Estonian eVikings

Analysis of the Estonian ICT Sector Innovation System

Executive Summary

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Objectives

Societal inclination towards a fast acquisition of modern technologies, willingness to experiment with new solutions and internationally successful promotional campaigns have introduced Estonia on the international arena as a rapidly evolving information society. Indeed, the broad picture seems to confirm this concept, as figures and early growth rates are in some cases remarkable (particularly in the category of consumer goods and exports), and several initiatives that have been undertaken by either government or corporate agents are remarkable, inspiring other countries to imitate Estonian practices.

Still, the present report aspires to look behind the figures, to get down to the core issues that lie at the heart of Estonian information and telecommunications technology (hereafter ICT) sector competitiveness. The report concludes that many of the developments are generally misinterpreted when considering the innovation aspect and are driven to a large extent by attempts to brand Estonia internationally as an ICT state and an information society. In reality very limited resources are being put into real (new) knowledge production and often the developments occurring elsewhere are being imitated instead.

Nonetheless, Estonia has defined her research and development (R&D) strategy in a document entitled 'Knowledge-based Estonia. Estonian Research and Development Strategy 2001–2006' in which Estonia is seen as a place where research, orientated towards new knowledge, application of skills and knowledge and development of human resources, all combined in balance, are a source of economic and labour competitiveness and quality of life. The strategy also defines information society technologies (IST) as one of the three key areas for R&D in Estonia.

Estonia, however, is not an exception in giving priority to ICT. Camarero and Magnatti (2000, pp 99-100) report in their cross-country study of the technological sectors on which EU Member States are focusing their innovation policies that information society technologies appear as a focal sector in 27% of cases, and that almost every country has at least one measure targeted to this sector.

In order to develop an appropriate Estonian innovation policy, there has to be general understanding of the core problems of the Estonian ICT Sector Innovation System. The current study thus takes a closer look at the following issues:

- What are the elements of the Estonian ICT cluster, how is it performing, and how is the cluster functioning inside and with other sectors of the Estonian and international economy?
- What are the elements of the ICT Sector Innovation System and how can their interaction be described?
- What is the level of innovation in the ICT sector and what is the major reasoning to perform R&D?

Methodology

The study has been conducted by the Innovation Centre of the Archimedes Foundation (Estonia), whose aim is to enhance the participation of Estonian research, commercial and other organisations in EU research and technological development programmes.

Preparations for the eVikings project started at the beginning of 2001. In May 2001, a wide-scale survey of Estonian ICT companies was conducted. Both the turnover of companies and their innovation potential were considered as criteria for the selection of companies. Altogether, 133 companies where addressed by the interviewers, and 99 of them were ready to share information.

As few key market players declined to respond to interviews and filling-in the questionnaires, indirect information sources were used, and the current report still covers a total of 85–90% of the domestic ICT market by turnover (the estimation is based on the commercial registry database).

This executive summary is based on three working papers.

The paper **'ICT, Innovations and Innovation policy: The Case of Estonia'** provides the reader with relevant background information for understanding the developments of the Estonian ICT cluster in the light of transition to market economy and to the new techno-economic paradigm.

Based on the viewpoints of technology and innovation economists, the importance of the innovation process and a widely acknowledged approach to techno-economic paradigms are outlined. Innovation is defined as proposed in the Oslo Manual (OECD 1997): 'technological product and process innovations' comprise of implemented (i.e. introduced on the market or used within a production process) technologically new products (means both goods and services) and processes as well as significant technological improvements in products and processes'(p. 31).

The paper **'The Estonian ICT Cluster'** uses Porter's conditional model of cluster framework (1998), also known as Porter's diamond, as a methodological basis. Porter's diamond outlines four factor groups that serve as a precondition for emerging cluster relationships. These four groups embrace 1) factor conditions, 2) firm strategy, structure and rivalry, 3) related and supporting industries, and finally 4) demand conditions. As the focus of the current report is on innovation issues, the cluster argument is approached from the innovation and innovation system viewpoint.

Another approach in determining cluster relationships is based on statistical Input-Output (I/O) analysis (known also as Leontieff table), which indicates how many goods and services produced by one sector are used as production input by another sector. As such statistics is not available for Estonia, the I/O analysis conducted here is based on the questionnaires from the survey conducted in May 2001.

The third paper, **'IST R&D and Innovation in Estonia',** analyses the basic Estonian research and development input and output indicators from the innovation perspective. For a wider context, the European Information Society Technologies R&D strategy and visions until 2010 for ambient intelligence landscape are used. The European Community methodologies for Integrated Project Portfolio Analysis in the IST domain are applied to the Estonian ICT R&D project portfolio financed from public funds.

The first results of the study were discussed at a workshop on August 24, 2001 in Tallinn with the representatives of industry, universities and ministries. The results of the survey and the entire analysis were also discussed with several foreign experts.

Context for the ICT Sector Innovation System

1. ICT as techno-economic paradigm leader and the key role of the state

The 1980s and 1990s have been the era of rapid developments in ICT, leading to different theories of information society and arguments about the emergence of a 'new economy'. Whether economic fundamentals really have changed or such transformations have similarities in history, remains debated, although the authors of the paper are sympathetic to the historical approach and support the theory of economic waves.

