
DEPARTMENT OF SOCIAL SCIENCES & LAW

Iceland's Challenging Transition Towards a Knowledge-Based Economy

Sources of Inconsistencies Between Iceland's Knowledge-Based Policies and Progress

BA Thesis in Philosophy, Politics and Economics

Author: Pétur Steinn Pétursson

Supervisor: Dr. Francesco Macheda

(Fall – 2018)



HÁSKÓLINN Á BIFRÖST
BIFRÖST UNIVERSITY

Iceland's Challenging Transition Towards a Knowledge-Based Economy

Sources of Inconsistencies Between Iceland's Knowledge-Based Policies and Progress

This thesis is a 14 ECTS credit final project towards a BA degree in Philosophy, Politics & Economics, Department of Social Sciences & Law at Bifröst University

© Pétur Steinn Pétursson

Bifröst University, 2018

Grade: _____

Bifröst University

Fall 2018

Iceland's Challenging Transition Towards a Knowledge-Based Economy

Sources of Inconsistencies Between Iceland's Knowledge-Based Policies and Progress

Final project towards a BA degree in Philosophy, Politics & Economics

Author: Pétur Steinn Pétursson

Supervisor: Dr. Francesco Macheda

Abstract

This thesis deals with the role of knowledge as a basis for future economic growth in Iceland. It covers theoretical foundations to the concept of a knowledge-based economy, its integration into public policy and indicators of knowledge intensities in an economic context.

Through identifying knowledge-based objectives in Icelandic government policies and applying various knowledge indicators to assess Iceland's progress, its aim is to present the evolving state of several foundations essential to the country's sustained long-term economic growth. Further, it examines effects on such foundations brought by the 2008 financial crisis in Iceland and during its subsequent economic recovery.

Its main findings are that aforementioned foundations remain relatively underdeveloped in Iceland, contrary to general discernment of Icelandic government policy objectives, and that their deterioration post-2008 was significant although not all-pervasive. The use of incomparable benchmarks for international comparisons until 2013/14 was found to have impeded R&D performance which, together with distorted incentives from supply and demand dynamics between the educational system and the labor market, served as hindrance to Iceland's technological progress. A boom in labor-intensive, lower-skilled service sectors post-2008 discouraged generation of higher-skill jobs in Iceland, whilst its more resilient manufacturing sector exhibited distinctly low yet improving technology levels.

Keywords: Knowledge-Based Economy, Endogenous Growth, Science and Technology, Research and Development, Innovation, Policy and Progress, Iceland

Acknowledgments

I want to express gratitude to my supervisor, Dr. Francesco Macheda, for his encouragement, enthusiasm and enlightenment on the intricacies of economics. I am also indebted to my friends and colleagues whom I had the pleasure of spending countless hours with during my studies, especially Vera Dögg, Þórey Guðný, Árni Jökull and the team. It has been an honor and a privilege.

Most importantly, I am particularly grateful to my wife, Hanna Mjöll, for her relentless support, love and understanding in all of my endeavors, and our two daughters, Hafdís and Sóley Perla, for being my endless source of inspiration; never, ever stop asking questions.

Thank you.

Table of Contents

1. Introduction	1
2. Background: From Theory to Public Policy	1
3. Methodology and Structure of the Thesis	3
4. Knowledge-Based Economy of Iceland: Policy Objectives.....	4
4.1. Policy Declarations of Icelandic Governments 1995-2016.....	4
4.1.1. Government Policy Declaration 1995	5
4.1.2. Government Policy Declaration 1999	5
4.1.3. Government Policy Declaration 2003	6
4.1.4. Government Policy Declaration 2007	7
4.1.5. Government Policy Declaration 2009	8
4.1.6. Government Policy Declaration 2013	10
4.2. Objectives of the Science and Technology Policy Council 2003-2016	11
4.2.1. Science and Technology Policy 2003-2006	11
4.2.2. Science and Technology Policy 2006-2009	12
4.2.3. Science and Technology Policy 2010-2012	13
4.2.4. Science and Technology Policy 2014-2016	16
5. Knowledge-Based Economy of Iceland: Indicators	17
5.1. Expenditure on Education	18
5.2. Educational Attainment and Orientation	21
5.3. Expenditure on Research and Development.....	23
5.4. Employment of Researchers	25
5.5. Patenting and Intellectual Property Rights	27
5.6. Knowledge and Technological Intensities in Services and Manufacturing.....	29
5.7. Technological Classification of Exports and Product Complexity	32
6. Summary and Findings.....	35
7. Discussions and Conclusions	36
Bibliography.....	39

List of Figures

Figure 1	Iceland: Total expenditure on education per capita and as % of GDP	18
Figure 2	Iceland: Indices of GDP and education expenditure	19
Figure 3	Iceland: Per capita government expenditure on education by level and as % of total public expenditures	20
Figure 4	Nordics: Total expenditure on primary to tertiary education	21
Figure 5	Nordics: Total expenditure on tertiary education	21
Figure 6	Nordics: Share of 25-64 year olds with at least upper secondary education	22
Figure 7	Nordics: Share of 25-64 year olds with tertiary education	22
Figure 8	Nordics: Share of 25-64 year olds with tertiary degrees	22
Figure 9	Iceland: Share of new entrants in technology oriented education	23
Figure 10	Nordics: Share of tertiary graduates from technology oriented fields	23
Figure 11	Nordics: Gross domestic expenditure on R&D	24
Figure 12	Nordics: Government budget appropriations or outlays on R&D as % of total general govt. expenditures	24
Figure 13	Nordics: Government expenditure on R&D as % of GDP, world comparison	25
Figure 14	Nordics: Employment of researchers	25
Figure 15	Iceland: Researchers by sectors of employment and full-time equivalent positions (FTE)	26
Figure 16	Nordics: Business enterprise researchers as % of national total	26
Figure 17	Nordics: Government researchers as % of national total	26
Figure 18	Nordics: Higher education researchers as % of national total	26
Figure 19	Nordics: Total EPO patent applications by priority year	27
Figure 20	Nordics: Share of EPO patent applications in selected technology domains	28
Figure 21	Nordics: High technology EPO patent applications by priority year	28
Figure 22	Nordics: Triadic patent families	28
Figure 23	Nordics: Employment in services as % of total employment	29
Figure 24	Nordics: Employment in manufacturing as % of total employment	29
Figure 25	Iceland: Employment developments	30
Figure 26	Nordics: Employment in knowledge intensive services and high- and medium-high technology manufacturing as % of total	30
Figure 27	Nordics: Employment in knowledge intensive services as % of total in services	31
Figure 28	Iceland: Employment developments in selected service sectors 2008-2016	31
Figure 29	Nordics: Employment in high- and medium-high technology manufacturing as % of total in manufacturing	32
Figure 30	Iceland: Technological classification of manufactured exports (Lall)	33
Figure 31	Nordics: High and medium technology manufactured exports (Lall)	33
Figure 32	Nordics: EPO patent applications per 1m. inhabitants on gross domestic R&D expenditure	37

List of Tables

Table 1	Nordics: Average product complexity of top five exported products.	34
---------	---	----

1. Introduction

Developments in economic literature over recent decades reveal a trajectory of theories converging on the role of knowledge in economic growth. A testimony to this is an expanding terminology surrounding the concept and elevated efforts to account for its significance in theoretical models. As the resource from where technological advancements originate, facilitating productivity and growth, policies informed by standard economic theories now recognize knowledge as a key factor driving improvements in the living standards of societies.

The Organization for Economic Co-operation and Development (OECD) has reflected on the above developments, noting the “trend in advanced economies towards greater dependence on knowledge, information and high skill levels” (OECD, 2005, p. 28). This provided for a broad definition to what has been termed ‘The Knowledge-Based Economy’; the title of an epoch OECD publication on economies “directly based on the production, distribution and use of knowledge and information” (OECD, 1996, p. 6). Moreover, this trend signaled a shift in social structure as envisaged by sociologist Daniel Bell (1973; 1979) parallel to a transition towards a “post-industrialist” *knowledge- or information society* in where “a majority of workers will soon be producing, handling and distributing information or codified knowledge” (OECD, 1996, p. 13).

Acknowledging a growing need to discern the relationship between research, knowledge and its translation into economic impact, the OECD brought focus to the role of governments and the ‘science system’ in “diffusing and transferring knowledge to the private sector to enhance economic growth and competitiveness” (OECD, 1996, p. 27). To that regard, and in light of transpiring policy challenges, the referred paper and related publications offered reform guidance emphasizing the role of the firm, national innovation systems, apt infrastructures and incentives encouraging investment in research and training (OECD, 1996, pp. 18-19).

As set out in the literature, characteristics of the aforementioned trend closely mirror those mechanisms postulated by mainstream growth theory (*endogenous or new growth theory*), to which next section offers a broad background.

2. Background: From Theory to Public Policy

Although central to economic development throughout history, only in recent decades did knowledge as a factor of growth gain momentum in the analytical efforts of economists. Earlier theoretical models were, to a large extent, confined to parameters of savings, investment and population sizes associated with two production factors; physical capital and labor (Gürak,

2015, pp. 15, 37). Stress to the boundaries of such models and evolving debates between different schools of thought spurred the emergence of additional factors, orienting macro-economic inquiry in the latter half of the 20th century towards the role of technology and its origins.

In the late 1950s, economist Robert M. Solow introduced *technological progress* as a factor *exogenous* to his growth model, positing its essential yet unexplained function in raising productivity levels beyond a ‘steady state’ where the dynamics of capital and labor presumably settled. In just under a decade later, the concept of *human capital* began taking hold to the credit of such economists as Gary S. Becker (1962; 1964) and Theodore W. Schultz (1961).

In brief, the theory of *human capital* made *labor qualities* (i.e. knowledge, skills and competencies) amenable to economic analysis as inputs to production by introducing empirical variables capturing educational attainment, e.g. years of schooling or degrees of qualification, and its “strong correlation” to hourly earnings of workers (Toner, 2011, p. 39). Through extrapolation of this theory from a micro to macro level, from individual economic growth to growth of economies, it soon fused into the works of other thinkers seeking to uncover the principles governing economic growth.

Drawing from theories of *human capital* and *rational choice*, economist Paul M. Romer devised an *endogenous growth model* elaborated in his two papers published in the Journal of Political Economy; *Increasing Returns and Long-Run Growth* (1986) and *Endogenous Technological Change* (1990). Additional to basic inputs of physical capital (K) and physical labor (L), this model incorporated *human capital* (H) as “a distinct measure of the cumulative effect of activities such as *formal education* and *on-the-job training*” and, as means to index the level of technology, a *technological component* (A) unconstrained by upper bounds to growth (Romer, 1990, p. S79). In line with *rational choice theory*, whilst emphasizing linkages between human capital, research and technology, Romer posited that “technological change [...] arises from intentional investment decisions made by profit-maximizing agents” (Romer, 1990, pp. S71, S78)

With reference to the above, the endogenous argument for *knowledge* as a determinant factor of growth can be broadly summarized in the following manner; knowledge (1) arises from the aggregate output of research and (2) proliferates by virtue of education and training, consequently (3) raising productive capacities as it (4) manifests itself in the discoveries of new and improved technologies, production methods, products and services. It follows that investment in education, research and development activities, conceived as enlarging the ‘*stock*

of *human capital*' and thereby fostering technological progress, is essential to sustained economic growth.

Evidenced by the vast and growing literature, academics and policy makers observant of structural changes in the global economy proved accepting to this argument with both circles becoming increasingly occupied with its translation into economic policy. Over the past two decades, intergovernmental organizations such as the OECD, World Trade Organization (WTO), International Monetary Fund (IMF), World Bank and others, to include such interregional institutions as EU's European Commission, have published a series of papers on related topics providing policy guidelines and advocacy of standardization in progress measurements for its members.

The remaining sections of this thesis elaborate on such policy guidelines and progress measurements within a distinctly Icelandic context.

3. Methodology and Structure of the Thesis

This thesis adopts a mixed-method approach with a case study design. Qualitative and quantitative methods are combined in a critical analysis of knowledge-based objectives in Iceland's government policies and its progress in transitioning towards a more knowledge-based economy (KBE). Its scope spans just over two decades, 1995-2016; from the wake of an era where knowledge-based policies became actively promoted globally, e.g. in OECD's 1996 publication *The Knowledge-based Economy* and European Council's *Lisbon Agenda* in 2000 (OECD, 1996; European Council, 2000). Issues of data availability and government establishments in early 2017 determine the final year of 2016.

Its aim is to test two hypotheses. The first is that, contrary to general discernment of Icelandic government policy objectives, foundations essential to Iceland's sustained long-term economic growth remain underdeveloped. The second, that such foundations deteriorated during Iceland's economic recovery post-2008. Provided that either hypothesis holds true, it seeks to answer the question of "what are the sources of inconsistencies between Iceland's knowledge-based policy objectives and its inherent progress?"

Together these hypotheses represent an amalgamation of the author's own ponderings during the economic recovery and were ultimately triggered by the alarming words of Sigrún Davíðsdóttir, an Icelandic journalist and writer, who in May 2018 commented on the development of a "rudderless tourist economy", "diminishing opportunities for high skills and education", and "Icelandic parents [expressing] their worries of what the labor market will offer their children in the coming years." (Davíðsdóttir, 2018)

First, a qualitative method of analysis is used to identify KBE-aligned objectives within two sets of Icelandic administrative documents: (1) policy declarations of Icelandic governments established between 1995-2016, as set out in their respective coalition agreements, and (2) objectives and recommendations of the Icelandic *Science & Technology Policy Council* (STPC) since its establishment in 2003 through 2016.

Second, quantitative analysis of relevant indicators for Iceland is performed by means of descriptive statistics. Based primarily on data collected by the OECD, Statistical Office of the European Union (Eurostat) and the Icelandic Statistical Bureau (Statice), the analysis focuses on varied indicators devised for the assessment of knowledge and technological intensities in an economic context. A number of standardized approaches are employed together with methods for analysis of relevant economical characteristics. The latter includes such indicators as *Technological classification of exports*, elaborated by Lall (2000), and *Product Complexity* as construed by Hidalgo & Hausmann (2009). Where practicable, trends in Iceland are compared to those of other Nordic economies.

Finally, with the aim of identifying correlations or gaps between policy and progress, conclusions are drawn through comparison of findings from the qualitative and quantitative analyses. The thesis concludes with a discussion of overall findings and critical inquiry into potential origins of observed gaps.

4. Knowledge-Based Economy of Iceland: Policy Objectives

Demarcated by two sets of Icelandic administrative documents, this section highlights government policy objectives relevant to the underpinnings of a KBE. Here, ‘underpinnings’ refers to policy initiatives in such areas as education, research and development, innovation, and science and technology in general. With these areas altogether aligned with themes of knowledge, information and high skill levels, the purpose of this section is to assess the extent to which the Icelandic government has responded to the “increasing need for ready access to all of these by the business and public sectors” (OECD, 2005, p. 28).

