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Dependency on un-captured GDP as a source of resilience beyond economic value in countries with advanced ICT infrastructure: Similarities and disparities between Finland and Singapore

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ABSTRACT

The majority of countries with advanced information and communication technology (ICT) infrastructure have been experiencing extended stagnation due to an "embedded" trap in ICT advancement. However, certain countries have been able to sustain a high level of ICT-driven global competitiveness. This suggests that in these contexts there is resilience beyond economic value. Finland and Singapore can be considered countries of resilience with respect to ICT-driven global competitiveness because of their continued GDP growth despite the recession. While both countries share significant similarities including institutional strength in ICT, they demonstrate noteworthy disparities in their development trajectories: Singapore is growth-oriented based on captured GDP while Finland seeks happiness by shifting to un-captured GDP. This contrast can be attributed to their distinct co-evolution with their institutional systems characterized by government/business initiatives in ICT usage for economic efficiency and differences in the new economic index referred to as "happiness seeking". Given the increasing significance of un-captured GDP derived from the dramatic advancement of the Internet, this paper, will use a comparative analysis of ICT-driven development trajectories in six leading countries in the field over the last two decades. This analysis reveals the different option for maintaining economic resilience. A new method for measuring un-captured GDP was developed to assess the consequences and state of un-captured GDP in six countries. Institutional sources leading to this state were analyzed and a source of resilience beyond economic value was conceptualized and articulated.

1. Introduction

The majority of advanced information and communication technology (ICT) countries have been experiencing extended stagnation ("great stagnation" (Cowen, 2011 [2])) as demonstrated by their low GDP growth from the middle of the first decade of this century which is illustrated in Fig. 1. (See annual growth rate in Appendix 1). Singapore is an exceptional case in this regard.

Part of the stagnation itself can be attributed to a "trap" in ICT advancement[1] derived from the two-faced nature of ICT, that is, while advancement of ICT generally contributes

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[1] Against anticipation, excessive advancement of ICT results in its marginal productivity decline due to its prices decrease derived from its two-faced nature.

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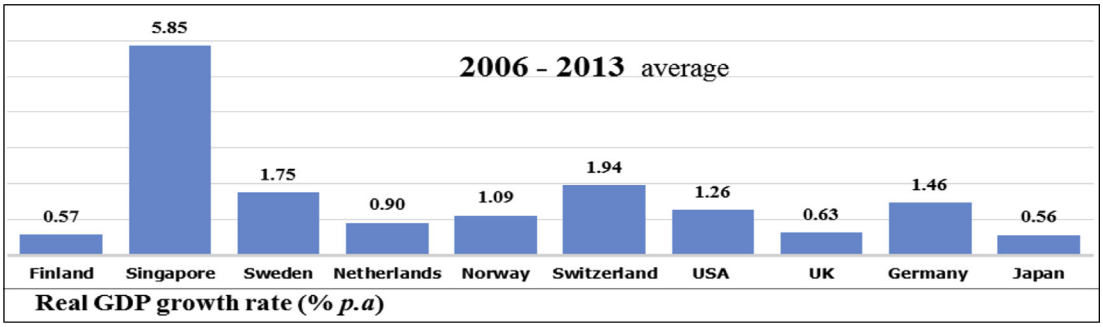

Fig. 1. Stagnation in economic growth in ICT advanced countries (2006–2013).
Source: World Economic Outlook Database (IMF, annual issues) [4].

Table 1
World ICT ranking top 5 countries (2011–2013).

ICT ranking	1	2	3	4	5
2013	Finland (3)	Singapore (2)	Sweden (6)	Netherlands (8)	Norway (11)
2012	Finland (3)	Singapore (2)	Sweden (4)	Netherlands (5)	Norway (11)
2011	Sweden (3)	Singapore (2)	Finland (4)	Denmark (8)	Switzerland (1)

Figures in parenthesis indicate global competitive ranking as tabulated in Table 2.
Sources: The Global Information Technology Report 2012, 2013, 2014 (World Economic Forum (WEF), 2012, 2013, 2014). The Global Competitiveness Report 2011–2012, 2012–2013, 2013–2014 (WEF, 2012, 2013, 2014).

to enhanced prices of technology by new functionality development, the dramatic advancement of the Internet reacts to decreased prices of technology due to its nature of "freebies", "easy copying" and mass standardization (Cowen, 2011 [2], Watanabe et al., 2014*b* [26], 2014*c* [27]).

Contrary to these circumstances, certain countries have been able to sustain a high level of ICT-driven global competitiveness, which suggests their resilience beyond purely economic value. Finland and Singapore can be considered resilient countries with respect to ICT driven global competitiveness as they have been maintaining the top level in the world rankings in ICT and also economic competitiveness as demonstrated in Tables 1 and 2 (WEF, 2014*a* [31], 2014*b* [32]).

Looking at Tables 1 and 2 we note that Finland and Singapore share the world's top ICT position both in 2012 and 2013, and also accomplishing a top global competitiveness position after Switzerland (Yusuf and Nabeshima, 2012 [33], WEF, 2013*a* [29], 2013*b* [30] 2014*a* [31], 2014*b* [32]).

Inspired by these conspicuous accomplishments in ICT-driven competence, Table 3 compares institutional factors governing competence in these ICT advanced six countries.

Table 3 demonstrates the conspicuous accomplishments of Finland and Singapore in global competitiveness, ICT competitiveness, human capital and quality of education with a similar size of population. However, if we look at the table carefully, we note that, in addition to these similarities, there are explicit disparities between the two countries. While Singapore demonstrates excellent economic performance such as a high GDP growth rate, low unemployment ratio and higher income level, and it is one of the advanced ICT countries, it remains far behind the "happiness and welfare" level as characterized by low inequality, high birth rate and happiness ranking[2] compared to Finland which demonstrates the highestlevels in these indicators compared to the other five countries compared.

This disparity reflects a number of factors including consumer behavior in their buying decision process and factors determining consumers choice in these two countries often characterized by the significant effects of national institutional systems (e.g., Hofstede, 1991 [3], Pieters et al., 1995 [16], Watanabe, 2009 [23]). For example, Internet merchants (Jarvenpaa et al., 2000 [8]). Rintamaki et al. (2006 [19]) have unveiled softer aspects of shopping, particularly such that the social dimension is decisive for consumers' shopping decisions in Finland's department stores. There is a similar tendency in Finland in the attitude formation towards online banking (Karjaluoto et al., 2002 [10]) and in factors affecting consumer choice for mobile phones (Karjaluoto et al., 2005 [9]). In contrast to these structures in Finland, Singaporean consumers generally pay attention to more pragmatic dimensions, such as price, content of products, transaction security and vendor quality, as demonstrated by Liao et al. (2001 [11]) in their survey

[2] Happiness ranking compares the degree of happiness in 156 countries taking following 7 factors: Happiness explained by levels of (i) GDP per capita, (ii) social support, (iii) healthy life expectancy, (iv) freedom to make, (v) generosity, (vi) perceptions of corruption, and (vii) influenced by the levels and trends of income inequality within the country and also between countries in the region.

Table 2
World competitiveness top 20 countries (2013).

1 Switzerland (1)	6 Sweden (4)	11 Norway (15)	16 Austria (16)
2 Singapore (2)	7 Hong Kong (9)	12 Taiwan (13)	17 Belgium (17)
3 Finland (3)	8 Netherlands (5)	13 Qatar (11)	18 New Zealand (23)
4 Germany (6)	9 Japan (10)	14 Canada (14)	19 United Arab Emirates (24)
5 United States (7)	10 United Kingdom (8)	15 Denmark (12)	20 Saudi Arabia (18)

Figures in parenthesis indicate the ranking in 2012.
Sources: The global competitiveness report 2012–2013, 2013–2014 (WEF, 2013, 2014).

Table 3
Comparison of factors governing competence in ICT advanced 6 countries (2013).

		Finland	Singapore	USA	UK	Germany	Japan	References
Population (million)		5.5	5.4	316.4	64.1	80.8	127.3	The Global Competitiveness Report 2014-2015 (World Economic Forum (WEF), 2014).
Global competitiveness (Rank out of 148)		(4) 3 [3]	(2) 2 [2]	(3) 5 [7]	(9) 10 [8]	(5) 4 [6]	(6) 9 [10]	*idem* ( ), [ ] indicate world ranking in 2014 and 2012
ICT competitiveness (Rank out of 148)		1 [1]	2 [2]	7 [9]	9 [7]	12 [13]	16 [21]	The Global Information Technology Report 2014 (WEF, 2014). See Table 6 [ ] indicates world ranking in 2012.
Global innovation (Rank out of 142)		4	7	6	2	13	21	The Global Innovation Index 2014 (INSEAD et al., 2014).
Human capital (Rank out of 122)		2	3	16	8	6	15	World ranking in 2012 The Human Capital Report (WEF, 2013).
Education (Rank out of 142)	Quality of primary edu.	1	3	41	31	25	21	The Global Competitiveness Report 2013-2014 (World Economic Forum (WEF), 2013).
	Quality of the edu system.	2	3	25	26	14	50	*idem*
	Quality of Math/Science edu.	2	1	49	50	21	34	*idem*
GDP per capita (1000 US$)		47.1 [14]	54.8 [8]	53.1 [9]	39.6 [23]	45.0 [18]	38.5 [24]	The Global Competitiveness Report 2014-2015 (World Economic Forum (WEF), 2014). [ ] indicates world ranking
GDP growth rate 2006-2013 (% p.a at fixed price)		0.57	5.85	1.26	0.63	1.46	0.56	World Economic Outlook Database (IMF, annual issues).
Unemployment ratio (%)		8.14	1.90	9.03	7.85	6.53	4.70	World Development Indicators (World Bank, 2014).
Inequality (GINI index)		19	45	47	39	35	34	2010 rank . Distribution of Household Income by Source (ILO, 2012)
Birth rate		1.9	1.2	2.1	1.9	1.4	1.4	2011 rank. World Health Statistics 2013 (WHO, 2013)
Happiness (Rank out of 156)		7	30	17	22	26	43	State in 2010-2012. World Happiness Report 2013 (The Earth Institute, Columbia Univ. et al., 2013).

on consumer attitudes to Internet-based e-shopping in Singapore.

These contrasting features in these two global ICT leaders with significant similarities, sheds light on possible development trajectory options amidst the "trap" embedded in ICT advancement: "happiness amidst great stagnation" as in Finland or excellent economic performance" rather than high levels of "happiness" as identified by this unique "happiness" index.