This way, the general understanding of scholars is fully supported: **ICT is one of the key technologies that are currently leading the paradigm** that started in the beginning of the 1990s. Similarly to other key factors (like cotton, coal and iron, steel, oil and plastics) that had all-pervasive influence in the productive sphere, and a capacity, based on a set of interwoven technical and organisational innovations, to reduce costs and change the quality of capital equipment, labour, and products, it is believed that the ICT also carries enormous potential.

As the success of all modern developed countries lies in industrial innovation, the role of state policies is crucial here. Actually, 'there is virtually no country, except Hong Kong, which achieved the status of an industrialised country without at least some periods of heavy state involvement in the developmental effort' (Chang 2001, p. 21).

2. Productivity increase as catching-up

The situation in the European Union (EU) candidate countries is that both R&D expenditure and average productivity are still much lower than the average within the EU. According to 1998 figures, the EU economy as a whole was 2.5 times more productive than that of the candidate countries. Trade, transport and communication, financial and business services are the most productive sectors within the candidate countries' economies, where labour productivity has reached 66% of the EU level. **The Estonian overall labour productivity is 37% of the EU,** which is also very

close to the candidate countries' average of 41%. Labour productivity is the highest in trade, transport and communications (55% of EU average), and in agriculture (46%). For manufacturing the figure is 26% for Estonia, 29% for Latvia and 30% for Lithuania (Eurostat 2001). In the Estonian ICT cluster, productivity is the highest in the telecommunications sector, and this sector has also the highest added value generating ability. Computer services hold a medium position.

The productivity increase has emerged mainly from domestic entrepreneurs, foreign enterprises and through foreign direct investments (FDI) resulting in major productivity increase in new, small enterprises or those sectors where foreign enterprises were willing to act as restructuring agents (Radoševic 1998). Those restructured enterprises seem to outperform domestic firms that are based on local capital.

During the last ten years, no active industrial policy has been pursued in Estonia. Still, the Estonian annual increase in manufacturing production for 1994–98 was 7.7% (6.2% for overall industrial production) while for the EU-15 labour productivity growth in 1991–99 has been only 1.7% (EC 2000, p. 9).

Estonia's rapid increase in productivity could be explained by the catching up model

Estonia's rapid increase in productivity could be explained by the catching up model, according to which (Abramovitz 1986), relatively backward countries grow faster than advanced countries, because they are able to imitate technological knowledge, and hence converge to the frontier value of per-capita income more rapidly. Technological accumulation plays a crucial role here, but besides technological aspects, there are also issues of 'social capability' that mark a broad description of the set of institutions that facilitate the international diffusion of technological knowledge. Among the factors that are considered of prime importance for 'social capability' are the educational and the financial system.

With catching-up and the resulting increase in productivity, two possible scenarios may follow. First, some labour is allocated into other sectors, or alternatively, additional demand (e.g. export) is created and the sector continues to employ the same number of people, or the number could even eventually increase. **The empirical evidence concerning Estonia seems to support the argument that with increasing productivity, the number of employed persons decreases in the respective sector** (see also Hernesniemi 2000, pp. 12–14). When comparing data from 1997 and 1994 (Statistical Office of Estonia 2001a), out of the 13 manufacturing

sub-fields where productivity growth was more than 14% annually, the same level or an increase in employment emerged in only four of them. Manufacturing of wood, paper, paper products, rubber and plastic products contributed positively to the employment increase, while 'manufacturing of furniture and other manufactured goods' remained stable. This process demonstrates the deepening of the lock-in effect, discussed in the next section.

3. Transition to innovative economy

With privatisation and technological upgrading, the **Estonian industrial structure started to depart from the factor-driven stage in the early 1990s.** The factor-driven stage is described by Porter (1998) as an economic system whose performance is dependent on the availability of primary factors, such as land, labour and capital. Sophistication of goods is low, whilst the main economic activities consist of assembly, labour intensive manufacturing and resource extraction. Technology is assimilated through imports, FDI and imitation.

However, higher quality FDI, venture capital and other factors move the economic system into **investment-driven economy**, where financial capital is invested into modern facilities and into complex foreign products as well as process technology; products incorporate typically more sophistication and the economy is concentrated on manufacturing.

Transition into investment-driven economy has been outstanding, as Estonia has been remarkably successful in attracting **foreign direct investments.** In cumulative FDI-inflows per capita terms (1989–2000) Estonia lags only behind the Czech Republic and Hungary among the Central and Eastern European Countries and the Commonwealth of Independent States (EBRD 2001, p. 22). As Estonia has advanced further with privatisation compared to other transition countries, this also has had an impact on the future FDI – according to the European Bank for Reconstruction and Development (EBRD), a strong positive relationship exists between cumulative privatisation revenues and cumulative FDI (EBRD 2000, p. 84).

At the same time, FDI does not necessarily contribute to the innovative capabilities of the local industry and thus to the changes in technological trajectories. This way the quality of FDI is more important for growth and competitiveness than the quantity alone.

The whole transition process seems to support the widely held position that neo-liberal approaches to economic policy help to revive the private sector, but that such a revival is invariably limited to small-scale, low technology, which does not require extensive state support (Chang and Rowthorn 1995). For example, Estonian manufacturing was dominated in 1999 by the manufacturing of food, beverages and tobacco products, energy supply and manufacturing of wood and furniture (Statistical Office of Estonia 2001a). Analysing the Estonian trade pattern and comparing it with OECD exports in 1997, Hernesniemi (2000) concludes that 'the Estonian competitive edge in exports lies in very traditional industries like wood industries and furniture production, textile and clothing industries and foodstuff industries. In inorganic chemicals, there is also evidence of competitiveness in OECD exports. It is on these industries that Estonia currently has strength' (p. 10).