4.1. Policy Declarations of Icelandic Governments 1995-2016

This section provides an overview of KBE-aligned objectives identified within six government policy declarations comprising the corresponding coalition agreements between parties to Icelandic governments in 1995-2016.

4.1.1. Government Policy Declaration 1995

The 1995-1999 majority coalition agreement between the Independence Party and the Progressive Party emphasized “reinforcements to the pillars of education and research”, together acknowledged as “precondition to innovation in the business sector” (Icelandic Government Offices, 1995). It marked an epoch in Icelandic administrative literature by directly incorporating objectives pertaining to the use of information technologies “to the benefit of economic progress, business sector development and scientific research” (Icelandic Government Offices, 1996).

In their order of appearance, the identified relevant objectives were: (a) addressing unemployment by increasing investment and innovation in the business sector, (b) facilitating structural reforms for increased efficiency of funding in education, (c) promoting innovation and advances in product development, (d) reinforcing research and development of agricultural products, (e) guaranteeing equal education opportunities regardless of residency and economic condition, and meeting individual needs for adult and continuing education, (f) reinforcing the secondary education level, not least vocational studies and training, and furthering the development of university institutes and tertiary level arts programmes, (g) recognizing strong research and development processes as precondition to progressive advances in the business sector, (h) ensuring optimized allocation of and equal access to funding of research and development by new and traditional sectors alike, (i) revising legislation concerning the Icelandic Student Loan Fund, (j) supporting the Icelandic Student Innovation Fund, (k) increasing student participation in research activities, (l) adapting public services to modern technology, e.g. by bringing public service institutions online, and (m) constructing a comprehensive policy on information technology and its dissemination, in collaboration with representatives of the business sector, for the purpose of enhancing productivity and competitiveness of Icelandic businesses (Icelandic Government Offices, 1995).

4.1.2. Government Policy Declaration 1999

The 1999-2003 majority coalition agreement between the Independence Party and the Progressive Party pledged continuity to the objectives of its 1995 precursor. Re-emphasizing the important pillars of education and research, together recognized as precondition to innovation in the business sector, it promoted the use of new information technologies to the benefit of economic progress, business sector development, scientific research and education.

In their order of appearance, the identified relevant objectives were: (a) attending to the tax framework to encourage research, development and general innovation in the business

sector, (b) increasing diversification in the business and export sectors, not least by empowering start-ups based on education and knowledge, such as in music, film and varied specialized services, (c) stimulating the operations of small- and medium-sized enterprises, (d) supporting entrepreneurs in the business sector, (e) implementing clear rules on patent ownership protection and intellectual property rights with the aim of strengthening conditions for Icelandic entrepreneurs and designers, (f) making education readily accessible, to include rural habitats (g) aligning support to employment development in rural habitats with other innovation and employment development efforts of authorities, (h) continuing research and development in sustainable energy fields, such as hydrogen, methanol etc., (i) reinforcing the information industry to generate new jobs across the country, not least those of interest to young people, (j) establishing conditions for experimentation and implementation of innovative ideas where information and communication technologies play a key role, (k) continuing efforts promoting growth in exports of software, hardware, services and consulting in those fields, (l) keeping communication services at the highest of standards, (m) ensuring a range of options, competition and improved operating conditions in the telecommunications market, (n) forming the basis for a progressive employment development policy within a creative research and innovation environment, (o) continuing adaptation of government services to modern technology, such as by bringing public service institutions online and facilitating electronic transactions, (p) guaranteeing equal education opportunities, regardless of residency and economic condition, and meeting individual needs for adult and continuing education for skilled and unskilled persons alike, (q) continue strengthening the education sector, especially vocational studies and -training at the secondary education level, (r) reinforcing education at the tertiary level with even more emphasis on research and science, (s) increasing distance teaching and -learning, in cooperation with schools currently operating at the secondary and tertiary levels, in order to provide access to such schooling for as many as possible, and (t) increasing utilization of information technologies and mobile services in health care, not least to raise service levels in rural habitats (Icelandic Government Offices, 1999).

4.1.3. Government Policy Declaration 2003

Citing positive results brought forward by its 1995 and 1999 precursors, the 2003-2007 majority coalition agreement between the Independence Party and the Progressive Party repledged continuity to previous objectives and emphasized reinforcements to the education system in particular.

In their order of appearance, the identified relevant objectives were: (a) focusing on efficient utilization of advantages brought by the information society and electronic public administration, to ensure equal and public access to necessary information and services, (b) strengthening research and development activity, e.g. by facilitating businesses in such funding and thereby stimulating entrepreneurial activities, (c) in accordance with new laws on the Science and Technology Policy Council, working towards targeted development of research activities and innovation in the broadest range of fields, (d) continuing development and research efforts to increase the value of marine products, (e) reinforcing educational and research institutions in the field of agriculture, and supporting innovation and recruitment in rural areas, (f) place particular emphasis on distance learning to make education locally accessible to as many as possible, (g) ensuring equal education opportunities regardless of residency and economic condition, (h) reinforcing university education and developing distance learning programs in cooperation with educational institutions at the secondary and tertiary levels, (i) furthering the development of a strong continuing education system in cooperation with the business sector, with particular emphasis on advancing vocational studies and training, (j) maintaining the Icelandic Student Loan Fund's key role in ensuring equal education opportunities for all, and (k) considering measures to ease repayment burden of student loans and revise the act on the Student Loan Fund (Icelandic Government Offices, 2003).

4.1.4. Government Policy Declaration 2007

The 2007-2009 coalition agreement between the Independence Party and the Social Democratic Alliance spanned a period marked by considerable economic turmoil. Nonetheless, it acknowledged successes brought in the years before and set the goal for Iceland to remain at the forefront amongst nations with the highest of living standards. Its terminology assigned weight to measures of economic stabilization and, in some respects, alterations in emphasis compared to its three precursors (e.g. by explicitly recognizing a “growing creative culture sector as a catalyst for innovation”).

In their order of appearance, the identified relevant objectives were: (a) continuing development of educational affairs, (b) acknowledging that the Icelandic business sector will become increasingly characterized by knowledge creation and ‘outvasion’, (c) appreciating cooperation between the business sector and Icelandic universities as key to improving performance and innovation in business operations, (d) recognizing that in coming years, ingenuity and technological know-how will determine the success of Icelandic businesses, (e) strengthening the high-technology industry and start-up environment, by such means as

reinforcing the Icelandic Research Fund and the Technology Development Fund, (f) facilitating continued growth of an increasingly important international service sector, to include financial services, in line with economic transformations during past years and allow for its advancement into new areas in competition with other market regions, (g) unleashing the forces of private enterprise to the benefit of specialized Icelandic knowledge and ingenuity in the ‘outvasion’ of energy companies, (h) modernizing public administration and increasing utilization of information technologies for the enhancement of public services, improved efficiency and simplification of communications between the public and authorities, (i) supporting students at the secondary education level in procuring educational materials, (j) giving special consideration to support for immigrant children in the school system, (k) bringing the entire national education system, from pre-school to university level, to the forefront in a global context, (l) promoting continued investment in research and the national education system, acknowledging that progress and economic growth in coming years will be driven by education, science and research, (m) placing emphasis on quality, flexibility and diversity in educational programs enabling everyone to find education to their suitability, (n) expanding the selection of educational programmes and increasing the emphasis on students’ freedom of choice and individualized learning, for the purpose of reducing dropout rates of students of college age, (o) reinforcing arts and vocational education on all levels and increase education- and employment counseling, (p) placing emphasis on creating new educational opportunities for those who have only completed compulsory education, and strengthening adult education within the school system and labor market, (q) placing effort in extending and increasing diversification in teaching studies, (r) revising the act on the Icelandic Student Loan Fund for further improvement of student conditions, (s) promoting ready access to education for the entire population regardless of residency, (t) increasing emphasis on reinforcement of infrastructures pertaining to telecommunications, (u) ensuring opportunity for everyone to benefit from the revolution in data transfer capabilities, (v) securing redundancy in data transfers to and from Iceland with a new marine cable, allowing for data transfer rates to increase in line with current developments, as good data communications facilitate access to education, services and innovation opportunities regardless of geographical location (Icelandic Government Offices, 2007).

4.1.5. Government Policy Declaration 2009

Still in the wake of the financial collapse of late 2008, a ‘declaration of cooperation’ was signed by the Social Democratic Party and the Left Green Movement on May 10th, 2009. The

declaration therewith replaced a ‘project task list’ published February 1st, 2009, on behalf of the same parties then serving as acting government. Remaining in effect until 2013, the declaration emphasized economic and social stabilization, a need for nationwide consensus to lay ground for the “resurrection of Iceland” and a new ‘stability pact’.

In their order of appearance, the identified relevant objectives were: (a) facilitating the establishment of a creative environment, including economic context, comparable to that of European countries and the Nordics in particular, (b) acknowledging education as a lodestar, together with science and culture, in light of its key role in resurrecting the country, (c) recognizing the importance of creative and critical thinking as key in education, (d) placing emphasis on research funds important to the progression of science and technology, (e) ensuring equal rights to education in light of its importance to reinforce education, science and culture, (f) guarding the educational level of the nation, (g) regarding free basic education as key to the nation’s long-term success, (h) revising the subsistence table of the Icelandic Student Loan Fund with the aim of its elevation, (i) ensuring strong adult education, including Icelandic teachings to foreigners, and encouraging the unemployed to pursue further education according to their suitability, (j) reshaping curriculums across all school levels with the objective of reinforcing creative and critical thinking throughout all education, (k) reassessing, in light of rapid growth at the university level, the organization and operation of universities, their potential cooperation, infrastructure and funding, programme offerings, and increasing opportunities for distance learning at the university level – altogether in consultation with the public and university society, (l) emphasizing innovation and entrepreneurship within businesses, (m) improving the environment for start-ups and innovative firms by amendments to tax laws enabling concessions for research and development, and temporary tax deductions for investment therein, (n) creating new job opportunities for young people, e.g. by reinforcing the Icelandic Student Innovation Fund, (o) revising rules and procedures of the Icelandic Student Loan Fund to facilitate students leaving the job market in furthering their education, (p) reinforcing research, development and production of domestic eco-friendly energy, with the aim of Iceland becoming a leader in associated experiments and production, (q) strengthening support networks for employment development, research and innovation across the country, (r) reinforcing data collection, research and education in the fisheries industry, and (s) forming an energy strategy focused on the development of eco-friendly high technology industries (Icelandic Government Offices, 2009).

4.1.6. Government Policy Declaration 2013

The 2013-2017 policy declaration of the Progressive Party and the Independence Party, having regained their majority in the preceding elections, reflected determination in “forging ahead” and “boosting the business sector by means of increasing value creation”. Government policy was to aid younger generations in obtaining faith in the future, knowledge and the “yearning for progress”, altogether described as basis for future prosperity.

In their order of appearance, the identified relevant objectives were: (a) placing particular emphasis on the growth of export sectors, innovation and seizing growth opportunities of the future, (b) supporting the development of an Icelandic Ocean Cluster by ensuring a sound operational environment, introducing incentives into the regulatory framework and elevating product development and marketing advancements, (c) reinforcing the provision of information and education in the marine industry, with regard to fishing and processing, and not least to take on new projects parallel to product development, innovation, marketing and sales, (d) placing strong emphasis on innovation in all business sectors, (e) increasing productivity, as it is considered a precondition to long-term economic growth to create an encouraging environment for innovation in operating businesses, public operations and new businesses, (f) coordinating the operational basis and environment of public institutions engaged in research and development, for the purpose of ensuring maximum efficiency of funding to research and development activities, (g) amending the tax framework to enable those engaged in research to stand on equal footing to foreign competition and cooperation, so that universities, businesses and individuals can enjoy the benefits of their proceeds in a manner similar to elsewhere, (h) stimulating cooperation and synergy between those engaged in larger development projects within specific sectors, to include the development of cluster policies, improving access to capital by start-ups and simplifying the support environment, (i) revising innovation, marketing and sales in the agricultural sector, (j) placing high emphasis on strengthening the education system, (k) increasing emphasis on education in fields of apprenticeship, vocation, technology, design and the arts, and strengthening the relationship between these subjects and the business sector, and establishing a cooperation platform between educational authorities, teachers and stakeholders in the business sector with regard to future vision and the shaping of educational policies for the aforementioned subjects, (l) employing measures to counter dropout rates in education, e.g. by strengthening educational- and employment counseling at the primary and secondary levels, (m) initiating cooperative measures between stakeholders in educational affairs with regard to development of the educational system and increasing the quality of education, (n) exploring methods to shorten education at the university level and increase

coherence between educational levels, (o) emphasizing support to creative subjects and making arts education both accessible and recognized, (p) examining the operational environment for creative subjects with the aim of their strengthening and advancement, and (q) enhancing public administration and services, by such means as electronic administration and utilization of information technology for communications with the public (Icelandic Government Offices, 2013).

4.2. Objectives of the Science and Technology Policy Council 2003-2016

The Science and Technology Policy Council (STPC) was established by law in 2003 as part of comprehensive organizational changes to support scientific progress and technological development in Iceland. As an interministerial council, succeeding a set of earlier institutions pertaining to research and development, it brought scientific and technological discourse to the highest administrative level. Headed by the Prime Minister of Iceland and supported by its working committees, the council sets the official policy on science and technology for three-year periods at a time (Parliamentary document no. 366/2002-2003).

Although relevant to the concept of a knowledge-based economy in their near entirety, outlining STPC policies in their full detail would far exceed the ambitions of this thesis. The below subsections, therefore, provide a bulleted overview.

4.2.1. Science and Technology Policy 2003-2006

The initial policy set by the STPC in mid-December of 2003 declared the long-term general objective to enhance Iceland's cultural and economic strength in a competitive international environment. Its aim was to bring the nation new knowledge and skills that promoted, amongst other things, sustainable use of resources, increased wealth creation and generation of attractive job opportunities in a knowledge society.

In their order of appearance, the identified main objectives were: (1) increasing funding resources to public competitive allocation funds and coordinating their operations, to the benefit of scientific and technological research and innovation in the business sector, (2) strengthening universities as research institutions, reinforcing and encouraging diverse research activities in universities, by making individuals and research groups in universities compete for grants from competitive allocation funds, and (3) reviewing the organizational structure and operational procedures of public research institutions, with the aim of uniting their strengths and coordinating their activities with universities and the business sector.

