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Operationalization of un-captured GDP - Innovation stream under new global mega-trends

Chihiro Watanabe [a, b, c, *], Kashif Naveed [a], Pekka Neittaanmäki [a], Yuji Tou [d]

[a] University of Jyväskylä, Finland
[b] National University of Singapore, Singapore
[c] International Institute for Applied Systems Analysis (IIASA), Austria
[d] Tokyo Institute of Technology, Japan

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ABSTRACT

With the understanding that current ICT-driven global development depends on a trend shifting from traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality to new co-evolution of the Internet, un-captured GDP, and supra-functionality beyond economic value, the following hypothetical view was postulated:

The disparity between the world's ICT leader countries with respect to happiness/welfare amidst great stagnation (Finland) or conspicuous economic growth (Singapore) can be attributed to the difference of the state in the above shifting trends.

The foregoing hypothetical view was demonstrated on the basis of an empirical analysis measuring dependency on un-captured GDP, which is a key factor identifying the state of the shifting trends. This dependency is based on a comprehensive review of the consequences of three mega-trends that lead to the respective co-evolution and on the review of the development of trajectories relevant to these mega-trends.

Noteworthy findings were obtained on the consequences of the development trajectory option, particularly on the shift from traditional co-evolution to new co-evolution resulting in differences in interactive return gain structure. Also significant policy suggestions essential for identifying government/business roles in the context of new innovation stream were received. The importance of transferring government ability in innovation, collaboration and absorption to business was stressed, as this creates a virtuous cycle between "muscular" economic environment development and increase in the "muscularity" of indigenous firms.

1. Introduction

1.1. ICT-driven development under Co-evolution of 3 mega trends

Advances in information communication technology (ICT) can largely be attributed to the dramatic advancement of the Internet.[1] This has changed the computer-initiated ICT world significantly. The Internet promotes free culture, the consumption of which provides utility and happiness to people but cannot be captured by GDP data (Lowrey, 2011 [18], Rifkin, 2014 [22]). With a greater volume of unpriced digital goods introduced each year, this traditional GDP heuristic is becoming less useful (Brynjolfsson and McAfee, 2014 [2]).

Un-captured GDP has become the major source of consumer's utility (happiness in consumption) as analyzed in an earlier paper (Watanabe et al., 2015 [32]). This corresponds to consumer preferences shift from economic functionality to supra-functionality beyond economic value, encompassing social, cultural, aspirational, tribal, and emotional values. This shift, in turn, induces further advancement of the Internet, leading to a co-evolution of the foregoing three mega-trends (advancement of ICT, paradigm change and people's preferences shift).

Consequently, the current ICT-driven global development

* Corresponding author. University of Jyväskylä, Finland.
E-mail address: watanabe.c.pqr@gmail.com (C. Watanabe).

[1] As shown by Tapscott in his best -seller "The Digital Economy" (1997) [26], the Internet has changed the way of business and daily life dramatically. The digital economy is also known as the Internet economy, the new economy, or web economy.

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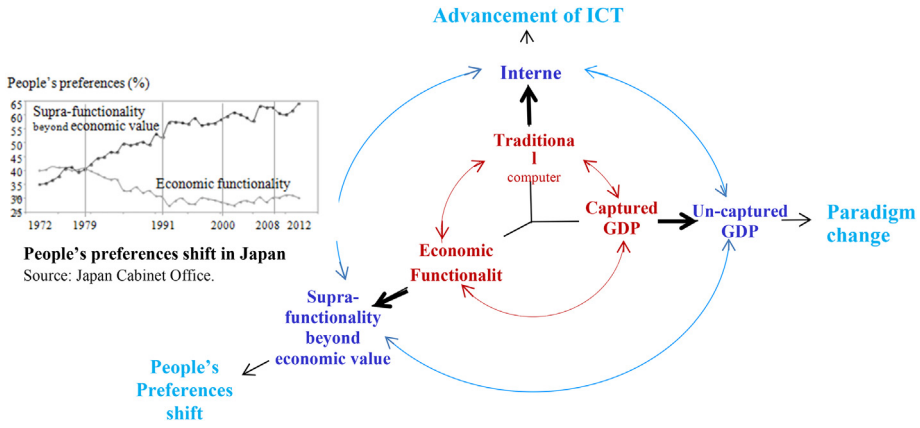


Fig. 1. Shifting Trend in the Co-evolution of the 3 mega-trends.

depends on the shifting trend in the following contrasting co-evolutional mega-trends as illustrated in Fig. 1:

a. Traditional co-evolution of ICT, captured GDP, and economic functionality.
b. New co-evolution of the Internet, un-captured GDP, and supra-functionality.

1.2. High competitiveness by global ICT leaders

1.2.1. Highest competitiveness during the great stagnation

While the majority of countries that are advanced in ICT confront "the great stagnation" due to a trap in ICT advancement (Watanabe et al., 2015, 2015 [31,32]), certain countries can sustain their highest ICT-driven global competitiveness as demonstrated in Table 1. This suggests resilience beyond economic value.

Table 1 suggests that Finland and Singapore, which hold the leading positions in both world ICT ranking and global competitiveness ranking, can be considered countries of resilience on ICT-driven global competitiveness.

1.2.2. Competitiveness structure in ICT-Advanced countries

Inspired by the foregoing observation, Table 2 compares institutional factors governing competence in 12 ICT-advanced countries in 2013.

Table 2 shows that Finland and Singapore, which are regarded as *ICT-driven countries of resilience on ICT-driven global competitiveness* share a notable similarity on institutional competitiveness as global competitiveness, ICT competitiveness, qualities of human capital and educational system and similar population size. They demonstrate significant disparity on economic performance (GDP/capita, GDP growth rate, unemployment ratio) and welfare/happiness level (inequality, birth rate, happiness).

1.3. Conspicuous contrast in growth rate between ICT leaders

Based on the foregoing review, Fig. 2 shows the contrast between economic performance represented by GDP growth rate and happiness/welfare level in 12 ICT-advanced countries.

Fig. 2 demonstrates a conspicuous contrast between the world's ICT leader countries, Finland and Singapore, with respect to their GDP growth rates and happiness/welfare levels. Despite the great stagnation of 0.57% *p.a.*, Finland enjoys the highest level of happiness/welfare, as demonstrated by inequality (the lowest level of inequality between nations measured by GINI index in 12 ICT-advanced countries compared), birth rate (the highest level after Israel and the US) and happiness score (the highest level after Denmark, Norway and Switzerland, which share the world top 3 levels). Singapore has the lowest level of happiness/welfare as well as the lowest inequality (highest GINI index) and birth rate and almost the lowest happiness score, notwithstanding its conspicuously high GDP growth rate as 5.85% *p.a.*

1.4. Hypothetical view

There is a conspicuous contrast between the world's ICT leaders as *ICT-driven countries of resilience with respect to ICT-driven global competitiveness*. Happiness/welfare under the great stagnation in Finland and economic growth in the "choking society" of Singapore prompt us towards a hypothetical view that such a contrast can be derived from the difference of the state in the shifting trend within 3 mega-trends (Fig. 1).

Table 3 compares the magnitude of the Internet use between Finland and Singapore in 2013.

The table shows that contrary to Finland's high dependency on the Internet, Singapore's dependency remains at a relatively lower level. Singapore's online shopping experience ratio remains at 30%, and its share of retail sales remains at 2% – much lower than Finland's 48% and 9%, respectively. A similar contrast can be observed

Table 1
World ICT ranking top 5 countries *(2011–2014)*.

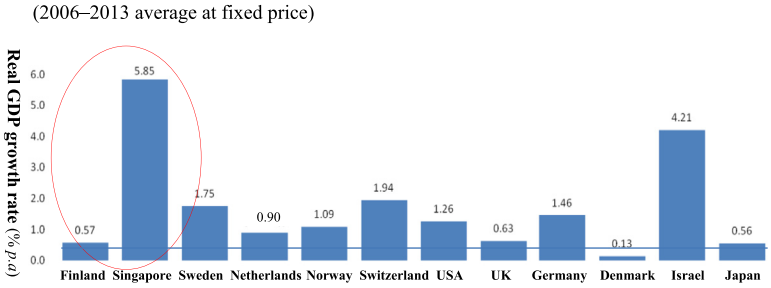
ICT ranking	1	2	3	4	5
2014	Singapore (2)	Finland (4)	Sweden (10)	Netherlands (8)	Norway (11)
2013	Finland (3)	Singapore (2)	Sweden (6)	Netherlands (8)	Norway (11)
2012	Finland (3)	Singapore (2)	Sweden (4)	Netherlands (5)	Norway (15)
2011	Sweden (3)	Singapore (2)	Finland (4)	Denmark (8)	Switzerland (1)

Figures in parentheses indicate global competitiveness ranking.
Sources: The Global Information Technology Report (WEF, annual issues), The Global Competitiveness Report (WEF, annual issues). [34-38]

Table 2
Comparison of factors governing competence in 12 ICT-advanced countries *(2013)*.

