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Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index

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Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index

Purpose: Over the past decade or so, successive Luxembourgish governments have sought to develop the country's information, communication and technology (ICT) sector. In this paper, we will examine how Luxembourg's relative position in the Networked Readiness Index (NRI), a key international benchmarking exercise published by the World Economic Forum, has evolved over time as these ambitions have been achieved. The paper also explores what policy initiatives could be implemented to further improve Luxembourg's ranking in the NRI.

Design/methodology/approach: A longitudinal case study based approach, drawing on secondary data and the annual publication of the NRI between 2003 and 2016, was adopted.

Findings: Luxembourg's position in the NRI has improved from 27th in 2003 so that it now ranks among the top ten countries in the world. In particular, Luxembourg has substantially improved its position with regards to "infrastructure" and "international connectivity". However, there are also areas, mainly linked to education, the provision of human resources and policies that allow for and stimulate entrepreneurship where further improvements appear possible.

Social implications: The paper highlights the need for an overall, holistic, ICT development strategy. Such a strategy would cover not only cover infrastructural and technical aspects but also educational, social, regulatory and economic issues as well.

Originality/value: The paper charts the evolution over time of Luxembourg's position in an important international ICT index and identifies its current strengths and weaknesses in terms of the different elements that constitute the NRI. This paper represents the first attempt to investigate the position of a small country, which are often overlooked in the literature, in terms of its changing position and the policies developed and enacted by a national government.

Keywords: ICT sector, Luxembourg, Networked Readiness Index, policy development

Paper type: research paper

1. Introduction

Academics and practitioners alike have given considerable attention to the measurement of "information" for policy, development and investment decisions. Many national and international organisations, such as the International Telecommunication Union (2015), Mateus (2015), OECD (2015), or the Partnership on Measuring ICT for Development,[1] produce rankings and assessments about the development of national information and communication technology (ICT) capabilities and infrastructure. These ranking indices can perform powerful policy-shaping roles, as the media fanfare and debates stimulated often provoke policy responses from governments. Moreover, politicians and policy makers often refer to such assessments to justify their decisions (De Fooz, 2014; Henry, 2014; Sorlut, 2014) or promote the comparative advantages of their country in relation to their international competitors (European Commission, 2015a, 2015b; Katz, Koutroumpis, & Callorda, 2013; Lechman, 2009).

For the measurement of the 'information society' many proxies or indicators have been developed using aggregate statistics and the application of largely quantitative methods to gain insights into, amongst other things, e-Readiness, e-Leadership or the 'digital divide'. Taylor (2006) provides an introduction into the history of ICT indices starting in the early 1960s and the ongoing search for different information age indicators, which were subsequently called information technology indicators, including telecommunications, the internet, broadcasting and computing technology. Taylor notices that most of these indicators use statistical analytics to correlate multiple factors to identify relationships between information stocks, information flows and technology as well as other economic and social factors. Many indicators combine national and international empirical data sources. This raises the question of how to group these factors, how to define their relative weightings[2] and how to build combinations of these. Taylor (2006, p. 15) concluded that "the identification of approaches likely to yield meaningful data for developing an exploratory and predictive understanding of the interactions of key information proxies with other selected factors in the human environment" constitutes a "grand challenge" and subsequently argued for an organised collective effort and the development of a "coherent academic field of study" and in a first step to "establish mechanisms by which the relevant documents and datasets could be more easily accessed and become readily available, the various approaches systematically mapped, those interested could meet and exchange ideas and develop cooperative ventures,

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[1] See http://www.itu.int/en/ITU-D/Statistics/Pages/intlcoop/partnership/default.aspx

[2] For example by expert's opinions or some elaborate statistical methods such as Structured Equation Modelling (Hair, Black, Babin, & Anderson, 2010).

and stakeholders could discuss their needs and appraisal of the instruments and findings"
(Menou & Taylor, 2006; Taylor & Zhang, 2007).

In this paper, we provide an overview of some of these indicators or indices and discuss their
inherent limitations before looking in-depth at one of the most popular of such indicators, the
Networked Readiness Index (NRI) that is published annually by the World Economic Forum
(Baller, Dutta, & Lanvin, 2016; Bilboa-Osoria, Dutta, & Lanvin, 2014; World Economic
Forum, 2015). We do this in the specific context of Luxembourg, one of the smallest
countries in the world, because Luxembourg has been trying over several years to improve its
position within the NRI. Luxembourg's officials closely monitor the NRI and set the
ambitious goal of positioning the country in the "top 10" of this index (Cencetti, 2014).
Luxembourg is often overlooked in research despite its open and service-based economy, its
central location in Europe, its influence in the EU as one of the founding members and its
leading position in many international league tables in areas such as GDP/capita or quality of
life (STATEC, 2016). Furthermore, Luxembourg could be compared to an economic or
metropolitan region of larger countries and thus looking at Luxembourg might help to provide
insights into other small and open economies with similar features such as, for example,
Singapore. We also provide a contribution to a better understanding of the ICT sector in
Luxembourg to fill this gap in existing research. Finally, we provide an illustration of what
governments might be able to achieve when coordinating their policy and financial efforts to
improve their countries' positions in international rankings.

Government efforts and significant funds channelled to ICT developments (Binsfeld, 2013;
Binsfeld, Whalley, & Pugalis, 2014; SMC, 2010) have indeed allowed Luxembourg to reach,
in 2015, a position among the 10 top countries in the world in terms of the NRI
(Gouvernement du Luxembourg, 2015b; Dutta, Geiger, & Lanvin, 2015; Zoenen, 2015) as
well as in the International Telecommunication Union's ICT Development Index (Henry,
2013; International Telecommunications Union, 2015; Iochem, 2014). The main objective of
this paper is to identify Luxembourg's major strengths and weaknesses according to the NRI,
to draw lessons about the relevance of this index for understanding the ICT ecosystem and to
identify areas in which additional policy initiatives could help further strengthen
Luxembourg's position within this index.