In addition to the above main objectives, other recommendations and objectives identified were: (a) constructing strong research groups to operate in an international environment, giving priority to the most competent individuals, institutions and businesses, (b) encouraging cooperation between research institutions, universities and businesses in constructing knowledge clusters capable of achieving a strong international competitive position, (c) making research and development activities attractive to businesses and facilitating the development of high-technology firms based largely on research, (d) adding weight to research education of young scientists in an international research environment, (e) ensuring free public access to results of publicly funded research databases and other academic information, and enhancing use thereof to benefit the society, (f) passing laws incentivizing scientists to protect rights to their intellectual property in the form of patents, and for institutions and businesses to organize the management of their employees' intellectual property, and (g) performing regular quality assessment of research conducted by universities and research institutions on the basis of subjects, sectors or clusters, and account for such results in funding decisions and prioritization (Science and Technology Policy Council, 2003).

4.2.2. Science and Technology Policy 2006-2009

The 2006-2009 science and technology policy emphasized the importance of a 'future vision' and taking advantage of opportunities brought by rapid technological-, social- and market developments. It stated favorable conditions for conducting scientific research, technology developments and the use of practical knowledge for diverse innovation in the business sector and public services, highlighting the social benefits brought forward by the funding of education and aforementioned activities. Attention was brought to the need for a coordinated, joint effort by the state and businesses to bring Iceland to the forefront in terms of scientific and technological progress, providing for a strong and efficient business sector.

In their order of appearance, the identified main objectives were: (1) building an education and science system of the highest standard in an international community, operating in close cooperation with the business sector, capable of responding to and leading rapid developments, (2) reinforcing public competitive allocation funds and combining/merging them within related fields, (3) encouraging businesses and the state to engage in a joint effort to advance research and development activities for improved results with regard to profitable innovation and international competitiveness on the basis of knowledge, (4) redefining the support role of the state in monitoring and research, to the benefit of the public, environmental protection and economic progress, guided by the aim of enhanced achievements.

In addition to the above main objectives, other recommendations and objectives were separated into four categories: coordinated advance, education at the forefront, progress in innovation - stronger businesses, and research to the benefit of the public. These were: (a) increasing public funding of research and development activities in terms of percentage of GDP, (b) increasing the share of funding by the business sector, proportionally to that of the public sector, by 10% per year and up to the level of 60% in 2009, (c) directing research funding increases primarily to competitive allocation funds and programmes operating on the basis of applications and professional evaluation, (d) merging those funds intended for public research into larger competitive funds for the purpose of increasing grants, enlarging projects and ensuring comparable professional deliberations on applications, (e) reviewing basic funding to research institutes and universities with regard to performance evaluations, (f) adding weight to targeted initiatives in line with the council's priorities, (g) ensuring funding of a targeted initiative in genetics favoring health- and nano technology in the years 2007-2009, (h) increasing transparency and cohesion in the operational procedures of competitive funds, (i) encouraging active collaboration between the state and business sector in shaping science and technology policy and carrying out performance evaluations, (j) encouraging participation in international science and technology collaboration, (k) promoting the construction of a knowledge cluster in the central-capital region, (l) reviewing the organizational structure and role of universities and research institutions with the aim of improving efficiency, (m) bringing education to the forefront by reinforcing the educational system from pre-primary to tertiary level, defining a quality criteria for education and research at the university level, promoting research freedoms and international doctoral studies, strengthening connections from universities and research institutions to society, business sector and innovation, and reinforcing continuing education as well as education- and employment counseling, (n) facilitating advances in innovation and strengthening of business enterprises, by continuing efforts in utilizing recent advancements in information technology, improving the operational environment of businesses to incentivize research, development and innovation, and stimulating such activities through public tendering, and (o) acknowledging societal benefits brought forward by research in cultural, environmental and health related fields (Science and Technology Policy Council, 2006).

4.2.3. Science and Technology Policy 2010-2012

The 2010-2012 Science and technology policy noted implications brought by the collapse of the Icelandic financial system in 2008 and the need to leverage opportunities for reconstructing

the Icelandic society in the 21st century. It stressed the importance of synthesizing science and innovation as it warned of threats to achievements of past years by public funding of research and development. In addressing such challenges it encouraged increased cooperation between businesses, entrepreneurs, universities and research institutions, and emphasized the role of competitive funds and tax incentives to innovative firms.

Guided by three principles, i.e. cooperation and sharing, quality and benefits, and international science and innovation, the policy comprised eight categories: universities and research institutions, innovation, quality and benefits, international research and development cooperation, competitive funds, research and innovation infrastructures, open access to research findings, and recruitment.

The identified recommendations and objectives were: (a) sharing of resources and establishing cooperation between research institutions, universities and businesses, (b) exploring potential mergers of universities and institutions, (c) merging and transferring similar projects between universities and institutions, (d) identifying and prioritizing those projects dependent upon long-term public funding, (e) building research infrastructures with regard to efficiency in collecting, storing and providing access to data, (f) ensuring safe storage and open access to collected data funded by the public, (g) facilitating the diffusion of research findings from universities and research institutions to the business sector, such as through patents and the establishment of new firms, together with knowledge transfer from the research environment to businesses, (h) increasing active support to the participation of businesses in international research cooperation as well as in fields of technology- and knowledge diffusion, (i) increasing the effectiveness of support to startup-firms introducing products to international markets, by providing sound consultation based on knowledge of market- and legal environments in the respective countries, (j) amending legislation impeding to research freedoms, without sacrifice to safety, ethical standards and quality, (k) supporting the development of startup-firms based on research, development and innovation, through competitive funds, research and educational institutions as well as the Icelandic Centre for Research and Innovation Center Iceland, (l) encouraging businesses, research- and educational institutions to employ creative studies in their operations, (m) strengthening independent analysis of research, development and innovation outcomes, (n) increasing cooperation between the Icelandic Centre for Research and Statistics Iceland in assessing research contributions of Icelandic parties to improve performance measurements on research institutions, (o) making public funding to science and innovation dependent upon quality and performance, and ensuring that transparency and professional assessment applies to allocations

from competitive funds, (p) making the Icelandic Centre for Research, in cooperation with appropriate audit bodies, monitor value creation and other outcomes of public support, (q) establishing a quality council of foreign specialists responsible for quality monitoring of university teachings and research, (r) assessing the scope, commitments and opportunities in international research- and innovation cooperation, (s) reinforcing the Icelandic Centre for Research as a support- and analytical institution for research and innovation in Iceland, (t) mapping support services to Icelandic applicants for foreign cooperative funds and seek cooperation in merging services to those cooperative projects Iceland is a member of, (u) making the science committee and technology committee active participants in shaping and implementing science- and innovation policy in the Nordics and in Europe, as well as other multinational plans, and utilize their experience in local policy making, (v) increasing the share of public funding to research and innovation allocated through competition funds, (w) compiling an overview of and review all public research- and innovation funds with recommendations to the STPC regarding potential transfers of their administration or merging, (x) making public funds use similar criteria for assessment of project costs and give regard to realistic overall costs for research and development, (y) considering the role of competitive funds and the overall system in the review of applications, including potential value creation and cultural and societal innovation, (z) incorporating new targeted initiatives of the STPC into legislative- or regulatory framework requiring professional evaluation and decision making, (aa) guaranteeing future national access to databases and electronic journals, (ab) encouraging Icelandic scientists to participate more actively in international research cooperation utilizing methods of eScience, (ac) appointing a working group for preparations to the ‘future structure of databases in Iceland’-project which regards their coherence, open access, intellectual property rights, accessible user interface, safety, use, operation and maintenance, (ad) reviewing rules on tax rebates for procurements to scientific research funded by grants, (ae) reviewing the act on the Equipment Fund, for it to cover the entire research infrastructure in Iceland, and rename it to Infrastructure Fund, (af) enhancing the focus in international cooperation on research infrastructure, so that Icelanders may become more active participants in the international building of such infrastructure, (ag) giving special consideration to the building of infrastructure in areas already strong in Iceland, (ah) requiring that findings of publicly funded research be made publicly accessible and shaping public policy to that regard, (ai) giving consideration to necessary infrastructures for open access which coordinates storage libraries, access thereto, and ensures sustained storage, (aj) defining rights of use to findings of research conducted in public institutions, or in collaboration between public institutions and individuals

or businesses, (ak) promoting general acknowledgement of the importance of open access to research findings within the science- and innovation community, (al) increasing utilization of the Research Study Fund to connect universities, research institutions and businesses, and its allocations to that of the Research Fund and others, (am) making the Research Fund place special emphasis on supporting young scientists with sizable grants, so that they can construct and conduct research in Iceland, (an) encouraging institutions and businesses to advance in the EU Marie Curie actions, (ao) greatly reinforcing continuing education in the labor market, education- and employment counseling, validation of competencies and other means providing potential opportunities and incentives for individuals and businesses to strengthen their position, and (ap) placing emphasis on encouraging individuals to attain education in technical and vocational fields (Science and Technology Policy Council, 2010).

4.2.4. Science and Technology Policy 2014-2016

The foreword to the 2014-2016 science and technology policy emphasized the importance of technological progression and innovation in all sectors, both private and public. With direct references to the government's policy declaration it underlined the necessity for increased productivity and acknowledged innovation as prerequisite to long-term economic growth. Amongst its main objectives was to increase appropriations to competitive funds and introducing measures facilitating private investment in research and innovation.

The policy comprised four categories: growth and economic value creation, human resources, collaboration and efficiency, and results and follow-up. Each objective was accompanied by a list of actions and methods of progress measurement.

The identified recommendations and objectives were: (a) increasing funding to science and innovation as a percentage of GDP, up to 3% in 2016, (b) strengthening funding to the university level, comparative to or exceeding the average of OECD economies in 2016 and the Nordics in 2020, (c) increasing the share of competitive financing in funding to universities and research institutions to approximately a third of total funding by 2016, (d) creating a transparent financial environment for universities and research institutions so that contributions become clearly linked to performance and quality, (e) ensuring that rules of Icelandic competitive funds on mutual operational costs and own contributions are in alignment with international developments, e.g. Horizon 2020, (f) utilizing the tax system effectively to encourage businesses and individuals to contribute to science and innovation, (g) implementing tax incentives to increase investment in innovative businesses, (h) creating an environment for active trading of shares in innovative businesses, (i) increasing participation in competitive

programmes and markets internationally, (j) increasing support and consultancy to innovative businesses heading for international markets, (k) shaping an action plan for the participation of Iceland in international research programmes, especially where such participation requires public funding, (l) strengthening the cooperation of universities and the business sector with schools at the primary- through upper secondary level to ensure integration between the school system, community and businesses throughout the country, (m) raising the number of graduate students in scientific, technical and vocational fields, (n) reviewing the primary through upper-secondary levels of the education system with the aim of students finishing upper-secondary studies sooner and decreasing drop-out rates, (o) encouraging increased cooperation between universities, research institutions and businesses on research-based graduate education, doctoral studies in particular, (p) increasing funding of doctoral studies, with the aim of providing full funding to 200 doctorates annually from domestic competitive funds by the year 2016, (q) ensuring international competitiveness of the Icelandic labor market for those engaged in science and innovation, (r) increasing recruitment by targeted efforts, (s) reviewing the organizational structure of the science and innovation system in Iceland, simplifying legislation and work towards integration; merging universities, research institutions and research centers where appropriate, (t) increasing opportunities for support and incentives to promote cooperation between educational institutions, research institutions and the business sector, (u) defining those subjects requiring long-term funding, ensuring their funding and practical application to research and innovation, (v) developing a comprehensive information system on results of scientific and innovation activities in collaboration with universities, research institutions and the business sector, (v) evaluating the quality and results of scientific and innovation activities according to international criteria, (x) evaluating regularly the distribution of public funding to science and innovation and respond to different participation levels of particular groups by providing information and encouragement to participate, and (y) improving statistical data on the Icelandic economy with regard to research, value creation, export and innovation, and use statistics for continued improvements in education, science and innovation (Science and Technology Policy Council, 2014).

5. Knowledge-Based Economy of Iceland: Indicators

This section covers selected proxy-indicators for human capital investment and formation, as well as for knowledge creation and its absorption in an economic context. With the aim of identifying relevant trends in the Icelandic economy, several datasets are analyzed and

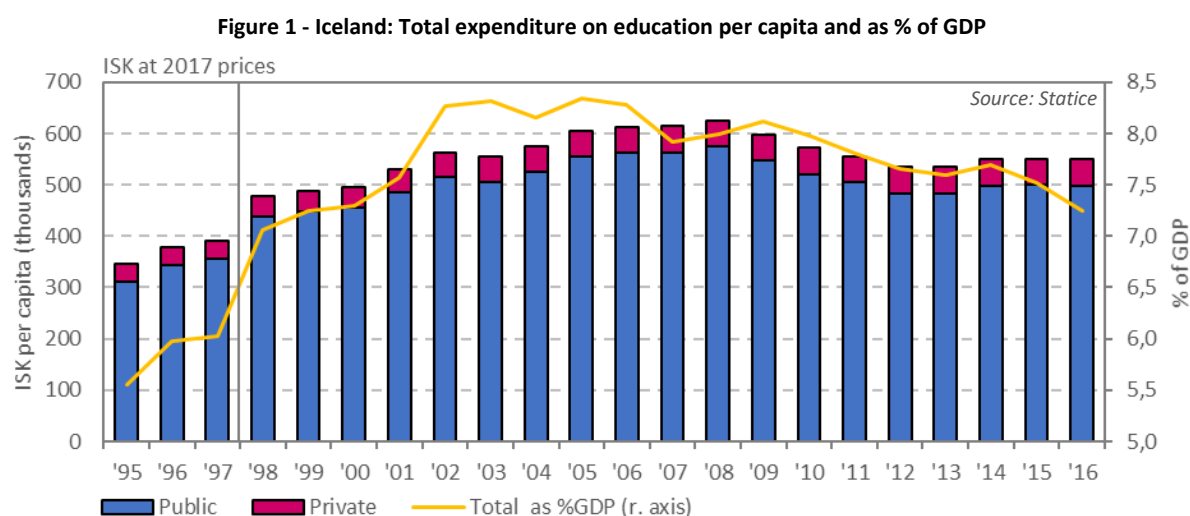
presented by means of descriptive statistics. Comparison of Iceland to other Nordic economies is performed with the aim of discovering potential dissimilarities.

The first subsections cover expenditures on education, educational attainment and orientations in fields of study as per the *International Standard Classification of Education* (ISCED) and *Classification of the Functions of Government* (COFOG), followed by coverage of expenditure and employment statistics in the domain of research and development (R&D). Next, output from R&D activities is gauged in terms of number of patent applications to the European Patent Organization (EPO) and their respective *International Patent Classification* (IPC). Knowledge intensities and technology levels in service and manufacturing sectors are then explored as per *Statistical classification of economic activities in the European Community* (NACE rev. 1.1 and 2) and Eurostat aggregations based thereon, before concluding with a review of product export characteristics as described in the corresponding sections.