Advances in ICT can largely be attributed to the dramatic advancement of the Internet (McKinsey Global Institute, 2011 [14], ITU, 2013 [5], Watanabe et al., 2014*a* [25]), which has changed the computer-initiated ICT world significantly. Many authors pointed out the significance of the increasing role of un-captured GDP[3] by referring to Lowrey's postulate that "*th*e Internet promotes a free culture, the consumption of which provides utility and happiness to people but cannot be captured through GDP data that measure revenue" (Lowrey, 2011 [12]) and unveiled the increasing conflict between captured GDP and un-captured GDP leading to growing anger and frustration among consumers (Watanabe et al., 2014*c* [27]). This can be the one source of great stagnation on the demand side and provides insight by indicating the options many countries have been choosing in terms of their development trajectory: happiness amidst the great stagnation or excellent economic performance rather than high level of happiness (Rifkin, 2011 [17], Rifkin, 2014 [18]).

To date, quite few studies have been conducted to advance our understanding of the development trajectories of the nations (e.g., UNDP, 2007 [22], Ministry of Employment and the Economy, Finland, 2010 [15]). However, none have specifically analyzed the significance of these two trajectory options in the context of the ICT "trap" resulting from the dramatic advancement of the Internet and subsequent increasing shift from captured GDP to un-captured GDP.

Given the increasing significance of un-captured GDP because of the dramatic advancement of the Internet, this paper attempted to illustrate a new trajectory towards economic resilience which goes beyond purely economic value. Based on the comparative empirical analysis of ICT

[3] Un-captured GDP can be defined as added values providing utility (satisfaction of consumption) and happiness beyond economic value to people but cannot be measured by traditional GDP accounts (captured-GDP) that measure economic value. Supra-functionality beyond economic value (see below) can be the typical example.

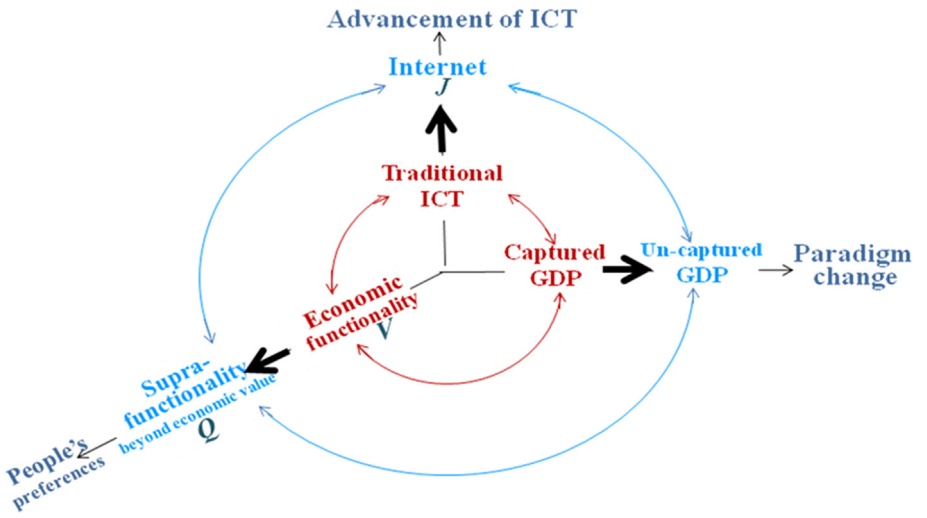

Fig. 2. Co-evolution between the internet, un-captured GDP and supra-functionality.

driven developing trajectories in six leading countries over the last two decades, particularly world ICT leaders, Finland and Singapore, we focus on understanding the factors and dynamics which position countries to be resilient. We analyzed performance in order to restructure a virtuous cycle between consumption and GDP increase in a co-evolutionary[4] and dynamic process between the dramatic advancement of the Internet, increasing shifts to un-captured GDP and consumer preference to supra-functionality beyond economic value[5] was analyzed.

Section 2 reviews the sources of the ICT advancement "trap" from the demand side. Section 3 compares the two countries performance toward a possible reconstruction of a virtuous cycle between consumption and GDP increase. Section 4 assesses the significance of dependency on un-captured GDP. Section 5 analyzes the institutional sources of "competence". Finally, section 6 briefly summarizes noteworthy findings, policy implications and also for the next steps in future studies.

2. Sources of the ICT advancement "trap" from the demand side

2.1. Co-evolution between the internet, un-captured GDP and supra-functionality

The advancement of the Internet accelerates a shift from captured GDP to un-captured GDP. While the Internet promotes a free culture, the consumption of which enhances utility (satisfaction of consumption) this cannot be captured through GDP that measures revenue (Lowrey, 2011 [12], Rifkin, 2014 [18]).

Table 4
Marginal propensity to Consume[6] in 6 countries before and after the Lehman Shock in 2008.

	1990–2007[a]	2008–2012[b]
Finland	0.42	0.23
Singapore	0.32	0.21
USA	0.74	0.64
UK	0.70	0.37
Germany	0.55	0.44
Japan	0.59	0.34

[a] 1990–2006 in USA and Germany.
[b] 2007–2012 in USA and Germany.
Original sources: Household Final Consumption Expenditure (United Nations Statistics Division, annual issues).

In line with the general shift from a commodity-oriented society to a service and information-oriented society, consumer preference has been steadily shifting from an economic functionality driven preference (which can be captured by GDP) to what we term "supra-functionality" beyond economic value (JCO, 2012 [7], Watanabe et al., 2014*c* [27]). Here, supra-functionality beyond economic value encompasses social, cultural, aspirational, tribal and emotional values which are not necessarily captured by GDP (Watson and McDonagh, 2004 [28], McDonagh, 2008 [13], Watanabe et al., 2011 [24]).

This shift in consumer preference induces the advancement of the Internet, which in turn accelerates a consumer preference shift. Thus, advancement of the Internet, shifts to un-captured GDP and consumer preference shifts to supra-functionality proceed co-evolutionary as illustrated in Fig. 2 (Watanabe et al., 2014*c* [27]).

[4] Co-evolution implies mutually inspiring virtuous cycle.

[5] Supra-functionality beyond economic value encompasses social (e.g., creation of and contribution to social communication), cultural (e.g., brand value, cool and cute), aspirational (e.g., aspiration of traditional beauty), tribal (e.g., cognitive sense, fellow feeling) and emotional (e.g., perceptional value, five senses) values (see detailed structure Watanabe et al., 2014*c* [27]).

[6] An increase in consumption caused by an addition to income divided by that increase in income, and depicted by coefficient b in the following consumption function: $C = a + bY, \quad b = \Delta C/\Delta Y$ where Y: GDP (income) and a: base consumption.

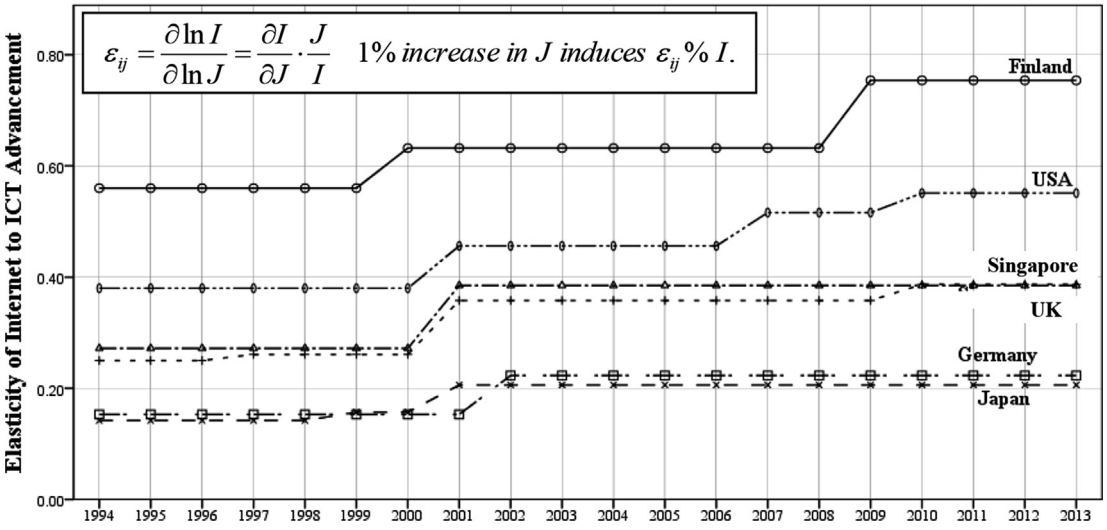

Fig. 3. Trends in the elasticity of the internet to ICT advancement (1994–2013).

2.2. Conflict between captured GDP and un-captured GDP

Under this co-evolutionary dynamism, conflict emerges between captured GDP and un-captured GDP during this shift. This conflict leads to growing anger and frustration among consumers resulting in the decline of consumption as demonstrated in Table 4 (Watanabe et al., 2014*c* [27]). This can be considered one source of the great stagnation from demand side.

3. Reconstruction of a virtuous cycle between consumption and GDP increase

3.1. Utility enhancement against consumption decline

During the great stagnation due to this "Trap" or conflict in ICT advancement derived from the two-faced nature of ICT on the supply side and also from the emerging conflict between captured GDP and un-captured GDP in demand side. From an economic perspective, the only possible option for sustainable growth comes from enhancing utility (satisfaction of consumption) through the Internet inducement of ICT stock. Therefore, theoretically, the virtuous cycle between consumption and GDP increase can be reconstructed by this enhancement (Watanabe et al., 2014*c* [27]. See Appendix 2):

$$J \rightarrow I \rightarrow U \rightarrow C \rightarrow GDP \rightarrow C$$

where J: Internet, I: ICT stock, U: utility, and C: consumption.

3.2. Performance toward reconstruction

Thus, our concern goes toward analyzing how well ICT leaders are doing in developing this type of reconstruction. An empirical comparative analysis of the performance of six countries on this cycle over the last two decades was conducted by utilizing the following data:

Internet dependency: ITU, world telecommunication/ICT indicators database[7] (ITU, 2014) [6].
ICT stock: Author's estimate with reference of The Conference Board, total economy database™, http://www.conferenceboard.org/data/economydatabase/ [20].
Household consumption: UN Statistics Division, Household Final Consumption Expenditure (UN, 2014) [21].
GDP: IMF, World Economic Database (IMF, 2014) [4].

3.2.1. Elasticity of the internet to ICT advancement

Performance toward the reconstruction is triggered by the efficiency of the Internet (J) inducement of ICT stock (I) and this can be assessed by the elasticity of the Internet to ICT stock[8] which represents the efficiency of the Internet in inducing ICT stock and can be quantified by computing the ratio of the percent change between them. This elasticity was computed using the significant correlation between J and I (see equations (A7) and (A8) in Appendix 3.1). Computation results are compared in Fig. 3 (see details Table A2 in Appendix 3.1).

Looking at Fig. 3, we note Finland which maintains world's top ICT position demonstrates a conspicuously high elasticity of the Internet to ICT stock increase and provides strong promising trend of increasing consumption and the reconstruction of a virtuous cycle between consumption and GDP increase. The USA follows Finland, and Singapore at the 3rd level in terms of this elasticity.

[7] ITU measures percent of population using the Internet based on the HH7 national questionnaire "*Have you used the Internet from any location in the last 3 (previously 12) months?*" (see details Appendix 6).

