Nokia building (7th Floor)

13:30 Presentation by Mr. Markus Alitalo, VP, Smart Devices, Lumia Engineering
Presentation by Mr. Wang Kongqiao, Nokia's research activities and university cooperation
15:30 Nokia Factory tour guided by Mr. Mika Salomaa, Head of Nokia Factory

18:00 Arrival at the hotel

Wednesday, January 16th

08:45 Departure from the hotel
10:00 Visit International Technology Transfer Center
No. 49 Suzhou Street, Haidian District, Tel: 82696139
http://en.ittn.cn/
10:00 Meeting with Mr. Nicolas Zhang, Vice Director of ITTN
10:30 Presentation by Dr. Li Shijie, Professor of Peking University
11:00 Presentation by Mr. Han Zhang, General Manager, IP Assets Ltd
11:30 Q&A

12:00 Lunch

14:00 Zhongguancun Technology Park
No. 8 West Dongbeiwang Road, Haidian District
http://www.zpark.com.cn/en/entrepreneurial.aspx
14:00 Introduction of Zhongguancun Park and ZPark, by Mr. Yang Lan, Vice President, ZPark
14:30 Visit ZPark Cloud Center
Visit Sino-Israel Innovation Center

15:30 Meeting with Mr. Kaiser Kuo, Director of International Communications, Baidu Inc.

Baidu Campus, No. 10, Shangdi 10th Street, Haidian District
http://is.baidu.com/index.html

18:00 Arrival at the hotel

Thursday, January 17th

09:00 Meeting with Team Finland
Fortune 2, Millennium Hotel
Mr. Juho Simpura, Second Secretary, Energy, Environment, Technology, Embassy of Finland in Beijing
Ms. Eija Tynkkynen, Counsellor Commercial, Head of Finpro Beijing
Ms. Grace Si, Project Manager, TEKES Beijing
Ms. Zhang Shuo, Marketing Communication Manager, Cleantech Finland

12:00 Lunch in hotel

14:00 Presentation by Prof. Zhang Zhanbin, Director of Economy Research, Chinese Academy of Governance: Chinese Ecological Progress and Needs of Clean Technology
http://nsaww.nsa.gov.cn/
http://www.chinareform.org.cn/people/Z/zhangzhanbin/resume/
15:40 Coffee break
16:00 Presentation by Dr. Zhang Di, School of Journalism and Communication, Renmin: Eco-system and Development of Chinese Media by University of China
http://jcr.ruc.edu.cn/

18:00 Reception hosted by H.E. Ambassador Lars Backstrom in his residence
No. 30 Guang Hua Road

Friday, January 18th

07:45 Departure from the hotel
08:45 Visit ABB factory
No. 10 North Jiu Xian Qiao Road, Tel: 58217788
http://www.abb.com.cn/
Presentation by Mr. Jari Yli-Juuti, R&D Manager on ABB activities in China
Factory tour

11:30 Lunch hosted by Beihang University
http://ev.buaa.edu.cn/about/index.php
12:30 Visit Beihang Art Gallery

13:00 Campus tour

14:00 Meeting with Mr. Hu Chun Ming, VP, School of Computer Science and Engineering, and Prof. Niu Jianwei, School of Computer Science and Engineering

Group discussion with professors and PhD and master students from School of Computer Science and Engineering