	FIN	SGP	SWE	NLD	NOR	CHE	USA	UK	DEU	DNK	ISR	JPN
	Finland	Singapore	Sweden	Netherlands	Norway	Switzerland	USA	UK	Germany	Denmark	Israel	Japan
Population (million)	5.5	5.4	9.6	16.8	5.1	8.0	316.4	64.1	80.8	5.6	7.9	127.3
Global *rank* competitiveness	3	2	6	8	11	1	5	10	4	15	27	9
ICT *rank* competitiveness	1	2	3	4	5	6	7	9	12	13	15	16
Human capital *rank*	2	3	5	4	7	1	16	8	6	9	25	15
Quality of *rank* education system	2	3	17	12	18	1	25	26	14	21	56	50
GDP/capita (1000 US$)	47.1	54.8	57.9	47.6	100.3	81.3	53.1	39.6	45.0	59.2	37.0	38.5
GDP growth rate (2006–13% *pa*)	0.57	5.85	1.75	0.90	1.09	1.94	1.26	0.63	1.46	0.13	4.21	0.56
Unemployment ratio (%)	8.14	1.90	8.00	6.73	3.50	3.16	9.03	7.85	6.53	7.02	6.28	4.70
Inequality (GINI index)	19	45	30	28	38	26	47	39	35	28	41	34
Birth rate	1.9	1.2	1.9	1.8	1.9	1.5	2.1	1.9	1.4	1.9	2.9	1.4
Happiness *rank*	7	30	5	4	2	3	17	22	26	1	11	43

Sources: Watanabe et al., 2015 [32] Table 3. [39,40]



World Rank/level		FIN	SGP	SWE	NLD	NOR	CHE	USA	UK	DEU	DNK	ISR	JPN
ICT (rank)		1	2	3	4	5	6	7	9	12	13	15	16
Global competitiveness (rank)		3	2	6	8	11	1	5	10	4	15	27	9
Happiness / Welfare	Inequality (GINI index)	19	45	30	28	38	26	47	39	35	41	34	41
	Birth rate	1.9	1.2	1.9	1.8	1.9	1.5	2.1	1.9	1.4	2.9	1.4	2.9
	Happiness (Score)	7.5	6.5	7.5	7.5	7.7	7.6	7.1	6.9	6.7	7.3	6.1	7.3

Fig. 2. Conspicuous Contrast in GDP growth rate in ICT-Advanced countries *(2013)*. Sources: Same as Table 2.

Table 3
Comparison of the magnitude of the internet use between Finland and Singapore *(2013)*.

		Finland	Singapore
Internet dependency (%)		93	75
Online shopping (%)	Experience ratio	48	30
	Share of retail sales	9	2
	Clothing/footwear purchase	Popular	4
B2B Internet use (world rank)		1	16

Sources: ITU (2014) [11], WEF (2014) [38], Statistics Finland (2015) [25], Singapore Department of Statistics (2015) [24].

also in B2B Internet use.

As analyzed in an earlier paper (Watanabe et al., 2015 [32]), the lower level in the Internet dependency in Singapore corresponds to that country's lower level of dependency on un-captured GDP. In addition, lower dependency on the Internet translates to a lower level in shifting from economic functionality to supra-functionality beyond economic value that corresponds to consumers' contemporary preferences, as demonstrated also in an earlier paper (Watanabe et al., 2015 [31]).

These observations prompt us for a hypothesis developed further with respect to the shifting state in the co-evolution of the 3 mega-trends (Fig. 1); that is, **while Finland has shifted from "*traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality*" to "*new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality*", Singapore has kept to its former type of co-evolution.**

While a huge number of analyses have been conducted on the impacts of the advancement of the Internet, no-one has ever undertaken the analysis of the structural impacts of the above shift.

This paper attempts to demonstrate the above hypothetical view by measuring un-captured GDP of the two world's ICT leader

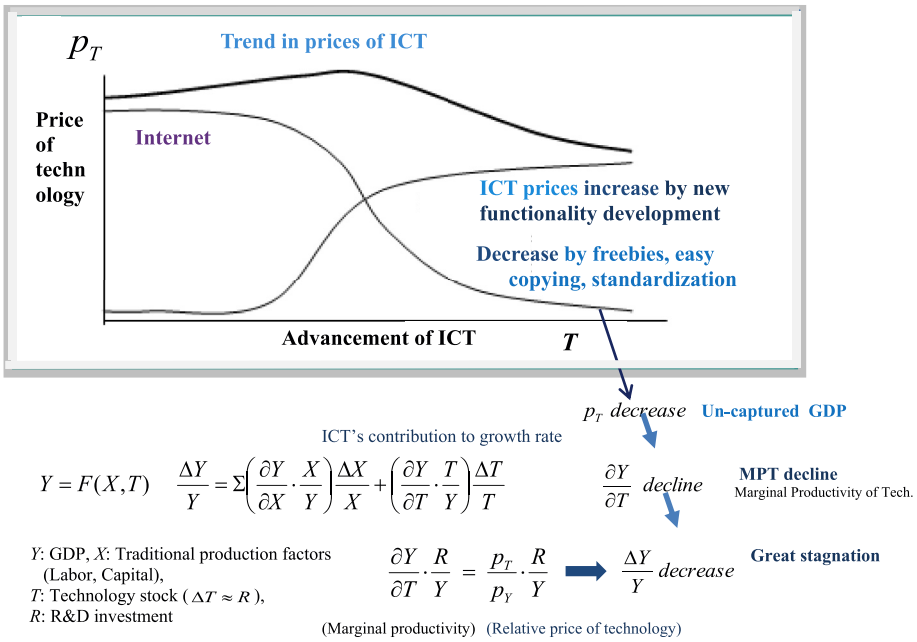


Fig. 3. ICT's two identical faces.

countries over the last two decades. That un-captured GDP explicitly demonstrates the state of the shifting trend in the co-evolution of 3-mega-trends.

To date, several attempts have been made to measure un-captured GDP in the context of *beyond GDP*, which includes "true wealth and the well-being of nations" (Wesselink et al., 2007 [33]), "quality of human life while living within the carrying capacity of the supporting ecosystems" (Costanza et al., 2009 [5]), "quest for a measure of social welfare" (Fleurbaey, 2009 [7]), "well-being, economic welfare and sustainability" (Bleys, 2012 [1]), and "global genuine progress" (Kubiszewski et al., 2013 [17]). However, no-one has so far attempted to measure un-captured GDP due to digital economy and derived from the dramatic advancement of the Internet. In order to link this issue to un-captured GDP problem driven by digital innovation, Brynjolfsson and McAfee (2014 [2]) have pointed out that "the rise in digital innovation means we need innovation in our economic metrics." Prompted by this understanding, a practical method to measure un-captured GDP was developed by following up earlier efforts in developing a new method for measuring the magnitude of un-captured GDP (Watanabe et al., 2015 [32]). Consequently, the state in the shifting trend in co-evolution of 3-mega-trends was identified.

Section 2 reviews the consequences of the 3 mega-trends. Section 3 compares the development trajectories impacting on un-captured GDP of the world's ICT leader countries. In Section 4, numerical analyses are conducted to demonstrate a hypothetical view to measure un-captured GDP. Based on this demonstration, Section 5 reviews the consequences of the strategic option. Finally, Section 6 briefly summarizes noteworthy findings, implications and suggestions for further advancement of service innovation.

2. Consequences of the 3 mega-trends

2.1. Advancement of ICT and the trap in it due to its two faces

As reviewed in an earlier paper (Watanabe et al., 2015 [31]), while advancement of ICT generally contributes in enhancing the prices of technology by increasing new functionality development, the dramatic advancement of the Internet tends to decrease prices of technology due to its nature (incl. freebies, easy copying and mass standardization), as demonstrated in the upper part of Fig. 3.

Consequently, the prices of technology in economies that are highly advanced in ICT may start experiencing a decreasing trend. This decrease in prices corresponds to the decline in marginal productivity of technology given the maximum profit behavior under the competitive circumstances, resulting in decreasing growth rate as outlined in the lower part of Fig. 3. This can be the structural source of the trap in ICT advancement for ICT-advanced nations/firms facing a vicious cycle between advancement of ICT and its marginal productivity decline. The above decrease in prices can be thought of as an economic representation of un-captured GDP.

2.2. Un-captured GDP

2.2.1. Emerging mechanism

While the dramatic advancement of the Internet has accelerated ICT advancement, it also has significantly changed the computer-initiated ICT world. The Internet promotes freer culture, the consumption of which provides utility and happiness to people. However, this utility and happiness cannot be captured through GDP that measures revenue. Such shifting from captured GDP to un-captured GDP could correspond to the transfer of production efforts as explained below.

Traditionally, all production efforts have been attributed to the motivation of the producer who tries to obtain a compensating return. However, certain production efforts have been transferred from producers to consumers, which justifies freebies to both producers and consumers.

Consequently, un-captured GDP has become the major source of consumer utility (happiness and gratification by consumption).

Thus, un-captured GDP can be traced, from both sides of the transaction, as.