The remainder of the document is structured as follows. The next section provides an
overview and discussion of the literature regarding different ICT related measurements and
indexes. Section 3 discusses the NRI and its limitations while Section 4 presents the evolution
of Luxembourg's NRI ranking as well as its strengths and weaknesses according to the most

recent NRI publications. Section 5 moves on to discuss the outcomes of this analysis and provides conclusions and recommendations for additional policy initiatives with the hope that these recommendations might help Luxembourg's officials to further improve its NRI position and thereby contribute to develop its ICT sector. The final section explores some wider implications and suggests avenues for further research.

2. Measuring information society: a grand challenge?

There is an extensive range of literature available on different ICT related indices and it is only possible to present here a small subset here[3]. In this section, therefore, we focus mainly on the discussion of the generic classification of indices, their underlying limitations and proposals for improving them, with the objective to illustrate the complexities and limitations of such indices.

Hanafizadeh, Hanafizadeh & Khodabakhshi (2009b) established a detailed taxonomy of 'E-readiness' measures. Like others before them, they identified the problem of defining what to measure and for what purpose and presented several different approaches. They classified measurement methods into measures that use questionnaires, measures that employ statistical methods and mathematical analysis of secondary data; measures, which draw on historical analysis most for a specific country (or group of countries) and measures that use best practices and experiences from other countries. They identified sources of data according to six "dimensions", that is, infrastructure and access, access to and use of ICT by households and companies, E-Business, E-education, E-government and basic enabling and social indicators. A wide range of references and data sources is provided as well as a detailed list of indicators for each dimension. As such, this taxonomy is an excellent starting point for any discussion of ICT indicators.

Golinski (2012, p 4) argued that the "monitoring of traditional telecommunications was relatively easy as there were a limited number of providers of services and two groups of consumers: private and business subscribers". Initially the analysis of IT was straightforward because of less diverse hardware and limited "convergence" between different technologies. He builds on the "grand challenge" notion mentioned above and provides a typology of indicators according to whether these are ICT related, non-ICT related, quantitative or qualitative, hard or soft, demand or supply side related. He provides a good initial overview of the different sources and actors in ICT related measurements, for example, the national

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[3] Over 50 different ICT related indicators are presented in, for example, Pena-Lopez (2009) which is an excellent and complete reference document.

statistic offices, regulatory authorities, international organisations and commercial companies. The main issues identified are, improperly documented methodologies, weak and not generally agreed definitions, the lack of data sources in some countries, the lack of standards and the competition between authors of studies. Golinski (2012) further argued that it is probably best to use large sets of indicators from different sources in order to address not only the technological but also the related social, economic and political aspects. This multifaceted approach seems to be more appropriate for capturing the reality behind ICT and this method seems to be the currently preferred one that is applied by many (official) institutions.[4] However, these sets of indicators are difficult to obtain and this has led to a tendency of establishing so called composite indicators (CI).

Freudenberg (2003) presents and compares some of these indicators and discusses the positive and negative aspects of CI. He concludes with a comparison of the most popular composite indices in terms of their theoretical foundations, their structure, the quality of the underlying data, the difficulties in their interpretation and their ability to be independently verified. He finds evidence that, whilst there are some tools for evaluative research, which are worth being published and promoted, there also some popular indices for which the marketing aspects seem to dominate over their factual knowledge.

Vaezi & Bimar (2009) classified 'E-readiness assessment models[5]' into 'E-economy' and 'E-society' oriented ones. They argued that there is no single most suitable approach but that the right tool is contingent on the user's needs. All models have limitations but ideally indices "should provide a set of measurements for the range of factors that influence e-readiness, they should describe how these measurements can be used, they should clearly describe how to apply the tool depending on the different users' needs and it should indicate how to use the results, including identifying potential difficulties with implementation" (Vaezi & Bimar, 2009, p. 8).

Along the same lines, several authors have commented on the many limitations of ICT indicators. Minges (2005), for example, focussing on Latin America and the Caribbean, also provided a summary of the main e-indices available at the time. He also compared the underlying "purposes and objectives" for the different models and discussed the question whether a "general framework" would exist and came up with the following categorisation: Infrastructure (networks, pricing, quality), Usage (intensity and type), Education (literacy,

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[4] National Regulatory Authorities, National and international statistical offices, International organisations

[5] Of which the NRI is one example

School Enrolment, ICT labour), Policy/Regulatory Environment (specific to ICT but also more general in nature), ICT Sector (output, productivity, investment), and Socio-Economic (GDP, governance).

Minges (2005) also pointed to some methodological issues like subjectivity, limited availability of data, questions about underlying data collection processes and unclear definitions of what to measure,[6] statistical flaws, errors made in data transformation and calculation of rankings and most important the weightings (implicit or explicit) of the different sub-indices or individual indicators.

Similarly, the Global Information Society Watch, an organisation for the collaborative monitoring of implementation of international (and national) commitments made by governments towards the creation of an inclusive information society, has discussed in several documents the limitations of the ICT indicators (de Munck, 2009; de Munck, 2010; Jensen & Mahan, 2008; Mahan, 2007). They focussed on the use and potential misuse of such indicators for advocating policies or political approaches and showed that indicators are not neutral. They provide, for example, illustrations of the missing consideration of gender, human rights issues, press freedom or green ICT and propose adaptations to include such topics into existing frameworks. They show that ICT indicators can depend on the authors' beliefs, intentions, and limited knowledge. The numerical expression of underlying issues creates an impression of objectivity, which may be misleading.

Schlichter & Danylchenko (2014, p. 1) also looked at four specific indices (including the NRI) and concluded "that they fail to highlight the deep meaning of ICT usage and to distinguish between its manifests". Consequently, they propose an integrated framework that incorporates the actual levels of ICT usage in order to obtain a better understanding of the level of information society development within a country.

Many researchers have not only discussed the limitations of ICT indicators but proposed extensions or improvements to the models of which Table 1 (below) provides a non-exhaustive summary. It can be seen, through the many adaptions proposed, that academics have adopted over time increasingly sophisticated approaches and techniques to rank countries. Whilst these initiatives present some potential for improving information society measures, they have not yet led to internationally accepted methodologies and generally

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[6] For example, models include from 3 to 12 different indicators for the relatively straightforward aspect of infrastructure.

available data sets. For some of these proposals it is far too cumbersome to collect the underlying data on a recurring basis so that no comparisons over time are possible. Often, the underlying data may not be available for all countries. It can be questioned, therefore, whether all these efforts have really helped to lead to a better understanding of the digital economy and what the ranking of the different countries really means.