5.1. Expenditure on Education

Education and learning are essential functions in knowledge-based economies and central to the concept of human capital. Although readily acknowledged that human attributes develop in both formal and informal settings, standardized measurements of formal education expenditures serve to quantify aspects of human capital investment (OECD, 1998, pp. 16,36).

Figure 1 shows the trend in expenditure on education in Iceland during the observation period via two indicators; real expenditure per capita and the total as share of gross domestic product (GDP). Note that comparability is affected by a break in time series in 1998 due a change in standards (COFOG and ESA2010). Numbers for the period 1995-1997, where presented, are thus to be viewed as informative only.



Real expenditure on education per capita in Iceland (fig. 1, l.axis) gradually increased by a total of 38% between 1998 and 2008, from an initial low of 477 thousand ISK to a high of 625 thousand at fixed 2017 prices, respectively. Over the next four years, this latter number dropped by more than 14% down to 536 thousand in 2012, followed by a relatively stagnant period in where it regained 2.6% and leveled off at 550 thousand by 2016. Overall, this corresponded to a 15.2% increase between 1998 and 2016 with the share of public expenditure at 90-92% of the total. By this measure, education expenditure in 2016 corresponded to that in 2003, some 13 years prior (2003:555 thous.; 2016:550 thous.).

In terms of share of GDP (fig. 1, r.axis) total education expenditure increased by more than 18% between 1998 and 2005 or from 7.07% of GDP to a high of 8.35%, respectively. By 2008 however, this latter number had decreased by 0.35 ppt down to 8% of GDP and an additional 0.75 ppt to 7.25% in 2016. The gradual decrease between 2008-2016 thus corresponded to more than 9%, bringing overall gains in 1998-2016 to well under 3% (2.6%). By this measure, the level of total expenditure on education in 2016 corresponded to that in 1999, some 17 years prior (1999:7.24%, 2016:7.25%).

Comparison of indices for aforementioned trends (fig. 2), together with GDP developments and government expenditure on education as share of total government expenditures, reveals contractions and/or stagnation during an extended period of notable GDP growth. Although apparent in terms of real expenditure from 2008 and as share of GDP from as early as 2005, the most prominent contractions were observed in the share of total government expenditures in 2008 which, despite partial recovery, ended notably lower in 2016 than in 1998.

Total annual aggregates offer a broad overview but limited insight into potential underlying trends. Figure 3 (following page) presents government expenditures on education grouped by selected levels, i.e. compulsory, upper-secondary and tertiary education, as well as other levels and related expenses. Trends in per capita real government expenditure on education reflect previously described characteristics of gradual initial growth followed by contractions post-2008.

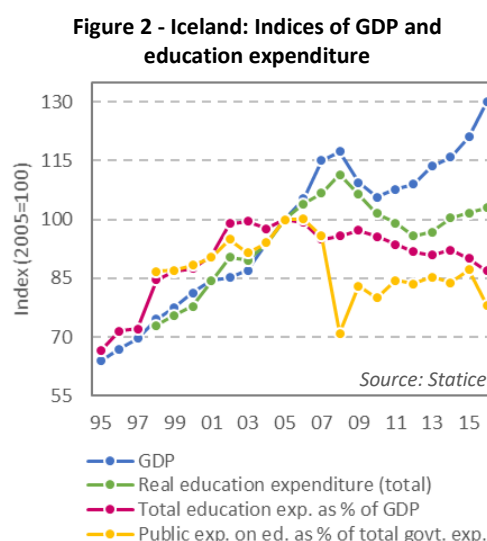
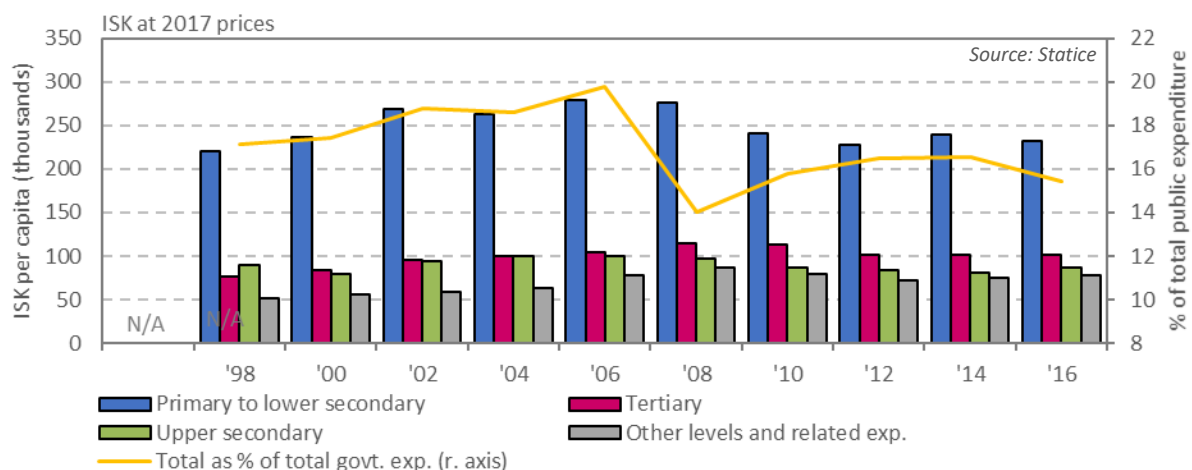


Figure 3 - Iceland: Per capita government expenditure on education by level and as % of total public expenditures



In 1998-2008 this indicator shows a combined 32% increase from an initial 437 to 575 thousand ISK, followed by a 13% decrease down to 498 thousand in 2016. As a result, the overall increase during the 1998-2016 period corresponded to a little under 14%. In addition to a combined 16% contraction at the primary to lower-secondary levels post-2008, notable shifts are revealed at higher levels. By this measure, expenditures on upper-secondary and tertiary levels decreased by 11% and 12% respectively during the 2008-2016 period. However, although the tertiary level was not exempt from such contractions, its associated expenditures surpassed those at the upper-secondary level during the overall 1998-2016 period. The former enjoyed an increase of almost 32% whilst the latter suffered a contraction of a little under 3%.

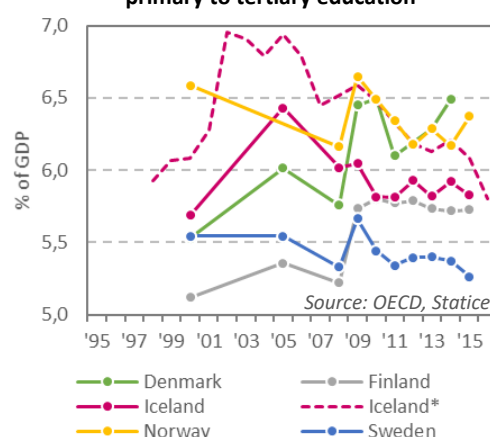
In terms of total government expenditure, the share of education increased by more than 15% between 1998 and 2006 or from an initial 17.1% to 19.8% of the total. However, by 2008 the latter figure had dropped by 29% down to 14% of the total and, despite some evident recovery during the remainder of the observation period, closed at 15.5% in 2016. Using more exact figures this corresponded to a 10% (9.9%) overall decrease in 1998-2016.

In shifting the focus towards country comparison of education expenditures, limited data for earlier periods together with other constraints produces some uncertainties, e.g. due to structural differences of school systems and/or classification of expenditures. It should be noted that, alluding to such constraints, the Icelandic government has maintained that the OECD underestimates actual education expenses in Iceland and cites ongoing revisions by Statice (Ministry of Education, Science and Culture, 2005; 2015, pp. 7-8).

Figures 4 and 5 (following page) provide an overview of expenditures on selected education levels in Nordic economies in terms of share of GDP, using a combination of OECD and Statice (*) data.

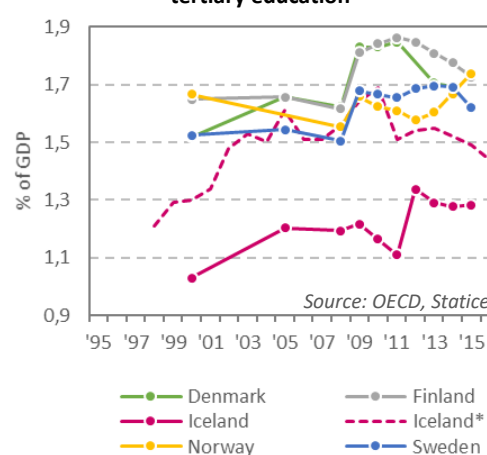
OECD data shows that Iceland's total education expenditures on the primary to tertiary levels (fig. 4) ranked high compared to other Nordics prior to 2008 and close to average onwards. Following an increase from 5.7% of GDP at the turn of the century to a high of 6.4% in 2005, this number for Iceland suffered a negative rebound to 6% in 2008 and leveled off in that region throughout 2015. Statice (*) data reflects a similar albeit more progressive downward trend.

Figure 4 - Nordics: Total expenditure on primary to tertiary education



In comparing expenditures at the tertiary level only (fig. 5) Iceland lacks considerably behind other Nordics according to the OECD. Statice (*) data suggests this gap is not as significant but nevertheless places Iceland at the bottom in general. Icelandic authorities have commented on this divide, citing aforementioned comparability issues and/or potential underestimates with particular reference to funding of university research activities.

Figure 5 - Nordics: Total expenditure on tertiary education



Interestingly, trends based on OECD and Statice (*) data post-2009 reflect mismatches as the former suggests an intermittent increase of over 5% in the 2009-2015 period, whereas data from the national statistical bureau (Statice) indicates a decrease of 9-12%, depending on whether 2015 or 2016 are used as end reference.

5.2. Educational Attainment and Orientation

As mentioned in the previous section, standardized measurement of formal education attainment is one approach, albeit imperfect, to gauge human capital formation. Such measurements refer to the highest level of education completed by an individual or, in macro contexts, groups of individuals fitting a given criteria based on classifications of education programmes such as ISCED (OECD, 1998, pp. 15-16). This section provides an overview of selected trends in educational attainment of the Icelandic adult population, with a special emphasis on science and technology orientation.

Figures 6 and 7 cover general trends in the age group of 25-64 in Nordic countries, indicating significant improvements at the upper-secondary and tertiary levels in terms of educational attainment relative to population size.

Figure 6 - Nordics: Share of 25-64 year olds with at least upper secondary education

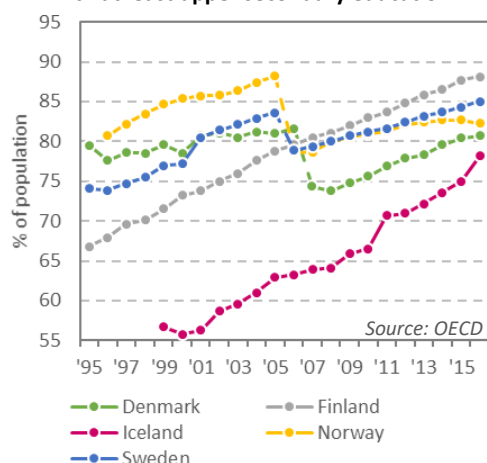
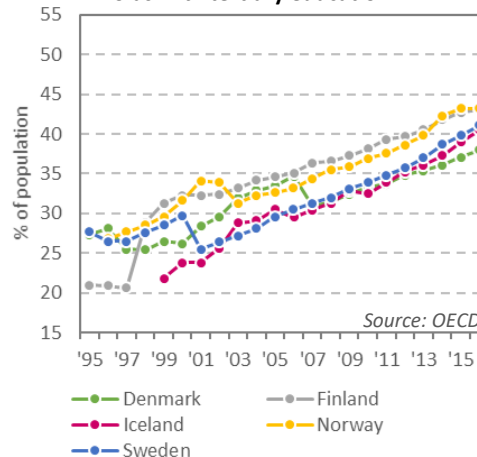


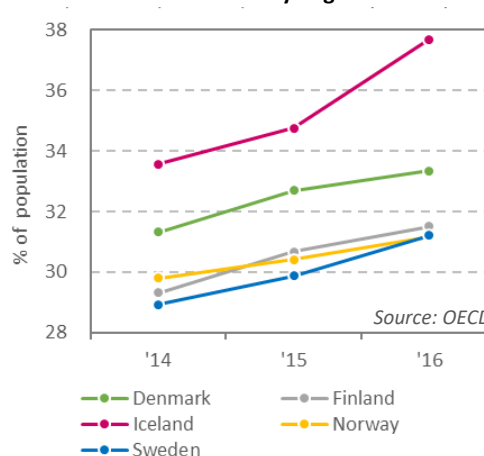
Figure 7 - Nordics: Share of 25-64 year olds with tertiary education



Available data for Iceland in 1999-2016 shows a 21.5 pp or 38% overall increase within the age group of 25-64 years at the upper secondary level (fig. 6, 1999:56.7%, 2016:78.2%), and 18.7 pp or 86% at the tertiary level (fig. 7, 1999:21.8%, 2016:40.5%). Despite notable improvements, it follows from figure 6 that the share of individuals in Iceland who have yet to complete upper secondary education remained in excess of that in other Nordics.

However, the trend at the tertiary level shows greater improvements for this age group in Iceland overall, surpassing Denmark and measuring near the average alongside Sweden at just under 41%. In fact, by excluding short-cycle tertiary programmes using more detailed data available for 2014-16 (fig. 8), Iceland is revealed as having a significant lead over its Nordic neighbors in terms of tertiary level degrees (bachelor's, master's, doctoral or equivalent).

Figure 8 - Nordics: Share of 25-64 year olds with tertiary degrees



The next set of figures (fig. 9 and 10) shows technology orientation in fields of study for students at the upper-secondary and tertiary levels. Here, 'technology oriented' represents such fields as the natural sciences, mathematics and statistics; information and communication technologies (ICT); and engineering, manufacturing and construction.

Figure 9 shows that the number of new entrants in technology oriented vocational programmes, proportional to the total number of new entrants at the upper secondary level in whole, decreased by more than 17% from 1997 to 2016 and remained within the region of 15-22% of the total. At the tertiary level however, an increase of 68% is observed during the same period or from an initial 17% of the total number of entrants to almost 29% in 1997 and 2016, respectively.

Aforementioned indicators for the two groups of new entrants can be viewed as either directly or indirectly linked to the indicator for tertiary graduates shown in figure 10. This last indicator reveals that graduates from technology oriented fields at the tertiary level in Iceland represent a relatively low proportion of overall tertiary graduates compared to other Nordics, and significantly lower than in the leading two; Finland and Sweden.