The problem of specialisation in low-tech, labour-intensive low-wage industries remains to be tackled

Consequently, considering Estonia's current competitive advantage and the problems with the decreasing attractiveness for FDI, the problem of specialisation in low-tech, labour-intensive low-wage industries leading to lock-in in low and medium technology sectors remains to be tackled.

The next stage in Porter's scheme, **innovation-driven status**, realises itself through efficient and sophisticated technological solutions, extensive research and development that generates innovative products, continual training of the workforce in order to sustain intellectual capital and the capacity to maintain competitive advantages. Firms compete on low cost due to high productivity rather than on low factor costs.

Reaching the innovation-driven stage, however, needs strong support from the state in the form of proper industrial and innovation policies. Innovation policy focuses in those elements of science, technology and industrial policy that 'explicitly aim at promoting the development, spread and efficient use of new products, services and processes in markets or inside private and public organisations' (Lundvall and Borrás 1999, p. 37). Innovation policy is therefore fundamentally oriented towards the establishment of a functioning National Innovation System, but such an active and influential policy is missing in Estonia so far.

Reaching the innovation-driven stage needs support from proper public policies.

4. Estonian innovation policy as 'no-policy policy'

Estonia's transfer to market economy could be used as a standard economics textbook example of the neo-liberal, *laissez faire* approach to economics. **Estonian economic policy is described as having a heavy reliance on market mechanisms, 'getting the state out of the economy', rapid and large-scale privatisation, free trade and liberal investment laws.** Much of the focus was on establishing a stable currency and the approval of balanced state budgets. This way the major concern of Estonian policy-makers was market failure in the sense that the main concern, and thus the objective of state intervention was to create 'enough markets' with demand and an appropriate price mechanism.

As mentioned earlier, Estonia has indeed been successful in moving from the factor-driven stage to the investment-driven one. However, the initial conditions for catching-up were sufficiently advanced compared to other transition economies (e.g. infrastructure, human capital) and the successful transition was mainly a result of business opportunities exploited by foreign investors and domestic entrepreneurs.

Still, Estonia has innovation policy documents. The building blocks are two documents: The Estonian State Innovation Programme (approved in June 1998) and the National Development Plan for the years 2000–2002 (1999), but none of these were actually implemented (Hernesniemi 2000, p. 9). Although there are other economic policy documents, they propose neither explicitly nor implicitly industrial or innovation policy measures; they are mostly composed for international organisations or are written for specific reasons, but they do not propose a long-term vision, systematic approach and implementation mechanisms.

Implementation of the strategy "Knowledge-based Estonia" remains crucial

The new strategy 'Knowledge-based Estonia' (Riigikogu 2001), however, clearly emphasises other failures besides market failures as well, proposing that for remedying such failures, the state has to act as an investor, catalyst and regulator. On the other hand, due to its political nature, the document is full of value statements and does not present detailed action plan, although it also acutely emphasises the need to strengthen innovation policy implementation structures. The latter remains crucial, as without properly functioning public policy instruments, the document, although trying to create noteworthy public discussion and to increase general awareness, remains just a document, as the Estonian recent history track record on innovation policy evidently shows.

Without a proper innovation policy and staying at the present knowledge-intensity level and R&D investments growth rate, Estonia would likely end up in the EU, but would be forced to compete using extensively basic factor advantages, marginalised in terms of technology development and high value added production linkages, excessively dependant on budgetary transfers (Radoševic 1999).

It is therefore essential that the mechanisms for co-ordination between the various national policies that affect RTD and innovation should be developed further. The rise of the public expenditure planned in Estonia and several other Candidate Countries should be actually forthcoming for the support of the national RTD strategies.