(i) New function of online intermediaries such as e-commerce, online advertising and search engines, and

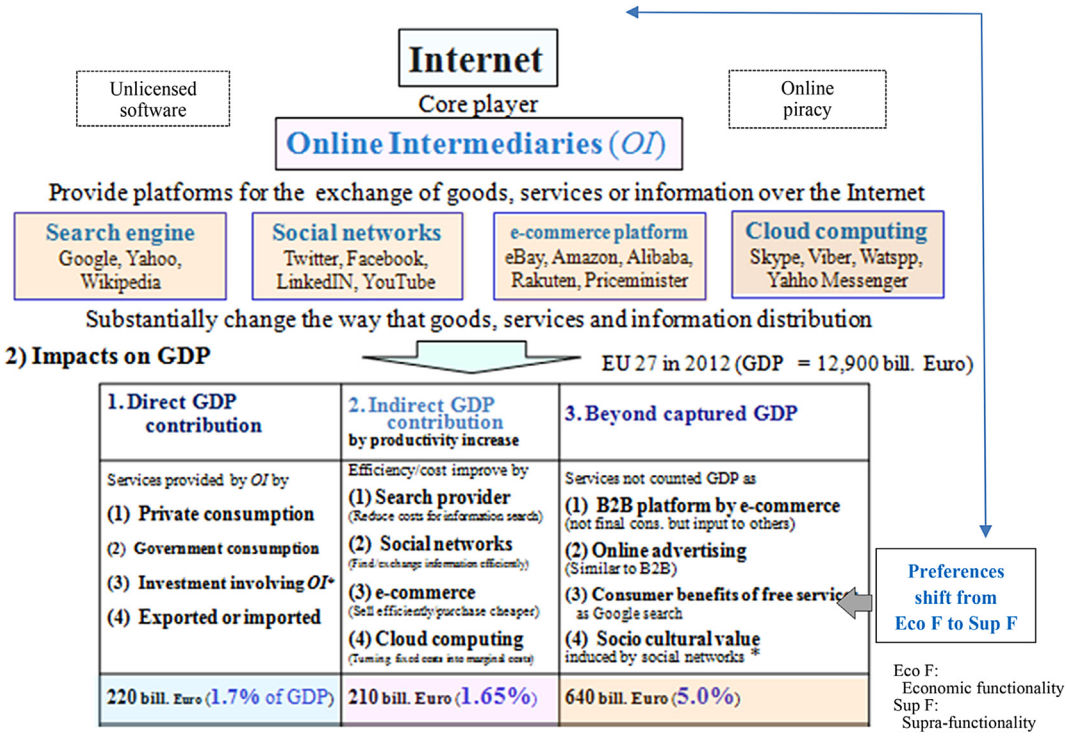


Fig. 4. Sources And impacts of un-captured GDP in the context of Co-evolution. Figures in the bottom raw indicate estimated impacts on EU 27 in 2012 exclusive of marked * (1 (3) and 3 (4)). Source: Based on Copenhagen Economics, 2013 [4].

(ii) Consumer's preferences shift from economic functionality to supra-functionality beyond economic value.

2.2.2. Both sides of un-captured GDP emergence

2.2.2.1. New services provided by online intermediaries. Emergence of un-captured GDP stems from the identical nature of online intermediaries who provide platforms for the exchange of goods, services or information over the Internet. Sources and impacts of un-captured GDP in the context of co-evolution of the Internet advancement and people's preferences shift are illustrated in Fig. 4.

While the dramatic advancement of the Internet creates significant value for e-commerce related to the B2B platform, this

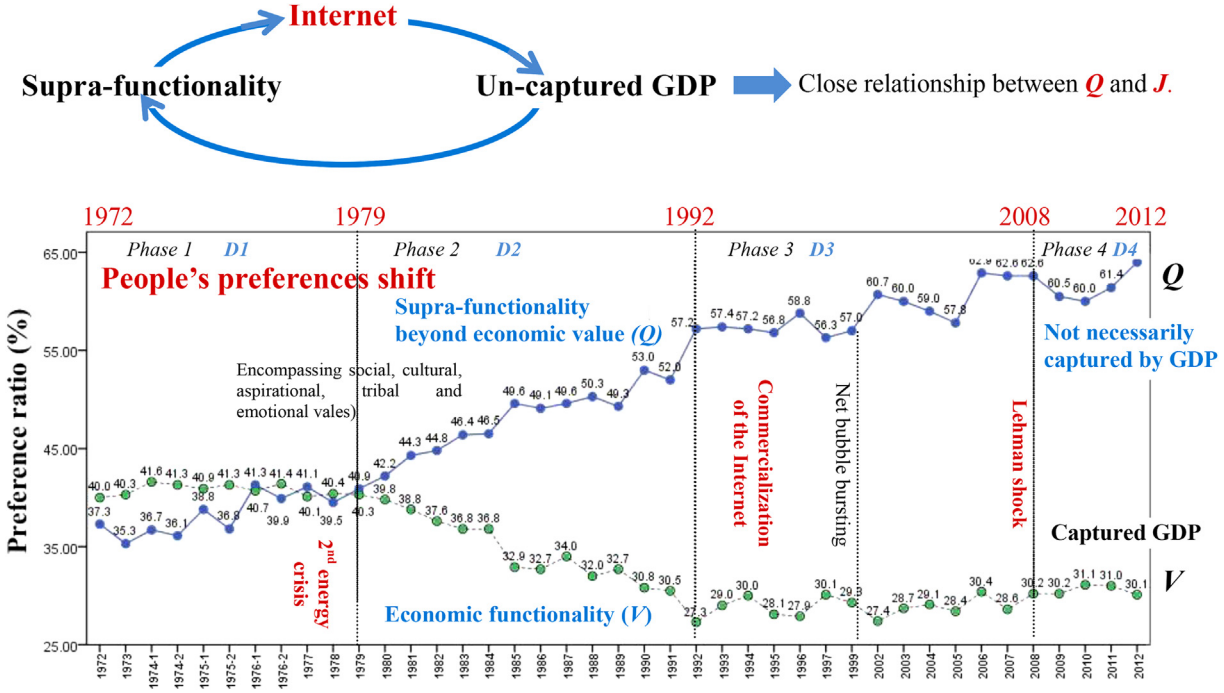


Fig. 5. Trends In the shift of Japanese People's preferences *(1972–2012)*. Source: National Survey of Lifestyle Preferences (Japan Cabinet Office, annual issues) [13].

Elasticity of Utility to Consumption in 6 Countries (2013)

	Finland	Singapore	USA	UK	Germany	Japan
Efficiency of *J* inducement of *I* 1. *J* elasticity to *I* (ε_{ij})	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})	**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**

U: utility *C*: Traditional consumption, *J*: Internet Dependency, *I*: ICT stock,

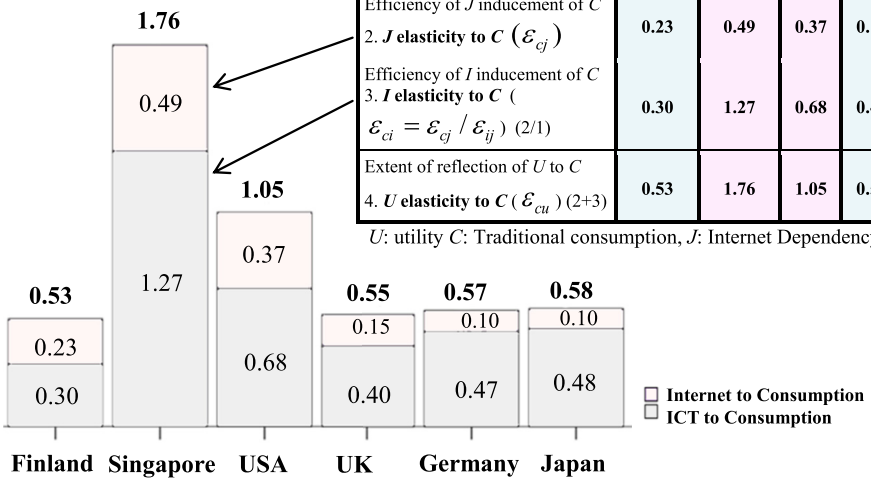


Fig. 6. Elasticity Of utility to consumption in six countries *(2013)*.

value is not captured in the traditional GDP as it does not represent final consumption but rather consumption by other business sectors as an input to final products. This applies to the value of online advertising as well. Like B2B, e-commerce is not final consumption and therefore not included in GDP. While consumers benefit greatly from free services such as Google search, the value of these services is not captured in GDP as there is no direct payment for the search engine. Huge socio-cultural values derived from social networks are similar to supra-functionality beyond economic value and also remain beyond the capture of traditional GDP.

The EU estimated that un-captured GDP, exclusive of that induced by social networks, amounts to 5% of EU27's GDP in 2012 (Copenhagen Economics, 2013 [4]). If the significant shift in people's preferences to supra-functionality beyond economic value, as estimated in an earlier paper (Watanabe et al., 2015 [31]), and the subsequent huge un-captured GDP had been derived from the mountainous socio-cultural value, the estimated value of 5% would be more than double. In addition, we should note that un-captured GDP derived from unlicensed software and online piracy, among other illegal or unauthorized ways, is indispensable for those in the computer-initiated ICT world.

2.2.2.2. Consumers' preferences shift. Dependency on un-captured GDP corresponds to the shifting trend in people's preferences from economic functionality to supra-functionality beyond economic value, as analyzed in an earlier paper (Watanabe et al., 2015 [31]). Supra-functionality induces further advancement of the Internet, as demonstrated in the same paper.