[8] Elasticity is the measurement of how responsive an economic variable (X) to a change in another (W). Elasticity of X to W (X elasticity to W) ε_{wx} implies 1% increase in X increases ε_{wx}% increase in W and represents the efficiency of X inducement of W.

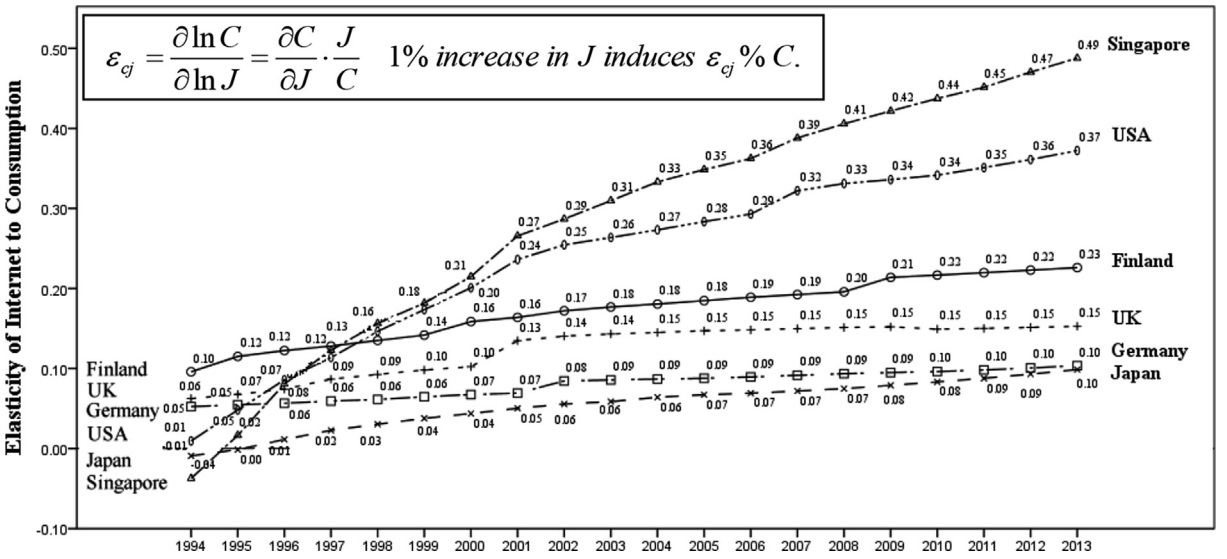

Fig. 4. Trends in the Elasticity of the Internet to Consumption (1994–2013). 2013 are estimated by trend.

3.2.2. Elasticity of the internet to consumption

Next, efficiency of the Internet in inducing consumption was assessed by a similar mathematical approach by measuring the elasticity of the Internet (J) to consumption (C). This elasticity was computed by means of a consumption function governed by I and J (see equations (A10) [9] and (A11) in Appendix 3.2). The results are compared in Fig. 4 (see details Table A3 in Appendix 3.2).

Looking at Fig. 4 we note that while the majority of advanced ICT countries have been shifting to stabilize their elasticity of the Internet to consumption, Singapore continues to increase its elasticity successively leading to a conspicuously higher level than the other countries compared. This conspicuous level is similar to its exceptionally higher GDP growth rate as reviewed in Fig. 1 and suggests us certain causality between them (see Appendix 4).

In contrast, Finland's elasticity of the Internet to consumption is much lower than Singapore which follows Finland in terms of its position as one of the world ICT leaders.

These contrasting observations prompt us to consider the hypothetical view that there might be certain fundamental disparities between Singapore and other ICT advanced countries, headed by Finland, with respect to measurement of consumption value.

Given the increasing co-evolution between the advancement of the Internet, un-captured GDP increase and a consumer preference shift to supra-functionality as defined in Section 2, this hypothetical view prompts us to further consider that, against traditional theory, utility under great stagnation does not necessarily reflect consumption in certain ICT advanced countries as a consequence of the increase in un-captured GDP. This can be plausible by given consumer preference shifts to supra-functionality beyond economic value (JCO, 2012 [7]) which are not necessarily captured by GDP (Watson and McDonagh, 2004 [28], McDonagh, 2008 [13]).

In order to test and demonstrate this hypothetical view, with the understanding that elasticity of utility to consumption demonstrates the extent of reflection of utility to consumption, we attempted to measure this elasticity that corresponds to less dependency on un-captured GDP.

4. Dependency on un-captured GDP

As reviewed in the preceding Section, under the ICT driven economy, utility consists of not only the value from economic functionality but also this new measure referred to as "supra-functionality beyond economic value". Furthermore, under the great stagnation both are governed by ICT stock (I) and Internet dependency (J). Based on these observations, a new method in measuring elasticity of utility to consumption (based on the extent of the reflection of utility to consumption corresponding to less dependency on un-captured GDP) was developed with the finding that, under such circumstances, this elasticity can be transformed into a total sum of elasticity of ICT to consumption and elasticity of the Internet to consumption (see Appendix 5). Since both elasticities can be estimated by the preceding estimates in Figs. 3 and 4, the elasticity of utility to consumption in six countries over the period 1994–2013 was measured by using these estimates (see equation (A15) in Appendix 5) as demonstrated in Fig. 5. The vertical axis of Fig. 5 indicates the elasticity of utility to consumption and demonstrates the extent of the reflection of utility to consumption which corresponds to the degree of captured GDP.

Looking at this Figure we note that while Finland demonstrates the most advanced un-captured GDP as demonstrated by the lowest level of elasticity of utility to

[9] While almost all factors in 6 countries examined demonstrate significant at the 1–10% level,Singapore's ICT and Germany's Internet demonstrate significant at the 15% and 30% level, respectively.

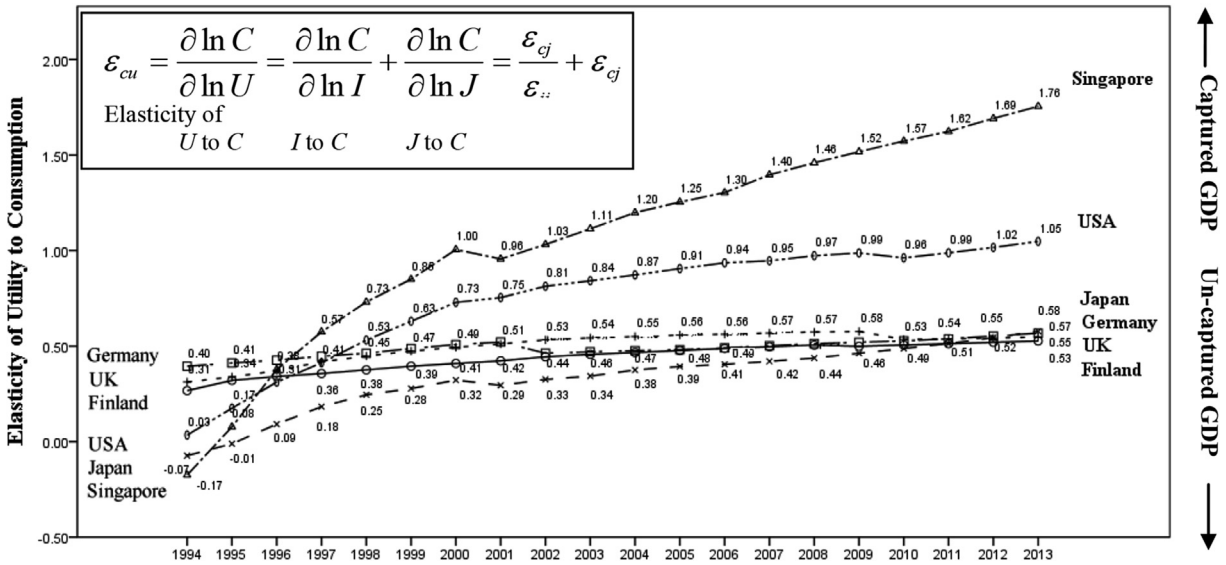

Fig. 5. Trends in elasticity of utility to consumption in 6 countries (1994–2013).

Table 5
Elasticity of utility to consumption in 6 countries in 2013.

	Finland	Singapore	USA	UK	Germany	Japan
Efficiency of *J* inducement of *I* 1. *J* elasticity to *I* (ε_{ij}) (Fig. 3)	0.75	0.39	0.55	0.39	0.22	0.21
Efficiency of *J* inducement of *C* 2. *J* elasticity to *C* (ε_{cj}) (Fig. 4)	**0.23**	**0.49**	**0.37**	**0.15**	**0.10**	**0.10**
Efficiency of *I* inducement of *C* 3. *I* elasticity to *C* ($\varepsilon_{ci} = \varepsilon_{cj}/\varepsilon_{ij}$) (2/1)	**0.30**	**1.27**	**0.68**	**0.40**	**0.47**	**0.48**
Extent of reflection of *U* to *C* 4. *U* elasticity to *C* (ε_{cu}) (2 + 3)	**0.53**	**1.76**	**1.05**	**0.55**	**0.57**	**0.58**

J: Internet, *I*: ICT stock, *C*: consumption, and *U*: utility. The bold figures in table refers to the figures used in Fig. 6.

consumption, it, together with Germany[10] and the UK, depended most highly on captured GDP among the six countries compared in the early half of the 1990s. This shifted steadily to un-captured GDP dependent nation leading to what some scholars have referred to as "happiness beyond economic value" during the great stagnation by means of captured GDP.

In contrast, Singapore, which remained at a lower income level than the other 5 countries in the early 1990s, was unable to efficiently capture GDP during this era and demonstrated the lowest level of elasticity of utility to consumption. However, it continued to rapidly increase in captured GDP leading to current conspicuously high captured GDP level and demonstrates a growth oriented economy, and high economic performance rather than this focus on uncaptured GDP or what is referred to as elements beyond "economic value" or "happiness".

These observations demonstrate a contrast in dependency on captured GDP and un-captured GDP, Table 5. Fig. 6 compares the current state of elasticity of utility to consumption and its attributes in the six countries studied.

Looking at Table 5 we note that contrary to the lower level of the Internet elasticity to ICT (ε_{ii}), Singapore demonstrates the highest utility elasticity to consumption (ε_{cu}). This can be attributed to conspicuously high elasticity of ICT to consumption (ε_{ci}) derived from high elasticity of the Internet to consumption (ε_{ci}) despite the low level of the Internet elasticity to ICT (ε_{ii}). In contrast, Finland's highest Internet elasticity to ICT (ε_{ii}) reacts to the decrease of ICT elasticity to consumption (ε_{ci}). We suggest that this implies its ICT advancement induced by the Internet contributes in some-way to the supra-functionality beyond economic value rather than to purely economic value. Furthermore, this measure does not reflect consumption captured by GDP data, thus demonstrating this shift from captured GDP to un-captured GDP increases as ICT advances.