15:15 Group picture in front of the New Building

15:30 Visit Aeronautical Museum

16:00 Visit State Key Lab of Virtual Reality

17:30 Acrobats show

Dongtu Theater, No. 85 East Jiaodaokou Street, Dongcheng District

http://www.damai.cn/ticket_24040.html

19:00 Closing dinner

Xi He Ya Ju, North Ritan Road

http://www.dianping.com/shop/509307

Saturday, January 19th

08:30 Departure to Beijing Capital International Airport

11:55 Finnair flight AY052 Beijing–Helsinki

14:20 Arrival in Helsinki-Vantaa Airport

Contacts Finpro Beijing

Ms. Eija Tynkkynen, Head of Finpro Beijing

Ms. Li Ying, Consultant

Mr. Justin Di, Consultant

5 Beijing study tour reports

Summary of the visits in January 14th–18th, 2013

Monday, January 14th

Tsinghua University

Tsinghua is one of the top universities in China. It is situated in what used to be the Imperial Gardens of Qing Dynasty and is claimed to be one of 14 most beautiful campuses in the world. It started out in 1911 as Tsinghua School, in 1952 it was a polytechnic, and evolved into a comprehensive university in 1970s to 2000s. Tsinghua University has 32,800 students, most international students in China and more members of the academy (39) than any other university in China. It is the only non-American university in world top 20 ranking. Since 1911 170,000 students have graduated and many top positions in Chinese government and businesses are held by Tsinghua alumni.

Tsinghua has a lot of international cooperation and exchange. International experience is gained both "over seas" and "on campus". Over seas experience includes joint masters programs (with Paris, Aachen, Tokyo Tech, MIT, Carnegie), overseas research, student exchange and conferences and on campus experience includes e.g. international summer schools (with Berkeley, Tokyo, Seoul). Tsinghua also offers 12 masters programs fully in English. The language used in scientific writing depends on the field and department. Engineering usually publishes is international journals, while humanities may prefer writing a monograph thesis in Chinese.

Tsinghua University has an interdisciplinary design program in the department of Information, art and design. The department was established in 2005. The aim is to combine the fields of technology, art and media as well as bring together students from humanities, sociology, technology and business.

The pervasive HCI group from the Computer science department focuses on surface computing, GUI, mobile interaction and smart home in their research. Surface computing means for example researching interaction on multiuser, multitouch, huge (2x4meters) touch table (uTable). On the GUI side they research for example adaptive satellite cursor. Mobile interaction research projects include picopet, a projectable "pet" that is aware of where it is projected (ceiling, apple, water etc.) and acts accordingly, and device position detection i.e. making your phone aware on which pocket it is in. Related to smart home the group is researching universal control interfaces and location systems.

Three students presented their research. The first was about context aware mobile interaction. This means using sensors to gather data from the environment, sending the data to be processed and receiving action guidelines related to the identified context. Examples include fall detection, device location recognition and deciphering persons comfort or anxiety from the way they hold their feet while seated. The second presentation was about the huge touch table called uTable. The third presentation was about brain-computer interface based attention training program for ADHD children. By sensing the brain waves of children while they are doing an ordinary task such as reading the developed program will reward the child with virtual stickers for being attentive or help inattentive children concentrate by playing baroque music.

Tsinghua lab visit

Prof. Shi's lab focuses on ubiquitous computing and HCI. Students demonstrated four different research projects:

Mobile application for following students' performance. This application allows parents to check their kid's performance at school. With the help of their interactive map, students' home achievement can be integrated into school performance.

Mobile phone position detect accuracy. This application used Nokia mobile phone, and accurately detects the position of the mobile phone. It is an application which can be used at smart home.

Scholar explore. This is a useful tool developed for academic research. It helps to analyze any published paper's references and notes, create the link among all the references, etc.

Detection and recognition software. This is an application to detect impassion, emotion, voice, to make dialect conversion, speech-song conversion, 2D talk convert, and emotion recognition.

Tuesday, January 15th

Nokia in China

After an hour bus ride from the hotel to the Nokia building the day started with a very informative and interesting presentation by Mr. Peng Jing, GM of Nokia Telecom Ltd about Nokia's business in China. Nokia started its operation 27 years ago in 1985 with only five people in a hotel in Beijing, China. Since then, Nokia has contributed a lot to China's success. This has been done through investing, employing, sourcing, manufacturing and innovating in China. Currently, two manufacturing sites, Beijing and Dongguan, are serving global and local needs with the slogan "created in China, made for the world". These sites have produced 1.1 Billion phones so far. Nokia has four research and development (R&D) sites in China, in Beijing, Chengdu, Hangzhou and Shenzen, making China Nokia's innovation hub. China has core sites for both mobile phone and smart phone R&D where focus is on Windows phone for WCDMA/LTE/TD-SCDMA. Among 120,000 Microsoft's applications, 25000 applications have been developed in China. They also believe that business success goes hand in hand with social responsibilities. Nokia's aim is to create a vibrant ecosystem by co-operating with the internet players, operators, innovating for China and the world and co-operating with developers along with its services and devices.