Thus, new co-evolution of the advancement of the Internet, increasing dependency on un-captured GDP and people's preferences shift to supra-functionality emerges as illustrated in Fig. 5.

The new co-evolution satisfies utility by corresponding to consumers' preferences shift to supra-functionality beyond economic value. Such utility, depending on un-captured GDP, does not increase consumption as measured by traditional GDP data.

Thus, elasticity of utility to consumption, which represents percentage increase in consumption in response to 1% increase in utility, demonstrates the state of a country's shift from traditional

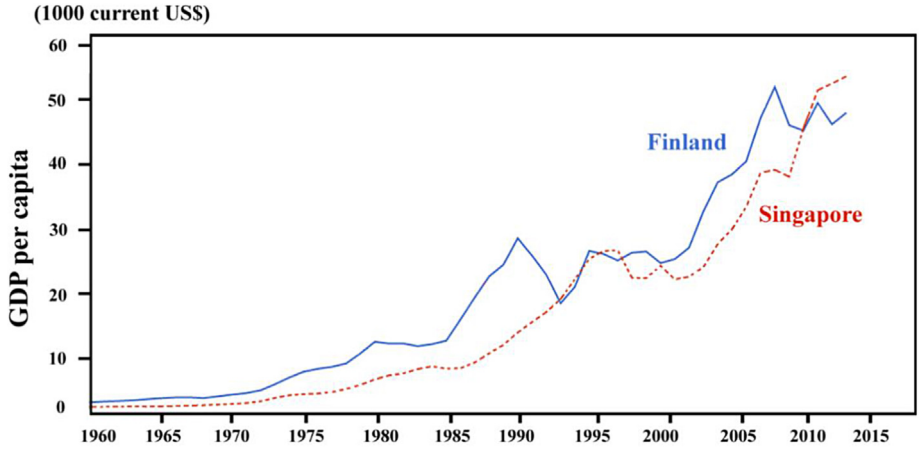


Fig. 7. Trends in GDP per capita in Finland and Singapore *(1960–2013)*. Source: World Development Indicators (The World Bank annual issues) [28].

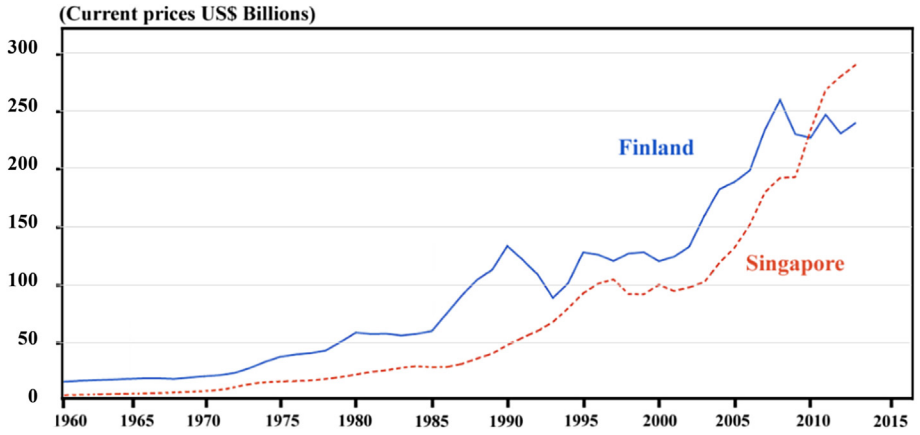


Fig. 8. Trends in GDP in Finland and Singapore in current prices *(1960–2013)*. Source: World Development Indicators (The World Bank annual issues) [28].

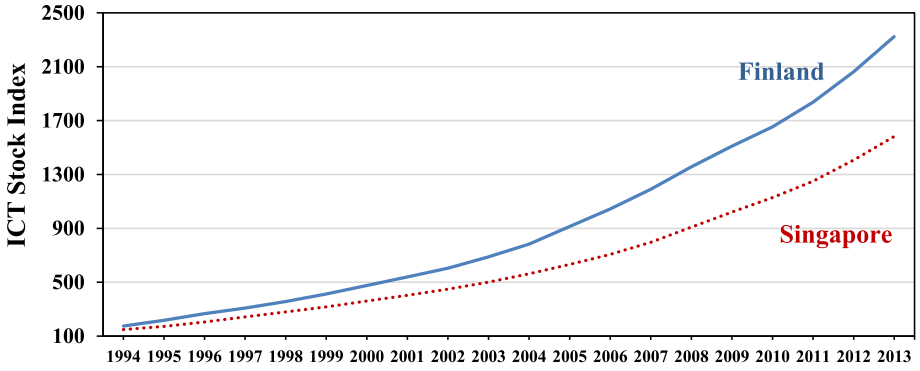


Fig. 9. Trends in ICT stock in Finland and Singapore - index (1994 = 100) *(1994–2013)*. Source: Author's estimate with reference to the Conference Board, Total Economy Database [27].

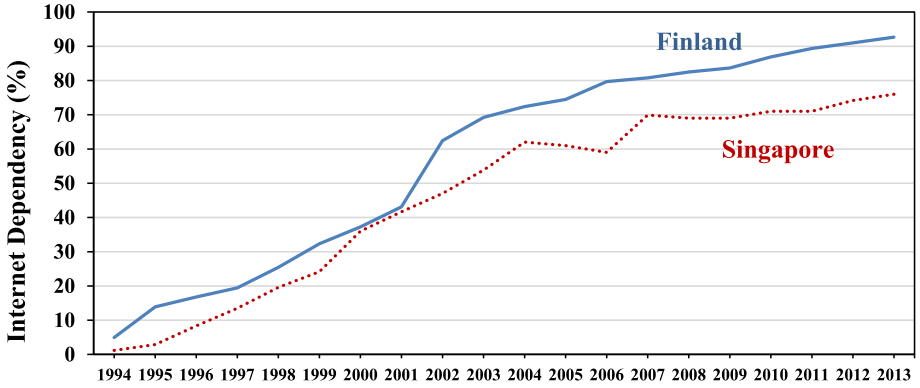


Fig. 10. Trends in internet dependency in Finland and Singapore *(1994–2013)*. Source: ITU's World Telecommunication / ICT Indicators Database [11].

co-evolution of ICT, GDP and economic functionality to this new co-evolution.

Fig. 6 compares this elasticity between six ICT-advanced countries in 2013 (Watanabe et al., 2015 [32]). The figure clearly demonstrates the contrast between the world's ICT leader countries, Finland and Singapore. Contrary to the low level of this elasticity (which represents high dependency on un-captured GDP and high state in the shift to new co-evolution) in Finland, Singapore demonstrates extremely high level of elasticity suggesting high dependency on traditional co-evolution based on traditional GDP, which enables high rate of GDP growth.

This observation supports the hypothetical view that while Finland has shifted from "*traditional co-evolution of ICT, captured GDP, and economic functionality*" to "*new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality*", Singapore has kept to the type of former co-evolution.

3. Trajectories impacting on un-captured GDP in the world's ICT leader countries

Inspired by the foregoing postulate that un-captured GDP can be traced, from both sides, as a new function of online intermediaries and consumer's preferences shift, the development trajectories

Table 4
Trends in ICT usages by individual, business and government in Finland and Singapore *(2010–2014)* – world rank.

		2010	2011	2012	2013	2014
Individual Usage	Finland	2	5	6	6	5
	Singapore	7	10	11	10	11
Business Usage	Finland	8	5	3	2	4
	Singapore	10	14	14	15	14
Government Usage	Finland	24	17	10	8	17
	Singapore	3	2	1	1	1

Sources: The Global Information Technology Report (WEF, annual issues).

3.2. ICT/internet development trajectory

Second, ICT development trajectories of ICT stock, Internet dependency and ICT usage in the two countries over the last two decades were compared.

3.2.1. ICT stock

Over the last two decades, Finland has maintained a growth level of ICT stock that is higher than that in Singapore, as compared in Fig. 9.

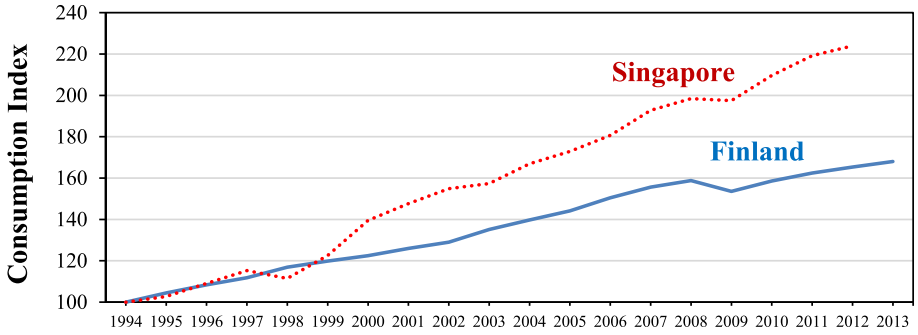


Fig. 11. Trends in household consumption in Finland and Singapore- index (1994 = 100): *(1994–2013)*. Source: UN Statistics Division, Household Final Consumption Expenditure (UN, 2014) [29].