5.3. Expenditure on Research and Development

Together with educational functions, research and development (R&D) are core activities essential to knowledge-based economies. Such activities are defined by the OECD as “creative and systematic work undertaken in order to increase the stock of knowledge - including knowledge of humankind, culture and society - and to devise new applications of available knowledge.” (OECD, 2015) Measurements of expenditures devoted to R&D thus serve as key indicators of efforts placed in the generation of new knowledge.

R&D expenditure is generally monitored by government institutions and collected by intergovernmental organizations for purposes of country comparison and policy assessment. In an effort to incorporate such statistics into national accounting systems compliant to international standards, Iceland revised its methodological approach causing a structural break in R&D related time series in 2013/14 (STPC Working Group, 2016, p. 1). As shown below, this revision produced significantly lower numbers yielding concerns and debates of potential

Figure 9 - Iceland: Share of new entrants in technology oriented education

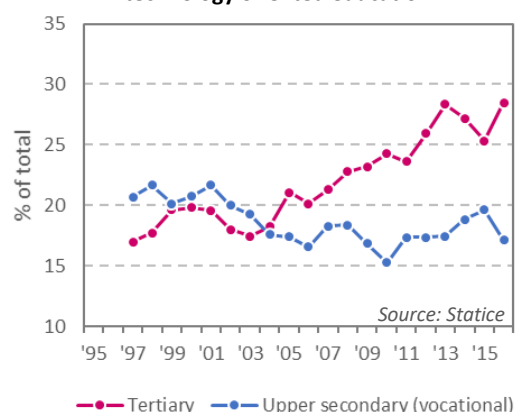
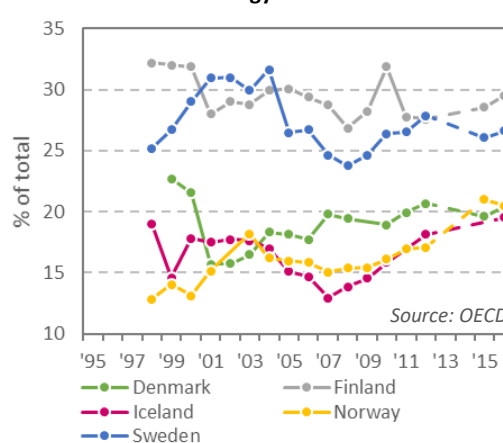


Figure 10 - Nordics: Share of tertiary graduates from technology oriented fields



historical overestimates and/or incomparabilities (Magnússon, 2015; Jónasson, 2015). Here, focus is therefore brought to dominant trends within two distinct periods, 1995-2013/14 and 2013/14-16.

Figure 11 provides an overview of trends in gross domestic R&D expenditure in Nordic economies during the observation period. For Iceland, this indicator shows a progressive 88% relative increase in expenditures during 1995-2001. This trend of growth appears line with or surpassing those in other Nordics at the time, aside from Norway which remained relatively stagnant. From a high point in 2006 however, Iceland shows a gradual-intermittent decline until 2011.

Noting aforementioned revisions, a significant drop to below 1.8% of GDP is observed in 2013, extending Iceland's divide from the three Nordic leaders whose ratio measured in the range of 2.9%-3.3%. By 2016, expenditures on R&D in Iceland saw an upward rebound to 2.1% of GDP, corresponding to that of Norway, while Finland's decreased from an already high level towards those of Denmark and Sweden in the region of 2.8%-3.3%. Here, the 2013-2016 period of four years is considered comparable and representative of actual expenditure levels according to international standards.

A second indicator, government budget appropriations or outlays on R&D (fig. 12), serves as a signal to the priority placed by governments on knowledge production in terms of public support through funding (Eurostat, n.d.-a). Providing an overview of such trends in the Nordics, proportional to their respective government total expenditures, this indicator reveals intermittent overall contractions in the case of Iceland during 1998-2008, followed by a rapid rebound halted only in as late as 2014. By this measure, government funding of R&D in Iceland generally remained above that of other Nordics for the majority of the observation period until dropping well below their average in 2014-16. Viewing the drop in 2014 in light of aforementioned revisions, these numbers suggest that the Icelandic government devoted 1.2-1.3% of its total budget

Figure 11 - Nordics: Gross domestic expenditure on R&D

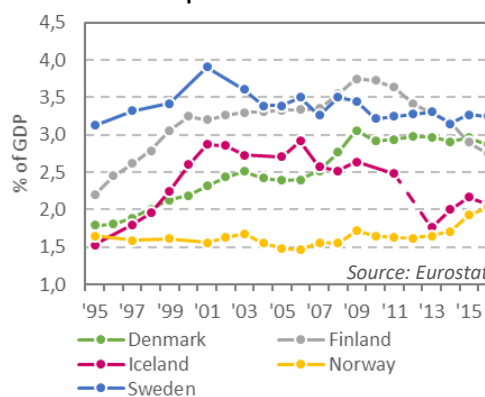
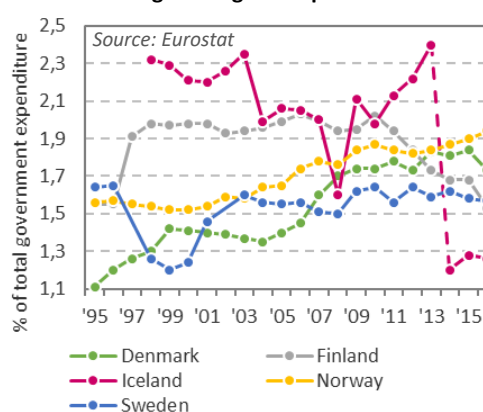
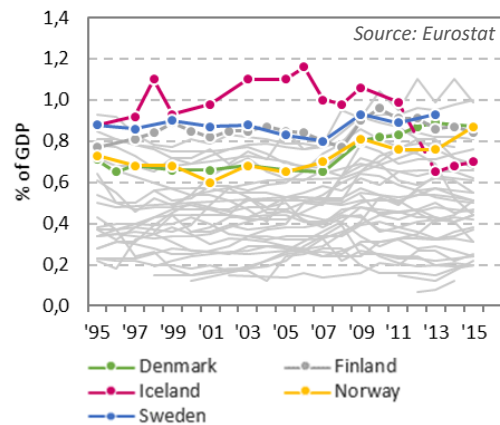


Figure 12 - Nordics: Government budget appropriations or outlays on R&D as % of total general govt. expenditures



appropriations or outlays to R&D in 2014-16. During this final period the same ratio measured significantly higher in other Nordics or in the range of 1.6-1.9%, corresponding to a comparative divide of 33-46%. A final indicator shown in figure 13 presents government expenditure on R&D as percentage of GDP. Interestingly, this indicator shows Iceland as towering above *every* country subject to Eurostat monitoring until the drop to below other Nordics occurs a year earlier, in 2013.

Figure 13 - Nordics: Government expenditure on R&D as % of GDP, world comparison



5.4. Employment of Researchers

A skilled labor component directly engaged in knowledge production is a critical resource to knowledge-based economies. Researchers and other professionals employed in the domain of R&D are amongst those “human resources” constituting “the crucial link between technological progress and economic growth, social development and environmental well-being.” (OECD, 1995, p. 3) Through international collaboration, significant effort has thus been placed on the development of proxy-indicators for resources of this nature. One result of such efforts is data presented in figures 14-15, i.e. employment of researchers as share of total employment. Although breaks in time series affect comparability between periods, the indicators provide means for observing trends in Iceland within individual segments.

Data on researcher employment shown in figure 14 reveals varied growth patterns except in the case of Finland which generally ranked first. For Iceland, similarities to trends in expenditures on R&D are apparent; initial increase followed by a drop, here presumed a result from revisions to statistical methodologies in 2013/14. Re-emerging divergence between Iceland and leading Nordics suggests confirmation of anticipated linkages between funding of R&D and intensities of researchers engaged therein.

Figure 14 - Nordics: Employment of researchers

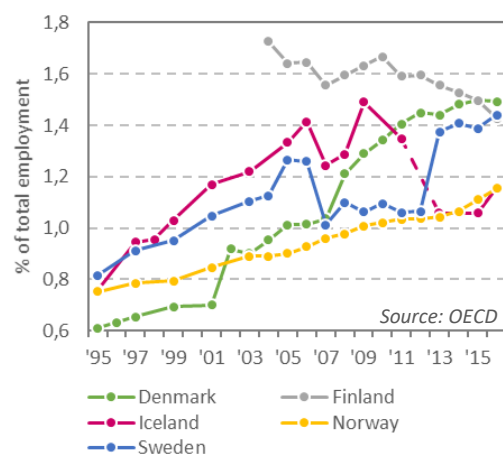
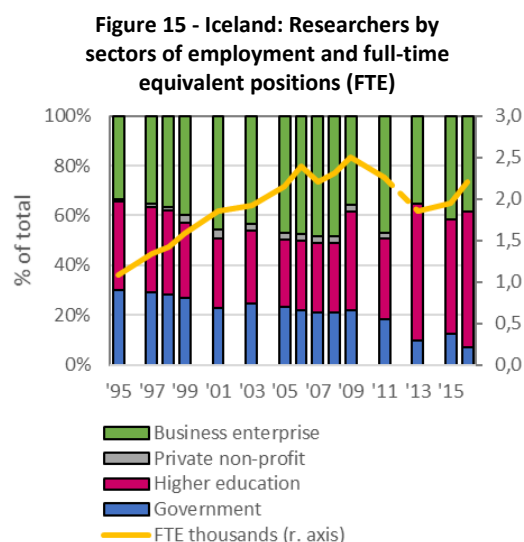


Figure 15 reveals a consistent trend in per sector full-time equivalent (FTE) researcher positions during 1995-2009 parallel to an advance of the business enterprise sector. This trend appears broken prior to revisions in 2013/14, resulting in a 19% reduction of business enterprise researchers in 2009. However, this was offset by a notable 53% increase within higher education and by 14% in the government sector. Numbers for 2015/16 signal the return of an upward trend with FTE positions gradually rising throughout 2016.



Source: Statice

The above figure, together with the structure of researcher employment shown in figures 16-18, indicates that the Icelandic government did not counter the sharp contractions post-2009 directly. Moreover, progressive developments in higher education together with a soft rebound in the business sector did not overcome an overall decrease of 16% between 2009 and 2016.

Figure 16 - Nordics: Business enterprise researchers as % of national total

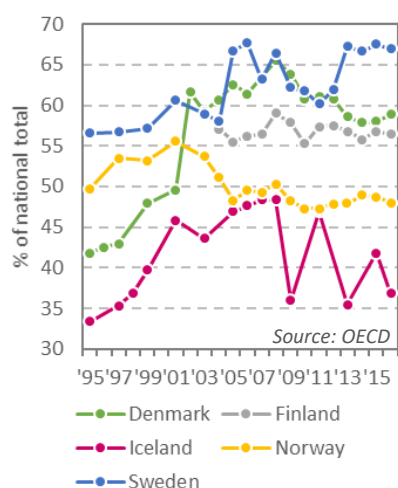


Figure 17 - Nordics: Government researchers as % of national total

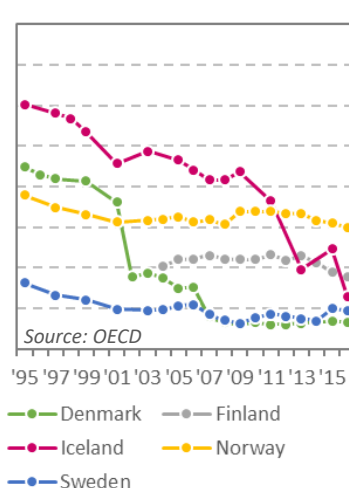
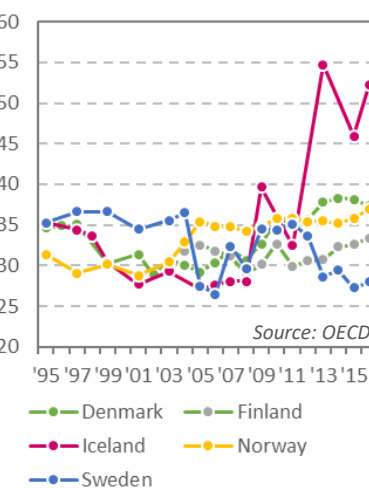


Figure 18 - Nordics: Higher education researchers as % of national total



Figures 16-18 depict a pattern of trends in employment of researchers in Nordic business, government and higher education sectors. With focus on Iceland, the overall pattern suggests that (1) business enterprise researchers in Iceland comprise a significantly lower portion of the national total than in the three leading Nordics, in particular from 2009 onwards, (2) the proportion of government researchers in Iceland has suffered more progressive relative contractions than in other Nordics post-2009, and that (3) in terms of proportion, the higher

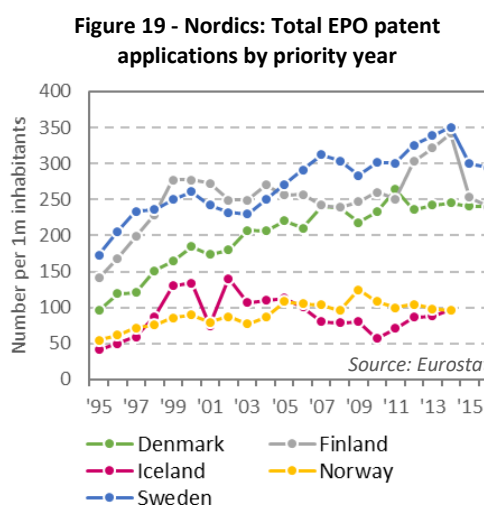
education sector in Iceland has either absorbed or produced the impact of/on 1 and 2, resulting in pronounced abnormalities when compared to the other Nordics in 2009 onwards.

With the onset of oscillations in researcher employment trends and initiation of progressive contractions occurring as early as 2009, well ahead of already mentioned methodological revisions, the extent of their impact on the above observations remains unclear.

5.5. Patenting and Intellectual Property Rights

Patents provide means for ownership protection of knowledge production outputs often embedded in new or improved technologies and certain other intellectual works. As a legal and economic device, the supranational system of intellectual property rights (IPRs) encourages research and inventive activities by facilitating competition and the development of markets for new knowledge and, consequently, enabling monopolization of their economic returns by their respective inventors (and investors). Although neither free of imperfections nor from debate, this system serves as a framework supporting technological progression, enhanced economic performance and growth. Patent statistics are thus amongst the (few) indicators available to gauge levels of inventive activity or, in other terms, means to quantify outputs from systematic processes of knowledge production; R&D (OECD, 1999, pp. 21-26).