Estonian ICT Cluster and the Respective Innovation System

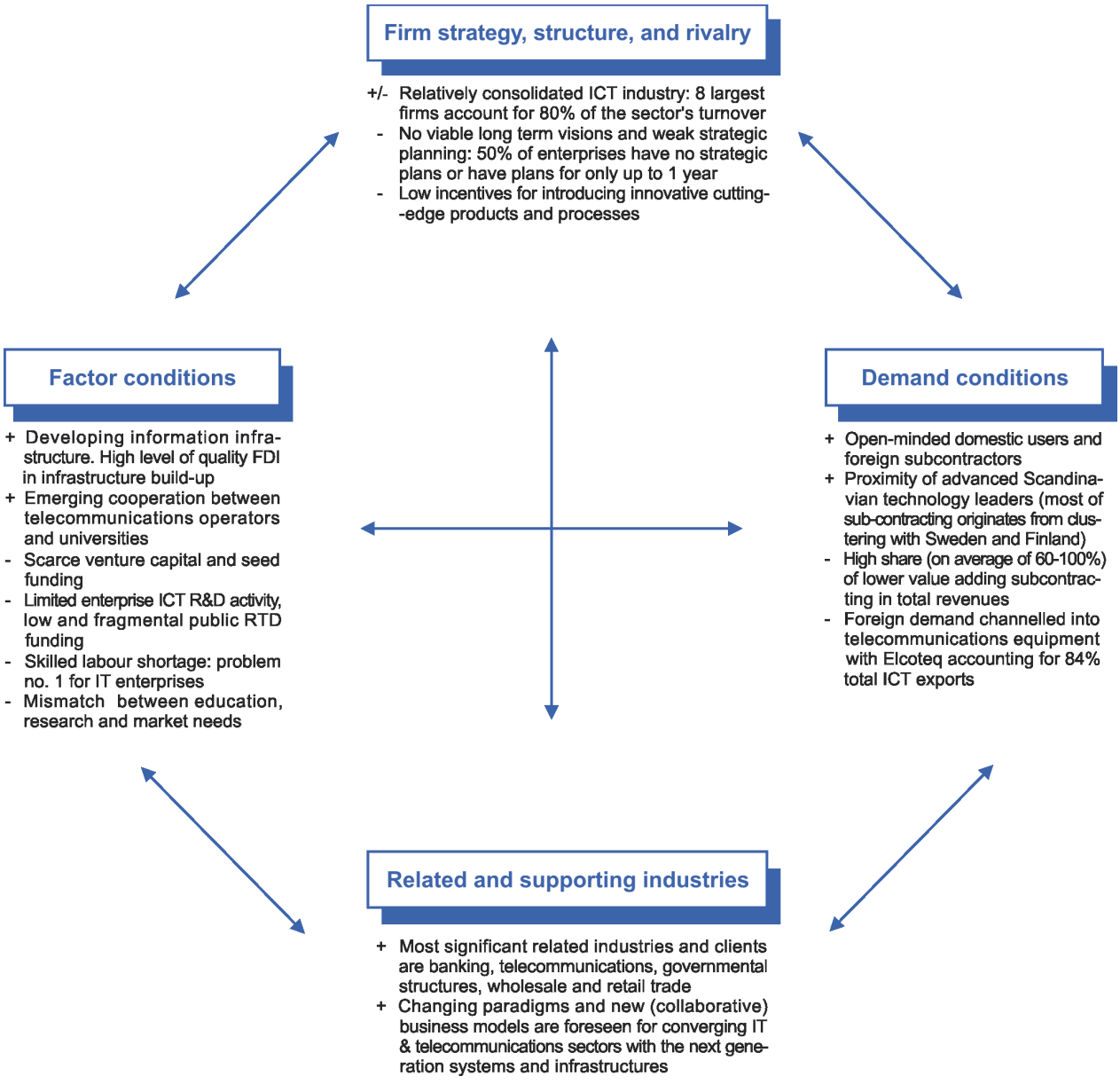
1. Porter's diamond as theoretical approach

Michael Porter (1998) defines four broad attributes which shape the economic environment in the form of an efficient cluster-based network and contribute to the emergence of a national competitive advantage. These determinants are observed in the context of a certain economic domain, the cluster, which represents a value-adding chain of activities frequently spanning over different sectors. The four cornerstones for gaining sustained national competitive advantage are embodied in:

- **factor conditions** that are present in the economy and used in the value adding chain;
- **demand conditions** that pose the direction for further product development and the characteristics of the entire value adding process;
- **firm strategy, structure and rivalry** that determine the level of competition within the cluster and reinforce innovative incentives;
- and **related and supporting industries,** which interact with the observed cluster and thus have substantial influence on its performance directly as well as indirectly.

The present study shows that the basis for a close interrelation between the above determinants potentially exists (Figure 1), but that it is not realised at the present moment. All the broad attributes of Porter's diamond are still evolving, but their interaction has been by far too occasional to form a distinctive and internationally competitive ICT cluster.

Figure 1: Estonian ICT cluster - Porter´s diamond



2. Factor conditions

Factor conditions in the Estonian ICT industry comprise of labour, physical, administrative and information infrastructure, capital market and scientific as well as research infrastructure. There are shortcomings in almost all the named categories; the most serious deficiencies that form major barriers are discussed in detail in sections 2.1 and 2.2.

Proximity of advanced Scandinavian technology forerunners is a significant driver

The physical, administrative as well as information infrastructure are rapidly developing. In this context, the proximity of advanced Scandinavian technology forerunners is a significant driver. The rapid uptake of novel technologies, enhanced wireless communication infrastructure, a high number of conventional telephone lines and Internet hosts has created a favourable platform for building up appropriate forms of applications.

The capital market is functioning, although it is not efficient enough to provide funding to start-ups and new companies. The main sources for outside funding are banks, but claims for collateral eradicate almost every possibility for a smaller company to receive the necessary development financing. Seed and venture capital is scarce, with only a couple of small funds with very short-term and close-to-market orientation present, thus leading to insufficient channels for bringing new ideas to the market.

2.1. Education as priority factor

56% of the Estonian ICT companies (all data derives from the eVikings survey from May 2001 if not indicated otherwise) are in immediate need for specialists on specific products or technologies, 39% seek for project managers and sales staff. Only 10% are currently in the need of research and development personnel, and 20% expect a need for the additional R&D staff emerging only in the longer term.

Admittance to ICT bachelor and master studies in the universities has risen significantly during the second half of the 1990s. At the same time, roughly one-half of the students are leaving the university before graduation, which happens typically after 2-3 years of studies. Unfortunately, no specific studies have been conducted on the performance of the Estonian ICT higher education system and the employers' or students' satisfaction.

