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THE ESTONIAN GENOME PROJECT AND ECONOMIC DEVELOPMENT

Rainer Kattel[1] and Riivo Anton[2]

[1]Tallinn Technical University, [2]University of Tartu

Abstract. According to its initiators, one of the objectives of the Estonian Genome Project (EGP), a nation-wide health and DNA database launched in 2001, is to positively impact Estonia's economic development. This article asks under which conditions can the EGP have such an effect. We argue that knowledge-intensity of technological structure of the existing industry indicates, first, degree of existence of local clusters of economic value-added, and thus secondly, capacity to absorb technological development. Taken together, third, this indicates competitiveness of an economy in terms of ability to export and at the same time to raise real income (virtuous circles of growth). We find that the technological structure of Estonia's industry is developing since mid-1990s towards less complexity, thus rendering locally produced current and future high technology and knowledge (e.g. the EGP) virtually without impact as far as economic development in Estonia is concerned (and not the success of individual ventures). The article also explores the policy options available that could remedy current situation.

Keywords: economic development, innovation, genetic databases

1. Introduction

W. Brian Arthur has recently described what he calls casino of technology strategizing for high technology and high risk ventures as follows:

> *Imagine that all technology strategizing takes place in a big casino. There are gaming tables everywhere, and Larry Ellisons and Bill Haseltines of the world are all wandering from table to table wondering which game to join. There's new game forming – let's say it's broadband or digital banking. Haseltine, who runs Human Genome Sciences, is the first to the table, and he says, "I want to play this game." The croupier says, "Fine, Mr. Haseltine. You can play." Haseltine says, "How much will it be to ante up?" The croupier says, "For you, it will be $4 billion." Haseltine says, "Fine – who else will be playing?" The croupier says, "We do not know until they arrive." So Haseltine says, "OK. What products are we going to be playing with?" The croupier says, "We do*

> *not know until we see them." Haseltine asks, "How well will they work?" The croupier says, "No one knows that until the future." Haseltine replies, "What are the rules?" The croupier says, "The rules will be formed when people sit down."* (Arthur 2003:48)

Arthur could have just as well picked anything from biotechnology,[1] for example genetic databases. In this case Estonia could be considered a player in Arthur's high-technology casino, too. Estonia has set a legal background for genetic databases[2] and launched the Estonian Genome Project (EGP) in 2001. The EGP is creating a nation-wide health and DNA database of the Estonian population and will provide access to the database for the purpose of performing genetic studies of common diseases. In addition, however, the initiators of the project have declared as one of the objectives of the EGP to increase the international competitiveness of the Estonian economy. According to the mission statement of the EGP, the competitiveness is to be strengthened by development of medical, gene technology and research institutions' infrastructure, as well as investments in high technology, creation of new jobs, and the emergence of knowledge-intensive products and services in the stated fields.[3]

However, the entire state budget of the Republic of Estonia for 2004 is less than $4 billion mentioned above by Arthur, and it is roughly one third of the Estonian GDP (estimated $15.2 billion in purchasing power parity in 2002[4]). Moreover, to borrow from Arthur again, other players have also sat down at the gaming table: Iceland has deCode,[5] UK has initiated Biomedical Population Collection (now named The UK Biobank),[6] and Germany's independent science funding agency *Deutsche Forschungsgemeinschaft* has recently called for and endorsed founding such a database also in Germany.[7]

Whatever one thinks of the EGP, it can hardly be denied that this is a scientific and technology-intensive project aimed at creating new knowledge. Thus, the economic benefits of the EGP should occur via innovation process; innovations, in turn, are arguably the major determinants of economic growth and development.[8]

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1 Modern biotechnology is understood here according to OECD definition as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services" (OECD 2001a).

2 Estonian Parliament passed Human Genes Research Act on 13th of December, 2000 and it entered into force on 8th of January, 2001.

3 The mission statement and further details are available at www.geenivaramu.ee/mp3/ trykisENG.pdf.

4 See www.cia.gov/cia/publications/factbook/geos/en.html.

5 For brief comparison of deCode and the EGP, see below.

6 See www.ukbiobank.ac.uk for further information.

7 See www.biomedcentral.com/news/20030910/02.

8 The OECD Franscati Manual (1993) admits that the word "innovation" can have different meanings in different contexts and the one chosen will depend on the particular objectives of measurement or analysis. In the context of this study we understand innovation in its original Schumpeterian definition. According to Schumpeter, an innovation is the use of a discovery or invention, or of a newly discovered or invented combination or use of known items or processes, within the economy, so as to create an economic advantage, and are produced by entrepreneurs. (See Schumpeter [1939]1989:58–61; on

Thus, the question we try to answer is rather straightforward: under what circumstances can the EGP have positive impact on the Estonian economy?

We propose to take a comprehensive approach and start – as the EGP does – from the competitiveness. Following OECD we define it as a capacity of an economy "to produce internationally competitive products and services (export), while *at the same* time maintaining or increasing the actual income of people."[9] (Tiits and Kattel 2003) In what follows, we will briefly sketch the theoretical background of what determines competitiveness (Part I). This will give us the necessary setting to look at, first, the technological and export performance of Estonian industry in the 1990s and real wage dynamics, and, second, to examine the EGP and its possible impact on the Estonian economy (Part II).

2. Part I. Technology and its impact on the economic development

2.1 Knowledge and competition

Following the definition given above, to positively impact competitiveness of an economy means to raise its ability to export and compete with imported products on the domestic market without decreasing the actual income of people. In other words, competitiveness of an economy indicates the presence of positive feedbacks or increasing returns to scale (Arthur 1994 and 1996), in short virtuous circles of growth (Reinert 1999 and 2003) in the economy. However, virtuous circles of growth mean that most of technological (or otherwise made) advancement in economic productivity[10] is not taken out as lowered price on the market (as an advantage compared to competitors) but generally as higher salary (positive salary competition).

Generally this happens because of the varying nature of competition. Where competition is mainly about price advantage, gains in productivity are available to all participants on the market. Therefore, the competition is nearly perfect as there are hardly any informational asymmetries involved (e.g. in service industries;[11] for agriculture, see below). On the other hand, where gains in productivity and market power take place in leaps due to strong informational asymmetries (products and

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Schumpeterianism, see most recently Freeman 2003) Innovations can involve a series of scientific, technological, organizational, financial and commercial activities. It is important to note that an innovation has been implemented only if it has been introduced to the market (product innovation) or being used in production processes (process innovation) (OECD 1993).