Figure 19 shows trends in numbers of patent applications to the EPO by inventor's country of origin, per 1 million inhabitants and by priority year corresponding to their earliest date of filing. Here, in cases of multiple inventors, contributions are accounted for in proportion to their respective nationalities (Eurostat, n.d.-b). By this measure it is revealed that Iceland, together with Norway, lags considerably behind leading Nordics over the observation period or until 2014 when their available time-series come to an abrupt end. Throughout this period, Iceland averages just under 90 applications per year whilst the three leaders, Sweden, Finland and Denmark, average over 270, 250 and 200 respectively. The relative overall increase is nevertheless considerable in all countries. Iceland exhibited an overall increase of just above 130% while aforementioned leaders reported an increase of over 100, 140 and 150 percent, respectively, and Norway managed over 70%.



Narrowing down to EPO patent applications in selected technology domains, figure 20 offers a comparison of inventive activity in the Nordics with regard to technology orientation. More specifically, these domains are bio-, nano- and medical technology, pharmaceuticals, information and communication technologies (ICT), and selected climate change mitigation technologies. It is to be noted that the total number of patents applied for by Icelandic inventors averaged only 25 during the observation period (annual total of 6-40 throughout), while Norway averaged close to 400 and the remaining three within the range of 1,100 to 2,400. Fluctuations in the case of Iceland may thus appear more pronounced. Nevertheless, this indicates that the proportion of EPO patent applications in the selected technology domains, applied for by Icelandic inventors, generally succeeded or met that of their Nordic colleagues in general.

Returning to measurements relative to population sizes, figure 21 offers insight into the domain of high-technology patent applications to the EPO. i.e. micro-organism and genetic engineering, communication technology, and computer and automated business equipment. Although oscillatory, the major trend in Iceland from 1999 onwards reflects a gradual downward pull to under two applications per 1m inhabitants in 2013. Spikes observed in 1999, 2003 and 2007 were found to originate from varied improvements in several technology aggregates.

A final patent-based indicator (fig. 22) shows the number of registered triadic patent families (TPF) per 1m inhabitants in the Nordics. TPFs are comprised of those (often high-value) inventions concurrently protected by a set of patents filed at the EPO, Japan's Patent Office (JPO), and United States Patent and Trademark Office (USPTO).

Figure 20 - Nordics: Share of EPO patent applications in selected technology domains

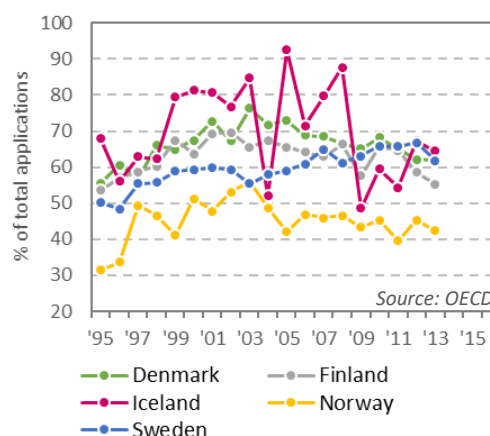


Figure 21 - Nordics: High technology EPO patent applications by priority year

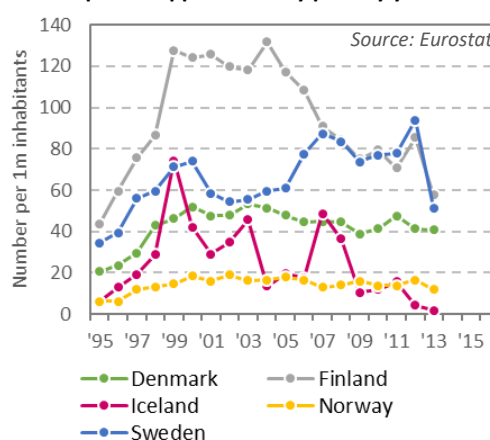
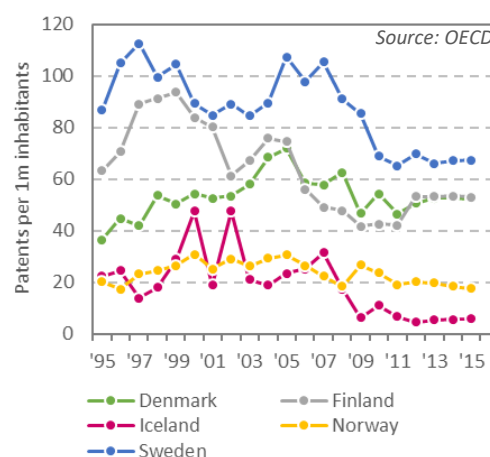


Figure 22 - Nordics: Triadic patent families



Comprised only of patents applied for in the same set of countries, TPFs are considered amongst those patent-based indicators best placed for international comparison (OECD, 1999, p. 71). The ranking of Nordic countries according to this TPF-based indicator resembles that of EPO applications only (fig. 19). On the other hand, it shows a more pronounced downward drift in the trend for Iceland and near-complete stagnancy from 2009 onwards, as was the case in most Nordics.

5.6. Knowledge and Technological Intensities in Services and Manufacturing

Providing an overview of variants in the evolution of modern economies, this section offers insight into advancing structural changes characterized by the “growing share of services and the production of increasingly complex products” (Stiglitz, Sen, & Fitoussi, 2009, p. 11). Such transformations coincide with increasing intensities in the development and application of new or improved technologies and growing demand for knowledge-based services, together recognized as driving gains in productivity and employment over the longer-term (OECD, 1996, p. 10).

The first set of figures (fig. 23, 24) shows directional alignment of trends in sizes of Nordic service and manufacturing sectors in terms of employment numbers. Note that due to revised NACE classifications in 2008 (Rev. 1.1 and 2), separate time series are used to cover the observation period resulting in its split into two segments; 1995-2007 and 2008-2016.

Figure 23 - Nordics: Employment in services as % of total employment

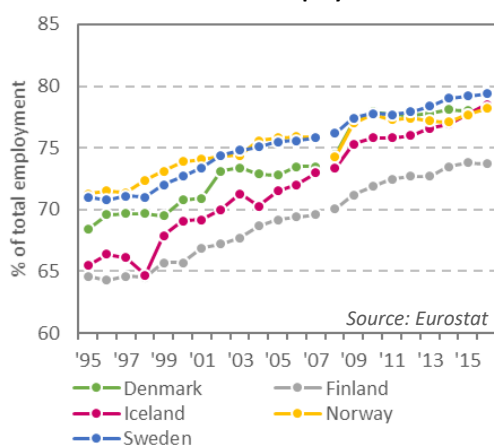
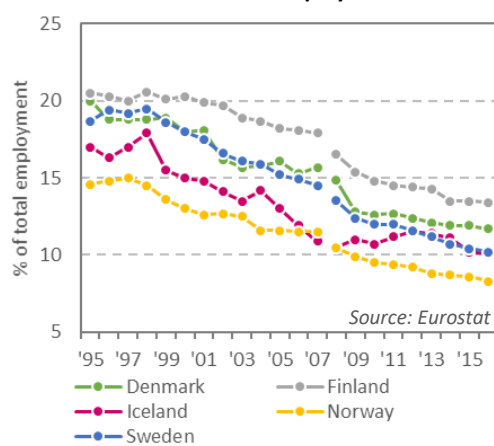


Figure 24 - Nordics: Employment in manufacturing as % of total employment



In terms of share of total employment, Iceland’s service sector grew at an average annual rate of 0.91% and 0.86% in the first and second time segments, respectively; above that in other Nordics whose growth in services measured in the range of 0.52 / 0.62% and 0.52 / 0.66%.

However, the share of manufacturing contracted at an annual average rate of -3.64% and -0.48% in Iceland, respectively, whilst this rate in the Nordics measured within ranges of -1.12/-2.10% and -2.57/-3.44%. It follows that aforementioned structural changes occurred at a quicker pace in Iceland, especially in the second segment, with the exception of Iceland's more resilient manufacturing sector in 2008-2016. With employment numbers in manufacturing remaining relatively stagnant in the latter segment, concurrent to the rise of services, the brunt of contractions post-2008 or 4.7 pp were suffered jointly by the primary industries (e.g. fisheries and agriculture) and energy, construction and infrastructure sectors, corresponding to their combined relative decrease of over 29% in terms of their previous share of total employment (see fig. 25).

Bringing the focus toward topics of knowledge and technology, figure 26 presents an indicator based on Eurostat aggregations using such factors as share of tertiary educated persons in services, and R&D expenditure on value added in manufacturing. This indicator serves as measure to reflect on the knowledge intensity and technology level of the two sectors, here in terms of corresponding employment numbers. In the case of Iceland, the aforementioned NACE revision and updated aggregate definitions result in a notable upward shift in 2008, as detailed later.

Covering trends in the five Nordic economies, the above figure reflects various growth patterns in pre-2008 with Iceland ranking at the bottom. Moreover, it reveals an extended period of pronounced stagnation in the case of Iceland during the final six years of the second segment. For the purpose of highlighting underlying trends, figures 27-29 (following pages) focus on the more knowledge/technology-intensive activities within service and manufacturing, proportional to their respective sector totals.

Figure 25 - Iceland: Employment developments

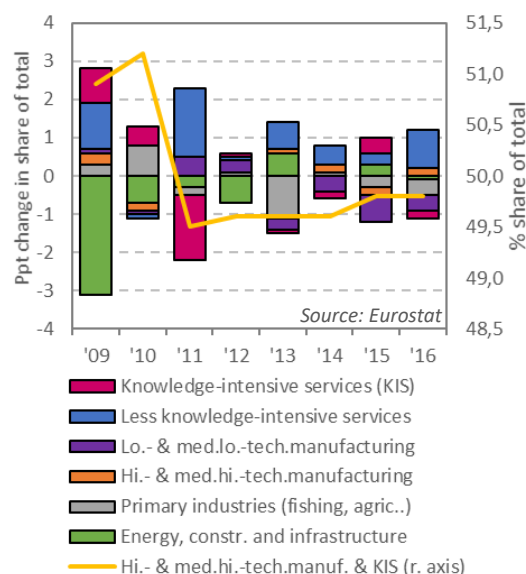


Figure 26 - Nordics: Employment in knowledge intensive services and high- and medium-high technology manufacturing as % of total

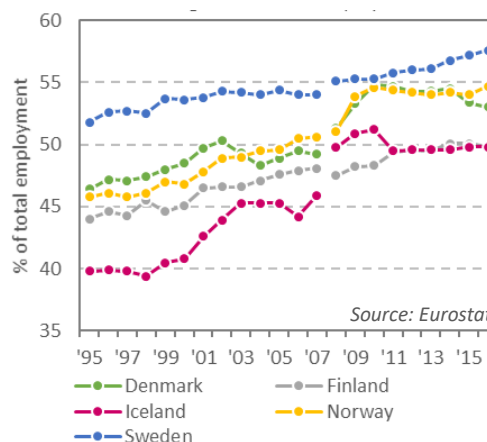


Figure 27 shows that knowledge intensities in Nordic service sectors generally resumed a gradual upward trend in the region of 56-64% in the first segment with Iceland alongside the majority within 56-61%. Revisions of NACE classifications produce a notable 6 pp upward in the case of Iceland in 2008 as additional sub-sectors were included in the new aggregate. From this point onwards an inverse trend of decline parted Iceland from the Nordic leaders (Sweden and Norway) who, together with Finland, continued on a steady path of growth.

The noticeable trend reversal in Iceland from 2008 onwards calls for more in-depth analysis of developments in its service sector. In terms of job numbers, figure 28 shows changes in the size of selected service sectors during 2008-2016 relative to the overall total in services. It reveals that parallel to a 26% decrease of jobs in the financial and insurance sector (-2.01 ppt from its previous 6% share of services), a high proportion of new jobs generated during this period were in tourism related activities. This provides for an explanation to the gradual decline in the share of knowledge-intensive services (KIS) as the tourism sector is generally considered both labor-intensive and low-skilled (Sutherland & Stacey, 2017). In fact, of those tourism-related activities listed, only air and water transport are included in Eurostat's KIS aggregate (Eurostat, n.d.-c). The result is that in under a decade the share of less knowledge-intensive tourism activities increased by 6.94 ppt to a total of 17.4% of the service sector by 2016. This supports concerns voiced by the director of the Icelandic Directorate of Labor who in 2018 noted that “the majority of new jobs created in recent semesters were those not requiring extensive education or specialization, nor jobs for persons with vocational training or other types of upper education.” (Icelandic Directorate of Labor, 2018, p. 4)

Figure 27 - Nordics: Employment in knowledge intensive services as % of total in services

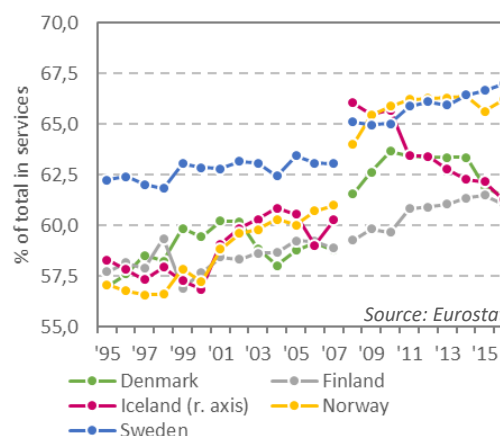
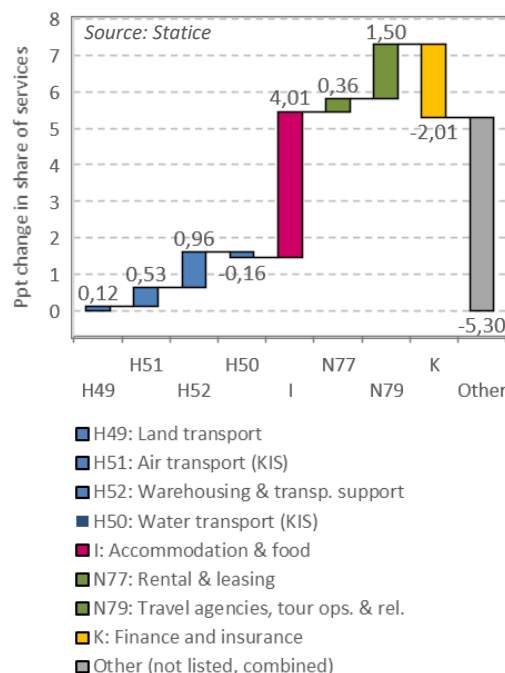


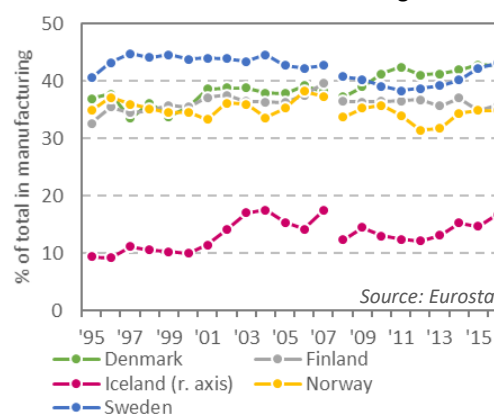
Figure 28 - Iceland: Employment developments in selected service sectors 2008-2016



Turning to high and medium-high technology manufacturing sectors, figure 29 reveals a considerable divide between Iceland and other Nordic economies in terms of share of total employment in manufacturing. However, although the extent of fluctuations across most Nordics appears somewhat similar, Iceland's performance improved considerably or by 85% in the first segment; from 9.4% of the total in 1995 to 17.4% in 2007. Continued increase is evident in the second

segment, albeit at a slower rate, with this share rising by 36% or from 12.4% of the total in 2008 to 16.8% in 2016. Nevertheless, the most prominent observation is that the ratio of upper level technology manufacturing in Iceland remained within the regions of 9-18% and 12-17% in the first and second segments, respectively. This ratio is significantly lower than in other Nordics who all measured between 32-45% and 31-43%, respectively.