Table 1: Examples of some extensions and improvements proposed over time

Author(s)	Adaptations proposed
Grigorovici & Taylor (2004)	Use of advanced statistical techniques like structured equation modelling (SEM), to address the issue of weighting of sub-indices and factor analysis to reduce the amount of input variables
Vehovar, Sicherl, Hüsing, & Dolnicar (2006)	A multivariate log-linear modelling, compound indices, a time distance approach as well as more inclusion of qualitative methods
Barzilai-Nahon (2006)	Argued for the use of "compound" or "comprehensive" indicators over the "mono-topical
Mutula & Van Brakel (2006)	Developed an "information rich" tool with different "segments": enterprise e-readiness segment, human resources e-readiness segment, information readiness segment, ICT readiness segment and external environment readiness segments
Al-mutawkkil, Heshmati, & Hwang (2009)	Inclusion of broadcasting infrastructures, parametric approach using factor analysis for the weightings
Hanafizadeh, Hanafizadeh, & Khodabakhshi (2009a)	Used 37 other information society and digital divide models and used the knowledge embedded in these models as proxies for expert's opinions to define the weighting to the different contributing indicators
Hanafizadeh, Saghaei, & Hanafizadeh (2009b)	Use advance data mining methods, Markov Chain Monte Carlo for aggregating the indicators and multi-stage factor analysis for aggregating the indicators avoiding thus the use of equal weighting or the need to rely on experts' opinions
Kyriakidou, Michalakelis, & Sphicopoulos (2013)	Applied structured equation modelling to define their ICT maturity level index based on 3 sub-indices: access, use and skills
Hilbert, López, & Vásquez (2010)	Argued for the need to extend the scope of analysis beyond equipment or infrastructure availability to include information processing power
Mateus (2015)	Digital Economy and Society Index" tries to assess the actual uptake and use of the digital technologies and infrastructures by identifying 5 different aspects: connectivity, human capital, use of internet, integration of digital technology and digital public services
Gerpott & Ahmadi (2015)	Use a partial least square structural equation modelling approach to construct the weighting of 11 "first-level" indicators into the "telecommunications development index"

3. The Networked Readiness Index

Bearing in mind the difficulties and limitations identified above, we focus in the rest of the paper on the NRI. It was published for the first time in 2001 and developed by the Harvard Business School with a survey of initially 75 countries. From 2002 (Dutta, Lavin, & Fiona, 2003), this survey was extended and coordinated by INSEAD and is published on an annual basis along with comments and discussions of various topics in the so-called *Global Information Technology Report* (Baller et al., 2016; Bilbao-Osorio, Dutta, & Lavin, 2013; Bilboa-Osoria et al., 2014; Dutta, Geiger, & Lanvin, 2015).

Since 2003, Luxembourg has also been included in the list of countries assessed and since 2009, the full details of the NRI and its different underlying variables are available free of charge.[7] The NRI and the Global Information Technology report receive a lot of attention in the media (Iochem, 2014), and are often regarded by the media and politicians as being the most authoritative and comprehensive assessment of how ICT shapes the competitiveness and wellbeing of nations.

The NRI measures the propensity for countries to exploit the opportunities offered by ICT. The index seeks to better understand the impact of ICT on the competitiveness of nations and is a composite of three components:

- the environment for ICT offered by a given country or community (market, political, regulatory, and infrastructure environment);
- the readiness of the country's key stakeholders (individuals, businesses, and governments) to use ICT; and,
- the usage of ICT among these stakeholders.

A set of variables is collected and divided into four sub-indexes or pillars:

- the general political, regulatory, business and innovation environment;
- readiness defined in terms of infrastructure and digital content;
- affordability and skills, usage by individuals, businesses and government; and since 2012,
- economic and social impacts (Dutta & Bilboa-Osoria, 2012).

The different indicators are derived from quantitative data such as Eurostat, International Telecommunications Union, OECD and as well from qualitative surveys and interviews that are conducted globally by local partner organisations. The exact number of indices as well as

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[7] See https://www.weforum.org/reports accessed 9.7.2016

the split between survey and statistical sources varies from year to year, as does the number of countries included in the survey. A ranking is established based on the combination of the different sub-indexes not considering any specific weighting (other than the number of indicators per sub-index). WEF does not provide all details of their underlying methodology, which makes it difficult to replicate the results while providing WEF with a "competitive advantage" over those who would wish to replicate it. This does, of course, somewhat hide its underlying objectives and purposes, and makes it a bit difficult to criticise its methodology.

Nevertheless, the NRI has received a wide range of criticism. Minges (2005) and Vehovar et al (2006), for example, have pointed out the methodological issues related to aggregated indexes: subjectivity, limited availability of data, the underlying data collection processes, and unclear definitions of what to measure, statistical flaws, errors made in data transformation and calculation of rankings. Perhaps the most important criticism has been reserved for the weightings (implicit or explicit) of the different sub-indices or individual indicators. Quite simply, how are they determined and susceptible are the outcomes to (minor) changes in the weights?

More specifically, Goswami (2006a) questioned the relevance of some of the underlying indicators and identified some that were, from his perspective, missing such as, for example, the degree of competition in the market or the performance of the national regulatory authority. Schlichter & Danylchenko (2014) argue that the NRI focusses too much on "readiness" measures and does not sufficiently consider the actual "ICT usage" by individuals or companies.

Along the same lines, the Austrian national regulatory authority for the telecommunications sector (RTR, 2011) criticised the scaling between 1 and 7 of most of the indicators and the fact the categories between 0 and 1 and between 6 and 7 are not achieved. They also questioned the "objectiveness" of the surveys conducted by the local partners as these can have an important impact on the outcome of the study. How are, for example, the interviewees chosen and what were the actual questions asked? How skilled are the interviewers as these are different persons in each country? Another key question raised about the methodology reflects the fact that the interviewees will not be the same persons over time, so, quite simply how comparable are the answers given? What about those respondents that are only sent a questionnaire and not even interviewed, which is the case for Luxembourg?