9 The definition is based on OECD 1992; see further Reinert 1994. The problem of external constraints through negative balance of payment and its effect on the ability to compete internationally is not touched upon in this article; see on Estonia in this context further in detail Tiits et al.

10 This includes also, e.g., technological upgrading and organizational change new to a particular economy; see also UNCTAD 2003a: 7-9.

11 For most recent data, see Wölfl 2003.

technologies are or can be protected from competitors), the competition is imperfect or dynamic.[12]

In other words, economic activities are not qualitatively the same.[13] In addition, this quality changes over time as dynamic imperfect competition changes via spread of technology and information, imitation, learning etc., to a more perfect competition.[14] (Tiits et al.:38) Thus, the change of quality of an economic activity over time is caused by the changing degree of intensity of knowledge or technological advance.

Yet, not only does the nature of competition change, but also the organizational nature of a particular industry as well as its impact on other industries. Industries in strong dynamic competition, i.e. very knowledge-intensive industries (as today's e.g. biotechnology), tend to demand also very large externalities (costs covered by somebody else, e.g. by government) in terms of infrastructure, levels of education, possibilities for cooperation and so forth. These industries require a strong division of labor. However, a growing division of labor and specialization is also what results of these industries as they are bound to develop fast and thus require new or different (upgraded) specializations in order to grow. In other words, knowledge-intensive industries require as prerequisites a very strong division of labor as an externality, at the same time these industries further in quality the existing division of labor as well. This in turn means that these industries are largely dependent on human capital and institutions that foster it.[15] This is also the reason for positive salary competition enabled by dynamic competition, where increasing returns to scale make enormous productivity and value-added gains possible (i.e. these industries are able to compete internationally and raise actual incomes).

On the other hand, knowledge-intensive industries transform – via creating more division of labor in knowledge-intensive sectors – over time also the technological structure of other related and supplier industries as new technological input or as new partners in economic activity.[16] Thus the competitiveness of these industries rises in terms of the ability to compete internationally and raise real incomes (this being process of upgrading or modernization). Obviously, these developments take time, and they tend to be increasingly path dependent (Arthur 1994; UNCTAD 2003a; Krugman 1991), both in negative and positive sense;[17] and it makes a huge difference where the initial starting point for catching-up

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[12] This is the basis of Schumpeterian "creative destruction" (1950:83). On dynamic competition, see further Ellig and Lin 2001; and on the role of financial capital here Minsky 1996 and Burlamaqui 2000.

[13] Reinert's work here has been groundbreaking, see Reinert 1999 in particular.

[14] Herein lays also one of the most important aspects of globalization; see further UNCTAD 2003a.

[15] On foreign direct investments, human capital and competitiveness, see UNCTAD 2003a: 3–4.

[16] Excellent case study of chemical industry's development from the 19th through 20th century is Arora et al. 1998; on pharmaceuticals, see McKelvey and Orsenigo 2001, and Henderson et al.

[17] Moreover, at the beginning of this development there has historically always been a strong involvement by the state (Reinert 1999, Chang 2002). Why this is theoretically so can be explained in a number of ways, see Reinert 1999; from financial risk point of view, see Minsky 1996; Stehrer and Wörz 2003 build quantitative models to prove path dependency.

is.[18] However, the entire logic of the much praised knowledge-based economy lies herein. (See generally Freeman and Louçã 2001)

2.2 Technological revolutions and techno-economic paradigms

History of capitalism tells us that not any technological development or innovation is of similar importance and impact. As economic activities are qualitatively different, so are also technologies or technology systems. Yet, it is not technology that creates new markets, products and industries; rather, it is the free market system that creates new technological and innovative solutions and products. The logic developed above of positive feedbacks and varying nature of competition explained precisely this phenomenon: with the spread of technology the nature of competition becomes more perfect and thus productivity gains from knowledge-intensity decline, and eventually new productivity gains from even more knowledge-intensive areas and technologies are sought (because there are less imitators, less perfect competition, and thus more chances of monopolistic markets).

These surges and leaps in productivity tend, however, to form periods of roughly half a century to go about, before another picks up. Nikolai Kondratjev was the first scholar to statistically show the existence of such waves. (1926 and 1944) Famously, however, Kondratjev did not explain why these waves happen.[19] Indeed, it took nearly 80 years before a comprehensive theory explaining waves of development emerged. Carlota Perez develops a theory of techno-economic paradigms (waves), which start with a technological revolution. A technological revolution is defined as "a powerful and highly visible cluster of new and dynamic technologies, products and industries, capable of bringing about an upheaval in the whole fabric of the economy and of propelling a long-term upsurge of development." (8) It brings about technological innovations that pave way for completely new products and processes, and a new infrastructure. Furthermore, each of those technological breakthroughs spreads far beyond the sector or industry where they originally developed and the new leading technology or set of technologies influences the development of all economic activities. (Ibid.) As the technological revolution guides the economic development of a particular time and has spill-overs to all spheres, it is called a *techno-economic paradigm*.

However, following the logic of techno-economic paradigms developed by Perez and of free-market development described above, new technologies arise where the older ones reach their respective developing frontiers. By and large these frontiers lietoday in processing and manipulation of organic materials, and this is also where

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[18] For by now classic arguments, see Abramovitz 1986.

[19] While imprisoned by Stalin, Kondratjev wrote between 1930 and 1932 on *The Basic Problems of Economic Static and Dynamics*; the manuscript, perhaps one of the most interesting attempts to write 'philosophical economics', is cut off before it discusses the nature of dynamic development (although it includes one of the best discussions of Schumpeter, see Kondratjev 1991:287–296). The manuscript is now published in Russian.

IT, biotechnology and nanotechnology meet.[20] It is reasonably certain that biotechnology will be one of the technologies to provide next generation's technological input for traditional industries from agriculture to equipment.[21]

Estonian Parliament has adopted an R&D strategy for 2002–2006, *Knowledge-based Estonia*, which specifies biomedicine, user-friendly IT services and nanotechnology as the key areas which public policy should specifically promote and develop. The strategy also specifies respective policy programs to be built by the government in order to develop the key areas.