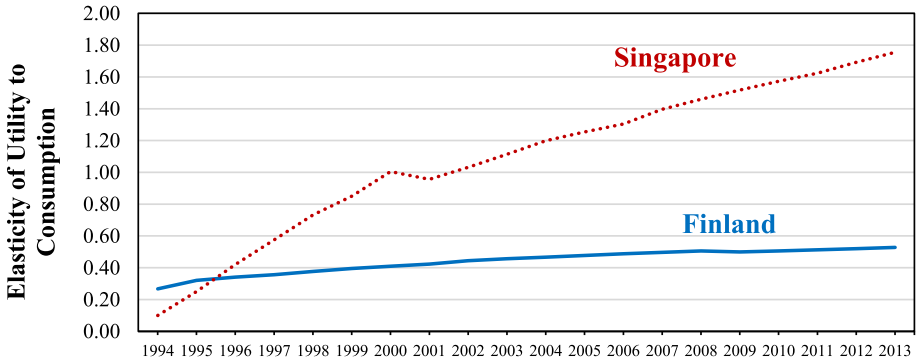


Fig. 12. Trends in elasticity of utility to consumption in Finland and Singapore *(1994–2013)*. In order to avoid statistical noise, Singapore's elasticity for 1994–1996 are adjusted taking backward trend between 1997–2000. Source: Authors Computation (Technology in Society 41(2), 2015, Fig. 5).

impacting on the emergence of un-captured GDP in the world's ICT leader countries were traced.

3.1. Captured GDP trajectory

First, GDP growth trajectories in Finland and Singapore were compared.

3.1.1. GDP per capita

Fig. 7 demonstrates that Finland and Singapore maintain parallel paths for their GDP per capita increase. Singapore slightly exceeds this path orientation level from 2010 onwards.

3.1.2. GDP at current prices

A similar trend can be observed in both countries also in their GDP at current prices, as shown in Fig. 8.

3.2.2. Internet dependency

Both countries maintained almost a similar level of Internet dependency in the 1990s. Since the start of the new millennium, however, Finland has maintained a level that is significantly higher than that of Singapore, as demonstrated in Fig. 10. This suggests that in case of the two countries there is a certain reason for the contrast in un-captured GDP dependency.

3.2.3. Trend in ICT usage: correspondence to People's preferences shift

ICT usage by individuals, business and government was compared. Given the dramatic advancement of the Internet and its correspondence to people's preferences shift to supra-functionality beyond economic value, countries' efforts for new co-evolution of 3 mega-trends should be devoted to enhancing the usage level of individuals and business and not only that of government.

Table 4 compares the trends in ICT usage by individuals, business and government in Finland and Singapore over the last 5 years.

The table indicates that while Finland has devoted itself

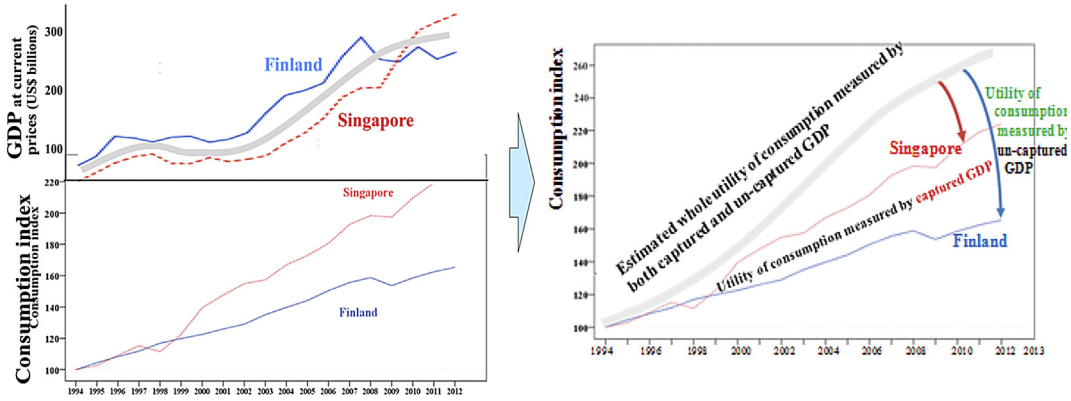


Fig. 13. Utility of consumption measured by un-captured GDP.

primarily to individual and business ICT usage, Singapore demonstrates a conspicuous reliance on its government's ICT usage rather than relying on individual and business usages. This observation suggests that Finland's shift to new co-evolutionary trajectory has been more extensive than that of Singapore.

3.3. Consumption behavior

Third, consumption behavior, both by volume and quality, was compared.

3.3.1. Household consumption

In order to examine the volume of consumption measured by captured GDP, the trends in household consumption in both countries were traced as illustrated in Fig. 11. The figure demonstrates that, notwithstanding with the similar level of income as shown in the comparisons of Figs. 7 and 8, Singapore depends on consumption at a much higher level than Finland. This contrast suggests the differences in the ways of consumption in the two countries: in Singapore the consumption is dependent on captured GDP and in Finland on un-captured GDP.

3.3.2. Dependency of GDP – elasticity of utility to consumption

By means of the measurement of the elasticity of utility to consumption, as introduced in Fig. 6, the trends in this elasticity in Finland and Singapore over the period 1994–2013 were measured as illustrated in Fig. 12. These trends support the above view with respect to dependency on consumption related to captured GDP in Singapore and consumption related to un-captured GDP in Finland.

4. Measurement of un-captured GDP

4.1. Suggestion based on factual observation

The foregoing factual observations with respect to development trajectories impacting on the emergence of un-captured GDP in Finland and Singapore, the world's ICT leader countries, suggest the following conceptual idea which is supportive of measuring un-captured GDP.

The significant difference in consumption levels between Finland and Singapore (Fig. 11), notwithstanding the similar level of GDP of those countries (Figs. 7 and 8), can be attributed to the difference in consumption based on un-captured GDP as illustrated in Fig. 13.

This difference can be attributed to the difference of the state of spin-off in the shifting co-evolution of the 3 mega-trends.

The locomotive for such spin-off impacting un-captured GDP can be:

(i) Stimulation from ICT advancement, and
(ii) Inducement by people's preferences shift.

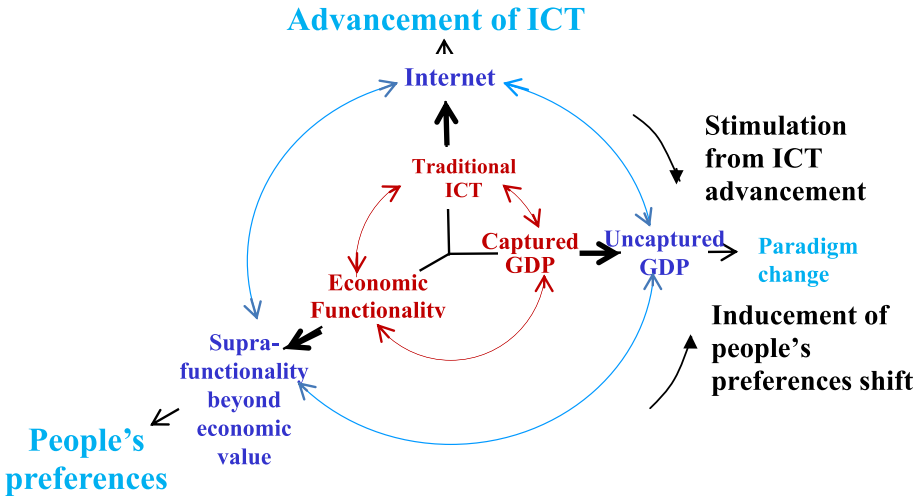


Fig. 14. The locomotive for the spin-off impacting un-captured GDP.

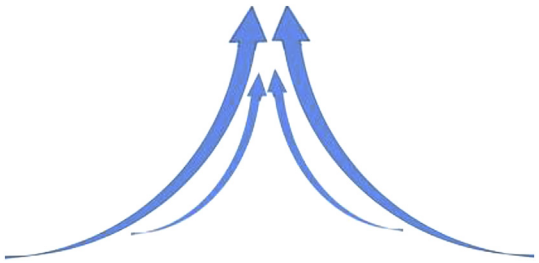


Fig. 15. Concept of the Locomotive of Spin-off derived from an Equilibrium Leading to Lifting Power.

as reviewed in Section 2 and illustrated in Fig. 14.

Both maintain equilibrium, leading to a lifting power as illustrated in Fig. 15. This can be depicted by the following equation consisting of primary impacts and secondary impacts.

Impacts on un-captured GDP $Z = A \cdot X^{\alpha} \cdot e^{\beta Y^n} \approx A \cdot X^{\alpha}(1+\beta \cdot Y^n) \qquad \beta \cdot Y^n << 1$

Scale factor Primary impacts Secondary impacts

X and Y refer to stimulation/inducement by the advancement of the Internet and people's preferences change, α, β are coefficients, and n is the power factor.

4.2. Estimate of un-captured GDP in World's ICT leader countries

On the basis of the foregoing suggestions, an equation measuring the Internet-driven un-captured GDP was developed as summarized in the Appendix. Utilizing the equation, an empirical analysis identifying the governing factors of un-captured GDP in Finland and Singapore over the period 1994–2013 was carried out. The results of the analysis are summarized in Tables A1 and A2 in the Appendix.