On the other hand, some of the indicators are very difficult to influence through political or business decisions and some might take a long time before changes can be measured. The

implicit weighting of the different indicators is also a matter of criticism, for example, in the 2010 version only three indicators were used to measure usage of governments as opposed to 16 for businesses and 17 for individuals. For some indicators, the measurement range varies from year to year as it is set by the lowest and the highest value achieved in a specific year. Additional problems arise with the ranking as a confidence interval (two standard deviations) must be considered, and this is dependent on the actual sampling size. Sometimes the absolute differences between countries are very small and thus the ranking may not be statistically correct.

Kauffman & Kumar (2005) also question the validity of some of the underlying indicators used as these may come from different sources and, therefore, may not be entirely comparable internationally. On a more general note, Luyt (2006) questioned the whole idea of a competitive ranking between different countries and commented that the business aspects seem to be more prominent than the needs of individuals.

Despite of these limitations and criticisms, the NRI is a popular tool for policy- and business decision makers as well as when drawing comparisons between different countries. It is well documented in the media[8] as it provides a single composite indicator to measure ICT performance and to establish a country ranking. It is published annually by a well-established and renowned body, and covers a wide range of countries with the consequence that it is useful for benchmarking and rankings. It can also be accessed freely and its constituent indicators are disclosed, although the methodology is only partially documented. In particular, Luxembourg's officials have closely monitored its evolution (Diederich, 2001) and set the ambitious goal to position the country in the top 10 of this index (Cencetti, 2014; Gouvernement du Luxembourg, 2015b).[9]

4. The evolution of Luxembourg's NRI position between 2003 and 2016

In the following section, we focus on Luxembourg and present the NRI and its evolution over time for Luxembourg with the objective of identifying how Luxembourg's position has changed over time and what have been or are its strengths and weaknesses according to the different NRI pillars. As discussed above, this time series analysis needs to be treated with care as the methodology, the number of countries and the split between quantitative and qualitative measures has considerably evolved and continues to change nearly every year.

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[8] For example, a Google search for the term revealed over 160,000 results, accessed 8th of January 2017.

[9] This was confirmed via an interview with the head of Service des médias et des communications (SMC) in May 2014.

At this stage, it is also worth highlighting some operational details about the underlying data collection process and its limitations, which are not disclosed publicly, but which we have been able to collect directly form the organisation involved in the data collection process in Luxembourg. Indeed the data are being collected on an annual basis, using an online survey, as subset of the much more extensive "global competitiveness report" (Schwab, 2013). An online questionnaire is sent out to about 700 people that are supposed to constitute a representative sample of the Luxembourgish economy. However, only about 100 of these respond to the survey. Therefore, the outcome constitutes a snapshot of the "feelings" of the different respondents and there is no guarantee that year-on-year the same 100 people respond to the survey. It would appear from the results that Luxembourgish natives tend to be more critical about the local situation, whereas foreigners living and working in Luxembourg take overall a more optimistic view. Given the relatively small sample size, it is not impossible to influence the results by actively contacting some of the respondents and discussing their views with them. It was also reported that some countries are indeed analysing the underlying measures in depth and try to create a policy environment that is aligned with the questions posed such as, for example, the number of days to set-up a business.

Bearing this in mind, Table 2 and Figure 1 show the actual values of the NRI and for its sub-indexes environment, readiness, usage and (since 2012) impact, as well as the rankings in the different pillars. A percentage change has been calculated between 2003 and 2016 – calculating intermediate values was problematic as even the scaling has changed over time. It can be seen that on most indicators as well as on the so-called pillars, Luxembourg has improved over time and on some occasions this improvement has been substantial. There are only four pillars for which this not the case: infrastructure environment - which is surprising as most of the government initiatives have gone into the development of infrastructure - business readiness and skills. With regards to the affordability pilliar, Luxembourg's position has stayed more or less constant since 2003, which shows that the pricing levels of the underlying services have not really decreased.

In terms of the absolute ranking, the long-term tendencies are also pointing towards improvement and Luxembourg's position has improved from 27 to among the top 10 countries in the world. However, in the period between 2005 and 2010 this did not appear to be the case. Luxembourg, although improving in absolute terms, declined relative to its competitors. It would, however, appear that the efforts made by politicians and regulators have been able in recent years to counter this trend and have put Luxembourg amongst the top 10 countries in the world (Dutta, Geiger, & Lanvin, 2015). Examining the policy initiatives

that subsequent governments have taken over time (Binsfeld, Whalley, & Pugalis, 2015), it can be seen that this was the period when Luxconnect, a second state owned telecommunications operator, was established and became operational. Indeed, in 2006, the government decided to directly invest into telecommunications networks infrastructures by creating a network operator and providing it with the necessary capital to build alternative national and international fibre optical networks as well as data centres.

Table 2 - Networked Readiness Index Evolution over time (source: World Economic Forum)