Within this framework as well as in terms of techno-economic paradigms, the EGP holds great potential both as a business venture and as a potential impact for the Estonian economy as such. However, from science to innovation, and from innovation to economic growth and competitiveness is not only a long way, but also one with very high risks. The risks – once we leave basic science behind – arise mainly from the fact that knowledge-intensive industries experience strong dynamic competition. On the one hand, this kind of competition is bound to raise real income, yet on the other hand it creates monopolistic markets and thus opportunities of great loss (Schumpeterian creative destruction).[22]

Biotechnology is obviously already today experiencing very strong dynamic competition.[23] Thus, if we want to even in approximation answer the question what conditions (in addition to the emergence of biotechnology-based techno-economic paradigm) need to be fulfilled in order for the EGP to have a major economic impact, we need to answer first the question how high is the current and possibly also future ability of the Estonian industry to absorb scientific and technological advances that *could* result from the EGP and biotechnology generally.[24] In order to

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[20] For discussions of convergence of IT, biotechnology and nanotechnology, see Antón et al. 2001, Roco and Bainbridge 2002, European Commission 2003:380–406.

[21] There are a number of studies trying to specify the possible technological impact on agriculture and manufacturing industry, for very concise and accessible accounts see Economist 2003, and Rauch 2003.

[22] See also Evans and Schmalensee 2001.

[23] We do not attempt to determine exactly how dynamic the competition in biotechnology as such and in its different sectors is. Just as an example, almost half of biotechnology products by European public biotechnology companies are in pre-clinical phase (Ernst&Young 2003a: 38), which means that these products have not yet entered markets.

[24] See also generally for Central and Eastern European countries, Radosevic 2003. National innovation system theory can be applied here as well. National innovation system (NIS) is a set of institutions whose interactions determine the innovative performance of national firms (Nelson 1993:4–5). NIS involves universities and research institutions, government financing schemes for innovation, but also, in wider context, the national education system, entrepreneurial climate, legal environment etc. Yet, classical science, technology and innovation measures like R&D intensity, number of publications and patents, and so forth, would yield very little in our context as they are much too narrow and especially in Central and Eastern Europe leave the existing industry almost untouched. See, however, Radosevic 2002 for comparative data for Central and Eastern European economies; Radosevic 2002 also develops innovation capacity index (based on above-mentioned classical measures) and, as was to be expected, this is negative for all Central and Eastern European countries.

do that, we need to understand the technological structure and knowledge-intensity of the Estonian industry, and the development path to the current structure.

3. Part II. Technological structure of the Estonian industry and the EGP

3.1 Technological structure of Estonian Industry

The experience of 20th century capitalism tells us that technological development in industry brings forth higher wages, in services and agriculture, but lower prices on the market. One of the main reasons for this phenomenon is that for service and agricultural sectors, technological change is an input (as e.g. new machinery), which eventually is available for all those active on the market. Technological change in an industry can often be protected from competitors, patent being the obvious example here. As we argued above, the more knowledge-intensive an industry, the more it will require and also produce new division of labor, specialization and in sum clustering. This does not mean that there will not be an industry if these conditions are missing. Rather, this industry will have to be either very cost-effective (i.e. low wages) or part of an outside cluster's value-added chain.[25]

Estonia, as other Central and Eastern European countries,[26] experienced radical opening of markets in early 1990s and with it a drastic change in the structure of its industry.[27] In order to understand structural changes caused by the radical change of environment, we look at the change in value-added as share of total production from 1994 to 2001 in respective sectors and industries. Raising share of value-added indicates constant or increasing returns to scale; lower value-added share indicates raising costs with raising, constant or even lowering scale, and thus in sectors with lower value-added share there is hardly any technological or knowledge-intensive advantage.

The highest rise in share of value-added from 1994 to 2001 took place in Estonia's agricultural sector; with rising technological complexity or knowledge-intensity, Estonian companies also show lessening (up to 18% in medium technology) of value-added as share of total production.[28] (See Figure 1)

This shows diminishing returns to scale the more complex the technology. That is, with rising knowledge-intensity Estonian companies also face the problem of raising costs whatever the scale. Accordingly, the medium and lower technology sectors do not compete on the bases of technological (knowledge-based) advantage, and need to compensate it with raising costs. One of the most obvious costs is that of labor, and as Figure 2 shows, Estonian low and medium technology companies have achieved increases in productivity which are to a large extent attributable to cutting

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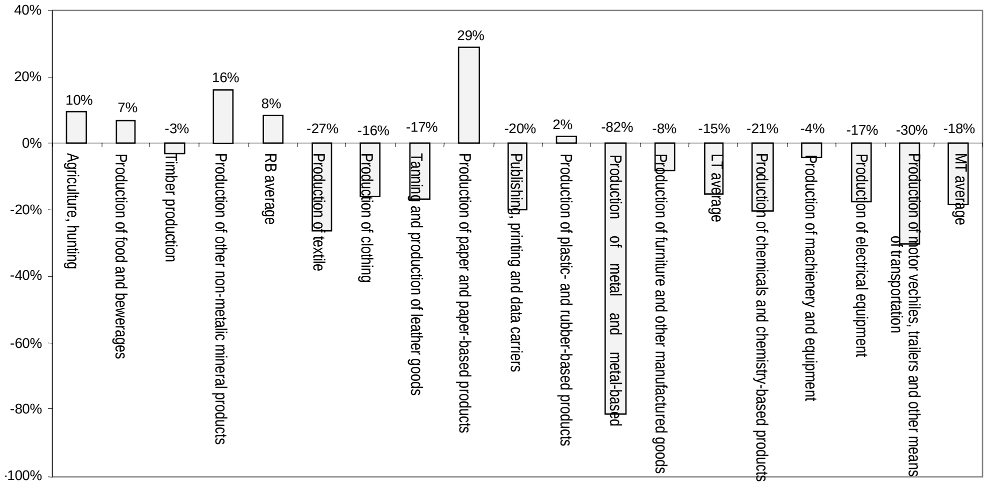
25 The latter has happened to Estonian ICT sector in 1990s, see Kalvet et al. and Kalvet 2003.