Fig. 6 demonstrates noting contrast between world ICT leaders, Finland and Singapore in this elasticity. While Singapore demonstrates conspicuously high elasticity, Finland demonstrates opposite, the lowest level among six countries compared.

[10] It should be noted that time series analysis of German's Internet inducement of consumption over the period 1994–2013 (Table A3) demonstrates significant at the 30% level due to inconsistency of statisticaldata in the early 1990s immediately after its integration in 1990.

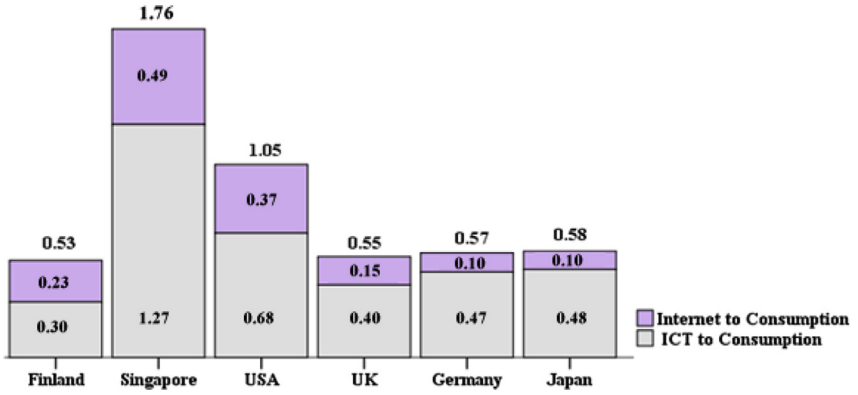

Fig. 6. Elasticity of utility to consumption in 6 countries in 2013.

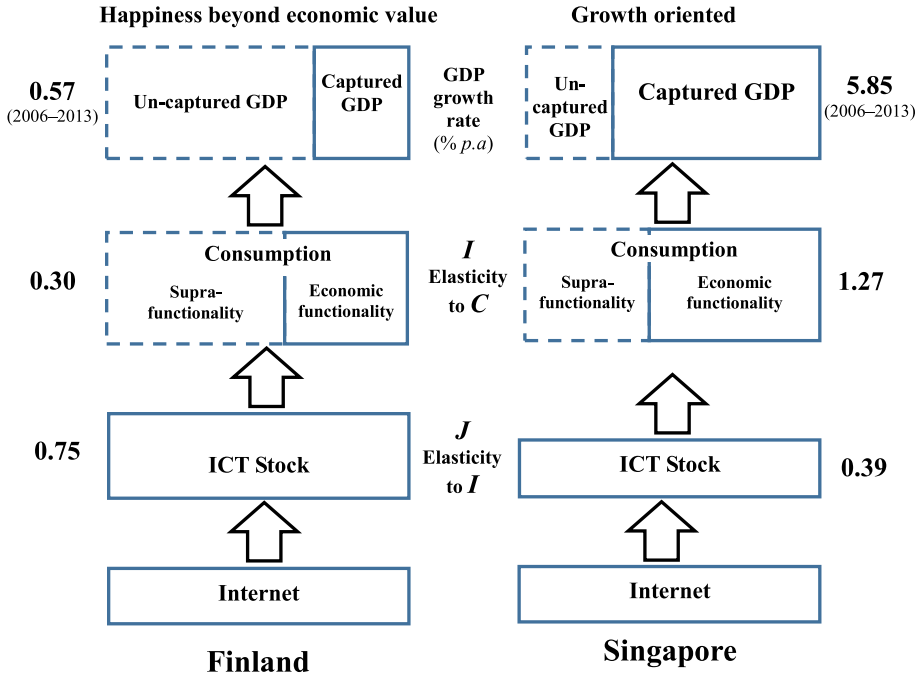

Fig. 7. Contrasting Development Trajectory in World ICT Leaders, Finland and Singapore (2013). *J*: Internet, *I*: ICT stock, *C*: Consumption. GDP growth rate is an average between 2006 and 2013.

With this observation in mind, Fig. 7 illustrates a contrast between the development trajectories in these world ICT leaders. This Figure clearly demonstrates a contrast between Finland and Singapore with respect to development trajectory. Finland effectively utilizes the Internet in inducing ICT stock as demonstrated by its highest Internet elasticity to ICT stock (Fig. 3). Its induced ICT stock contributes significantly to satisfying consumer preference to supra-functionality beyond economic value rather than just economic functionality. Consequently, increased ICT does not reflect a consumption increase which is measured by the GDP value resulting in a lower GDP growth rate. While its ICT makes a significant contribution to supra-functionality beyond economic value, it cannot necessarily be captured by GDP.

Contrary to Finland's behavior, while Singapore's ICT inducement by the Internet is smaller than Finland, it contributes largely to the consumer preference for economic functionality which is captured by GDP value leading to a the high GDP growth rate (5.85% in Singapore vs 0.57% in Finland in average 2006–2013) as observed in the very beginning of this paper (Fig. 1).

5. Institutional sources

5.1. Governing factors for ICT competitiveness

In order to better explain these contrasting trajectories in world ICT leaders, institutional sources leading to this contrast were analyzed. First, on the basis of the

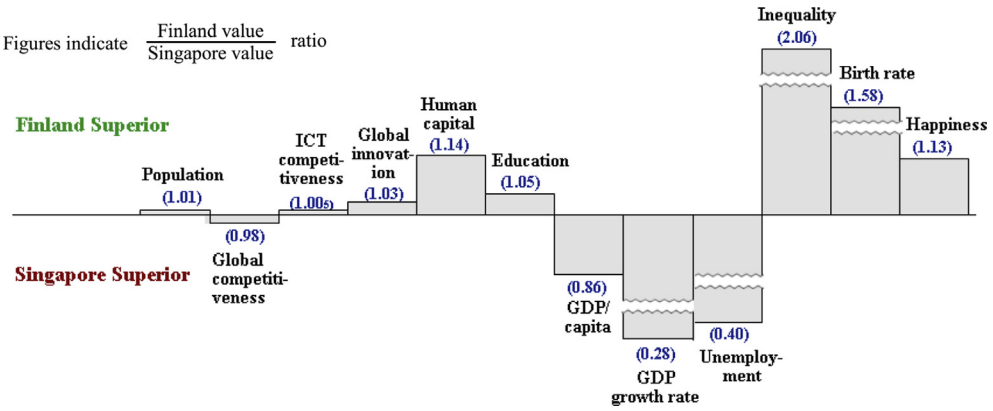

Fig. 8. Comparison of Factors Governing Competitiveness between Finland and Singapore. 1. Ratios of above factors are based on the respective values used for ranking. 2. Education is the average of 3 factors in Table 3. 3. GDP growth rate, unemployment and imbalance are ratios of deviation between average values of six countries.
Sources: See references in Table 3.

Table 6
ICT level by networked readiness index in 6 countries (2013).

	Finland		Singapore		USA		UK		Germany		Japan	
	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)	Rank (148)	Value (1–7)
Networked readiness (NRI) index 2014	**1**	***6.0***	**2**	***6.0***	**7**	***5.6***	**9**	***5.5***	**12**	***5.5***	**16**	***5.4***
A. Environment subindex	**3**	***5.6***	**1**	***5.9***	**15**	***5.2***	**5**	***5.5***	**17**	***5.1***	**21**	***5.0***
1st pillar: Political and regulatory environment	3	*5.9*	1	*5.9*	22	*5.0*	5	*5.7*	10	*5.4*	16	*5.2*
2nd pillar: Business and innovation environment	9	*5.4*	1	*5.8*	7	*5.4*	10	*5.3*	31	*4.9*	40	*4.8*
B. Readiness subindex	**1**	***6.6***	**6**	***6.2***	**5**	***6.3***	**21**	***5.7***	**8**	***6.2***	**19**	***5.8***
3rd pillar: Infrastructure and digital content	1	*6.9*	16	*6.3*	4	*6.8*	15	*6.4*	11	*6.5*	21	*6.1*
4th pillar: Affordability	18	*6.4*	46	*5.9*	21	*6.4*	79	*5.2*	43	*5.9*	54	*5.7*
5th pillar: Skills	1	*6.5*	2	*6.4*	32	*5.6*	28	*5.7*	12	*6.0*	29	*5.7*
C. Usage subindex	**2**	***6.0***	**4**	***5.9***	**11**	***5.6***	**12**	***5.6***	**13**	***5.5***	**9**	***5.7***
6th pillar: Individual usage	6	*6.4*	10	*6.1*	18	*5.8*	8	*6.3*	19	*5.7*	16	*5.9*
7th pillar: Business usage	2	*6.0*	15	*5.2*	9	*5.6*	17	*5.1*	5	*5.8*	4	*6.0*
8th pillar: Government usage	8	*5.6*	1	*6.3*	11	*5.5*	17	*5.4*	27	*5.0*	22	*5.2*
D. Impact subindex	**2**	***5.9***	**1**	***5.9***	**8**	***5.4***	**9**	***5.4***	**14**	***5.2***	**16**	***5.1***
9th pillar: Economic impacts	1	*6.0*	6	*5.6*	9	*5.2*	14	*5.0*	8	*5.2*	11	*5.1*
10th pillar: Social impacts	7	*5.8*	1	*6.2*	12	*5.6*	9	*5.7*	20	*5.2*	23	*5.1*

Source: The Global Information Technology Report 2014 (World Economic Forum, 2014).

comparison of factors governing the level of ICT competitiveness used to compare countries in Table 3, Finland and Singapore were specifically compared as demonstrated in Fig. 8.

Fig. 8 demonstrates the disparity between two countries with respect to economic performance and happiness and welfare, even though these two countries look similar when comparing global ICT leaders in terms of global competitiveness, ICT competitiveness and quality of education.

These similarities and disparities prompt us to consider a hypothetical view that institutional sources embedded within both countries have lead to the contrasting development trajectories. With this hypothetical view we further analyzed the institutional sources governing ICT competitiveness and happiness and typical dimensions of similarity and disparity of two countries.

5.2. Governing factors of ICT competitiveness

The World Economic Forum (WEF) assesses ICT competitiveness of the countries of the world using the Networked Readiness Index (*NRI*). *NRI* consists of 4 dimensions, 10 pillars and 54 factors such as (i) Environment with 2 pillars (*political and regulatory environment*, and *business and innovation environment*) and 18 factors, (ii) Readiness with 3 pillars (*infrastructure and digital content*, *affordability*, and *skills*) and 12 factors, (iii) Usage with 3 pillars (*individual usage*, *business usage*, and *government usage*) and 16 factors, and (iv) Impact with 2 pillars (*economic impact*, and *social impact*) 8 factors.

Table 6 tabulates governing factors of ICT competitiveness (see ICT competitiveness rank in Table 3) in six countries in 2013 by means of *NRI*'s 4 dimensions 10 pillars.