NRI and its pilars	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	% change 2003-2016 (or latest year)
NRI	4.55	4.76	1.04	0.8	4.9	4.94	5.1	5.02	5.14	5.22	5.37	5.53	5.6	5.7	**25%**
Rank	**27**	**14**	**17**	**26**	**25**	**24**	**21**	**17**	**14**	**21**	**16**	**11**	**9**	**9**	
Environment	4.81	4.64	1.44	1.24	4.62	4.67	4.82	5.33	5.5	5.27	5.25	5.31	5.4	5.5	**14%**
Rank	18	9	13	17	22	23	22	13	8	13	13	11	10	9	
Market Environment	3.79	4.27	1.14	0.86	4.46	4.86	5.02	5.4	5.41						43%
Rank	33	8	19	22	24	20	16	4	3						
Political and regulatory environment	5.03	5.17	1.4	1.19	5.31	5.44	5.39	5.99	6.06	5.79	5.77	5.73	5.8	5.9	17%
Rank	15	10	13	22	22	18	13	4	5	5	4	4	3	1	
Infrastructure environment	5.59	4.48	1.78	1.67	4.1	3.71	3.84	4.59	5.02						-10%
Rank	3	18	10	12	22	35	29	19	18						
Business and Innovation environment										4.75	4.73	4.9	5	5	5%
Rank										27	34	29	27	27	
Readiness	4.93	4.96	0.94	0.51	5.05	5.29	5.26	5.09	5.17	5.86	5.79	5.91	5.9	5.9	**20%**
Rank	**30**	**25**	**14**	**28**	**26**	**26**	**28**	**20**	**12**	**19**	**18**	**18**	**19**	**19**	
Individual readiness	5.07	5.04	0.85	0.83	6.05	6.07	5.95	5.22	5.44						7%
Rank	32	28	20	24	18	24	27	25	22						
Business readiness	5.12	5.19	0.54	0.29	4.82	4.79	4.78	4.82	4.76						-7%
Rank	22	25	27	35	29	38	39	30	22						
Goverment readiness	4.61	4.65	1.44	0.42	4.29	5.01	5.05	5.23	5.32						15%
Rank	28	28	7	33	32	21	18	10	7						
Infrastructure and digital content										6.17	6.43	6.29	6.3	6	**-3%**
Rank										13	12	17	18	26	
Affordability										5.74	5.61	5.73	5.7	6	5%
Rank										36	48	56	50	36	
Skills										5.66	5.33	5.73	5.8	5.9	4%
Rank										31	33	27	18	20	
Usage	3.9	4.67	0.75	0.66	5.02	4.87	5.21	4.65	4.74	5.26	5.62	5.73	5.8	5.9	**51%**
Rank	**31**	**8**	**26**	**30**	**19**	**20**	**15**	**23**	**20**	**15**	**10**	**8**	**7**	**5**	
Individual usage	4.57	6	1.36	1.66	4.93	4.72	5.69	5.82	6.05	5.91	6.47	6.43	6.5	6.8	**49%**
Rank	8	1	13	13	9	9	4	5	3	7	4	5	6	2	
Business usage	3.56	4.62	0.8	0.74	5.38	5.18	5.29	3.94	4.16	5.03	4.97	5.27	5.4	5.4	52%
Rank	49	19	25	30	26	27	23	28	18	18	16	13	11	15	
Government usage	3.56	3.4	0.09	-0.42	4.76	4.7	4.64	4.19	4	4.83	5.41	5.48	5.4	5.4	52%
Rank	52	43	48	73	31	25	27	41	42	20	13	10	11	9	
Impact										4.5	4.81	5.17	5.3	5.4	**20%**
Rank										28	21	15	12	9	

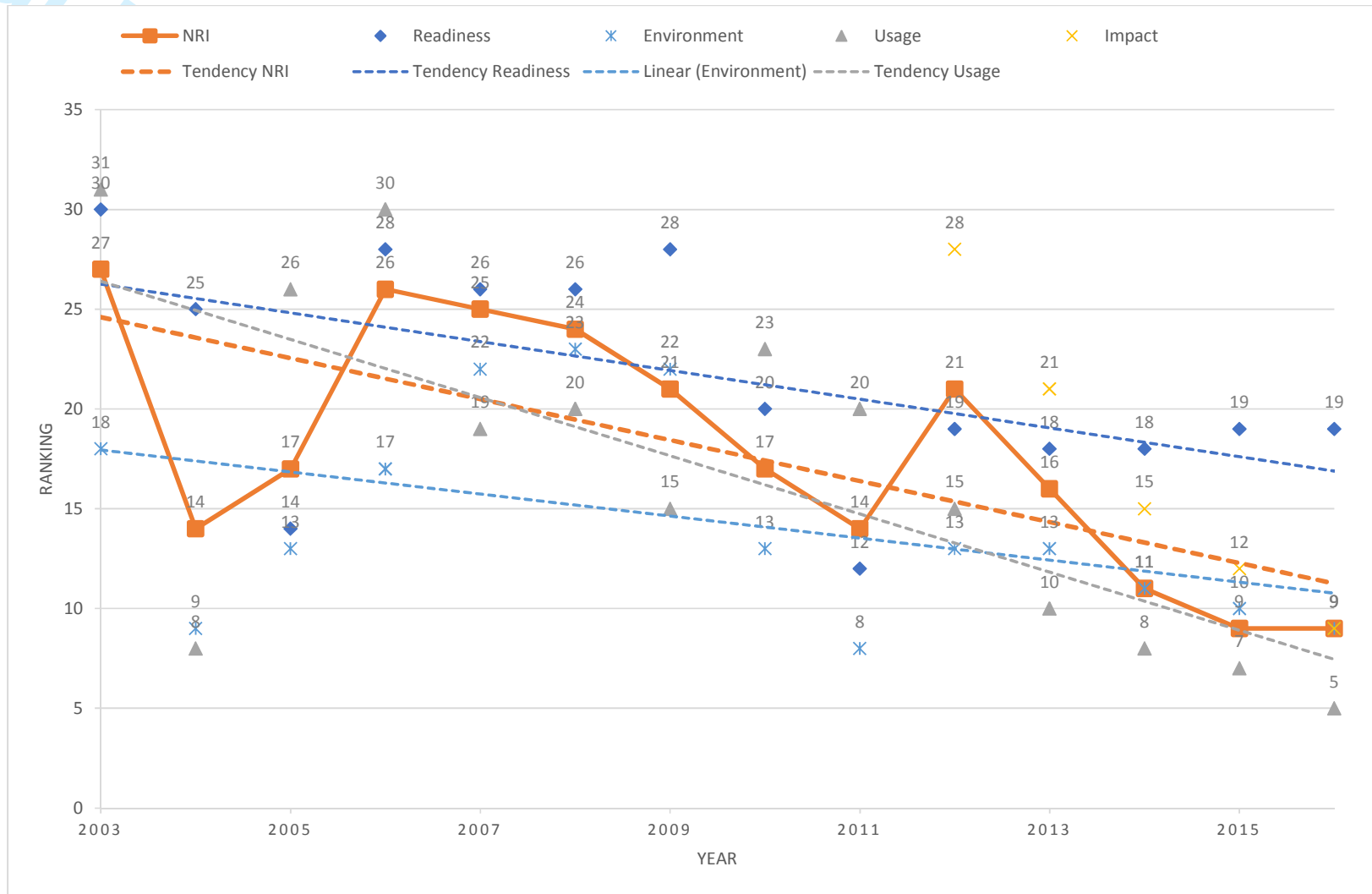*Figure 1 - Evolution of NRI over time (source: World Economic Forum)*

This public intervention can be considered as a general economic policy to increase Luxembourg's ICT competitiveness and, considering the upcoming financial crises in 2008/2009, it was also expected to be a counter cyclical investment that would stimulate the recovery of the economy. For a more detailed discussion about this process see, for example, Binsfeld et al. (2014) and Zahlen (2016). Apparently, this initiative has helped to improve Luxembourg's overall position substantially as it did create a significantly improved national and international connectivity as well as datacentre capacity. This stimulated competition, which, in turn, attracted many new telecommunications operators and service providers (Binsfeld, 2013). In addition, the government also initiated its ultra-high broadband strategy that sought to develop large scale fibre connectivity to almost all of the country's business and private users (SMC, 2010).