26 The best theoretical treatment for this region and its transformation can be found in Drechsler et al.

27 See Tiits et al. for detailed treatment and data.

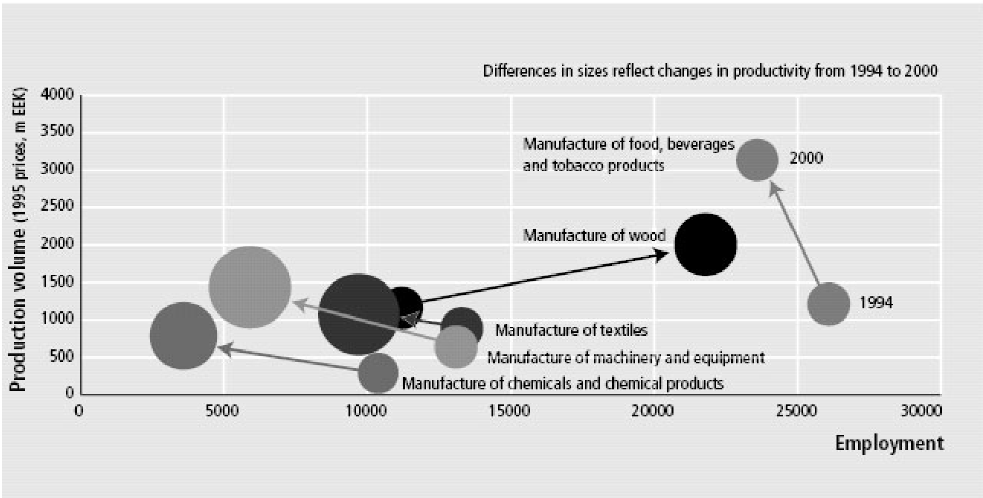
28 Similar pattern emerges in productivity gaps towards EU average (agriculture having the smallest gap), and the pattern is similar for all accessing countries from Central and Eastern Europe. (Stephan 2003: 11, chart 2; calculations are not albeit done for specific industrial sectors)

labor costs (employment). Strong exception here as well as in value-added is wood producing industry.



Source: Statistical Office of Estonia (www.stat.ee); calculations by the authors.[29]

Fig. 1. Change of share of value-added to production in industry and agriculture 1994–2001



Source: Tiits et al.:29.

Fig. 2. Productivity, employment and gross production in selected branches of industry, 1994–2000

[29] RB = resource-based; LT = low technology; MT = medium technology. For high technology the data available from Statistical Office of Estonia did not allow for calculations over this time range. Taxonomy is based on Lall 2000, and is used throughout the current article.

There is hardly anything surprising in the strong performance of the agricultural sector – during the last 100 years or so in almost all developed countries productivity in agriculture has been rising faster than in industry.[30] Obvious question why then most developed countries, most notably the European Union and USA, use such massive measures to protect respective agricultural producers, is answered by the logic described above. In agriculture, productivity rise is due to technological change; however, technological change is a production input in agriculture (and in services). This means, to repeat, that most producers on the market are in similar position as far as technological change is concerned – they can all acquire it. However, often the supplier of that particular new technology is in a much different position of near monopoly or at least of strong informational asymmetries. In other words, technological change that causes rise in value-added in agriculture can be hindered by financial power, but not by advantages due to knowledge-intensity (investments into R&D), causing price competition to take place. This means that eventually the value-added is 'taken out' by the producer of technology, and not by the user of technology (or these advantages are very short-lived) who has to lower the price.

A recent study by OECD shows that any kind of government subsidy to agriculture that is tied to production scale, inevitably leads to new investments, of which more than one third will be invested into technological change.[31] In Estonia this has been probably fostered by adjustments made by the companies in order to comply with EU directives.[32]

The technological change in Estonian companies is clearly illustrated by employment numbers. In manufacturing industry the employment has decreased around 60 % from 1989 to 2003; in agriculture more than 350%. In 1989 the manufacturing industry had 26% of the total employment, at the beginning of 2003 it was 23%; in agriculture 18% and 6% respectively. (Statistical Office of Estonia; calculations by the authors.)

At the same time the number of blue-collar workers in employment has basically stayed the same (1989 compared to 2002); number of white-collar workers has decreased around one third; number of skilled workers has decreased by half and the number of agricultural and fishery workers has decreased more than 4 times. (Ibid.)

Together (share of value-added and employment numbers and structure) these numbers indicate, on the one hand, strong modernizing and catching-up; on the other hand, strong concentration and very probably a lessening of specializations (or of scope).

Low and medium technology companies are operating under diminishing or constant returns to scale, indicating that they are not competing on the basis of technological advantage and that they are experiencing very strong price competi-

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30 See, e.g. Bowlby and Trant 2002 for data.

31 See OECD 2003.

32 Detailed calculations can be found in the Ministry of Agriculture 2002/2003; for a detailed and comparative overview of Estonian agricultural policies and support measures for agriculture in 1990s, see OECD 2001b.

tion; apparently every technological advantage gained leads to lowering the price on the market because most competitors use similar technology already (if not, value-added would rise).

The same is indicated by relative productivity growth from 1994 to 1998: the lowest in medium technology sectors, highest in electrical equipment[33] and resource-based industry (calculations by the authors based on Havlik 2002). Productivity in these industries was rising above the average of the whole industry. However, calculating from 1995–2000 (Havlik 2003), the picture changes in as much as in particular food and beverage, rubber and plastic products have been falling behind average productivity; medium technologies, in particular chemicals, are in turn approaching average productivity.

Apparently the lower-technology industries have reached the ceiling of current technological development, while medium technologies still gain from upgrading. This also corresponds to the stronger presence of foreign direct investments in manufacturing since late 1990s (Tiits et al.:23–24, further Sinani and Meyer 2001). Additionally, according to the self-assessment of the manufacturing companies, as much as 60% of their expenditure on innovation goes into acquisition of new machinery (Kurik et al.). This in turn means that Estonian manufacturing companies innovate mostly via technological upgrading.