Fig. 16 demonstrates the estimated un-captured GDP ratio (Un-captured GDP/captured GDP) in Finland and Singapore over the period of 1994–2013 with the highest and lowest possible estimates. Based on this, Figs. 17 and 18 show estimates of un-captured GDP at current prices in Finland and Singapore over the same period.

As the figures show, while Finland's captured GDP is lower than that of Singapore after 2010, Finland has a higher gross GDP (the sum of captured and un-captured GDP) as it depends on a much higher level of un-captured GDP than Singapore. This agrees with the preceding estimate comparing the elasticity of utility to consumption (Figs. 6 and 11) and suggests that Finland has shifted largely to un-captured GDP dependency while Singapore has kept its traditional GDP dependency.

People's preferences have been shifting to supra-functionality beyond economic value (Watanabe et al., 2015 [31]) and cannot necessarily be measured by GDP. In this, there is a great difference between the world's ICT leader countries: happiness and wellbeing amidst the great stagnation in Finland and economic growth amidst the choking society of Singapore (as explained in Section 1) can be explained by the contrasting un-captured GDP trends in the two countries.

4.3. Significance of a shift to new Co-evolution

With the above estimation of un-captured GDP in mind, in order to identify the possible shift from traditional co-evolution to new co-evolution, correlation between *the shift from computer-initiated ICT (I) to the Internet(J) initiative* and *the shift from captured GDP to un-captured GDP* in Finland and Singapore over the period 1996–2013 was analyzed. Aiming at measuring the advancement of the Internet in ICT-driven economy, the Internet productivity to ICT (I/J) was used as the proxy for this while un-captured GDP ratio (η) was used as the proxy for the shift to un-captured GDP.

The results of the analysis are summarized in Table A3, and the contrast between Finland and Singapore is illustrated by the correlation in Fig. 19. Looking at the figure, we note that Finland's inflection towards co-evolution of ICT advancement by means of the Internet productivity increase and increase in un-captured GDP dependency occurs around 2002 immediately after the bursting of the net bubble in 2000 and the subsequent emergence of

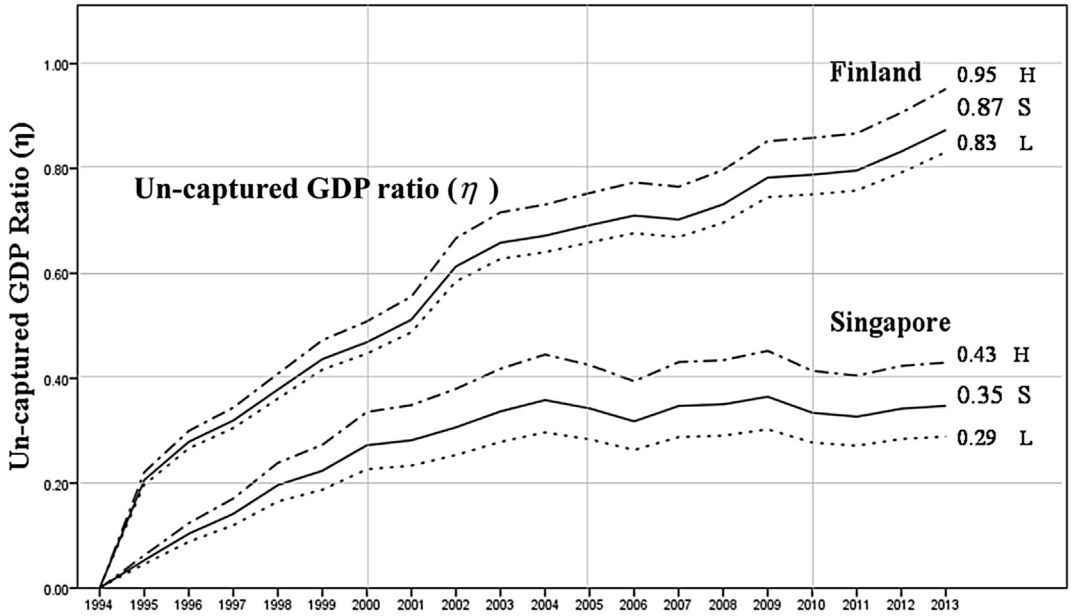


Fig. 16. Trends in un-captured GDP ratio in Finland and Singapore *(1994–2013)*. Un-captured GDP ratio (η) = Un-captured GDP/Captured GDP. S: Standard estimate, H: Higher possible estimate, L: Lower possible estimate.

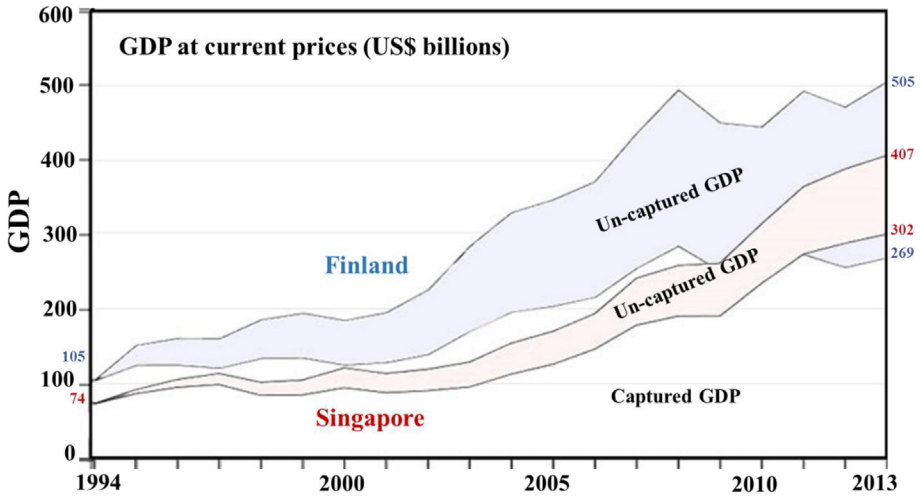


Fig. 17. Trends in captured and un-captured GDP in Finland and Singapore (*1994–2013*).

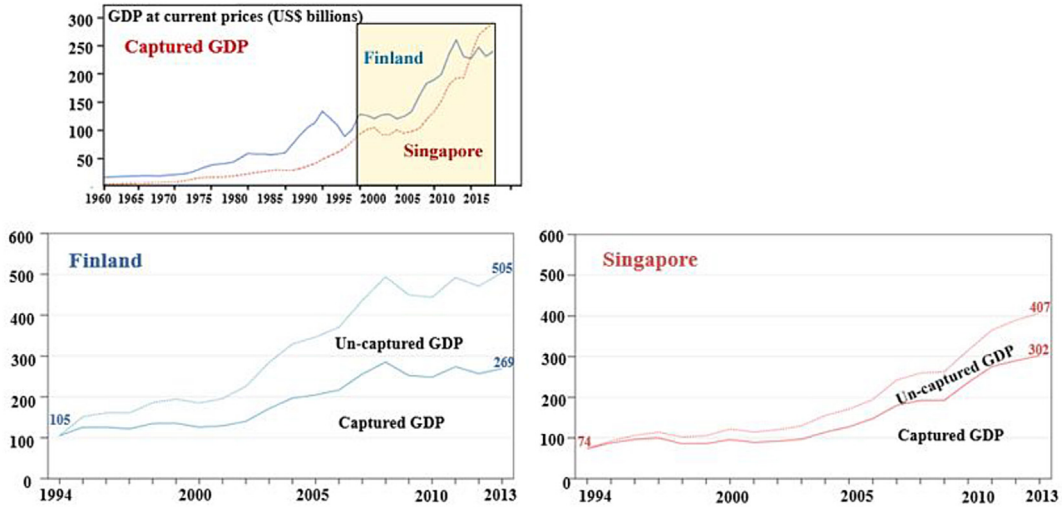


Fig. 18. Comparison of captured and un-captured GDP in Finland and Singapore *(1994–2013)*.Sources - Captured GDP: World Development Indicators (The World Bank, annual issues). Un-captured GDP: Author's estimate by Captured GDP x Un-captured GDP ratio (η).

substantial digital economy. Since then, Finland has shown higher elasticity of ICT advancement to un-captured GDP ratio, which suggests their active co-evolution. Contrary to such a conspicuous co-evolution in Finland, Singapore demonstrates its inflection to co-evolution fairly late, in around 2004, 2 years behind Finland and still with slightly negative elasticity.

As reviewed earlier, there has been significant co-evolution of the advancement of the Internet and un-captured GDP dependency and co-evolution of people's preferences shift with the advancement of the Internet as well. The contrasting co-evolution of the advancement of the Internet and un-captured GDP dependency in the two countries suggest that while Finland has shifted from "*traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality*" to "*new co-evolution of the advancement of the Internet, un-captured GDP, and supra-functionality beyond economic value*," Singapore has still kept to the former type of co-evolution.

Fig. 20 shows the contrast of co-evolution of each respective mega trend pair in Finland and Singapore over the period 1996–2013, adding a convincing demonstration on the above suggestion.