Strengths

By looking in more detail into the individual components of the four pillars,[10] it is possible to identify Luxembourg's main strengths (see Figure 3) and weaknesses (see Figure 4) and the Appendix. According to the 2016 report (Baller et al., 2016), Luxembourg's main strengths seem to be related to its small size and its flexibility in adapting to market changes and its telecommunications infrastructure. This is demonstrated by the fact that most households, businesses as well as the government administrations are using computers and the internet. The government's willingness and vision to develop ICT appears to have been successful as documented by the fact that laws relating to ICT, the government's vision and the efficiency of the legal system are identified several times amongst Luxembourg's strong points between 2009 and 2015.[11] In addition, the availability of the latest technologies - next generation broadband access, 4G - as well international connectivity are also mentioned several times as is the high percentage of knowledge-intensive jobs that might be due the requirements of the financial sector. Finally, Luxembourg is amongst the top ten countries with regard to specific laws for intellectual property exploitation.

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[10] Detailed data is only available between 2009 and 2015 (inclusive).

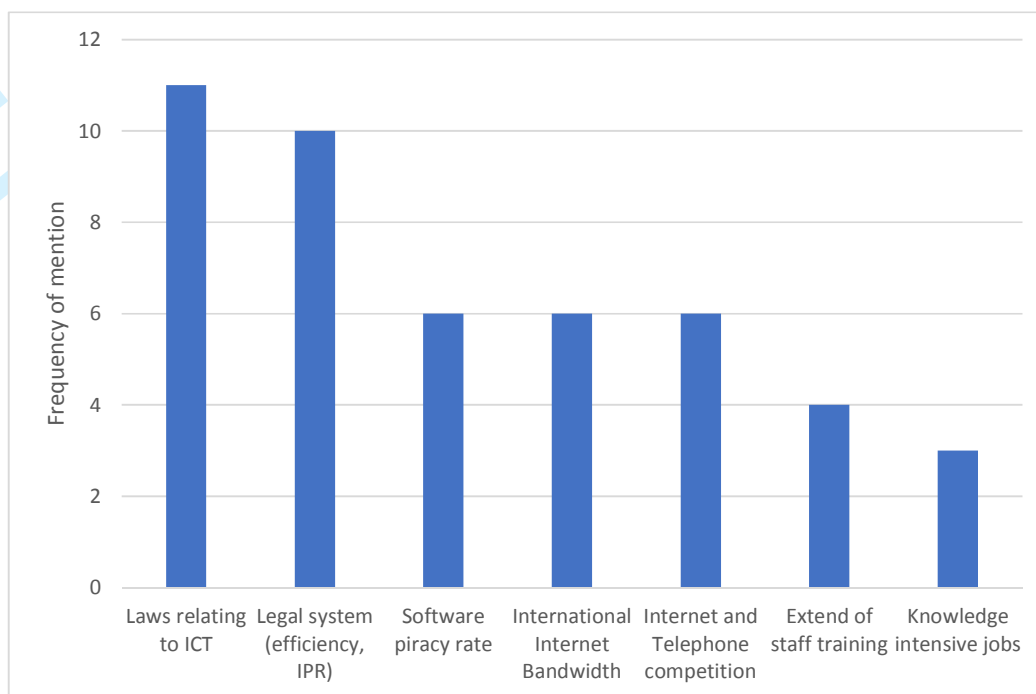[11] The data are only available for free for this period in time.

Figure 2 - Main strengths between 2009 and 2016 according to the number of times mentioned (source: World Economic Forum)

Weaknesses

On the other hand, many of the weaknesses (as shown in Figure 4) appear to be linked to education as Luxembourg scores badly on "tertiary education, management schools", "tertiary education gross enrolment data" and the "overall quality of the educational system". Although these issues are not directly linked to ICT, they appear to have had a major impact on Luxembourg's current NRI position. So far this issue has not received prominent attention on the digital policy agenda in Luxembourg. It is only quite recently that the government launched a new overall strategic initiative called "Digital Lëtzebuerg" (Antzorn, 2014; Bettel, 2014; Land, 2014) and tried to address this with specific actions such as "Digital4Education" (Gouvernement du Luxembourg, 2015a) at the level of formal education and continuous professional development. These initiatives may contribute to improving the situation in the years to come, but will not have any immediate effect at it generally takes a long time before curricula are adapted and students re-oriented towards new areas.

In addition, the prices of some ICT services are comparatively high and, therefore, could limit the uptake of such services. This issue seems to be linked to the fact there is only limited competition in specific segments of the market, which may be the consequence of the small size of the country. Another important weakness appears to be linked to establishing a new business venture as it is reported several times that Luxembourg performed poorly on the

"number of days to start a business" indicator. This can take a long time and there are cumbersome procedures in place that must be gone through to establish a business in Luxembourg.