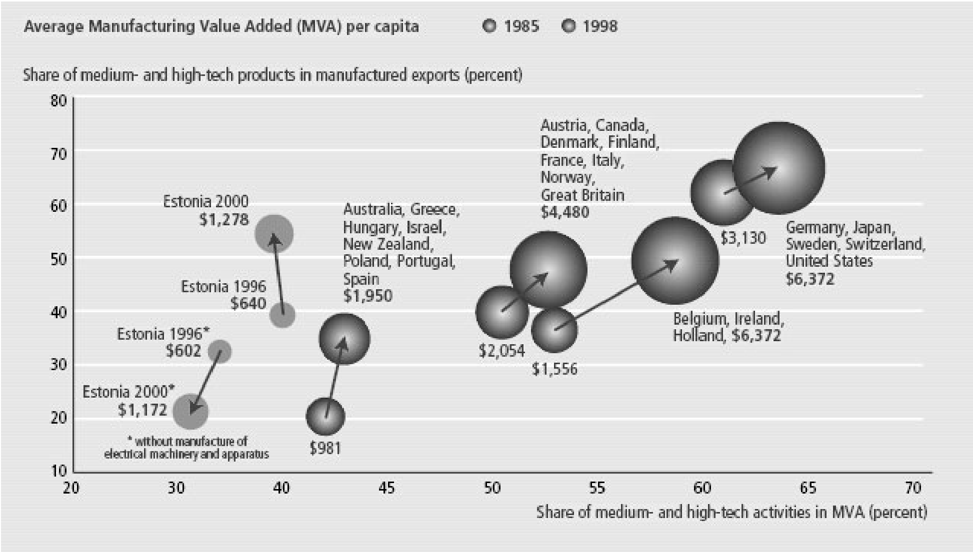
That this process of catching-up in medium technology will be rather short-lived is indicated by a change in the revealed comparative advantages towards EU. Revealed comparative advantages towards EU have been growing (1999–2000 compared to 1995–1996) in resource-based industries and in electrical equipment, both low and medium technology witness lowered comparative advantage (calculations by the authors based on Havlik 2002). Qualitative assessment of manufacturing industry trade competitiveness (toward EU) done by Havlik (2003) shows that trade in medium technologies experiences a rising deficit from 1995–2001; at the same time wood and textile industries experience growing surplus, and most other resource-based and low technology industries show low or stable deficit (calculations by the authors based on Havlik 2003).

In sum: deficits in trade in medium technology originate from the same circle as surplus in lower technologies – technological change via acquiring new machinery and equipment from outside value-chains. Also the development of electrical equipment industry (mobile phones) in the second half of the 1990s does not change the picture; Figure 3 tries to capture these developments.

The share of value-added created by the medium and high technology industries is *decreasing*: “This in turn highlights that despite the enviable records of economic growth Estonia’s industrial structure in 1996 was in better shape than in 2000.“ (Tiits et al.:27)

All industries in Estonia and in particular agricultural and resource-based industries (wood producers especially) have been very successful in modernizing and making companies effective, but almost none of this change has grown out of

[33] See, however, Figure 3 below.



Source: Tiits et al.:27.

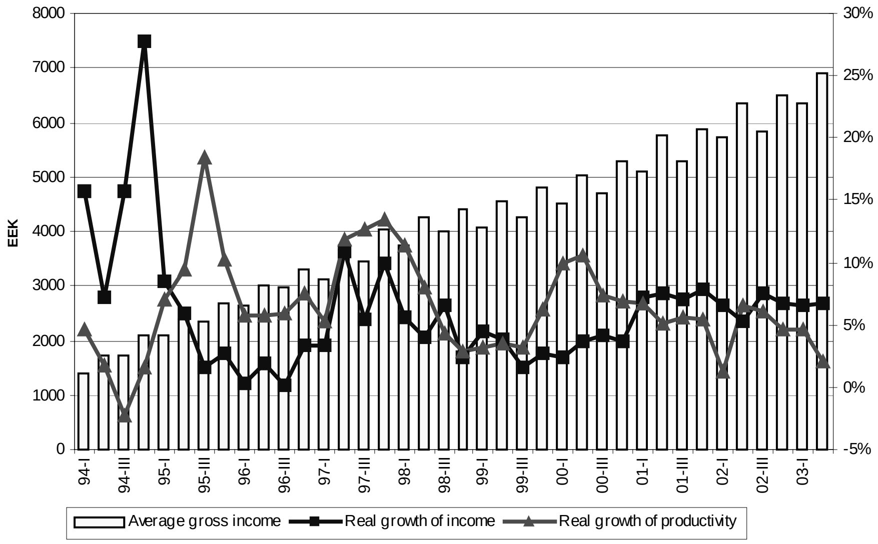
Fig. 3. Cluster analysis of the technological development of the manufacturing industry in industrial countries and transition economies, 1985–1998; in Estonia 1996–2000

local value-chains. In other words, value-added and productivity gains made by Estonian companies will not stay in Estonia and they do not create additional specialization, but rather the gains and specialization will profit value-chains of original technology producers. More often than not these value-chains represent Scandinavian value-chains.

The technological structure of Estonian industry is not developing into a more complex one; since early 2000 the growth of real wage is slowing down (Figure 4), thus the competitiveness of the economy is actually going down, as are the skills and the number of skilled workers. In sum – the capacity to develop and absorb new technologies is dropping. Any attempt directed towards higher technologies is bound to if not to fail, then rapidly diminish in value-added produced because local externalities are so low.[34] It is probably one of the strongest signs of the emerging path dependency as specialization into less knowledge-intensive industries (or parts of industries) as skills and knowledge-base are becoming less.

Today's technological structure of the Estonian industry does not show complex clustering or growing specialization; for future technological upgrading via biotechnology generally this means that there is almost no possibility for clustering, and biotechnological development would follow suit of the 1990s industrial develop-

[34] An interesting case in Central and Eastern Europe is the rapid increase in foreign direct investments in automotive industry (investments growing strongly, UNCTAD 2003b:60–61) and the relocation in electronics from CEE at the same time (particularly Hungary, UNCTAD 2003b:62).



Source: Statistical Office of Estonia; calculations by PRAXIS.

Fig. 4. Real wage, productivity and average gross wage in Estonia, 1994-2003

ment of specialization into lower end of knowledge-intensity and thus not raise the competitiveness of the economy.