There is a mismatch between the skills developed and the needs of ICT industry

Also, the available data and analysis point generally to a mismatch between the skills developed and the needs of industry and commerce (Estonian Institute for Future Studies 2001), which is certainly true for ICT sector as well.

2.2. Research and technological development as crucial factor

2.2.1. RTD funding

Although foreign direct investments into Estonia have shown a constant annual growth since 1992, funding allocated to research and development activities still remains comparatively low. RTD investments comprised 0.7% of the Estonian GDP in 1999 and 2000, which is significantly below the EU and OECD average. The Estonian public sector RTD expenditure comprises 79% of the gross expenditure on RTD (GERD), while the proportion in OECD countries is the opposite with public funding comprising only 39% and the rest deriving from private sources.

Public funding agencies have allocated around 0.7 million € to the ICT R&D activities in 2000, which is approximately **5% of the total Estonian public R&D funding provided.** The project team reviewed the ICT R&D projects supported from the public sources in 2000 and 2001, concluding:

- 14 ICT R&D projects with the average amount of 43.5 thousand € per year or 6% of the total targeted funding were allocated for ICT R&D in 2000.
- The Estonian Science Foundation provided around 40 grants of 3.8 thousand € per year on average, which comprised 3.5% of the total R&D grant funding from ESF.
- The newly established Estonian Technology Agency (ESTAG) had in June 2001 only four ICT product development loans (actually these contracts have been inherited from the Estonian Innovation Foundation - predecessor of ESTAG) with an estimated 128 thousand € total amount in force, so that it did not have any significant impact on the development of ICT R&D in Estonia.

Extreme fragmentation of tiny public R&D funding, relatively low competition and the large number of small projects are clearly some of the main weaknesses of the current R&D funding system. The system in place does not encourage the launching of new high-risk and possibly high-return R&D themes. Nor is it proactive in anticipating prospective socio-economic development scenarios, allocating the priorities accordingly.

Estonian innovation system does not encourage the launching of new high-risk and possibly high-return initiatives

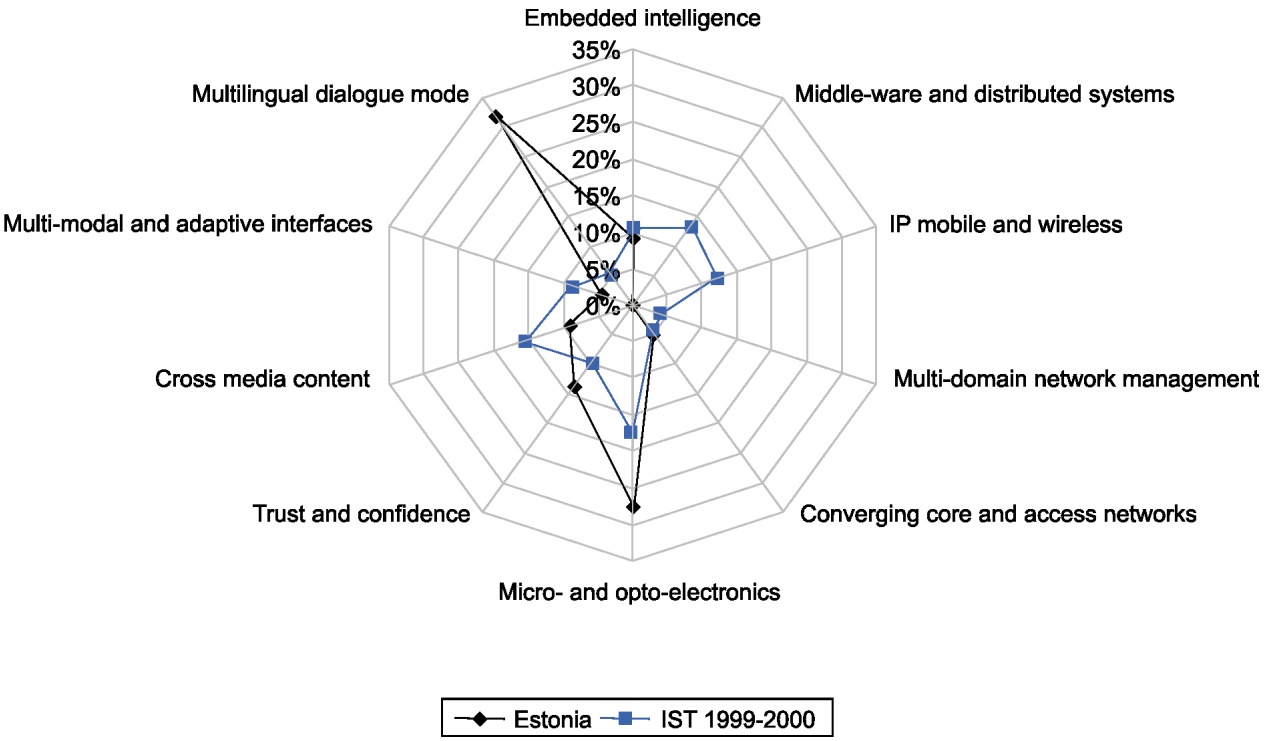
Comparing the portfolio of publicly-funded projects against the European common IST vision (Information Society Technologies Advisory Group 2001) leads to the following conclusions:

- the large majority of current academic research themes are useful

in sustaining and improving the quality of higher education, but the majority of the projects have a limited chance for innovation. For example, small and under-financed Estonian research teams with no respective local industry in the cluster are not able to compete alone in segments that are dominated by large international corporations (software technologies, microelectronics, etc.);

- the research response to the developing information society, to the needs of the society and emerging new markets is weak; only up to one-third of the projects contribute to the development of the Key Emerging Technologies needed for making the European IST vision reality;
- of the Key Emerging Technologies, **micro- and opto-electronics, and language technologies** are met most substantially; there is also some focus on data security technologies (Figure 2).