Finally, electricity production has been identified to be, or to potentially become in the future, a major issue. Luxembourg does not produce any electricity locally and this makes the country dependent on electricity generation elsewhere in Europe.
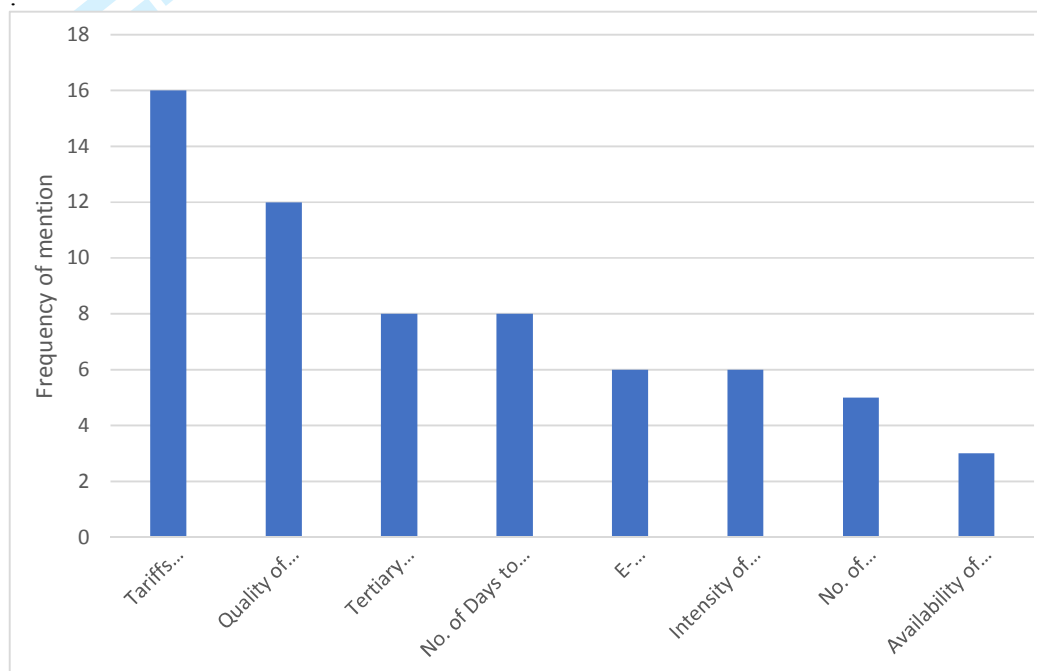

Figure 3 - Major weaknesses identified between 2009 and 2016 according to the number of times mentioned (source: World Economic Forum)

5. Discussion

The analysis undertaken in previous sections has shown how Luxembourg has successfully improved its position on the NRI over the course of the past 13 years. In both 2015 and 2016 Luxembourg was ranked by the World Economic Forum as being among the top 10 networked ready countries globally. Drawing on this analysis, it is possible to identify a series of lessons, some of which are limited to the specific context in which Luxembourg finds itself while others are of more general interest.

A series of government initiatives have contributed to the development of the underlying ICT infrastructure, in terms of international connectivity, broadband and ultra-high speed broadband as well as datacentres (Binsfeld, Whalley, & Pugalis, 2014). Competition in

several segments of the ICT ecosystem has increased, which has led to more appropriate pricing levels and a good level of take-up of these services. This can largely be attributed to the creation of Luxconnect as a second state-owned operator with the consequence that the state competes with itself rather than relying on market forces (Binsfeld et al., 2015). Luxembourg has, however, not developed local electricity production capability and instead relies on imports from surrounding countries. Currently, this can be seen as an advantage as the local energy prices are amongst the lowest in the EU (Enovos Luxembourg, 2014). However, in the long run, this may not be sustainable as the country is completely dependent on foreign electricity providers. Thus, the first lesson we can draw is the importance of infrastructure based competition for improving a country's NRI position. Significantly, this infrastructure is wider than ICT.

Luxembourg has not been able to establish the needed educational programmes and institutions that would allow to produce the necessary IT skills on a local basis. Instead Luxembourg has relied on the importation of knowledge from neighbouring countries whilst focussing on its language skills and legal, financial and humanities education. This is increasingly a significant obstacle to continuing the further development of the ICT sector and further improvement of Luxembourg's position on the NRI. In a recent publication of the Digital Economy and Society Index (European Commission, 2015c), Luxembourg appeared last amongst EU member states in terms of the percentage of students embarking on the technical, scientific or mathematical studies that are often considered to form the basis of ICT skills. Different initiatives are under discussion within Luxembourg (Bettel, 2014; Land, 2014), both on the supply side (new training programmes, private schools, continuous professional development and vocational training) and on the demand side (promotion of Luxembourg as an attractive place to live and work, stimulation of e-skills amongst young age children). These will, however, take time before they become effective and provide the necessary skills. Thus, a second lesson that can be drawn is that skills are equally as important as infrastructure.

Concerning changes in the legal and regulatory environment that would facilitate the start-up of new businesses, the situation is a bit similar as a major change in terms of commercial law would be required. Currently, if an entrepreneur goes bankrupt, he or she is forbidden by law from starting a second (new) venture. Such a change would have to be accepted by all relevant stakeholders and political parties. It would, once again, take time to get these stakeholders on board and make the necessary changes to the legal framework. This gives rise to a third lesson that can be drawn, namely, the need to engage with all relevant stakeholders.

Overall, the case of Luxembourg's position in the NRI illustrates that in order to be in the ICT "premier league" a holistic policy approach is necessary. It is not enough to rely on the development of basic ICT infrastructures and the fostering of competition. The development of complementary infrastructures such as electricity generation is also necessary and, perhaps most importantly, efforts are required on a social level in terms of, for example, education systems and priorities, the promotion of ICT usage and the development of e-skills.

6. Conclusions

Through examining the NRI this study has allowed an initial, albeit high level, assessment of the forces at hand within the ICT ecosystem and provides an indication of how successful or not Luxembourg has been in developing its ICT sector over the course of the last dozen years. This analysis has been based on focussing on the evolution of Luxembourg's NRI position. This paper represents, to the best of our knowledge, the first attempt to investigate the position of a small country, which are often overlooked in the literature, in terms of its changing position and the policies developed and enacted by a national government.

Given the many critiques and limitations of ICT related aggregated indices in general, and the specific limitations of the NRI, this analysis is far from definitive and needs to be confirmed by additional research. This additional research could take the form of including the views and opinions of actors in the ICT ecosystem in Luxembourg – see, for example, Binsfeld et al. (2015a). While the small size of Luxembourg has facilitated direct access to the sector's major stakeholders and decision makers, the scope of this research could be expanded. Luxembourg's position on the NRI index could be compared with other indices such as those published by the ITU or EU. This, however, must be done with care, as the underlying information may not be readily available for different countries or regions on a yearly basis.