After a short coffee break the day proceeded with a very interesting presentation about the political system and future of China. The presentation was given by Zhu Yi, currently Senior Policy Analyst for Nokia and previously employed by the government for 10 years working with economic forecast. Zhu Yi asked everyone in the group to individually answer what word they relate to China, and the most common answers were "Huge", "Economy", "Productivity", "Food", "History", "Communist party" and "Innovative". All the words but food were common elements in the presentation he gave. The Communist Party of China, CPC, consists of 80 million party members, and the Central Committee of the Communist Party of China, CCCPC, is the highest authority within the party. Recently CPC got its 18th party congress and Xi Jinping is the current general secretary. The current members of CCCPC are Xi Jinping, Li Keqiang, Zhang Dejiang, Yu Zhengsheng, Liu Yunshan, Wang Qishan, Zhang Gaoli and the new leadership style is officially closer to the people, more open, without formalism and clean. Nokia has good relations with the current committee, 4 of the committee members have already visited Nokia house. The party is labeled as a communist party, but it should really be considered as a mixture between communism and capitalism, and there are fierce ideological debates within the party. The main ideologies among the party members are socialists with Chinese characteristics, Maoists, liberalists, populists, democratic socialists and nationalists. The main goal of the party, and perhaps the Chinese dream, is to surpass the United States in GDP by 2020, then reach a level of GDP 1.5 times higher than the United States by 2030 and finally reach double the American GDP by 2050. How will they get there? Reform, reform, reform…

Nokia Beijing

Nokia factory in Beijing is the only factory of Nokia that produces the Lumia smartphones. Most of the employees in the factory are engineers and technicians, who some of them have master degrees. The average career length in Nokia-Beijing is 10.3 years. The employees have the possibility of improving their ranking in the company by showing encourage, and the company does not put any limit for that.

The demand for the Lumia phones drives the production rate in the company. Nevertheless, the average production rate was about 16 devices per second based on the last year statistics. The labour working hours is quite long in the factory as 12 hours per shift. However, it seems that the quite long shift is supported by the employees.

Nokia-Beijing is also the head of Nokia's R&D in Asia. In total, 1500 people are working in R&D section in Nokia, in which one third of them are sitting in Oulu, Finland and the rest are located in Beijing, China. Knowing that the software of Lumia smartphones comes from Microsoft and the chip design comes from other suppliers, the number of the R&D employees in Nokia-Beijing shows how complex the design of Lumia is. The Lumia production process is framed into four distinguishable phases as: 1- pre-concept process, 2- concept phase, in where the road map and the milestones of the device are defined, 3- execution process, and finally 4- sales and maintenance processes.

The R&D section in Nokia develops the new products based on two trends: 1- the current need of the customers, and 2- the future needs that the R&D personnel in Nokia believe that the consumers will have.

Nokia in Beijing has also an NRC lab (Nokia Research Center), which are basically the open innovation centers of Nokia. The concepts that are researched in NRC are about the algorithm engines for mobile platforms. For instance, NRC in Nokia-Beijing is working on algorithms for face and hand gesture detection and recognition on mobile devices. The face and hand gestures are the most popular patterns in the daily life that can be utilized in the future to ease the communication between the humans and the devices. Such innovative and pioneer researches will later help Nokia to develop its user interfaces (UI) in the future devices. However, one of the challenges of using face and hand gestures as UI is that they are somehow culture dependent and will vary from region to region; though the variation in face and hand gestures is not large compared with the variation in body and language gestures.

Wednesday, January 16th

International Technology Transfer Center (ITTN)

The center provides smooth linkage to international companies by partnering. The center is sponsored by government of china and the municipality of Beijing. It also shares risk with domestic companies going international. Within the country, ITTN narrows cultural gaps through interaction and mutual communication.

ITTN provides support at different stages of development ranging from supporting basic and applied R&D to commercialization and industrialization. By establishing technology request database, ITTN also provide a platform for technology demand and supply linkage.