Yet it would be wrong to try to revitalize, e.g. machinery and equipment production since extrenalities to be created are very high and markets strongly consolidated. In order to break out of the path dependency developed in the 1990s Estonia would need to target the next generation of medium to high technologies and these are today's ICT and biotechnology (and future convergent technologies based on both and/or nanotechnology). In other words, Estonia would need to 'import' (parts of) ICT and biotechnology-based production and development value-chains. However, it is vital that these value-chains then include also the local existing industry or create new ones; perhaps the most obvious example in our context is pharmaceuticals industry. If not, the impact on raising competitiveness and therefore the living standard will remain marginal. Given the smallness of the Estonian economy, Estonia needs to upgrade the inflowing foreign direct investments to a higher quality.[35] However, the high technology sector needs to be geared towards these developments as well.

35 Cf. UNCTAD 2003b:66–68.

3.2 Estonian Biotechnology Sector and the EGP

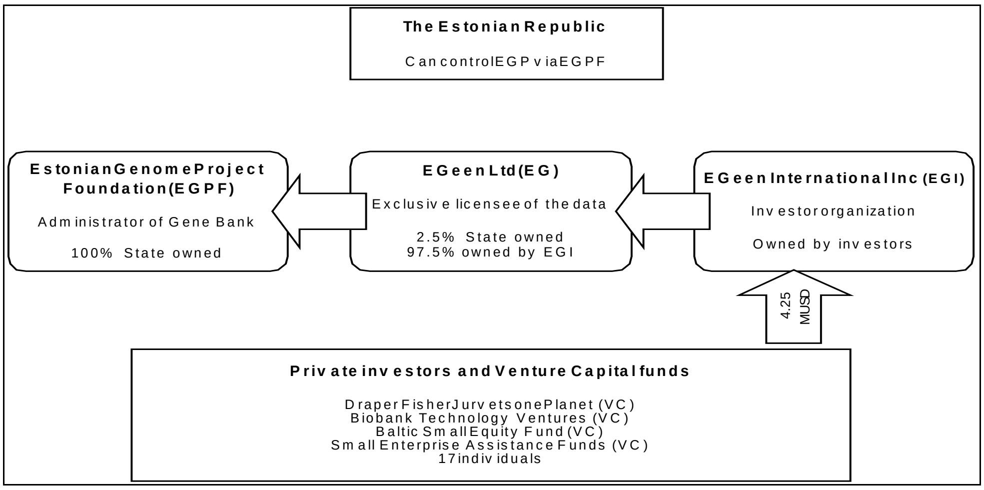
Estonia's biotechnology sector is small.[36] Depending on counting methodology Estonia has either 11 core biotech companies with some 145 employees or 24 companies which employ around 160 people with turnover below 100 million EEK in both cases. The companies have specialized mainly in biomedical field or related bioinstruments.

As major weaknesses the Fraunhofer study stresses that Estonian biotechnology companies have no explicit business strategy, rely on incremental growth in order to minimize financial risk, and therefore have no clearly defined marketing strategy and experiences of management. Additionally, Estonian biotechnology companies do not possess active patenting strategy due to lack of knowledge and financial resources and thus do not fulfill important prerequisites for acquiring venture capital. The companies cooperate mainly with partners from Scandinavia and Germany. Similar pattern emerges from cooperation of research institutes.

On this basis, the Fraunhofer study proposes similarly to this article, "dual stage master plan of *Biotechnology Implementation into Economy*", which "allows synergistic effects between the biomedical sector, which is already advanced in scientific and technical terms, and the low and medium tech industries. On this basis the total costs of the program are estimated to about 350 million EEK for five years." This refers to national biotechnology program that should be implemented according to *Knowledge-based Estonia* by the government. However, apart from the Fraunhofer study, the programming as such has not reached any significant stage and it is probably fair to say that the main reason for this is the severe lack of administrative capacity in terms of sheer manpower and leadership as well as general political disinterest in the issue so far.

The EGP is a public-private partnership initiative. The state controlled Estonian Genome Project Foundation (EGPF) is the administrator of the Gene Bank proper. It has the right to organize the taking of DNA samples, to prepare, code, decode, destroy and issue descriptions of the state, health and genealogies, to perform genetic research, and to collect, store, destroy and issue genetic data. The exclusive commercial licensee of the EGP for 25 years is EGeen (EG). EGeen is established to engage investments into the project via investor company EGeen International (EGI). EGeen was 100% state-owned during the pilot phase of the EGP when all of the operational systems were tested and the first thousands of DNA samples collected. After the successful pilot project the shares of EG are in co-ownership of EGI (97. 5%) and EGPF (2. 5%). The 2.5% controlled by EGPF are accompanied by the anti-dilution clause. In other words, the Estonian state currently controls 2.5% of the exclusive commercial licensee (EG) of the EGP. However, this 2.5% is granted to stay at the same level even when the additional private investments will be engaged into the EGP (see also Figure 5).

[36] In the fall of 2002 Fraunhofer ISI carried out an extensive survey of the Estonian biotechnology sector; the following brief summary is based on this study.



Source: EGPF

Fig. 5. The ownership structure of the Estonian Genome Project

It is important to note that all possible patents created via the EGP will be in equal co-ownership of EG and EGPF, whereas EG pays 3 % of the turnover from transfer of created intellectual property rights to EGPF. In the case of EG's success this might become an important source of funding for the basic research. At the current stage it is too early to judge how this regulation will influence commercial activity originating from the EGP. However, the exclusive commercialization rights given to EG means that the EGP and in particular EG will have to be very competitive from the very beginning in order to survive. First, there is competition to engage additional investments and second, EG will have to seek commercialization at all costs. As the financial markets have recently not been particularly in favor of technology stocks,[37] the most obvious and easiest way is to try to use one of the strongest advantages Estonia offers – relatively cheaper, yet very educated labor in biotechnology. Again, we could see a drive for relatively less knowledge-intensive areas, and thus an early lock-in also in biotechnology, which in turn would mean that Estonia would trade in the raw materials of the 21st century – science.[38] The actual real danger becomes from the

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37 Since going public on NASDAQ in 2000, the share value of Icelandic Project – deCode – has experienced great fluctuations, and has lost 5 times of its value. However, due to major cuts in the expenses and filing a number of patents of good potential, the share value shows rising trends again. For more information see Quarterly reports of deCode available at www.decodegenetics.com.