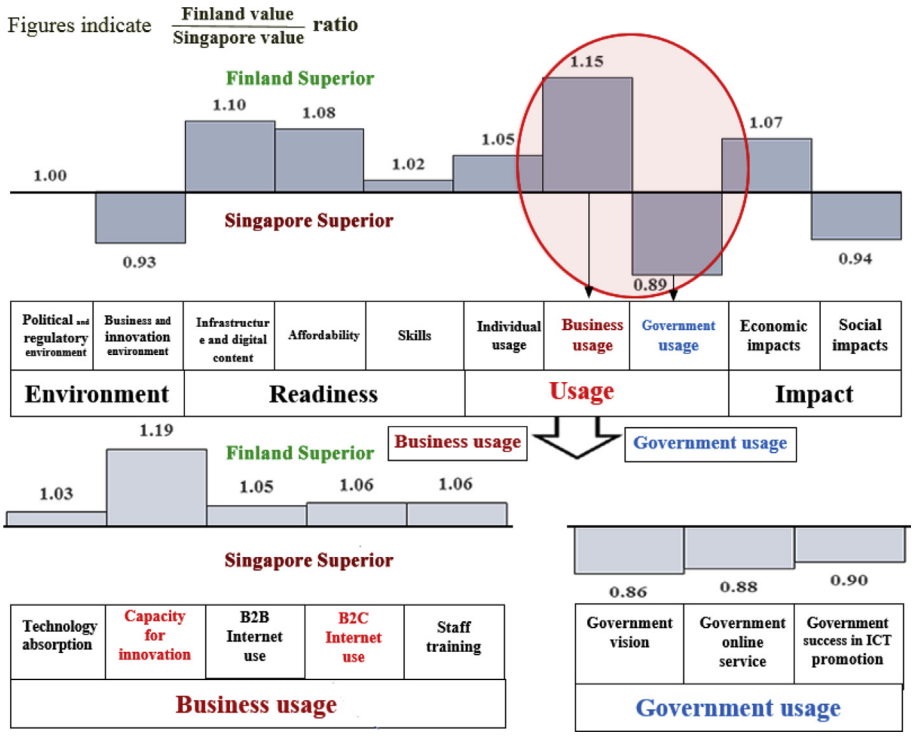

Fig. 9. Comparison of governing factors of ICT competitiveness between Finland and Singapore (2013).
Source: The Global Information Technology Report 2014 (WEF, 2014).

Table 6 highlights Finland and Singapore. However, if we examine what makes up their usage dimension (sub index) carefully, we note a clear contrast between them with respect to their pillars level. While Finland demonstrates a high level in business usage, unlike Singapore. This is totally opposite in terms of government usage. Contrary to Singapore's conspicuous level in its government usage, Finland is much lower.

In order to further explain this contrast, Fig. 9 compares factors of ICT competitiveness between Finland and Singapore focusing on their contrast in business usage and government usage at the factors level. Looking at this figure we note a distinctive difference in their ICT usage. Finland demonstrates superiority in business usage particularly in the firm's capacity for innovation. In contrast, Singapore demonstrates significant superiority in government usage in terms of a leading government vision, government online services and government success in ICT promotion. Since Singapore focusses on GDP growth and securing job opportunities, superiority in government usage leads to this captured GDP. The conspicuously high Internet elasticity to consumption as demonstrated in Fig. 4 can be considered a natural consequence of the nation's priority and policy.

Finland's superiority in business usage encourages more advancement in the area of consumer demand which has shifted from purely economic value. Given that consumer's preference has been shifting from economic functionality captured by GDP to supra-functionality beyond economic value initiated by un-captured GDP, this endeavor focuses on un-captured GDP. Consequently, despite Finland's highest Internet elasticity to ICT, induced ICT does not reflect a consumption increase which is measured by captured GDP as demonstrated by Fig. 4.

5.3. Governing factors of "happiness"

Contrary to the similarities in the foregoing ICT competitiveness at the aggregated level, the "happiness" ranking as a whole demonstrates a distinct disparity between as the two countries as compared in Table 3 and Fig. 8.

The happiness ranking published annually by the Earth Institute compares the degree of happiness in 156 countries using the following 7 factors: (i) GDP per capita, (ii) social support, (iii) healthy life expectancy, (iv) freedom to make decisions, (v) generosity, (vi) perceptions of corruption, and happiness influenced by (vii) the levels and trends of income inequality within the country and also between countries in the region. While some factors such as GDP per capita and income inequality are a reflection of the dimensions compared in Table 3 and Fig. 8, perception of happiness incorporates a multi-dimensional structure synchronizing multiple factors including these factors as reviewed earlier.

Table 7 compares the happiness ranking with contributing factors synchronizing and incorporating the foregoing structure between Finland and Singapore in 2013. Looking at this table we note that Finland demonstrates a distinct superiority in non-inequality, freedom to make life

Table 7
Comparison of factors governing happiness in Finland and Singapore.

	Influence by inequality	Explained by GDP per capita	Social support	Healthy life expectancy	Freedom to make life choices	Generosity	Perceptions of corruption	Total value
Finland	2.32	1.30	1.46	0.95	0.52	0.33	0.51	**7.39**
Singapore	1.53	1.39	1.36	0.96	0.43	0.19	0.69	**6.55**
Finland/Singapore	1.52	0.94	1.07	0.99	1.21	1.74	0.74	**1.13**

Source: World Happiness Report 2013 (The Earth Institute, Columbia University et al., 2013).

choices and generosity while Singapore demonstrates its superiority in GDP per capita and perceptions of corruption.

This contrast corresponds to the contrasting development trajectories as reviewed in Section 3 and also the varying strengths in terms of business usage and government usage in ICT competitiveness. For example, Finland's superiority in generosity, freedom to make life choices and also non-inequality correspond to consumer preference shifts from economic functionality to supra-functionality beyond economic valuenot captured in GDP. Singapore's superiority in GDP per capita, perceptions of corruption and high income inequality correspond to a growth oriented trajectory based on captured GDP. Government versus business usage in ICT competitiveness also supports this contrasting trend.

Fig. 10 clearly demonstrates this contrasting superiority between two countries.

These observations on the influence of institutional sources characterizing the similarities and disparities in ICT competitiveness and happiness between these two countries suggests the possibility of the influence of the national plan as well as a government plan (Yusuf et al., 2012 [33]).

5.4. Policy initiatives

Given that the contrast observed with respect to ICT usage and also some factors characterizing happiness in world ICT leaders can be attributed to their national as well as government informatization plans, Figs. 11 and 12 compare these plans by illustrating the history of informatization in Finland and Singapore. While both are noteworthy global ICT leaders in accelerating informatization, it is noted that the ICT advancement in Finland can largely be attributed to the combined efforts of private initiatives and public policies. Finland's ICT cluster, particularly Nokia, significantly boosted its economic performance. Contrary to these initiatives, Singapore's informatization has largely been dependent on strong government initiatives such as those typically observed in its successive e-Government action plans.

This contrast in national as well as government plans corresponds to the contrast in Finland's business usage and Singapore's government usage in ICT competitiveness as well as the contrast between Finland's generosity and freedom to make life choices and Singapore's perceptions of corruption in the happiness index.

5.5. Economic structure and historical perspectives

The institutional sources of this contrast in Finland's overall high happiness index during the great stagnation aligns with the data showing its shift to un-captured GDP and sustainable growth. This contrasts with the happiness index for Singapore which aligns with the focus on captured GDP. Both can largely be attributed to their economic structure and historical perspectives (Hofstede, 1991 [9], Watanabe, 2009 [22]) as compared in Table 8 and Fig. 13. This is the same in the contrast in national as well as government priorities. It goes without saying that these dimensions should be further analyzed in identifying their contrasting trajectories.

While in the preceding analyses on captured GDP and un-captured GDP in Sections 3 and 4 focused on particular

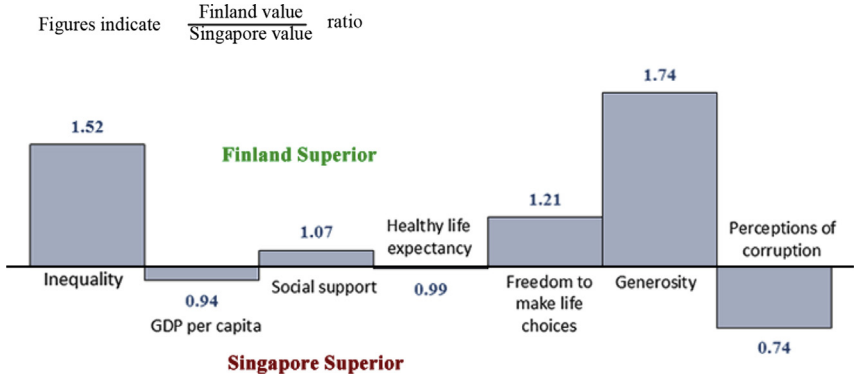

Fig. 10. Comparison of factors governing happiness in Finland and Singapore.

2013 SADe, Open Data Programme (2013 – 2015)
2012 Public Sector ICT Strategy, Govt. of Future, GIDE
2010 Legal right to broadband Internet, Suomi.fi
2008 The Broadband 2015, Ubiquitous Information Society
2002-07 **Euro replaces Markka**, eJUNA, e-Government, Information Society Council, KuntaIT
95 -00 **EU membership**, GSM phones exceeds NMT phones. FiCom in operation.
1994 Draft of "National Information Society Strategy".
1991-93 **"The Digital Big Bang".** GSM call, Linux,
1990 **The Financial Crisis in Finland**.
1988 **FICORA** (former TAC)
1982-86 **TEKES, The Science and Technology Policy Council**, EUnet, NMT450 ,NMT900, IRC
1980 **Finnish technology policy begins emphasize ICT.**
1970 Academy of Finland
1967 **Nokia Corporation**
1952 -60 Helsinki Olympic Games, IBM 650, ESKO
1939-45 World at War. The Finnish Army is the major employer in the telecommunications
1927-32 Telegraph Office + Finland Post. Automatic telephone exchanges started.
1917 **Independence,** Finnish Cable Factory (Nokia later)
1855 - 82 **1st** Telegraph line, Local telephone company
1638 1st steps of wireless comm. Postal in Finland (Itella)

	National plans	Government plans
2011-2014	Barrier-free information society GIDE, Open Data Programme, Intelligence in Transport	Public Sector ICT Strategy (2012-2020) SADe eServices and eDemocracy (2013)
2006-2010	National Knowledge Society Strategy Ubiquitous Information Society Intelligent Transport 2020 (2009) **Legal right to broadband internet**	IT Management in State Administration (2006) KuntaIT 2006, FINESSI 2007 Suomi.fi 2010 officially launched
2001-2005	Information Society Council (2003) Government Information Society Act on Electronic Signatures (2003)	e-Government Action Programme Openness of Government Activities (2002) suomi.fi launched (2002)
1996-2000	Information Society Advisory Board Decision-in-Principle (Public Management Reforms and Information Society, 1998)	eGovernment, JUNA (1999), Electronic ID Cards, PKI, Online Banking Personal Data Act 1999.
1991-1995	**Finland got EU membership (1995)** 'Finland – Towards an Information Society, A National Outline' (1995)	National Information Society Strategy (1994), Decision on electronic transactions (1995)
1986-1990	The Science and Technology Policy Council (1986) **Financial Crisis in Finland**	Re-Industrialization, de-regulations
1980-1985	Technology policy emphasizes ICT Telephone firms in competition. EUnet, NMT-450	**(1983) TEKES National Technology** Agent CMOS Progress Technology Project
1970	**Academy of Finland**	
1967	**Nokia Corporation** (Nokia Company+ Finnish Rubber..+Finnish Cable..).	SITRA, the Finnish Innovation Fund
1917	**Finland got Independence** Finnish Cable Factory (Nokia later)	

Fig. 11. History of Finland informatization.

aspects of reconstructing the virtuous cycle between (private) consumption and GDP increase, it goes without saying that other factors constituting GDP and also the industrial structure of the country should not be overlooked as significant institutional factors impacting the development trajectories discussed.