Figure 29 - Nordics: Employment in high- and medium-high technology manufacturing as % of total in manufacturing



5.7. Technological Classification of Exports and Product Complexity

Professor of development economics Sanjaya Lall (2000) elaborated a method of classifying product into four categories by levels of technology used in their manufacturing; resource-based, low, medium and high technology exports. Based on the *Standard International Trade Classification* (SITC) and other factors, this approach makes use of available indicators of technological intensities in the respective manufacturing sectors.

Comprising the first two groups, *resource-based* and *low technology*, are those product by which degrees of natural resource availability/access and lower wage environments largely determine their inherent competitiveness. On the other hand, products involving “high skill, complex learning and demanding technological activity” in their making comprise the latter two, *medium* and *high technology*. Commodities or natural raw materials, e.g. the primary products of mining, agriculture, forestry and fisheries, constitute a fifth group exempt from this method of classification (Lall, 2000, pp. 7-9).

Through the lens of Lall's technological classification, figure 30 shows trends in Iceland's product export structure in 1995-2016. An overall decline in the share of exports within listed product groups reveals that primary products constituted a gradually increasing share of the total; from 60% in 1995 to almost 74% by 2016 in where raw aluminum and fish fillets alone constituted 49% of the total. However, the portion of high- and medium-high technology exports remained in the region of 8-10% throughout this period, excluding a deviation in 2004-2009 resulting from a temporary spike in exports of aircraft and associated equipment (of which Iceland does not have an established manufacturing sector). This particular deviation reflects known complications in classifications of this sort as higher technology products may have been originally imported from sources external to the reporting country, later emerging in its export statistics following its relatively simple assembly and/or use (Lall, 2000, p. 7).

Using this same approach for comparison of Nordic economies (fig. 31), Iceland ranks lowest in terms of its average share of high and medium high technology exports. At an average of 8.5%, excluding aircraft and associated equipment (10.3% if included), Iceland (*) ranks considerably lower than the leading economies of Sweden (54%), Finland (46%), Denmark (39%), as well as Norway (18%). These rankings may reflect employment in higher-technology manufacturing sectors (fig. 29) except for Norway which parts from the group of leaders.

A second approach for comparison of country exports is by the *product complexity index* (PCI) developed by physicist César A. Hidalgo and economist Ricardo Hausmann (2009). Based on international trade data the PCI serves as a proxy measurement for the productive knowledge or “know-how” required to produce a given product, accounting for the number of countries capable of its production and diversity in their export structures; the lower the number of countries and greater the diversity, the higher the PCI (CID, n.d.).

Figure 30 - Iceland: Technological classification of manufactured exports (Lall)

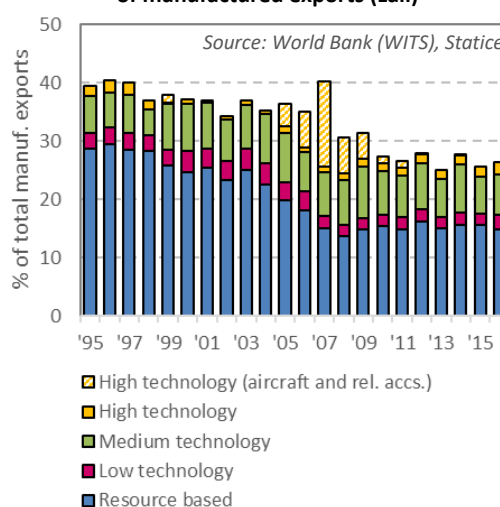
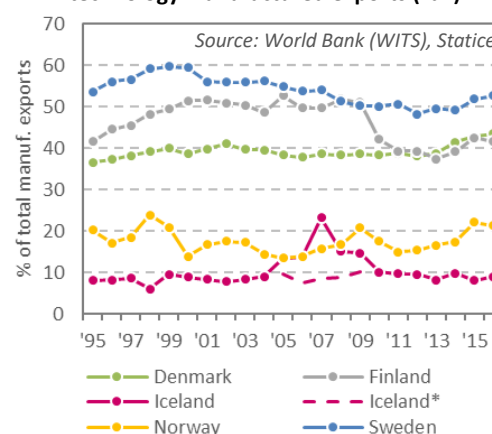


Figure 31 - Nordics: High and medium technology manufactured exports (Lall)



Adding to the previous approach, this indicator offers insight into the group of primary products excluded by Lall. Without enough data to construct this indicator in full, table 1 shows the top five exported products of 2016 in Nordic economies and the average complexity of those products.

Table 1 - Nordics: Average product complexity of top five exported products.

Country	Top five exported products					Share of total	Average product complexity
	1	2	3	4	5		
DEN	Packaged Medicaments	Pig meat	Human or Animal Blood	Refined Petroleum	Electric Generating Sets	21.5%	0.60
SWE	Cars	Refined Petroleum	Packaged Medicaments	Vehicle Parts	Kaolin Coated Paper	20.2%	0.53
FIN	Kaolin Coated Paper	Refined Petroleum	Large Flat-Rolled Stainl. Steel	Sawn Wood	Cars	25.2%	0.17
ISL	Raw Aluminum	Fish Fillets	Non-Fillet Frozen Fish	Processed Fish	Non-Fillet Fresh Fish	63.3%	-1.29
NOR	Crude Petroleum	Petroleum Gas	Non-Fillet Fresh Fish	Refined Petroleum	Raw Aluminum	58.9%	-1.63

Source: Simoes, A. & Hidalgo, C. A.. (Observatory of Economic Complexity)

As table 1 clearly shows, the average complexity of Iceland's top five exported products (-1.29), together with those of Norway (-1.63), is considerably lower than in the three leading Nordics (Denmark 0.6; Sweden 0.53; Finland 0.17). Another observation to be made from this data concerns the high share of less complex goods in Iceland's product export structure; these five products constituting more than 63% of the total suggests low export diversification and supports the notion that "goods exported from Iceland are on average less 'sophisticated' than suggested by its level of development." (IMF, 2010)

Finally, the aforementioned decline in number of employed persons in primary sectors (section 5.6), parallel to the rising share of primary products in Iceland's product export structure (fig. 30), signals ongoing technological displacements with increased automation replacing lower-skilled jobs. Such displacements and consequent productivity growth were particularly evident in the Icelandic fisheries industry (Hreinsson & Bender, 2015, pp. 6, 8-9).

6. Summary and Findings

This section presents a summary of findings from the two analyses conducted to (a) identify knowledge-based objectives in Icelandic government policies and (b) assess Iceland's progress in transitioning towards a knowledge-based economy.

Icelandic government policies in 1995-2016 were qualitatively found to contain numerous objectives and strategies supportive to the development of a knowledge-based economy. In general, OECD policy recommendations reflected through the means designated to achieve economic goals aligned with those predicated by endogenous growth theory.

The foregoing was evident for several subjects of which the most prominent was a strong and ubiquitous focus on educational affairs encompassing all levels. This included (1) equal opportunities and access to education, (2) reinforcements at the upper secondary and tertiary levels, to include vocational studies and training, and (3) the development of distance learning and continuing education programmes. Other prominent subjects included (4) initiatives encouraging to investment in R&D and innovative activities via tax incentives, (5) establishment of competitive funding programmes, (6) increasing the funding level of science and innovation, up to an all time high of 3% of GDP by 2016, (7) reinforcing national innovation infrastructures and framework for intellectual property rights, and (8) comprehensive restructuring of the overall science and technology system as implemented in 2003. Finally, in line with (9) a general emphasis on the role of business enterprises, (10) generating new technology oriented employment opportunities.

However, quantitative analysis revealed several foundations essential to knowledge-based economies as in a relatively underdeveloped state in Iceland. This was particularly evident in terms of (1) high share of adult population with less than upper-secondary education, (2) low technology orientation in education, (3) low number of business enterprise researchers, (4) low number of patent applications, (5) low employment numbers in medium and high technology manufacturing, and (6) low technology and complexity levels in Iceland's undiversified product export structure.

Aforementioned foundations were observed as either in stages of deterioration, stagnation or growth post-2008; (1) expenditure on education declined by several measures whilst educational attainment increased, (2) technology orientation at the upper-secondary education level remained stagnant whilst increasing at the tertiary level and, (3) although a structural break in time-series on R&D expenditures and number of researchers impeded performance comparisons, underlying trends signaled their decline in business enterprise and government

sectors parallel to their increase in higher-education. Such observations also showed that (4) patent numbers stagnated whilst the number of high-technology patents declined, (5) employment in knowledge-intensive services declined as share of the total in services, whilst the share of medium high and high technology manufacturing increased, (6) majority of new jobs generated post-2008 were generally low-skilled and, (7) technology levels in Iceland's product export structure remained relatively low and stagnant.

7. Discussions and Conclusions

It was a pleasant surprise that during the writing of this thesis, on October 8th, 2018, Paul Romer was awarded the Nobel memorial prize in economic sciences for integrating technological innovations into long-run macroeconomic analysis. Although focus was kept on a limited set of factors considered determinant of sustainable long-term economic growth, as per policy guidelines inspired by Romer's theory, the author hopes to have demonstrated their historical states in Iceland and reflected upon their governance, structure and interplay.

The thesis findings qualitatively revealed markedly high ambitions of past Icelandic governments in developing solid foundations essential for knowledge-based economies. However, empirical observations revealed the state of several such foundations as relatively underdeveloped. Its first hypothesis that, contrary to general discernment of Icelandic government policy objectives, foundations essential to Iceland's sustained long-term economic growth are underdeveloped, is thus considered confirmed.

Such inconsistency between policy and progress is concluded as originating from a mixture of two factors; (1) inadequate funding of research and development activities, masked by the use of incomparable benchmarks for international comparisons and budget appropriations until 2013/14, and (2) distorted incentives from supply and demand dynamics between the educational system and the labor market, in where a predominantly low-skilled manufacturing sector and low technology orientation in education produced a negative feedback loop; altogether culminating in a relatively low number of business enterprise researchers and low number of patents.

Findings from analysis of the post-2008 period showed aforementioned foundations in varied stages of development; while some were observed either in a process of deterioration or growth, others appeared stagnant. Its second hypothesis, that such foundations deteriorated during Iceland's economic recovery post-2008, is thus considered only partially confirmed.

Where deterioration was observed post-2008 it is concluded as originating primarily from a boom in labor-intensive, lower-skilled tourism sectors, impeding incentives to generate

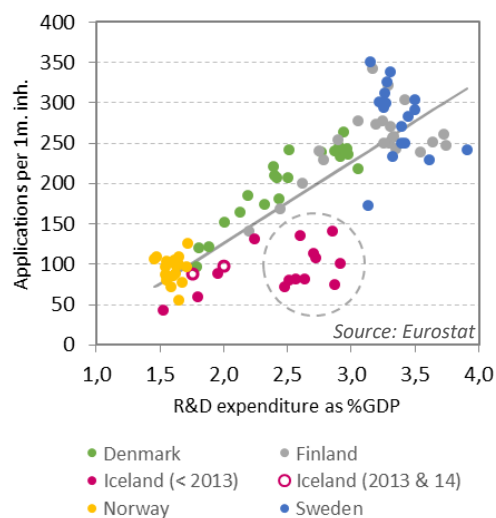
higher-skill jobs and directing financial and human resources away from engagement in more knowledge-intensive activities.

As to the conclusion of R&D statistics being amongst causal factors in Iceland's relatively low performance, it must be noted that such a finding is not indicative of inept or erroneous measurements. To the contrary, methods employed in 1995-2012/13 may in fact have produced more detailed and thorough data (as suggested by the compiling agency's director), albeit less suited for comparison with countries employing other methodologies. It could, therefore, be of interest to perform country comparisons based on this earlier method only. Should this method appear impracticable in other countries, insight might be gained into its potential shortcomings. Considering the margin by which results from the two methods differed, it is unfortunate that side-by-side measurements were not performed intramurally in Iceland parallel to the introduction of a new methodology. For informative purposes only, figure 32 shows a linear regression comparison of the Nordics based on available data for their annual gross domestic R&D expenditures and number of EPO patent applications. Although a plethora of factors weigh in to volumes of patented knowledge, an outlying cluster of measurements for Iceland may give rise to some consideration.

Other potential sources of inconsistencies concern economic and social dynamics. Acknowledging that low unemployment is generally viewed positively, an abundance of jobs with low entry barriers may discourage individuals from the arduous pursuit of developing high skills. Moreover, such circumstances may incentivize students to leave education prematurely and contribute to Iceland's relatively high ratio of population without upper-secondary education (which, according to OECD data, is still amongst the highest in OECD countries; 19% in the group of 25-34 year olds and 23% of 25-64 year olds in 2017). An environment characterized by low technological intensities and limited science literacy may also affect ambitions of younger generations. Additionally, low overall technology orientation may be influenced by the relatively small size of Iceland's economy in where less knowledge-intensive (albeit necessary) substructures draw disproportionately from its labor force.