Figure 2: Estonian public ICT R&D projects across Key Emerging Technologies



Several cumulative reasons (i.e. idle public and private R&D expenditure, weak domestic industries, no active access to international alliances, etc.) have lead in many cases to a situation where no significant new R&D directions are opened, and the system concentrates on saving the existing R&D personnel and research directions.

Public ICT R&D funding does not actively favour university-enterprise partnerships for applied R&D, whereas in the 'Western economies', an integrated R&D and product development cycle is the common practice for the elaboration of new technological solutions. Public funding to basic research alone does not sustain economic as well as scientific competitiveness. Accordingly, public funding principles are adjusted for better support to the development of the national innovation system, and to the formation of sustainable public-private (university-enterprise) RTD partnerships in advanced national innovation systems.

2.2.2. RTD personnel

The existence of qualified human resources is clearly the most important input to any kind of R&D activity. Nevertheless, the number of ICT R&D personnel is not directly available in the official statistics. The Statistical Office (2001b) reported 67 R&D personnel in computer services in 1999 in Estonia, while the estimated size of university ICT R&D staff could be 50–60 persons.

Publishing in international journals remains scarce

Publishing in journals of local importance is a highly characteristic for Estonian ICT scientists, while international publications remain scarce. Estonian authors have published 351 engineering, computing and technology related articles in international publications during the period 1996–2000 (Institute for Scientific Information, 1996 – 2000.). Only 14 of the above belong to information technology, communications systems, computer science engineering, computer engineering technology applications or electrical and electronics engineering. Further to that, roughly one-half of the articles belong more specifically to the domain of electronics design, whereas Prof. R. Ubar together with his colleagues has published six articles on the above.

There are also major differences reported between the public funding per R&D personnel and the rates of the ICT experts in the private sector, where the latter receive at least four times higher salaries. Different levels of compensation in ICT industry and public research labs facilitate institute staff to leave their places and search for more lucrative options in the private sphere.

3. Demand conditions

3.1. Subcontracting – insufficient condition for innovation

Foreign orders are very important for the Estonian ICT sector, as 73% of the subcontracting activity originates from abroad (all data follows from the eVikings survey from May 2001 if not indicated otherwise). Typically, subcontracting involves assembly of various communication equipment and software outsourcing. As a result, subcontracting revenues constituted 60–100% of the Estonian turnover of telecommunications equipment production, industrial automation, consumer electronics and components, and about 15% of the computers and office machinery sub-sector in 2000.

Due to high foreign demand, the export of the Estonian ICT industry has increased rapidly. On the downside, most of the rise can be assigned to a single company's activity – Elcoteq Ltd provides 83% of the total Estonian ICT exports and 96% of telecommunications equipment exports as the statistics for the year 2000 indicates.[2]

Estonian ICT cluster is a sub-part of the Scandinavian ICT cluster

The bulk of subcontracting activity originates from the local market as well as from Finland and Sweden, which are also the largest trade partners for the Estonian ICT industry; 84% of ICT goods are exported to these two countries (Statistical Office of Estonia 2001b). It may safely be assumed that the Estonian ICT cluster is actually a sub-part of the larger Scandinavian ICT cluster, where lower-value-added activities in the form of outsourcing and sub-contracting are performed.

The share of services, comprising only 4% (Bank of Estonia 2001), was marginal in total Estonian ICT exports in year 2000. The low share of services is an impeding factor for the cluster development as a whole, since services bind together a substantial part of accompanying activities such as consulting, maintenance, multimedia production and content creation, which comprise the actual application of existing hardware and software solutions. The neighbouring Scandinavian countries have by far a more balanced trade portfolio, as services account for one third of their ICT exports.

[2] This expert opinion is elaborated based on Statistical Office of Estonia and publicly available data.

Dual impact of Scandinavian ICT cluster can be observed

The effect of Scandinavia can be summed up in a dual manner: on the one hand, it has facilitated the uptake of novel technology and provided Estonian companies with sustainable income through subcontracting; on the other, it reinforces the lock-in effect as the Estonian ICT industry is captured in low value added activities with little promotion of incentives for innovation.

3.2. Information society developments as determinants of demand

Domestic advanced and open-minded users as well as foreign subcontractors determine the demand conditions in the Estonian ICT sector. **Internet banking solutions provided by Estonian banks have found good response among users.** However, in the other domains, the bulk of demand is derived either by local corporate institutions, government initiatives or foreign enterprises, which either outsource services or subcontract production from local ICT firms.

The early launch of the Estonian information society developments is frequently used as best practice for other countries. Without hesitation, the rapid development of the telecommunications market is a clear success story:

- A reasonable state policy has generated rapid catching-up both in the fields of fixed lines and mobile communications;
- Estonia has been one of the first countries amongst the CEE countries to open the telecommunications market for liberalisation, giving a good basis for further development;
- Public initiatives in the fields of eLearning and eGovernment are also good examples that other (especially Central and Eastern European) countries attempt to imitate. Like other transition economies, Estonia is experiencing very rapid developments in the technical sphere with a number of problems arising at the same time on the social scale, such as the digital divide.