Singapore largely depends on international trade, particularly on exports, 62% of which are for Asian countries which depend largely on captured GDP. In contrast, Finland depends less on exports than Singapore and 55% of its exports are to EU countries which depend mostly on uncaptured GDP.

In addition the industrial structure plays a key role. Singapore depends largely on finance and insurance whereas Finland depends largely on government initiatives. Finland's business initiatives accelerate services as healthcare, social work and education.

Fig. 13 demonstrates the historical perspectives of world ICT leaders by correlating respective national as well as government initiatives with contrasting trajectories on

2010 eGov2015
2006 **Intelligent Nation Master plan (iN2015)**
2003 e-Government Action Plan II
2000 e-Government Action Plan
1999 **Information Development Authority of S'pore (IDA)** (NCB + TAS)
1992 Reconstituted Telecommunication Authority of S'pore (TAS)
1982 Telecommunication Authority of S'pore (Postal Services Dept. + Telecoms)
1981 **National Computer Board (NCB)** National Computerization Plan
1980 Civil Service Computerization Program
1974 Telecoms (STB + Foreign communications)
1967 Singapore Postal Services Department
1955 Singapore Telephone Board (STB)
1879 Introduction of telephones

	National plans	Government plans
2010-2015	} iN2015	**eGov2015**
2006-2010		**iGov2010**
2003-2006	Connected Singapore	e-Government Action Plan II
2000-2003	Infocomm21	e-Government Action Plan I
1992-1999	IT2000	} Civil Service Computerization Program
1986-1991	The National IT Plan	
1980-1985	The National Computerization Plan	

Fig. 12. History of Singapore informatization.

Table 8
Comparison of economic structure between Finland and Singapore (2013).

	Finland	Singapore
Composition of GDP (%)		
Private consumption	55.2	35.0
Government consumption	24.9	9.8
Gross fixed capital formation	20.8	29.1
Net exports	−0.9	26.1
• Exports	*38.2*	*194.1*
• Imports	*−39.1*	*−168.0*
Total	**100.0**	**100.0**
Industrial Structure (Share of GDP %)		
Secondary Production	**26.9**	**24.5**
Manufacturing	16.6	18.6
Construction	6.5	4.4
Utilities	3.4	1.5
Other goods industries	0.4	0.0
Services	**70.5**	**70.6**
Wholesale and retail trade	10.0	18.2
Transportation and storage	5.1	7.0
Finance and insurance	2.5	12.2
Information and communication	5.2	4.0
Accommodation and food services	1.7	2.5
Other services[a]	46.0	26.7
Others	**2.7**[b]	**4.9**[c]
Total	**100.0**	**100.0**

[a] Healthcare, social work, real state, public administration, social security, education.
[b] Primary production (Agriculture, forestry and fishing).
[c] Ownership of dwellings.
Sources: Statistical Yearbook of Finland 2014 (Communication and Information Services, Statistics Finland, 2014), Structure of the Singapore Economy, 2013 (Ministry of Trade and Economy, 2014).

their un-captured GDP shifting and captured GDP oriented as reviewed in Fig. 5.

Provided that the respective national and government policies are induce new initiatives corresponding to the state of the trajectory, co-evolution between the elements within both systems should be further explored.

6. Conclusion

We analyzed the system dynamics in Finland and Singapore institutionally and economically, in light of the increasing significance of changes in global economic structural shifts due to ICT, such as a shift from captured GDP to un-captured GDP we attempted to develop a new method for measuring un-captured GDP and assessing the institutional sources incorporating factors including those from the happiness index. To test this measure we conducted a comparative empirical analysis of ICT-driven trajectories in six global ICT leaders over the last two decades, particularly focusing on Finland and Singapore. Noteworthy findings from this analysis include:

i. While the majority of ICT advanced countries have been experiencing great stagnation due to a "trap" in ICT advancement, certain countries have been able to sustain a high level of ICT-driven global competitiveness.
ii. Finland and Singapore demonstrate this and can be considered countries of resilience with respect to ICT-driven global competitiveness.
iii. While both countries share significant similarities which endorses their institutional strength in ICT, they demonstrate noteworthy disparities by their development trajectories: growth-oriented in Singapore and happiness-seeking in Finland.
iv. While Finland effectively utilizes the Internet in inducing ICT stock, its induced ICT stock contributes significantly to satisfying consumer preference to

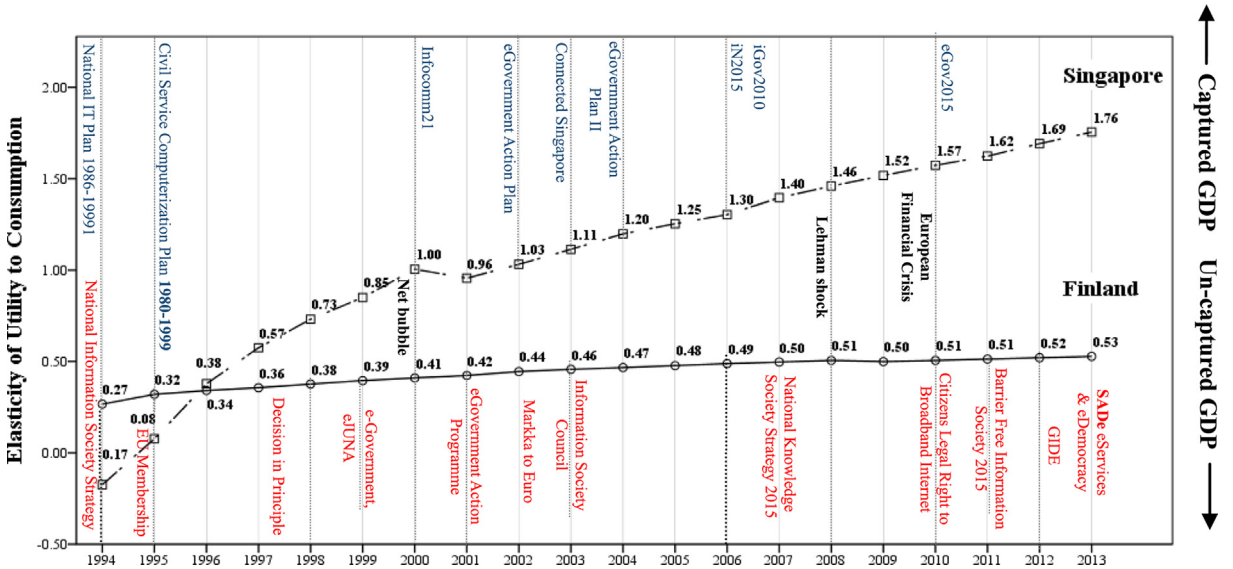

Fig. 13. Trends in national and government plans correlating to trajectories option **in Finland and Singapore** (1994–2013).

supra-functionality beyond economic value rather to economic functionality.

v. Consequently, increased ICT does not reflect a consumption increase which is measured by GDP value resulting in a lower GDP growth rate.
vi. In contrast to Finland, Singapore focusses mostly on satisfying consumer preference for economic value which is captured by GDP value leading to a conspicuously high GDP growth rate.
vii. Given the increasing significance of un-captured GDP derived from the dramatic advancement of the Internet, these contrasts provide significant insight to the development trajectory options amidst the changing economic realities of the 21st century.

These findings provide the following policy suggestions:

i. The sources of the great stagnation following 2008 should be carefully examined from both the supply and demand side.
ii. The co-evolutionary dynamism between the advancement of the Internet, increasing shifts of un-captured GDP and a consumer preference beyond economic value should be considered in policy making.
iii. Contrasting the development trajectories demonstrated by global ICT leaders should be further elucidated in order to conceptualize ICT-driven economic development in a system of increasingly un-captured GDP.

Future studies should consider taking other factors constituting GDP such as government consumption, capital formation and international trade. In this regard, perhaps a new national accounting system taking un-captured value could be developed. In addition, the conceptualization of the contrasting trajectories is highly stylized in this study and should be further developed for generalization. This would enable more applicability and adaptability to emerging economies. Finally, further comparative empirical analysis should be continued attempting to merge new theories to explain economic shifts particularly given the economic realities of the interconnected world of the 21st century and measures beyond GDP for global advancement.

Appendix 1. Trend in economic stagnation in ICT advanced countries

Table A1
Annual real GDP growth rate in ICT advanced countries (2006–2013) - *% p.a.*

Year	Finland	Singapore	Sweden	Netherlands	Norway	Switzerland	USA	UK	Germany	Japan
2006	4.06	8.86	4.30	3.82	2.30	3.75	2.67	2.76	3.88	1.69
2007	5.19	9.11	3.31	4.20	2.65	3.85	1.78	3.43	3.39	2.19
2008	0.72	1.79	−0.61	2.09	0.07	2.16	−0.29	−0.77	0.81	−1.04
2009	−8.27	−0.60	−5.03	−3.30	−1.64	−1.94	−2.78	−5.17	−5.09	−5.53
2010	2.99	15.24	6.56	1.07	0.48	2.95	2.53	1.66	3.86	4.65
2011	2.57	6.06	2.93	1.66	1.34	1.79	1.60	1.12	3.40	−0.45
2012	−1.46	2.50	0.93	−1.59	2.90	1.05	2.32	0.28	0.90	1.46
2013	−1.21	3.85	1.64	−0.72	0.65	1.93	2.22	1.74	0.53	1.52
Avg.	**0.57**	**5.85**	**1.75**	**0.90**	**1.09**	**1.94**	**1.26**	**0.63**	**1.46**	**0.56**

Source: World Economic Outlook Database (IMF, annual issues) [4].