On the other hand, the analysis has also shown how publicly available secondary information might be used to understand and assess underlying policy decisions and how this information can help to set the scene for further, more in-depth investigations. It is, therefore, questionable whether it is productive to develop, as illustrated in Table 1, an ever more complex and specific indices and measurement tools to understand the digital economy. Often these evaluations are based on underlying data that could be difficult to collect and compile and may end up being of poor quality. For some of these complex indices, it can be far too cumbersome to collect the underlying data on a recurrent basis so that no comparisons over time are possible. Also, the underlying data may not be available for different countries so that internationals comparisons may not be very reliable or meaningful. It can be questioned,

therefore, whether all these efforts have really helped to lead to a better understanding of the digital economy and what the ranking of the different countries really means. Thus, care needs to be taken when drawing comparisons, not only on the same indices but also between them. This should not be taken as suggesting that drawing high level comparisons should cease, but rather carefully entered into.

Bearing in mind these comments, the present paper provides an illustration of how a widely available index such as the NRI can be used to extract potentially valuable conclusions for policy makers and politicians. There are, however, not many such studies currently available in the academic literature, with one such example being (Park, Kim, & Jae Kim, 2014) who look at South Korea and use its digital divide index. The relative paucity of such studies suggests that there is certainly scope for additional research.

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Appendix – Main strengths and weaknesses identified in the NRI from 2009 to 2015

Year	Main Strengths	Ranking	Main Weaknesses	Ranking
2016	Knowledge Intensive Jobs	1	Tertiary education gross enrollment rate	97
	International Internet Bandwidth	1	No. of days to start a business	95
	Internet and Telephony Competition	1	Mobile network coverage	67
	Laws relating to ICT	1	Fixed broadband internet tariffs	65
	Intellectual property protection	2	Intensity of local competition	61
	Extent of staff training	2	Electricity production	60
	Software piracy rate	3	E-participation Index	54
	Secure Internet servers	3	Number of procedures to start a business	54
	Effectiveness of law making bodies	4	Prepaid mobile tariffs	47
	Households with Personal Computer	4	Quality of management schools	34
2015	Knowledge Intensive Jobs	1	Tertiary education gross enrollment rate	95
	International Internet Bandwidth	1	No. of days to start a business	93
	Internet and Telephony Competition	1	Prepaid mobile tariffs	74
	Laws relating to ICT	2	Fixed broadband internet tariffs	66
	Intellectual property protection	3	No. of procedures to start a business	58
	Software piracy rate	3	E-participation Index	54
	Extent of staff training	3	Electricity production	45
	Government's success in ICT promotion	4	Quality of management schools	39
	Households with Personal Computer	4	Mobile network coverage	39
	Secure Internet servers	4	Use of virtual social networks	33
2013	Laws relating to ICT	1	Tertiary education gross enrollment rate	112
	Internet and Telephony Competition	1	No. of days to start a business	81
	Software piracy rate	2	Fixed broadband internet tariffs	64
	Impact of ICT's on accesss to basic services	3	Quality of management schools	60
	Households with Personal Computer	3	Prepaid mobile tariffs	59
	Effectiveness of law making bodies	4	Intensity of local competition	58
	Extent of staff training	4	No. procedures to start a business	48
	No. of procedures to enforce a contract	5	Quality of math&siecence education	46
	Importance of ICT to government's vision	5	Business to consumer Internet usage	36
	Households with Internet Access	6	Quality of educational system	36
2012	Software piracy rate	1	Tertiary education gross enrollment rate	109
	Internet and Telephony Competition	1	No. of days to start a business	80
	Individuals using Internet	4	Fixed broadband internet tariffs	61
	Households with Personal Computer	4	E-participation Index	60
	Households with Internet Access	4	Quality of management schools	58
	Effectiveness of law making bodies	5	Prepaid mobile tariffs	53
	Laws relating to ICT	5	Government Online service index	51
	Efficiency of legal system in challenging regulations	5	Quality of math&siecence education	47
	Intellectual property protection	5	No. procedures to start a business	46
	Government prioritization of ICT	5	Intensity of local competition	41
2011	Financial market sophistication	1	Residential monthly phone subscription	111
	Internet and Telephony Competition	1	Tertiary education gross enrollment rate	108
	International Internet Bandwidth	1	Business monthly phone subscription	85
	Patent Cooperation Treaty application	1	Availability of scientists and engineers	81
	Software piracy rate	2	No. of days to start a business	72
	Efficiency of legal system in challenging regulations	3	Quality of management schools	66
	Households with Personal Computer	3	E-participation Index	66
	Government procurement of advanced technologies	4	Fixed broadband internet tariffs	58
	Buyer sophistication	4	Fixed phone tariffs	54
	Intellectual property protection	5	Government Online service index	51
2010	Financial market sophistication	1	Tertiary education gross enrollment rate	104
	Level of competition index	1	Residential monthly phone subscription	97
	Internet bandwidth	1	Availability of scientists and engineers	79
	Efficiency of legal system in challenging regulations	2	Education expenditure	79
	Government procurement of advanced technologies	3	No. of days to start a business	75
	Venture capital availability	4	Quality of management schools	73
	Effectiveness of law making bodies	5	Business monthly phone subscription	68
	Buyer sophistication	5	Intensity of local competition	64
	Extent of staff training	6	E-participation Index	64
	Internet users	7	Computer, communications import	60
2009	Internet bandwidth	3	Tertiary education gross enrollment rate	102
	Financial market sophistication	4	Local supplier quality	102
	Cost of mobile telephone call	4	Quality of management schools	86
	Business monthly phome subscription	6	Availability of scientists and engineers	82
	Internet users	6	Education expenditure	80
	Residential telephone connection charge	7	No. of days to start a business	71
	No. of procedures to enforce a contract	7	Intensity of local competition	64
	Business telephone connection charge	8	Government Online service index	59
	High-speed monthly broadband suscription	8	Quality of math&siecence education	54
	Mobile telephone subscribers	9	Quality of scientific research organisations	53