Large-scale public sector infrastructure projects provide definitely some incentives for innovation, but these alone are necessarily not enough, as far as energising the whole ICT industry for internationally competitive IST R&D is concerned.

Estonia's application of new technologies is therefore fully in line with the catching-up model. According to the model, however, all technologically

advanced countries in the application of new technologies. This is especially true for consumer goods (mobile telephones, Internet), where relatively little skills are needed and the usage level depends on the supply. Due to the greater importance of tacit knowledge, however, the catching-up model is less well working for knowledge-intensive areas like ICT systems development or even modern manufacturing.

4. Related and supporting industries,

Telecommunications sector, banking and governmental structures are the key drivers for innovation in Estonian ICT cluster

Of domestic industries, manufacturing, the telecommunications sector, banking, wholesale and retail trade, and governmental structures are the important drivers of the emerging Estonian ICT cluster, as they demand most of the production generated by the ICT sector.

Evidently, the fast development of the Estonian banking sector and the high-tech solutions elaborated by the banks' own product development departments have reinforced the need for quality software, and trustworthy and secure products, thus having also positive effects on generating innovative solutions.

Positive signs can be observed in the telecommunications sector, which has started to build strong links with universities and research groups, and pursues research activities also in-house.

Collaborative actions undertaken by the banks and telecommunications operators have established strong links between these two sectors, paving the way for future m-commerce related activities. However, in this context the relations with content providers are insufficient, meaning that these relations have to develop towards a more active involvement of external content service providers in order for a large-scale functioning m-business or m-leisure to appear.

Governmental structures are important users of telecommunications equipment and services, office machinery, computers and software, whereas the government's affection for novel technological solutions has had a positive effect on a number of public sector initiatives. Still, very clear long-term plans and related public R&D programmes should be developed to enable exploitation of the R&D potential of the universities, and encourage international interoperability and exports of the (e.g. eGovernment) solutions developed in Estonia.

One of the explanations for low private sector R&D expenditures (Estonian public sector RTD expenditure comprises 79% of the gross expenditure on RTD) and the lack of willingness to cooperate follows from Pavitt's sectoral taxonomy of innovations (1984). According to this approach, in supplier-dominated activities (such as agriculture, textiles, clothing), most innovations come from suppliers of equipment and materials; firms undertake generally little R&D and request few patents. In production-intensive activities (such as scale-intensive industries including cement and glass manufacturing, and machinery production), R&D is conducted in the larger firms; firms tend towards vertical integration and appropriation is linked to tacit knowledge, secrecy, and patents. Within science-based industries (e.g. electrical equipment manufacturing, fine chemicals including pharmaceuticals, and biotechnology) the main source of technology is in the R&D activities of the firms.

The majority of the customers of Estonian manufacturing enterprises belong to low-technology supplier-dominated or production-intensive groups. As the number of innovative acts in these sectors is relatively low everywhere, this could explain why Estonian enterprises are generally investing very little resources in research and development.

5. Firm strategy, structure and rivalry

5.1. Consolidation

According to turnover statistics, the Estonian ICT sector is in general terms relatively consolidated: **the eight largest companies account for approximately 80% of the Estonian ICT market,** dominated by telecommunications enterprises.

There are three rivals in the telecommunications services market, and considering the market size of Estonia, there is not much room left for newcomer operators. Free market competition in the telecommunications services domain has resulted in falling prices, but also a number of interesting ICT solutions (m-parking, m-payment systems) have been introduced to the market. Both liberalisation of the market as well as the changing paradigms of the telecommunications industry globally are heavily influencing the strategies taken by the Estonian operators. However, the changing paradigm prescribes also changing forms for rivalry, as collaboration between infrastructure and content providers is essential in facilitating the development of both – infrastructure as a platform for abundant applications, as well as services providing added value to customers. Thus, the openness of telecommunications operators for cooperation determines to a large extent the involvement of other companies in revenue sharing and developing novel and competitive application solutions.

The level of deployment of new applications depends on telecom´s willingness to co-operate

Additionally, there are a number of small ICT companies, but the market share they account for is almost irrelevant from the view of cluster development.

5.2. Firm strategy

Incentives for innovation of Estonian ICT companies are relatively low; companies do not perceive the necessity to elaborate their own cutting-edge solutions. Mostly, they try to be fast imitators and utilise novel products developed elsewhere. Only 9% actually cooperate with the domestic universities, but basically no cooperation with foreign universities or research institutes has been reported (all data derives from the eVikings survey from May 2001 if not indicated otherwise).

50% of the sample ICT companies reported their 'strategic' business plans being for up to one year or there being no plan at all. 24%

answered that they review and update their strategic plans on an annual basis, while 70% showed 3–6 months strategic plan update cycles. The latter cannot really be regarded as serious strategies, but should rather be considered as tactical decisions or operational management.

Normally, at least three-year planning and implementation periods should be presumed for the R&D activities, which will need follow-ups in the actual introduction of products to the market.

Patent statistics show that domestic competition in technology products is not on the level of the 'Western' standards yet. The overall number of patents applied for in Estonia during 1992–1999 is 2,234, yet domestic patent applications comprise only 4% of these. Mainly non-residents register patents in order to protect their intellectual property in Estonia.