As illustrated on the left hand side of Fig. 21, the above-described shifting co-evolution leverages spin-off from the co-evolution of traditional mega-trends to new co-evolution of new mega-trends, leading to a spirally developing self-propagating dynamism similar to the development trajectory of multi-functional mobile phones (Watanabe et al., 2004 [30]). Such a dynamism can be depicted by the logistic growth function within a dynamic carrying capacity (LGDCC) that incorporates logistic growth carrying capacity. This is a self-propagating dynamism. On the other hand, simple logistic growth (SLG) function (sigmoid curve) incorporates fixed carrying capacity without any self-propagating function (Meyer and Ausbel, 1999 [20]).

The trajectories for Finland and Singapore in shifting to co-evolution dependent on un-captured GDP were examined by applying this theory. The table on the right side of Fig. 21 compares the applicability of the two countries' trajectories to LGDCC. While Finland fits better to LGDCC, Singapore remains with SLG without incorporating significant self-propagating factors. This comparison demonstrates that while Finland has been shifting to new co-evolutionary dynamism which is developing spirally, Singapore has remained with traditional co-evolution without self-

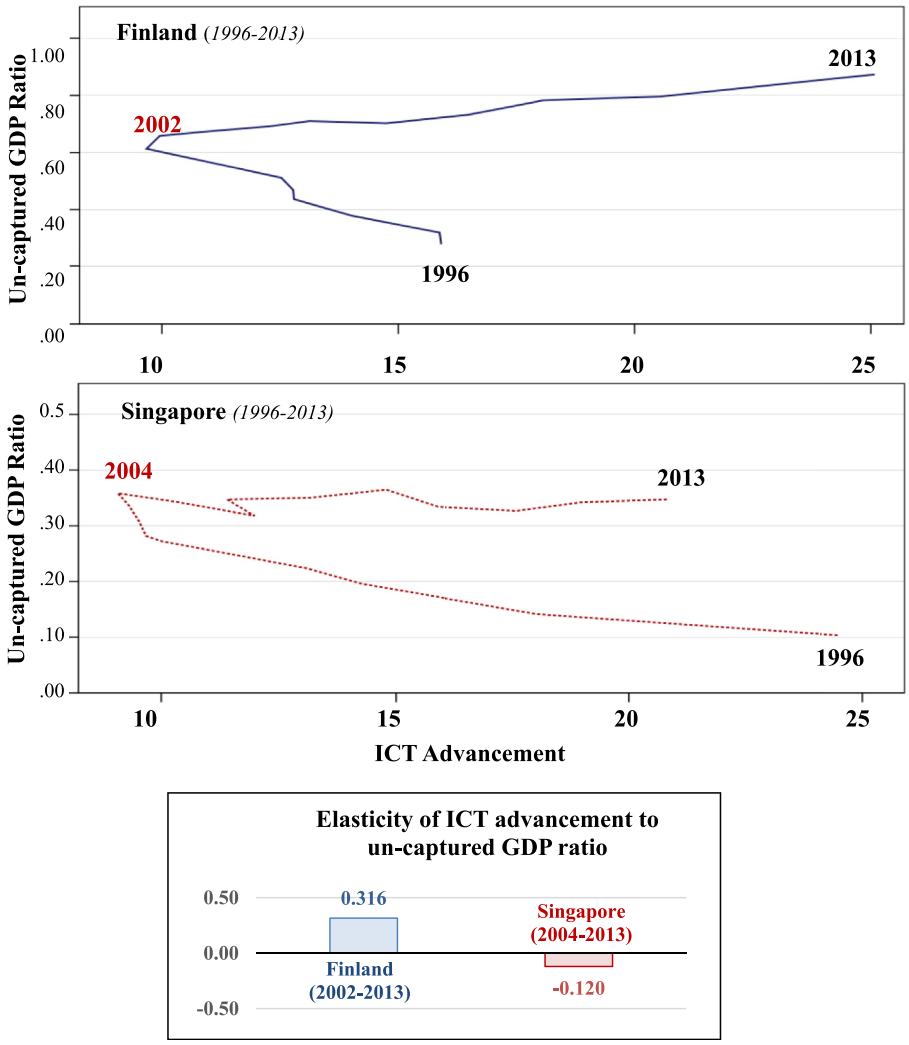


Fig. 19. Co-evolution of internet advancement and un-captured GDP shift in Finland and Singapore *(1996–2013)*. Internet advancement is measured by the Internet Productivity of ICT (*I/J*).

propagation.

All these analyses bear witness to the hypothetical view that while Finland has shifted from "*traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality*" to "*new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality*," Singapore has kept to the former type of co-evolution.

5. Consequences of the strategic option

Based on the above demonstration, the consequences of the strategic option were reviewed.

5.1. Interactive return gain structure from global interaction

5.1.1. Comparison of ICT-Advanced 12 countries

Fig. 22 compares the interactive return gain structure in ICT-advanced 12 countries.

Here the "Interactive return gain structure" implies nation's economic/industrial structure in a global economy and assesses whether the nation is gaining profits from abroad or losing domestic gains.

The top chart in Fig. 22 compares GDP growth rate in ICT-advanced 12 countries (Fig. 2), which again accentuates the contrasting trajectory between "happiness and welfare under the great stagnation" in Finland and other Nordic countries and "economic growth in a choking society" in Singapore and Israel. This contrast can be attributed to the difference in the state of the shifting co-evolution of the 3 mega-trends, as demonstrated in the preceding Section.

The chart in the middle of Fig. 22 compares the GNI (GNP)/GDP ratio. This ratio demonstrates the interactive return gain structure by comparing the state of gaining profits from abroad (value higher than 1) and the state of losing domestic gains (value lower than 1).[2]

It seems surprising that regardless of their notable GDP growth, both Singapore and Israel are losing their domestic gains while other countries are gaining profits from abroad in spite of being afflicted by the great stagnation.

[2] GNI (GNP) − GDP = Balance on income + Balance stemmed from the terms of trade. Balance on income has close relevance with Income balance in the international trade structure as Current balance = Trade balance + Service balance + Income balance + Current transfers (see the bottom chart in Fig. 22).

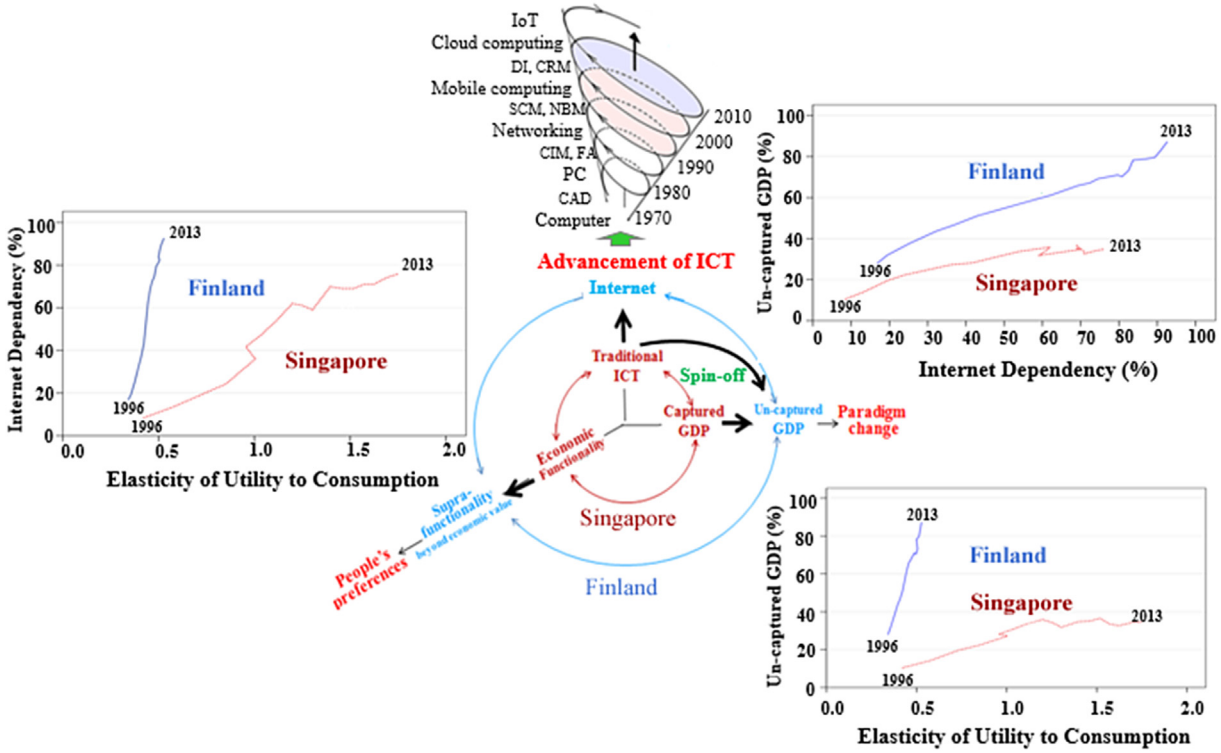


Fig. 20. Co-evolution of the internet, un-captured GDP and peoples preferences shift in Finland and Singapore *(1996–2013)*.

5.1.2. The structure resulting from losing domestic gains

It is a serious problem that "*growth-oriented countries lose domestic gains through interactions with other countries, notwithstanding their accentuating GDP growth*" as globally emerging digital innovation necessitates and accelerates multi-layer interactions.