Zhongguancun Technology Park

Zhongguancun Technology Park or so called Zhongguancun software park is located in No. 8 Middle Dongbeiwang street, Haidian District in Beijing. The construction started in 2001 with an area of 2.6 Km2. There are two phases of construction. First phase was completed and there are more than 200 high-tech companies in the park including international and domestic companies including IBM, Router, Oracle Corporation, Lenovo and Baidu with different sizes. About 27,000 people work in the park, among which 12,000 are on business travel so there are 15,000 people working the park. It is expected when the second phase complete, there will be 300 companies in the park. The aim of the technology park is to build a cluster of ICT companies to promote the development of ICT industries. It is also a platform for incubation of start-up companies.

The technology park focuses on ICT and energy efficiency management. IT of things, cloud computing and smart devices are included in the business area. The cluster will help companies to develop business in new generation of ICT and will be the innovation center in cloud computing. It will also the international technology transfer network in ICT in China. Consulting companies provide services for product evaluation, marketing, and IPR registration for the development of new products. It is considered as a window for internationalization of domestic companies and international cooperation between domestic and oversea companies in ICT. It encourages international cooperation especially between high-tech based companies.

In the technology park, environmental effects are considered and there are companies working for green energy and energy efficiency. The idea behind is to take advantages of advanced ICT to optimize energy utilization.

Z-Park Cloud Center

Cloud center or so called cloud valley is located in Zhongguancun Technology park. It focuses on cloud computing and related services. It aims to promote the innovation and development in cloud computing including basic cloud based technologies, applications and services. It helps companies to take advantages advanced technology and resources in the technology park to improve their competitiveness and lead in the field. There are companies include Cloud times which focuses on cloud end instrument and applications, skycloud technology which focuses on resource management systems, citicloud which focuses on security management, pekall focuses on android mobile cloud computing applications.

There is a customized model for data center construction which includes stories, houses and containers. Customers can make their own decision based on their size and their needs. The location of the model data center will in N 45 degrees and it is said that in N 45 degrees heat generated from data center can be released better. An ecosystem is designed to utilize the heat generated by the data center to support green house. In order to have low construction cost, all the materials for the construction are made ready and assembled in the place. Considering environmental effects, some solar cells and wind powers will be used for green energy. However, due to the estimation, the energy generated by solar cells and wind powers are far from that required by the data center.

Sino-Israeli Technology Innovation Center

Sino Israeli technology innovation center is located in the cloud center of Zhongguancun software park. It is a technology transfer center between china and Israel and is a cooperation project for Zhongguancun software park and Shirat enterprise. The original idea is to encourage cooperation between Chinese and Israeli companies especially in the field of IT of things, cloud computing, mobile applications, multimedia services and data center construction.

This innovation center will help Israeli companies to do the incubation and accelerate the commercialization of products. It is to introduce advanced innovation systems in Israel to import or transfer advanced technologies. The expectation is that this innovation center will be taken as an example for international cooperation between different countries.

Baidu

Baidu is named after the an old poem which means that a man is searching for a women hundreds or thousands of times and suddenly finds she is right there in a place. This is also the logic of company culture of Baidu for searching. Baidu does its efforts for searching good applications until find the right one. Baidu is the most popular searching engine and has share of about 80% Chinese searching market in China. There are more than 20,000 employees in the company and the average age is 25. Its headquarter is in Beijing Zhongguancun Software park and 5,000 employees working in the headquarter. Offices in Shenzhen (or Guangzhou) are also under construction and there will be 2,000 employees in the office in Shenzhen. Baidu is focus on Chinese market and so far there is no English website. In order to attract customers and keep their loyalty, Baidu keeps on developing new applications such as travel information search, song search, people search and you can read, images search, listen music, watch movies, or even play games online. Most of these applications are free and only a few charge due to copyright. These applications also work abroad when you search online by Baidu Chinese website.

For those who do not want to type or have difficulties to type, they can search on Baidu with voice recognition by asking directly the question with a microphone using your own voice.

Although Baidu focuses on domestic market, it also started to explore foreign market. It launches its website in Egypt and Brazil.