38 See Cooke 2001:279 on the development of German biotechnology, which, he argues, is locked-in into lower end of biotechnology because of institutional constraints that hinder development of venture capital plus rigid labor market rules, and strong reliance on government and large pharma funding. However: "Rather than viewing 'non-market' business institutions in Germany as obstacles, entrepreneurial firms in Germany might productively view these practices as ''tool

possibility (which is not small) that EG might collapse as a business venture, which in turn might halt the EGP as science outfit for researchers. In other words, EG might fall victim to dynamic competition in biotechnology.[39]

3.3 Policy options for developing the EGP's potential

Even though Estonian biotechnology sector is not specifically built around the EGP, the latter's failure might have a very strong negative effect on the Estonian biotechnology industry in general. The companies as well as research tend to be strong in biomedical fields, and for a number of local companies the EGP could be the essential key to success.[40]

Biotechnology and the EGP are very knowledge-intensive and thus operate under strong dynamic competition conditions, where knowledge-based monopolies or winner-takes-all markets can arise very quickly. As the EGP is mainly a basic research and science venture, its biotechnological commercial outlets will probably be patents or patented knowledge, and other intellectual property rights.[41] From 1990 to 2000, the Fraunhofer study found 7 Estonian biotechnology patent applications: "Although Estonian inventors were involved in those seven patent applications …, most of the patents were filed by foreign firms. The only Estonian institution that applied for a patent was the Estonian Biocentre. Estonian biotech

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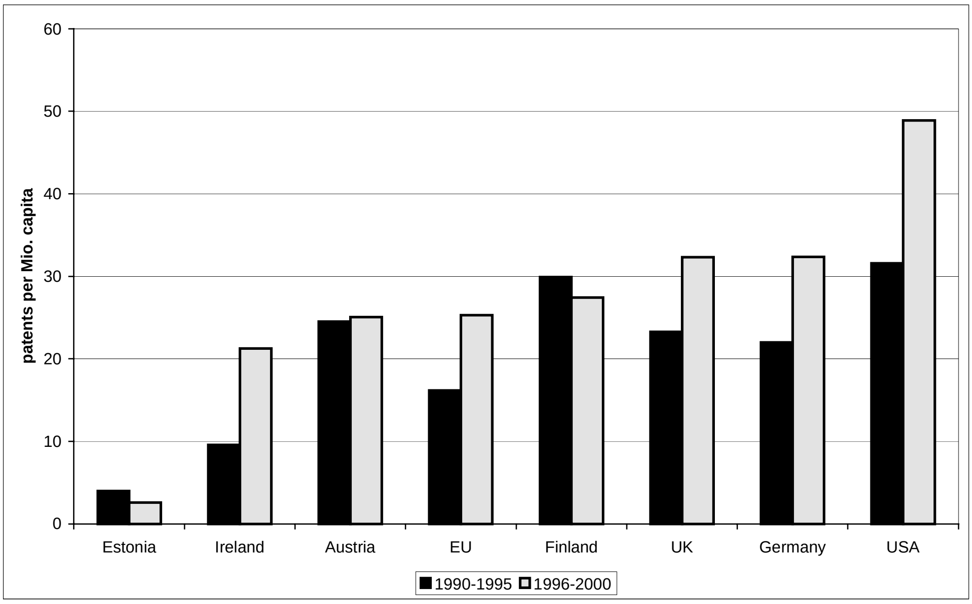
kits'' to selectively engage to develop hybrid business strategies. This perspective is potentially more powerful than the accommodation view, as it realizes the possibility for German firms to craft comparative institutional advantages in new technology areas that differ in business strategy from common practice in the USA and other liberal market economies." (Casper and Kettler 2000:21; see also similarly Casper, Lehrer and Soskice 1999) Yet, the situation of core biotechnology companies in Germany is today perhaps bleaker than ever, see Ernst&Young 2003b.

39 In January 2004 the EGP ran into financial difficulties as EG was not able to finance the EGP under current conditions. The investors expect EG to bring products to the market as soon as possible, and in order to do that the EGP research should focus on specific diseases rather than to the creation of the nation-wide biobank. This in turn would require the revision of the entire concept of EGP. The decision about the future of the EGP will be taken by the Estonian Government in February 2004. Until then the EGP is running its operations on reduced costs which are financed by the Government.

40 Asper Biotech Ltd could be one of the best examples. Asper concentrates on development and marketing of genotyping services. Extensive genotyping (variety of techniques that is used to identify the primary localization and mapping of genes implicated in human diseases) will be needed in order to give commercial value to the data collected into the Gene Bank. Due to similar ownership structure and local expertise Asper is a probable genotyping partner for the EGP.

41 Importance of IPR and patents specifically for different high technology industries is not the same, see Hall and Ziedonis 2001 on patenting paradox (high patenting activity, yet companies not relying on patenting for returns on R&D) in the US semiconductors industry in the 1980s. However, biotechnology and pharmaceuticals are exceptional in this sense, where patenting and innovating are strongly related, see Hall 2002: "If there is an increase in innovation due to patents, it is likely to be centered in the pharmaceutical and biotechnology areas, and possibly specialty chemicals". On debates whether genetic data can or should be patented at all, see OECD 2002.

firms, however, did not appear among the applicants so far." (Fraunhofer 2003; see Figure 6)



Source: Fraunhofer 2003.

Fig. 6. Patent applications in biotechnology per million capita

On the basis of the conducted interviews, the Fraunhofer study also stresses the problem with IPR as one of the most urgent ones for Estonian biotechnology sector insufficient knowledge and low quality of legal advice).

In the globalized economy where geographic distance plays lesser and lesser role, IPR is becoming an important measure to foster regional clustering and increase in specializations. In Estonia, thus, there is an obvious strong need for a public agency which should foster IPR intermediation and cooperation, and IPR services; an additional instrument to help companies and institutions deal with IPR could be to subsidy IPR acquisition (see, e.g. European Commission 2002). As management of intangible assets becomes important not only as far as business and technological development of companies are concerned, but also for accounting and financing schemes, public policy measures that target these areas are of utmost importance.

However, there is also a systematic problem of IPR and academic research in biotechnology. In academic research the use of publicly available databases in publications is usually encouraged, which may stand in contrast to business interest (Walsh et al. 2003:1021). These conflicting interests do not seem to infringe where strong research and business coexist, it rather seems to induce innovative activities and networking. However, with weak business networks around, academic research based on the EGP might not deliver much to local biotechnology business.