According to the US Patent Office (2001), there are altogether six patents registered on the name of Estonian residents (with one of these belong plausibly to the ICT domain). This makes only 4.3 patents per million inhabitants, whereas the average number of US patents granted to the EU Member States is around 70 per million inhabitants (European Commission 2001).

Altogether only up to five companies with a few thousand employees can be identified in Estonia which could be able to subcontract ICT R&D work from university research labs. In addition to that, another half a dozen ICT R&D intensive start-ups can be listed, while their growth potential will be determined to the large extent by the existence of adequate quality personnel and venture capital. About 30% of the observed ICT companies stressed the need for additional R&D and product development investments; about the same number were interested in incubating their novel products.

5.3. Cooperation between national institutions

The landscape of R&D activity in ICT is constrained by the number of qualified participants both from the academic and enterprise side. High value-added R&D activity is only the domain of a few institutional players, and the bulk of new knowledge created in the universities is mostly basic research oriented without significant market relevance.

Learning, both process as well as product innovation, primarily comes

from inside companies themselves. 77% of the interviewed ICT companies claimed to have introduced a new product, new service or pursued product development during 1999–2000. This share is relatively high, indicating that companies work on finding new solutions in the competitive environment.

Awareness about research institutions and their activity is very low among private enterprises. Only a scarce 35% of those interviewed indicated that they have some knowledge about the existing research institutes. The number of companies who have used professional help from such institutes is significantly lower: just 9%. More than one-half of the respondents referred to the excessive academic orientation of universities and R&D institutes as the reason for modest cooperation.

Most of the enterprises considered co-operation with universities unnecessary

Most of the enterprises considered cooperation with universities unnecessary – the locally focused business strategies taken by Estonian ICT companies simply do not assume knowledge intensities comparable to those of the more developed markets.

Due to the compartmentalisation of the research landscape and a lack of viable long-term ICT R&D strategy, primarily niche products of local importance, with relatively insubstantial market power, are developed.

Most of the (product) development orientated companies are, however, in the middle of the learning curve:

- imitating major development trends towards information society and selling their eBusiiness, eGovernment, etc. related production predominantly domestically;
- or sub-contracting their resources to the foreign clients, while relying on the relatively lower cost base in Estonia.

One can also observe the tendency of companies to collaborate more willingly between themselves than with research institutes. About half of respondents referred to incomplete information about such cooperation possibilities.

This leads to the fact that also cooperation between companies and support structures (science parks, intermediaries and public funding bodies) remains inefficient.

5.4. International cooperation

Estonia alone is unable to gain the critical mass needed to access international markets

Estonia alone is unable to gain the critical mass needed to access international markets, support technology standardisation activities or even to attract the best people world-wide with the specific knowledge needed. International research and technology development cooperation is therefore essential in gaining experience and skills, in adopting innovative solutions to the market needs, and for obtaining more market power via strategic alliances.

Estonian accession to the European RTD programmes opened a completely new perspective for research and technology development in Estonia. Estonia had 75 project proposals in the European Commission (EC) IST programme by June 2001. However, the Estonian participation success rate is only 17%, while the programme average is 25%. The majority of failures with the project proposals are caused by low scientific and technological quality, low innovation and weak exploitation plans, and come from weak strategic planning and innovation management.

However, most of the problems highlighted above could be minimised with the help of wider collaborative incentives, as it is possible to delegate some of the assignments to specialised institutions such as R&D institutes. Also, problems deriving from insufficient R&D financing can be overcome by tighter cooperation between the universities and industry.

Therefore, full exploitation of the opportunities offered by international cooperation is by large extent still dependant on specific national instruments to be launched both for strengthening the existing centres of excellence and building capacity in the research directions needed for the future competitiveness of the society.

Policy Recommendations

Tentatively, policy recommendations for improving the situation of the Estonian ICT sector would look, in synthesis, as follows:

- There is a need for activity-specific industrial policy, i.e. for a policy that would consider the competitive advantage of different sectors and their future perspectives. As a precondition, increase in public sector administrative capacity is needed.

- The National Innovation System should be approached via public policy as a system of institutions that are interacting and dependant on each other. Only a strong, well functioning and integral National Innovation System could lead to a gradual shift from the public sector dominated RTD financing to increasing private funding.

- An in-depth evaluation of the R&D funding schemes against the situation of the National Innovation System and the set objectives is recommended.

- A cluster-based strategic planning approach should be utilised, as the under-development of some sectors could discourage development in other sectors that form a cluster. For the ICT sector, there are few advanced support and demand conditions, and the cluster linkages so far remain weak.

- The mismatch between the skills developed and the needs of industry should be addressed via well-targeted education and training policies. National R&D resources, which are indeed very limited, should be invested first of all into strengthening the higher education and research system and improving human capital in the specific ICT and ICT-related areas of strategic importance for Estonia.

- Every effort should be made to enable public-private partnerships for improving ICT graduate education, to support capacity building, and to initiate further shifts towards an increasing industrial ICT R&D activity in Estonia. For example, the Northern eDimension framework for the Baltic Sea regional cooperation could be also utilised for establishing 'Virtual University' type of schemes.

- Properly managed foresight as the process for building widely accepted long term (10+ years) IST development visions could help both in improving local networking and strengthening the strategic planning capacity of the domestic players.

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