Thursday, January 17th

Team Finland: Embassy of Finland, Finpro, Tekes and Cleantech Finland

The morning at the hotel started by Yrjö's short presentation of MIDE and Erkki's introduction to Team Finland and its history. The first guest presentation was Juho Simpura from the Finnish embassy. It was interesting to hear about Juho's career path, and how the embassy is organized. The main content was related to how the embassy works and helps Finnish citizens in China, but also issues related to Finnish companies were discussed. For example, Juho told us that a big share of their business related services relate to IPR arrangements. Even though China has relatively strong IPR related legislation and patenting system, protecting IP in practice can be very tricky there. We also heard that Finland is considered as an "old friend" of China and that it actually smoothens things from time to time.

Finpro presented next their global organization and then concentrated on what is going on in China. They particularly brought up sales channel development as an area where Finnish companies need help. They can, e.g., assist in finding local experts and partners. This is also a good example of the development of China turning from being a mere supplier to an attractive market for Finnish companies. An example of a Finpro project related to energy efficiency was also presented. One interesting aspect there was that most China's environmental goals are tied to efficiency or intensity, meaning that with the current growth rates, the problems will only grow larger even though the targets would be met. Finally we saw a presentation by CleanTech Finland, which is an initiative for promoting Finnish CleanTech companies in several parts of the world.

The morning session ended with a group work related to abovementioned topics. The discussion was rich, and several concrete future actions were suggested. It remains to be seen if some them will be implemented!

Chinese Ecological Progress and Needs of Clean Technology – Prof. Zhang Zhanbin, Chinese Academy of Governance

The Chinese Academy of Governance is a ministerial-level institution, which trains civil servants at the provincial and ministerial level, leaders of major state-owned enterprises, and high-level administrators and policy researchers. It covers topics such public administration, innovation in government administration, and acts as a think tank providing ideas, services and advises to the Party and government on matters of policy. It includes some research as well as the National Emergency Respond Body.

China has another 20% to grow, but he mentions that foreign companies are afraid of this growing. In this area, aligned with the Five-Year Plan, China wants to shift from export economy into domestic one, with the aim to double the GPD in 2020, making some reforms considering integrated solutions, new types of organization and promoting the service industries. He commented that one point is that many officials are good at controlling, but not at providing services. Concerning Clean Technologies, Prof. Zhang Zhanbin commented they have a lot to learn from other countries, and that CleanTech is one of the priorities of the 12th Five-Year Plan. He mentioned one point they consider is the Ecology Economy Development.

China is now in the middle of industrialization and modernization of agriculture, and they think in tackle it acquiring and creating technology in this modernization of agriculture. They are concerned also about the social implications of this development (300 million people belong to agriculture), and topics such agriculture subsidies and food safety are issues they are considering, as well as they are concerned about the behaviour of some local authorities and simple officials, related with receiving bribes from farmers.

They are concerned about the implications of increasing the population in the cities and its potential unmanageability, and they plan to solve the problem in 10-20 years. Prof. Zhang Zhanbin commented they think in tackling the problems with the help of technologies, smart transportation and promoting the visits of mayors to some European cities in order to learn from them. Also from a human-oriented approach, and solving the problems of urban diseases, traffic restricting to drive on certain days depending on the registration plate number.

Eco-system and Development of Chinese Media – Dr. Zhang Di, School of Journalism and Communication, Renmin University of China

Dr. Zhang Di gave a presentation describing the historical development of Chinese media and also the current media ecosystem in China. The historical view focused on the evolution of the official (CCP (Chinese Communist Party) supported) and non-official market orientated media. Historical examples of official media documents were presented and translated to show the type of propaganda utilized by the party.

The current Chinese media landscape was explored through examples (presented by news videos clips). An especially illuminating example explained the recent confrontation between the Southern Weekly newspaper and a local CCP censorship office. In China newspapers and censors typically communicate before print to avoid confrontations over censorship. However, in this case the censors significantly changed an editorial after the editor had already signed off on it and without his knowledge. The incident caused protests outside the newspapers headquarters and significant international media coverage.