Appendix 2. Governing factors of utility under the great stagnation

(1) Possible option for sustainable growth under the great stagnation

During the great stagnation there is a “trap” in ICT advancement resulting from contrasting ICT business models on the supply side and also from emerging conflict between captured GDP and un-captured GDP in demand side, only a possible option for sustainable growth can be expected by enhancing utility (satisfaction of consumption) through the Internet inducement of ICT stock (Watanabe et al., 2014*c* [27]). This mechanism can be demonstrated as follows.

(2) Co-evolution between consumption and GDP increase

Consumption shares significant amount of GDP (55%, 35%, 69%, 61% in Finland, Singapore, USA and Japan, respectively in 2013). Thus, its increase is indispensable for sustainable growth.

Since consumption depends on GDP (income) as depicted in equation (A1), construction of a co-evolution between consumption and GDP increase is the key to overcome great stagnation due to a trap in ICT advancement.

$$C = a + b\,Y \tag{A1}$$

where *C:* consumption, *Y:* GDP (income), *a:* base consumption, and *b:* marginal propensity to consume.

(3) Utility for consumption increase

Consumption is subject to utility U which represents satisfaction of consumption and is depicted as follows:

$$C = \mathrm{C}(U) \tag{A2}$$

Since U is governed by economic functionality (V) and supra-functionality beyond economic value (Q) in the ICT-driven economy (Watanabe et al., 2014c [27]), and given that it is a total sum of utilities stemmed from V and Q with

constant returns to scale, it can be depicted as follows (Euler's theorem):

$$U = U(V,Q) = \frac{\partial U}{\partial V}\cdot V + \frac{\partial U}{\partial Q}\cdot Q \tag{A3}$$

Right hand side of the equation (A3) depicts utility stemmed from economic functionality and supra-functionality beyond economic value, respectively.

(4) Utility with constraints under the great stagnation

In order to enhance the utility under great stagnation with declines in not only general decline of marginal utility ($\partial U/\partial C$) that declines governed by the Law of diminishing value, but also marginal propensity to consume ($\partial C/\partial Y$) and marginal productivity of ICT ($\partial Y/\partial I$) which are engines of utility enhancement in normal occasion, new enhancing mechanism identical to this particular great stagnation circumstances should be found.

In order to attain this target, new mechanism which is not influenced by the above declining factors should be explored. With this objective, if the above three declining factors are extracted from utility function, equation (A3) can be rewritten as follows:

$$U = U(V,Q) = \frac{\partial U}{\partial V}\cdot V + \frac{\partial U}{\partial Q}\cdot Q = \frac{\partial U}{\partial C}\cdot\frac{\partial C}{\partial Y}\cdot\frac{\partial Y}{\partial I}\cdot I\left(\frac{\partial I}{\partial V}\cdot\frac{V}{I} + \frac{\partial I}{\partial Q}\cdot\frac{Q}{I}\right) \tag{A4}$$

Looking at this equation we note that the first 3 factors of the right hand side of the equation depict marginal utility, marginal propensity to consume and marginal productivity of ICT, respectively, and the remaining factors could only be an engine for utility enhancement under great stagnation.

This engine χ is depicted by a product of ICT stock (I) and sum of elasticity of V to I and Q to I as follows and suggests that V and Q inducement of I could be only a possible solution to enhance utility under great stagnation:

$$\chi = I\left(\frac{\partial I}{\partial V}\cdot\frac{V}{I} + \frac{\partial I}{\partial Q}\cdot\frac{Q}{I}\right) \tag{A5}$$

(5) Utility enhancement under great stagnation

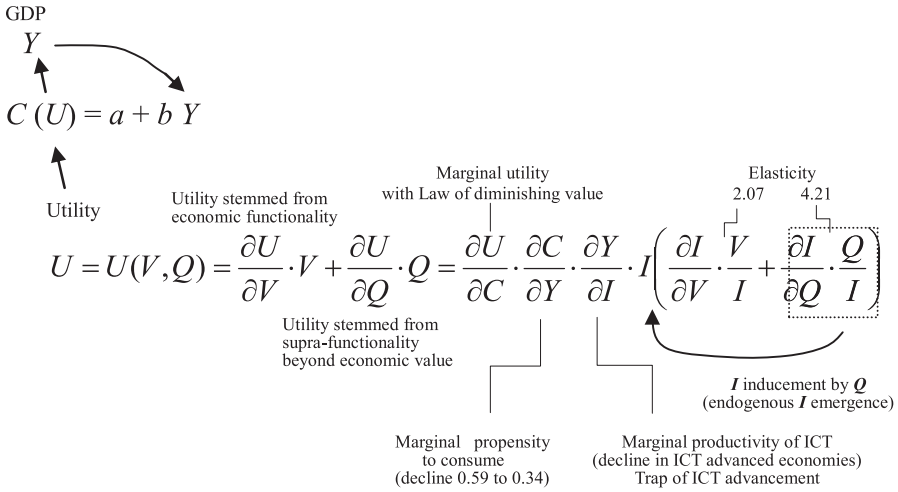

Fig. A1. Structure of utility under the great stagnation. *V*: economic functionality, *Q*: supra-functionality beyond economic value, *I*: ICT stock, and *J*: Internet. Figures demonstrate a case of Japan (1997–2007 and 2008–2012 comparison) (Watanabe et al., 2014*c* [27]).

On the basis of the foregoing review, under great stagnation due to a trap in ICT advancement, utility enhancing mechanism without influenced by declining factors can be illustrated as Fig. A1.

Fig. A1 demonstrates that (i) marginal utility, (ii) marginal propensity to consume, (iii) marginal productivity of ICT, (iv) ICT stock, and (v) elasticity of economic functionality as well as supra-functionality beyond economic value to ICT govern utility under great stagnation.

Since (i) marginal utility, (ii) marginal propensity to consume and (iii) marginal productivity of ICT decline due to the Law of diminishing marginal utility, conflict between captured and un-captured GDP, and a trap in ICT advancement, respectively, (iv) ICT stock inducement by economic functionality and/or supra-functionality can be only the solution to enhance utility for the compensation of consumption decline.

Given that supra-functionality induces ICT much higher than economic functionality and close relationship with the advancement of the Internet (Watanabe et al., 2014*c* [27]), enhancement of utility through the Internet inducement of ICT stock can be the possible solution in overcoming great stagnation by reconstructing a virtuous cycle between consumption and GDP increase as follows:

$$J \rightarrow I \rightarrow U \rightarrow C \rightarrow GDP \rightarrow C. \tag{A6}$$

Appendix 3. Measurement of elasticity

Appendix 3.1Elasticity of the internet to ICT advancement

Given the significant correlation between ICT stock (I) and the Internet (J) in the ICT-driven economy as depicted in equation (A7), elasticity of the Internet to ICT stock was computed as follows:

$$\ln I = a + b \ln J \tag{A7}$$

where a and b: coefficients.

Partial differentiation with respect to J leads to J elasticity to I ε_{ii} as depicted in equation (A8).

$$\varepsilon_{ij} = \frac{\partial \ln I}{\partial \ln J} = b \tag{A8}$$

By using equation (A7), coefficient b can be obtained by the time series regression over the period 1994–2013 as tabulated in Table A2 [11] thereby trend in J elasticity to I ε_{ii} can be identified as illustrated in Fig. 3.

Appendix 3.2Elasticity of the internet to consumption

Given the consumption in the ICT driven economy is governed by ICT stock (I) and the Internet (J), elasticity of the Internet to consumption was computed as follows:

$$C = C(I,J) \tag{A9}$$

This equation can be approximated as follows by conducting Taylor expansion to the secondary term[12]:

$$\ln C = a + b \ln I + c \ln J + d \ln I \cdot \ln J \tag{A10}$$

where a - d: coefficients

Partial differentiation with respect to J leads to the J elasticity to C ε_{ci} as depicted in equation (A11) (see Fig. 4).

Table A2
Correlation between the internet dependency and ICT advancement in 6 countries (1994–2013).

Finland	$\ln I = 4.054 + 0.560\ D_1 \ln J + 0.632\ D_2 \ln J + 0.754\ D_3 \ln J$					*adj.* R^2 0.936	D_1: 1994-99 = 1, D_2: 2000-08 = 1, D_3: 2009-13= 1	
	(12.18*)	(4.78*)	(7.82*)	(9.63*)		*DW* 1.02		
Singapore	$\ln I = 4.843 + 0.272\ D_1 \ln J + 0.385\ D_2 \ln J + 0.541\ D$					*adj.* R^2 0.935	D_1: 1994-00 = 1, D_2: 2001-13 = 1, D: 2009-11= 1	
	(34.91*)	(4.93*)	(10.36*)	(4.71*)		*DW* 1.06		
US	$\ln I = 4.250 + 0.380\ D_1 \ln J + 0.456\ D_2 \ln J + 0.516\ D_3 \ln J + 0.551\ D_4 \ln J$					*adj.* R^2 0.973	D_1: 1994-00 = 1, D_2: 2001-06 = 1, D_3: 2007-09= 1, D_4: 2010-13 = 1	
	(30.10*)	(8.10*)	(12.87*)	(14.71*)	(15.90*)	*DW* 1.65		
UK	$\ln I = 4.844 + 0.250\ D_1 \ln J + 0.261\ D_2 \ln J + 0.358\ D_3 \ln J + 0.387\ D_4 \ln J - 0.214\ D$					*adj.* R^2 0.973	D_1: 1994-96 = 1, D_2: 1997-00 = 1, D_3: 2001-09= 1, D_4: 2010-13 = 1, D: 2002, 03 = 1	
	(69.60*)	(3.15*)	(9.15*)	(19.77*)	(20.61*)	(-3.32*)	*DW* 1.80	
Germany	$\ln I = 4.814 + 0.153\ D_1 \ln J + 0.223\ D_2 \ln J + 0.430\ D$					*adj.* R^2 0.938	D_1: 1994-01 = 1, D_2: 2002-13 = 1, D: 2009-11 = 1	
	(63.27*)	(4.67*)	(10.67*)	(5.33*)		*DW* 1.45		
Japan	$\ln I = 4.841 + 0.142\ D_1 \ln J + 0.157\ D_2 \ln J + 0.206\ D_3 \ln J + 0.342\ D$					*adj.* R^2 0.937	D_1: 1994-98 = 1, D_2: 1999-00 = 1, D_3: 2001-13= 1, D: 2011, 12=1	
	(74.11*)	(3.62*)	(5.50*)	(11.93*)	(4.71*)	*DW* 1.03		

1. Figures in parenthesis indicate t-statistics (*: significant at the 1% level).
2. D_i ($i = 1$–3) and D are coefficient and constant dummy variables, respectively corresponding to the economic circumstances as follows:
   Years indicating in D_i and $D = 1$ while other years $= 0$.
3. In case of Singapore, for example,

$$\varepsilon_{cj} = \frac{\partial \ln C}{\partial \ln J} = c + d \ln I + (b + d \ln J) \cdot \frac{\partial \ln I}{\partial \ln J}$$
$$= c + d \ln I + (b + d \ln J) \cdot \varepsilon_{ji} \tag{A11}$$

By using equation (A10), coefficients b, c and d can be obtained by the time series regression over the period

	2001–2013				
	1994–2000	2001–2008	2009–2011	2011–2013	
D_1 (1994–2000)	1	0	0	0	Before Net bubble bursting
D_2 (2001–2013)	0	1	1	1	After Net bubble bursting
D (2009–2011)	0	0	1	0	Effects of the Lehman shock
1994–2000	$\ln I = 4.843 + 0.272 \ln J$				J elasticity to I 0.272
2001–2008	$\ln I = 4.843 + 0.385 \ln J$				J elasticity to I 0.385
2009–2011	$\ln I = 4.843 + 0.542 + 0.385 \ln J = 5.385 + 0.385 \ln J$				J elasticity to I 0.385
2012–2013	$\ln I = 4.843 + 0.385 \ln J$				J elasticity to I 0.385

[11] SPSS software was used for this regression analysis, same as the analysis in Table 3.