The increase of state investments in EG might be one of the ways to ensure that the EGP as a basic science project will continue in any case, independently of the business success of EG. The increase in state investments in EG, however, will most probably make the EGP less attractive for private investors, due to increasing regulations and political risks. Still, the state could act as a classical entrepreneur of the last resort, which would be nothing new in biotechnology as shows the case of UK's Celltech, initiated by the Labour Government of the mid-1970s in response to apparent institutional failure to invest in biotechnology. Recently, an idea of creating a public venture capital fund in Estonia has emerged.[42] Such a fund might be a good instrument for increasing state investments in EG (plus in the whole biotechnology sector) as enabling public investments under the principles of typical venture capital fund.

In any case, it is pivotal for public policy that the externalities already created by the EGP will not be lost, and moreover, that science and education projects grow in scope and scale. Indeed, very strong presence and thus very strong externalities in biotechnology science and education will very probably become much more important than one or two business ventures for public policy in terms of impact on economic development. This is especially so as the EGP's scientific use, let alone commercial, is yet unclear.

However, there are a number of technological solutions within biotechnology that are already on the market and strongly affecting the existing industries: for example the relevance of biotechnology for the innovativeness in pharmaceuticals industry has grown in US to 46% (European Commission 2003:376). In addition, one can perhaps argue that within the next 5 to 10 years antibodies, enzyme technology and DNA technology, to mention just a few, will technologically change the existing industries, especially agricultural and other lower technology industries like textile, food and beverages.[43]

In turn, perhaps the most hotly debated technologies in biotechnology like gene therapy, bioinformatics and technologies based on stem cells will take much more time to impact medicine and pharmaceuticals industry. Thus, for Estonia it is vital to start from specific technological programs that target the existing industries and biotechnology in order to slowly build up networks and competencies; and as a second step to try to bring significant parts of value-added of pharmaceuticals

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[42] Similar instrument is used, for example, in Finland. Finnish Sitra was established in 1967 and is under the supervision of the Finnish Parliament. It aims to promote Finland's economic prosperity by encouraging research, backing innovative projects, organising training programmes and providing venture capital.

[43] We owe this argument to Tiit Talpsep.

industry to Estonia that could use the EGP and build up strong IPR support structures.[44]

6. Conclusion

One of the objectives of the EGP, according to its initiators, is to positively impact Estonia's economic development. We asked in this article what are the conditions under which the EGP can have such an effect. We argued that knowledge-intensity of technological structure of the existing industry indicates, first, the existence of local clusters of value-added, and thus secondly, a capacity to absorb technological development; taken together, third, it indicates competitiveness of an economy in terms of ability to export and at the same time to raise real income.

We found that the medium technology sector of Estonian industry is apparently operating under diminishing returns to scale (or decreasing increasing returns), and also some lower technology sectors experience similar tendencies. All of the industrial sectors tend to specialize into lower, less knowledge-intensive sectors of respective technologies. This in sum means that the technological structure of Estonian industry is getting less complex, specialization is probably diminishing, and there seems to be hardly any clustering between different technological sectors. The capacity of Estonian industry to raise its competitiveness is thus diminishing; Estonian economy seems to be getting less knowledge-intensive, and not more. If general economic policies as well as innovation and industrial policies in Estonia stay more or less the same as they have been in the 1990s, then there seems to be almost certainly no possibility that in next 5 to 10 years the technological structure of the Estonian economy will get more complex. On the contrary, the pattern of specializations will probably flatten even more as path dependency is bound to strengthen. This, in turn, means that even if the government invests the amounts foreseen for the national biotechnology program, this will have marginal, if any, effect on the Estonian economy.

The development of the biomedical sector can turn out to be very positive, but it is, first, high risk-ridden, and, second, it can very easily become a part of an outside value-chain, and thus bringing almost no clustering effects to the Estonian economy. The smallness of local markets and the nature of global economy only strengthen these possibilities. Therefore, under current circumstances Estonia's

[44] Andersson and Leaf-Herrmann argue for strong missing production capacities in biotechnological drug manufacturing in the next years; sectors like these could be well targeted with direct government action to bring foreign investments to Estonia. In that respect the Technology Development Centers program initiated by Enterprise Estonia might be of importance for Estonia. The program concentrates on supporting research and development centers jointly established by enterprises and research institutions. The centers to be supported by Enterprise Estonia are not selected yet, however, there are number of applications aiming to establish centers that could cluster with pharmaceuticals. For the list of applicants and further information on their R&D projects see http://www.estag.ee/7004. Still, the sustainability of the program and the centers that will be created within it is yet unclear.

high technology ventures are unlikely to have a strong positive effect on the competitiveness of the economy.

Thus, there are a number of policy issues to be solved in order to create conditions under which the EGP as well as biotechnology generally could positively impact Estonia's economy. These are:

- targeting technological needs of Estonia's lower and medium technology industries in 10–15 years perspective in cooperation with local science and education system; this essentially means upgrading the present and future foreign investments via upgrading externalities offered (education and research facilities);
- targeting the development of technologies that could be used as possible technological inputs for the existing industries (i.e. antibodies, enzyme, DNA technologies), especially agricultural and other lower-technology industries like textile, food and beverages;
- the government should carefully reconsider its role at the EGP and ensure that in any case the EGP as basic science and research outfit will survive and develop;
- establishment of a public agency which should foster IPR intermediation, cooperation, acquisition, and IPR services;
- establishment of a public venture capital fund for providing high-tech SMEs with necessary funds and keeping them attractive investment targets for other investors;
- fostering public policy capacities in terms of quality (human resources) as well as instrumentally (administrative structure).

Yet, as we argue, biotechnology as an industrial sector experiences and exercises dynamic competition upon other sectors, and can therefore render any policy irrelevant and/or ineffectual very quickly. This makes the last policy option – public policy capacities – perhaps the key to future technological development of Estonia's industry and thus also of the EGP's success and impact.

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Address:
Rainer Kattel
Professor and Chair of Public Administration and European Studies
Tallinn Technical University
Sütiste tee 21
13419 Tallinn
Estonia
E-mail: kattel@staff.ttu.ee

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