The importance of China's rapidly growing micro blog services was also stressed. These blogs are similar to Twitter and gave ordinary Chinese alternative sources of information, a place to publically discuss (public sphere), and a popular mobilization channel. Finally Dr. Zhang Di gave his predictions as to the future impact of these new social media tools on the Chinese society. He predicts that these tools will help create more responsive and liberal state institutions but that they will not lead to a radical shift away from the current political power structure (specifically the CCP). He gave an example of the type of responsiveness micro blogs can elicit. The example detailed that user comments on a large micro blog helped overturn a recently enacted (and nonsensical) traffic law.

Friday, January 18th

ABB

ABB (China) Limited is quite unique story in the era of produce in the east and sell it in the west. This factory produces electrical drives. Contrary to popular belief, ABB's operations in China are not aimed at reducing production cost through cheap labour to enhance profit margin. Exports account for only 15% of the total revenue ($5.1 billion in 2011), which demonstrates strong local demand for ABB's products. Besides the strong local demand, R&D effort in localization of the products to cater customer needs paid off during the technology transfer. The future prospects seems very promising for ABB considering the fact that, promotion of energy efficiency measures and plan to introduce 500,000 electrical vehicles on Chinese roads are included in 12th five year plan.

Beihang University Campus

Beihang University – Prof. Chunmin Hu

The university consists of 130 faculties/ departments, and the Department of Computer Science alone has 35 professors and 47 Assistant Professors. Beihang University's Computer Science area is one of the top ranked ones right after Tsinghua University. Top talent students come from 100 provinces of China and enter through entrance exams. Frequent exchange of students is established between different countries with the most significant number of students between USA, UK, France and Germany. Research and development funding in the university is on constant increase with the figures of 1000 RMB in 1991 to 20,000 RMB in 2011 (some doubt about the RMB units). University has a serious collaboration with the high tech industries of China. Recently Beihang University has been as a new center for W3C technical staff and leadership activities in China while close cooperation is increasing with China clod industry association.

Beihang University – State Key Lab of Virtual Reality, Technology and Systems

China has created around 600 State Key Laboratories in each specific fields and Beihang University is hosting the lab on virtual realities. The research efforts focus on four particular areas: (i) modeling theory and virtual reality, (ii) augmented reality and human computer interaction methods, (iii) distributed virtual reality methods and technologies, (iv) integrated virtual reality environments and tools. It was established in 1994 and has received the key laboratory status in 1999. In 2007 the new lab facilities were constructed.

The laboratory employs 40+ Professors, 60-80 Doctoral students and approx. 250 Master students. The annual budget of the School of Computer Sciences is 200 million CNY (~25 million Euro), out of which 40 million CNY (~ 5 million Euros) are allocated to this lab. According to their own figures, the publication rate is 100 papers in English in reviewed journals and conferences. Their landmark achievement is the 'real-time 3dimensional graphic platform BH_graph'. For the Chinese Olympic Committee they have simulated the opening ceremony to simulate e.g. the effects of artistic performances and to plan the TV camera positions.

Beihang University – Aeronautical Museum


Bit Bang – Changing Global Landscapes: Role of Policy Making and Innovation Capability was the fifth multidisciplinary postgraduate course for Aalto University doctoral students. A total of 24 students from five Aalto University Schools participated in this two-semester course.

The course focused on global competition for leadership in innovation, policy-making, technology, and science and education. The fundamental objective of the Bit Bang courses is to teach the students teamwork, multidisciplinary collaboration and scenario building, as well as provide the students with global perspective, and industry and business foresight.

In addition to normal class activities the students worked in six person teams to study local and global strategies to strive for success.

This joint publication contains the final reports of the teamwork assignments. In the chapters the students seek answers to what makes the difference between the leaders and the followers.

The topics include e.g. the potential of additive manufacturing for bringing manufacturing industries back to Western countries, the link between national higher education systems and innovation capability at the nation level, and changing governmental structures to better match contemporary challenges.

The Bit Bang post graduate courses are organised by Aalto University's Multidisciplinary Institute of Digitalisation and Energy (MIDE). The earlier Bit Bang books are freely available from the MIDE web site.
http://mide.aalto.fi

ISBN 978-952-60-3633-5 (pbk), 978-952-60-3634-2 (PDF)

Aalto University