[12] Based on translog (transcendental logarithmic) cost function (See Christensen et al., 1973 [1]).

1994–2013 as tabulated in Table A3. Synchronizing estimated elasticity of the internet to ICT stock (ε_{ii}) (Fig. 3), trend in J elasticity to C ε_{ci} can be identified as illustrated in Fig. 4.

Since Singapore's b (marginal propensity to consume), C/Y (income to consumption level) and $\Delta J/J$ (Internet increase rate) are comparable to other countries compared, its conspicuous GDP increase rate can be attributed to high level of ε_{ci}.

Table A3
Impacts of the increase in ICT stock and the internet dependency on consumption in 6 countries (1994–2014).

Finland $\ln C = 10.120 + 0.142 \ln I - 0.129 D_1 \ln J - 0.134 D_2 \ln J - 0.148 D_3 \ln J + 0.024 \ln I \ln J$ *adj.* R^2 0.999
(52.31*) (3.61*) (-3.99*) (-4.07*) (-4.51*) (3.32*) *DW* 2.54

D_1: 1994-99 = 1, D_2: 2000-08 = 1, D_3: 2009-13= 1

Singapore $\ln C = 12.638 - 0.371 \ln I - 0.638 D_1 \ln J - 0.625 D_2 \ln J + 0.139 \ln I \ln J - 0.054 D$ *adj.* R^2 0.994
(11.46*) (-1.69****) (-3.13**) (-3.02**) (3.15*) (-3.54*) *DW* 2.49

D_1: 1994-00 = 1, D_2: 2001-13 = 1. D: 1998, 2003 = 1

US $\ln C = 16.692 - 0.248 \ln I - 0.532 D_1 \ln J - 0.543 D_2 \ln J + 0.114 \ln I \ln J + 0.017 D$ *adj.* R^2 0.998
(33.60*) (-2.35**) (-5.97*) (-6.10*) (5.74*) (2.95**) *DW* 2.02

D_1: 1994-09 = 1, D_2: 2010-13 = 1, D. 2006, 08 = 1

UK $\ln C = 12.126 + 0.260 \ln I - 0.096 D_1 \ln J - 0.092 D_2 \ln J - 0.095 D_3 \ln J - 0.108 D_4 \ln J + 0.019 \ln I \ln J - 0.025 D$ *adj.* R^2 0.999
(42.53*) (3.90*) (-2.45**) (-2.29**) (-2.28**) (-2.58**) (2.04***) (-5.45*) *DW* 2.22

D_1: 1994-96 = 1, D_2: 1997-00 = 1, D_3: 2001-09= 1, D_4: 2010-13 = 1, D: 2008, 11, 12 = 1

Germany $\ln C = 13.220 + 0.127 \ln I - 0.040 \ln J + 0.015 \ln I \ln J - 0.015 D$ *adj.* R^2 0.997
(41.04*) (1.94***) (-0.74 #) (0.97 #) (-4.27*) *DW* 2.03

D: 1994, 02, 03, 09 =1

Japan $\ln C = 20.180 - 0.165 \ln I - 0.232 \ln J + 0.051 \ln I \ln J - 0.015 D$ *adj.* R^2 0.971
(43.63*) (-1.83***) (-3.32*) (3.30*) (-3.63*) *DW* 1.72

D: 1998, 09 = 1

1. Consumptions in 2013 were estimated by trends.
2. Figures in parenthesis indicate t-statistics (*, **, ***, **** significant at the 1%, 5%, 10% and 15% level, respectively while # in German's J implies significant at the 30% level).
3. D_i ($i = 1$–4) and D are coefficient and constant dummy variables, respectively corresponding to the economic circumstances as follows:
   Years indicating in D_i and $D = 1$ while other years = 0.
4. In case of Finland, for example,

Appendix 4. High elasticity of the internet to consumption as a source of high GDP growth

Given the J elasticity to C ε_{ci}, and consumption function $C = a + bY$, GDP increase rate can be depicted by the following equation:

$$\frac{\Delta Y}{Y} = \frac{\varepsilon_{cj}}{b} \cdot \frac{C}{Y} \cdot \frac{\Delta J}{J}. \tag{A12}$$

Appendix 5. Elasticity of utility to consumption

Since utility under great stagnation due to a trap in ICT advancement can be depicted as $U = U(V, Q)$, and V and Q can be depicted as $V = V(I, J)$ and $Q = Q(I, J)$, respectively as reviewed in Section 2, U can be depicted as follows:

$$U = U(I,J) = \frac{\partial U}{\partial I} \cdot I + \frac{\partial U}{\partial J} \cdot J = \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial I} \cdot I + \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial J} \cdot J \tag{A13}$$

Then,

$$\varepsilon_{cu} = \frac{\partial C}{\partial U} \cdot \frac{U}{C} = \frac{\partial C}{\partial I} \cdot \frac{I}{C} + \frac{\partial C}{\partial J} \cdot \frac{J}{C} = \frac{\partial \ln C}{\partial \ln I} + \frac{\partial \ln C}{\partial \ln J} \tag{A14}$$

	1994–1999	2000–2008	2009–2013	
D_1 (1994–1999)	1	0	0	Before Net bubble bursting
D_2 (2000–2008)	0	1	0	After Net bubble bursting and before the Lehman shock
D_3 (2009–2013)	0	0	1	After the Lehman shock
J elasticity to I (ε_{ij})	0.560	0.632	0.754	
	$\ln C = a + b \ln I + c D_i \ln J + d \ln I \ln J$			
1994–1999	$\ln C = 10.120 + 0.142 \ln I - 0.129 \ln J + 0.024 \ln I \ln J$			
2000–2008	$\ln C = 10.120 + 0.142 \ln I - 0.134 \ln J + 0.024 \ln I \ln J$			
2009–2013	$\ln C = 10.120 + 0.142 \ln I - 0.148 \ln J + 0.024 \ln I \ln J$			
	$\varepsilon_{cj} = c D_i + d \ln I + (b + d \ln J)\, \varepsilon_{ij}$			
1994–1999	$\varepsilon_{cj} = -0.129 + 0.024 \ln I + (0.142 + 0.024 \ln J) \times 0.560 = -0.049 + 0.024 \ln I + 0.013 \ln J$			
2000–2008	$\varepsilon_{cj} = -0.134 + 0.024 \ln I + (0.142 + 0.024 \ln J) \times 0.632 = -0.044 + 0.024 \ln I + 0.015 \ln J$			
2009–2013	$\varepsilon_{cj} = -0.148 + 0.024 \ln I + (0.142 + 0.024 \ln J) \times 0.754 = -0.041 + 0.024 \ln I + 0.018 \ln J$			

Left hand side of this equation depicts elasticity of utility to consumption and demonstrates the extent of reflection of utility to consumption while right hand side depicts contribution of elasticity of ICT stock and the Internet to consumption, respectively.

Since, $\frac{\partial \ln C}{\partial \ln J} = \varepsilon_{cj}$ *and* $\frac{\partial \ln C}{\partial \ln I} = \frac{\partial \ln C}{\partial \ln J} \cdot \frac{\partial \ln J}{\partial \ln I} = \frac{\varepsilon_{cj}}{\varepsilon_{ij}}$, elasticity of utility to consumption ε_{cu} and contribution of I and J to this elasticity can be identified by the results of the analysis in Section 3 as follows:

$$\varepsilon_{cu} = \frac{\varepsilon_{cj}}{\varepsilon_{ij}} + \varepsilon_{cj} = \varepsilon_{cj}\left(\frac{1}{\varepsilon_{ij}} + 1\right) \tag{A15}$$

ε_{ij} and ε_{cj} are illustrated in Figs. 3 and 4, respectively.

Appendix 6. Internet dependency: percentage of individuals using the internet

Indicator: Percentage of individuals using the Internet

Proportion of individuals who used the Internet from any location in last 3 months (previously 12 months) reported in ITU's HH7 (households and individuals) national survey.

Table A4
ITU's HH7 Surveys for 'Percentage of individuals using Internet'

Indicators		Definitions and notes
HH7	Proportion of individuals who used the internet (from any location) in the last 3 months **Suggested model question:** "*Have you used the Internet from any location in the last 3 months?*"	The proportion of individuals who used the internet is calculated by dividing the total number of individuals who used the internet (from any location) in the last 3 months by the total number of individuals surveyed. The internet is a world-wide public computer network. It provides access to a number of communication services including the world wide web and carries e-mail, news, entertainment and data files, irrespective of the device used (not assumed to be only via a computer – it may also be by mobile phone, PDA, games machine, digital TV etc.). Access can be via a fixed or mobile network.

Source: Manual for Measuring ICT Access and Use by Households and Individuals (http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ITCMEAS-2009-PDF-E.pdf).

Database: ITU's World Telecommunication/ICT Indicators Database

ITU's World Telecommunication/ICT Indicators Database is the main source of global, and internationally comparable, telecommunication/ICT statistics.

Definitions and Methods

Internet: The Internet is a world-wide public computer network. It provides access to a number of communication services including the World Wide Web, e-mail, news, entertainment and data files, irrespective of the device used.

Internet Access: Individuals may have accessed the Internet by any means including a computer, mobile phone, PDA, games machine, digital TV etc. Access can be via a fixed or mobile network.

Method

The ITU conduct several surveys for World Telecommunication/ICT Indicators database to measure ICT access and usage by households and individuals. The HH7 survey calculates the proportion of individuals who used the Internet from any location in the last 3 months.

Survey Question: "*Have you used the Internet from any location in the last 3 months?*"

The proportion of individuals who used the Internet is calculated by dividing the total number of individuals who used the Internet in last 3 months by the total number of individuals surveyed.

Source: ITU's World Telecommunication/ICT Indicators Database

ITU's World Telecommunication/ICT Indicators Database includes time series for more than 140 indicators and around 200 countries. The data are collected directly from telecommunication regulatory agencies and/or ministries and national statistical offices by means of an annual questionnaire, and subsequently verified, harmonized and complemented by ITU.

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