Finally, one cannot dismiss another potential, more philosophical source to low technology orientation. As mentioned in the introduction, at the heart of endogenous growth

Figure 32 - Nordics: EPO patent applications per 1m. inhabitants on gross domestic R&D expenditure



theory lies another theory, one of rational choice in where individuals are hypothesized as rational agents actively maximizing their advantage in any situation and, conversely, minimizing their potential losses. In his article, *Risk, Ambiguity, and the Savage Axioms*, economic theorist Daniel Ellsberg (1961) postulated the effect of risk aversion on individual choices. In short, Ellsberg showed that individuals at large appear more risk-seeking when specific odds are known than when facing more ambiguous odds. This effect, commonly referred to as *Ellsberg's Paradox*, implies an inherent aversion to ambiguity or uncertainty. Recognizing that R&D efforts and technological innovations are generally resource-intensive, i.e. time-consuming and expensive, and that their outcome is often uncertain, the level of uncertainty seen by many as surrounding the Icelandic economy may elevate such aversive tendencies. It might, therefore, be unsurprising to some that Icelanders, more than others, opt for means facilitating short-term gains such as seizing less ambiguous opportunities and the occasional windfall. Based on the author's intuition, such windfalls tend to present themselves in forms where extensive education and high skills are not a necessary prerequisite for their capitalization.

In light of all of the above, should Iceland aspire for competitiveness in the 21st century, circumstances may require for the state to employ more definite means than incentives alone provide. The key question posed by current challenges is not, necessarily, whether the next economic downturn will be in the form of a hard or a soft landing, but rather if the economy has been constructed in a manner enabling Iceland to take flight again.

Bibliography

- Becker, G. S. (1962). Investment in Human Capital: A Theoretical Analysis. *Journal of Political Economy*, 70(5), pp. 9-49. Retrieved September 24th, 2018, from JSTOR: <http://www.jstor.org/stable/182910>
- Becker, G. S. (1964). *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. New York: NBER and Columbia University Press.
- Bell, D. (1973). *The Coming of Post-Industrial Society: A Venture in Social Forecasting*. New York: Basic Books.
- Bell, D. (1979). The Social Framework of the Information Society. (M. L. Dertouzos, & J. Moses, Eds.) *The Computer Age: A 20 Year View*, pp. 500-549. Cambridge, MA: MIT Press.
- CID. (n.d.). *Atlas of Economic Complexity: Glossary*. Retrieved November 2nd, 2018, from Center for International Development at Harvard: <http://atlas.cid.harvard.edu/learn/glossary>
- Davíðsdóttir, S. (2018, May 17). *Iceland: from fishing to tourism / 10 years on*. Retrieved August 16th, 2018, from Sigrún Davíðsdóttir's Icelog: <http://uti.is/2018/05/iceland-from-a-fishing-economy-to-tourism-10-years-on/>
- Ellsberg, D. (1961). Risk, Ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics*, 75(4), pp. 643-669. Retrieved November 7th, 2018, from JSTOR: <https://www.jstor.org/stable/1884324>
- European Council. (2000). *Lisbon European Council 23 and 24 March 2000: Presidency Conclusions*. Retrieved August 13th, 2018, from European Parliament: http://www.europarl.europa.eu/summits/lis1_en.htm
- Eurostat. (database). Accessed in September-November, 2018, at <https://ec.europa.eu/eurostat/data/database>
- Eurostat. (n.d.-a). *Government budget appropriations or outlays on R&D (gba): Reference Metadata in Euro SDMX Metadata Structure (ESMS)*. Retrieved October 16th, 2018, from Eurostat: https://ec.europa.eu/eurostat/cache/metadata/en/gba_esms.htm
- Eurostat. (n.d.-b). *Patent (pat): Reference Metadata in Euro SDMX Metadata Structure (ESMS)*. Retrieved October 25th, 2018, from Eurostat: https://ec.europa.eu/eurostat/cache/metadata/en/pat_esms.htm
- Eurostat. (n.d.-c). Aggregations of services based on NACE Rev. 2. In *Eurostat indicators on High-tech industry and Knowledge – intensive services*. Retrieved October 17th, 2018,

-
- from European Commission:
https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf
- Gürak, H. (2015). *Economic Growth and Development: Theories, Criticisms and an Alternative Growth Model*. Frankfurt a.M.: PL Academic Research.
- Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. (P. S. Dasgupta, Ed.) *PNAS*, 106(26), pp. 10570-10575. Retrieved September 26th, 2018, from PNAS: <http://www.pnas.org/content/106/26/10570>
- Hreinsson, E. O., & Bender, I. (2015). *Icelandic Seafood Market Report*. Íslandsbanki Research. Retrieved October 18th, 2018, from Íslandsbanki: <https://islandsbanki.is/library/Skrar/Seafood-Reports/Islenki%20Sjavarutvegurinn%202015%20-%20ENSKA.pdf>
- Icelandic Directorate of Labor. (2018). *Annual Report 2017*. Reykjavík: Icelandic Directorate of Labor. Retrieved August 16th, 2018, from Vinnumálastofnun [Icelandic Directorate of Labor]: <https://www.vinnumalastofnun.is/media/2064/arsskyrsla2017-final-web.pdf>
- Icelandic Government Offices. (1995, April 23). *Stefnuyfirlýsing ríkisstjórnar 1995 [Government Policy Declaration 1995]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]: <https://www.stjornarradid.is/rikisstjorn/sogulegt-efni/um-rikisstjorn/1995/04/23/Stefnuyfirlýsing-rikisstjornar-1995/>
- Icelandic Government Offices. (1996, February 12). *Ísland og upplýsingasamfélagið [Iceland and the Information Society]*. Retrieved August 2nd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]: <https://www.stjornarradid.is/verkefni/allar-frettir/frett/1996/02/12/Island-og-upplysingasamfelagid/>
- Icelandic Government Offices. (1999, May 28). *Stefnuyfirlýsing ríkisstjórnar 1999 [Government Policy Declaration 1999]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]: <https://www.stjornarradid.is/rikisstjorn/sogulegt-efni/um-rikisstjorn/1999/05/28/Stefnuyfirlýsing-rikisstjornar-1999/>
- Icelandic Government Offices. (2003, May 23). *Stefnuyfirlýsing ríkisstjórnar 2003 [Government Policy Declaration 2003]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]: <https://www.stjornarradid.is/rikisstjorn/sogulegt-efni/um-rikisstjorn/2003/05/23/Stefnuyfirlýsing-rikisstjornar-2003/>

-
- Icelandic Government Offices. (2007, May 23). *Stefnuyfirlýsing ríkisstjórnar 2007* [Government Policy Declaration 2007]. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/rikisstjorn/sogulegt-efni/um-rikisstjorn/2007/05/23/Stefnuyfirlýsing-rikisstjornar-2007/>
- Icelandic Government Offices. (2009, May 10). *Samstarfsyfirlýsing ríkisstjórnar 2009* [Government Cooperative Declaration 2009]. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/rikisstjorn/sogulegt-efni/um-rikisstjorn/2009/05/10/Samstarfsyfirlýsing-rikisstjornar-2009/>
- Icelandic Government Offices. (2013, May 23). *Stefnuyfirlýsing ríkisstjórnar 2013* [Government Policy Declaration 2013]. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/rikisstjorn/sogulegt-efni/um-rikisstjorn/2013/05/23/Stefnuyfirlýsing-rikisstjornar-Framsoknarflokksins-og-Sjalfstaedisflokksins/>
- IMF. (2010). Iceland: Selected Issues. *IMF Country Report, No. 10/304*. Retrieved October 17th, 2018, from International Monetary Fund:
<https://www.imf.org/external/pubs/ft/scr/2010/cr10304.pdf>
- Jónasson, H. (2015, May 6). *Útgjöld til rannsókna og þróunar 2011 og 2013* [Expenditures on research and development 2011 and 2013]. Retrieved October 26th, 2018, from Kjarninn: <https://kjarninn.is/skodun/utgjold-til-rannsokna-og-throunar-2011-og-2013/>
- Lall, S. (2000). The Technological Structure and Performance of Developing Country Manufactured Exports, 1985-1998. *QEH Working Paper Series, No. 44*. Retrieved August 16th, 2018, from Oxford Department of International Development:
<https://www.qeh.ox.ac.uk/publications/technological-structure-and-performance-developing-country-manufactured-exports-1985>
- Magnússon, M. K. (2015, April 29). *Það var nefnilega vitlaust gefið* [Hands were dealt incorrectly]. Retrieved October 28th, 2018, from Kjarninn:
<https://kjarninn.is/skodun/thad-var-nefnilega-vitlaust-gefid/>
- Ministry of Education, Science and Culture. (2015). *Samantekt úr Education at a glance 2015* [Summary from education at a glance 2015]. Office of Evaluation and Analysis, Reykjavík. Retrieved October 3rd, 2018, from Stjórnarráð Íslands [Icelandic

-
- Government Offices]: <https://www.stjornarradid.is/media/menntamalaraduneyti-media/media/frettir2015/Samantekt-MRN-ur-Education-at-a-Glance-2015.pdf>
- Ministry of Education, Science and Culture. (2005, February 10). *Útgjöld til háskólastigsins 1,3-1,7% af vergri landsframleiðslu árið 2002 [Tertiary level expenditures 1.3-1.7% of GDP in 2002]*. Retrieved October 6th, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]: <https://www.stjornarradid.is/efst-a-baugi/frettir/stok-frett/2005/02/10/Utgjold-til-haskolastigsins-1-3-1-7-af-vergri-landsframleidslu-arid-2002/>
- OECD. (1995). *Manual on the Measurement of Human Resources Devoted to S&T (Canberra Manual)*. Paris: OECD Publishing. Retrieved September 4th, 2018, from OECD iLibrary: https://www.oecd-ilibrary.org/science-and-technology/measurement-of-scientific-and-technological-activities_9789264065581-en
- OECD. (1996). *The Knowledge-based Economy*. Paris: OECD Publishing. Retrieved June 12th, 2018, from OECD: <http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD%2896%29102&docLanguage=En>
- OECD. (1998). *Human Capital Investment: An International Comparison*. Retrieved September 23rd, 2018, from OECD iLibrary: https://www.oecd-ilibrary.org/education/human-capital-investment_9789264162891-en
- OECD. (1999). *OECD Patent Statistics Manual*. Paris: OECD Publishing. Retrieved August 25th, 2018, from OECD iLibrary: https://www.oecd-ilibrary.org/science-and-technology/oecd-patent-statistics-manual_9789264056442-en
- OECD. (2005). *Oslo Manual: Guidelines for collecting and interpreting innovation data*. OECD Publishing. Retrieved August 25th, 2018, from OECD iLibrary: https://www.oecd-ilibrary.org/science-and-technology/oslo-manual_9789264013100-en
- OECD. (2015). *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development*. Retrieved August 25th, 2018, from OECD: <http://www.oecd.org/sti/frascati-manual-2015-9789264239012-en.htm>
- OECD. (database). Accessed in September-November, 2018, at <https://stats.oecd.org/>
- Parliamentary document no. 366/2002-2003. *Frumvarp til laga um Vísinda- og tækniráð [Parliamentary Bill on Science- and Technology Policy Council]*. Retrieved August 2nd, 2018, from Alþingistíðindi, A-deild, 128. löggjafarþing 2002-2003

-
- [Parliamentary Record, A-Section, 128th Legislative Session 2002-2003]:
<https://www.althingi.is/altext/128/s/0366.html>
- Romer, P. M. (1986). Increasing Returns and Long-Run Growth. *The Journal of Political Economy*, 94(5), pp. 1002-1037. Retrieved September 24th, 2018, from JSTOR:
<https://www.jstor.org/stable/1833190>
- Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98(5), Part 2, pp. S71-102. Retrieved September 24th, 2018, from NBER:
<https://www.nber.org/papers/w3210>
- Schultz, T. W. (1961). Investment in Human Capital. *The American Economic Review*, 51(1), 1-17. Retrieved September 26, 2018, from <https://www.jstor.org/stable/1818907>
- Science and Technology Policy Council. (2003). *Vísinda- og tæknistefna 2003-2006 [Science and Technology Policy 2003-2006]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/media/forsaetisraduneyti-media/media/vt/stefna-2003-2006.pdf>
- Science and Technology Policy Council. (2006). *Vísinda- og tæknistefna 2006-2009 [Science and Technology Policy 2006-2009]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/media/forsaetisraduneyti-media/media/vt/visinda-og-taeknistefna2006-2009-2021.pdf>
- Science and Technology Policy Council. (2010). *Stefna Vísinda- og tækniráðs 2010-2012 [Science and Technology Policy 2010-2012]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/media/forsaetisraduneyti-media/media/vt/vt2010-2012.pdf>
- Science and Technology Policy Council. (2014). *Stefna og aðgerðaáætlun Vísinda- og tækniráðs 2014-2016 [Science and Technology Policy and Action Plan 2014-2016]*. Retrieved August 3rd, 2018, from Stjórnarráð Íslands [Icelandic Government Offices]:
<https://www.stjornarradid.is/media/forsaetisraduneyti-media/media/vt/2014-5-22-stefna-adgerda-vt.pdf>
- Simoës, A., & Hidalgo, C. A. (n.d.). The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence. (2011). Accessed in September-November, 2018, at OEC: <https://atlas.media.mit.edu/en/>
-

-
- Statice. (database). Accessed in September-November, 2018, at <http://px.hagstofa.is/pxen/pxweb/en/>
- Stiglitz, J., Sen, A., & Fitoussi, J. (2009). *Report by the Commission on the Measurement of Economic Performance and Social Progress*. CMEPSP. Retrieved September 4th, 2018, from European Commission: <https://ec.europa.eu/eurostat/documents/118025/118123/Fitoussi+Commission+report>
- STPC Working Group. (2016). *Stöðuskýrsla um aðgerðaáætlun Vísinda- og tækniráðs 2014-2016 [Status Report on the Science and Technology Policy Council's Action Plan 2014-2016]*. Starfshópur um málefni Vísinda- og tækniráðs [Working Group on Science and Technology Policy Council Affairs]. Reykjavík: Prime Minister's Office. Retrieved August 3rd, 2008, from Stjórnarráð Íslands [Icelandic Government Offices]: <https://www.stjornarradid.is/media/forsaetisraduneyti-media/media/vt/stoduskysrsla-visinda-og-taeknir-mars-2016.pdf>
- Sutherland, D., & Stacey, J. (2017). Sustaining nature-based tourism in Iceland. *OECD Economics Department Working Papers, No. 1422*. Retrieved September 2nd, 2018, from OECD iLibrary: https://www.oecd-ilibrary.org/economics/sustaining-nature-based-tourism-in-iceland_f28250d9-en
- Toner, P. (2011). Workforce Skills and Innovation: An Overview of Major Themes in the Literature. *OECD Science, Technology and Industry Working Papers, 2011(01)*. Retrieved August 21st, 2018, from OECD iLibrary: https://www.oecd-ilibrary.org/science-and-technology/workforce-skills-and-innovation_5kgkdgdkc8tl-en
- World Bank. (database). World Integrated Trade Solution - WITS. Accessed in September-November, 2018, at <https://wits.worldbank.org/>