This irony can be attributed to the consequences of the strategic option as shifting to un-captured GDP initiated new co-evolutionary trajectory or when clinging to captured GDP (which reacts to GDP growth) initiated traditional co-evolution.

Fig. 23 illustrates structural sources for losing domestic gains in growth-oriented countries such as Singapore.

Singapore has been depending largely on multi-national companies (MNCs) for its sustainable development (Yusuf and Nabeshima, 2012 [42]). Corresponding to the world-wide shift from captured GDP to un-captured GDP (Lowrey, 2011 [18], Rifkin, 2014 [22], Watanabe et al., 2015 [31], Brynjolfsson et al., 2014 [2]), MNCs have been developing knowledge and skills for un-captured GDP in Singapore and gained popularity for their products in the global market. On the other hand, Singapore's indigenous home companies (HCs) have relied on captured GDP for GDP growth and, as a result, their products have lost popularity in the global market. Consequently, Singapore has been losing domestic gains rather than gaining profits from the global market while maintaining their GDP growth that is conspicuously higher than in other ICT-advanced countries.

5.2. Engine and brake for improving the domestic gains structure

5.2.1. Institutional sources generating the engine and the brake

The above structure due to which Singapore is losing domestic gains can be attributed to its institutional systems that demonstrate its competence. Generally, strong organizational inertia (brake) exists that impedes change in the system. Therefore, an institutional engine that can leverage systems' change and is strong enough to overcome this brake is essential (Hofstede, 1991 [8]). Table 2 compares factors governing competence in Finland and Singapore. Singapore's strength in economic performance is accentuated by the contrast between a high level of captured GDP and weakness in happiness/welfare factors representing a low level of un-captured GDP.

5.2.2. Possible sources of the engine and the brake

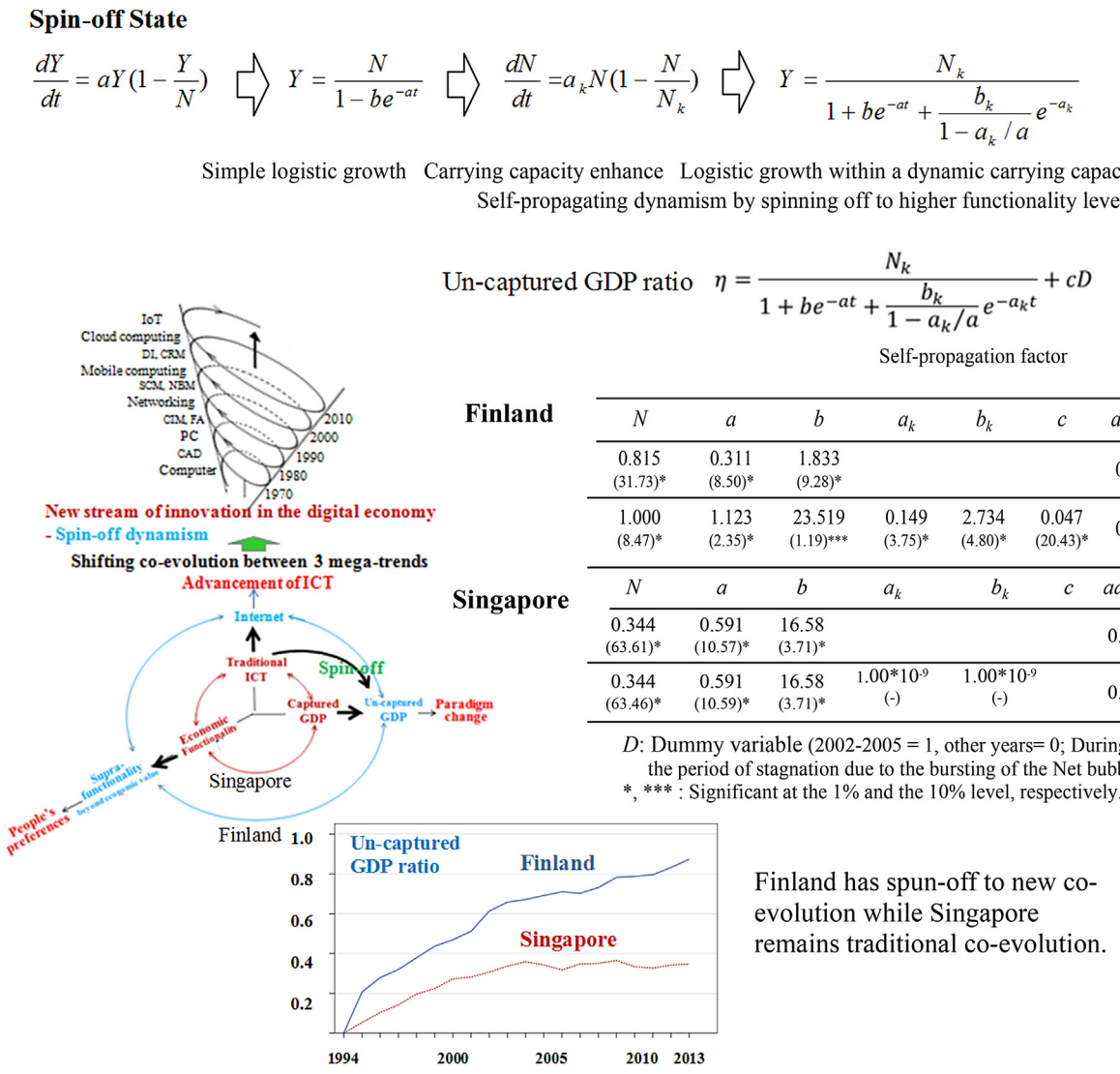
5.2.2.1. Government and business initiatives in ICT usage. Based on the foregoing identification and inspired by the preceding review of the contrasting trends in the world's ICT leader countries with respect to their government and business ICT usages (Table 4), we can draw a detailed structure for ICT in government usage in Singapore and business usage in Finland (Watanabe et al., 2015 [32]). Fig. 9, among other data, indicates Singapore's government's superiority in vision, online service and ICT promotion while Finland demonstrates its superiority in innovation, absorptive capacity, staff training in business, and in B2C and B2B Internet use.

5.2.2.2. Institutional sources of disparity leading to contrasting trajectories. Similarly, we can identify contrasting factors in the state of happiness in Finland and Singapore (Watanabe et al., 2015 [32] Fig. 10): while generosity, lower inequality and freedom of choice contribute to Finland's higher rating, Singapore excels in perception of corruption and has higher income level.

5.3. Consequences of digital innovation

5.3.1. Consequences of digital innovation in World's ICT leader countries

Global expectations for the emergence of digital innovation, particularly of social innovation in this century, have been met, to a great extent, by new business models that can satisfy the historical needs more effectively, efficiently and sustainably. While



Finland

N	a	b	a_k	b_k	c	$adj.R^2$
0.815 (31.73)*	0.311 (8.50)*	1.833 (9.28)*				0.965
1.000 (8.47)*	1.123 (2.35)*	23.519 (1.19)***	0.149 (3.75)*	2.734 (4.80)*	0.047 (20.43)*	0.985

Singapore

N	a	b	a_k	b_k	c	$adj.R^2$
0.344 (63.61)*	0.591 (10.57)*	16.58 (3.71)*				0.982
0.344 (63.46)*	0.591 (10.59)*	16.58 (3.71)*	$1.00*10^{-9}$ (-)	$1.00*10^{-9}$ (-)		0.982

D: Dummy variable (2002-2005 = 1, other years= 0; During the period of stagnation due to the bursting of the Net bubble.)
*, *** : Significant at the 1% and the 10% level, respectively.

Fig. 21. Comparison between Finland and Singapore of spin-off dynamism leading to higher un-captured GDP dependence (*1994–2013*).

advancement of ICT has accelerated this process, as it facilitates interactions between stakeholders, social innovation is creating new sets of stakeholders with potentially different interest, goals, procedures and relations. Activation of interactions between these stakeholders is essential for sustaining qualified social innovation.

Thus, digital innovation creates new business models, which in turn leverage the advancement of ICT, especially in service innovation. All this depends on the institutional systems of the country.

Table 5 compares ICT-induced new business models in ICT-advanced 12 countries in 2013. As anticipated, Finland, the world's top ICT leader, holds the top position also in this ranking. However, Singapore, another of the world's top ICT countries, holds position 10 in the ranking, notwithstanding its top ICT position. This contrast suggests the need for further elaboration of the engine and brake in the context of digital innovation.

Table 5 Comparison of ICT-Induced New Business Models in 12 ICT-Advanced Countries *(2013)*- Rank among 143 countries[3]

Finland's most significant achievement and its strength can be accounted by its free general education which creates capacity for industry innovation, small income disparities, little poverty, and wide participation of women in working life (EU, 2015 [6]). These components construct the foundation of its social innovation (Karjaluoto et al., 2005, 2015 [15,16]).

Moreover, associational capacity and collaborative practices are essential for social innovation, and Finland demonstrates a high level of collaboration (Hoyssa, Bruun and Hukkinen, 2004 [9]). Skills and experience in learning, communicating and working together can be more important than many specified skills. Higher absorptive capacity in Finland (Pot and Vaas, 2008 [21]) makes it easier to step over structural holes in an institutional system (Kallio et al., 2010 [14]). Absorptive capacity consists of acquisition, assimilation, transformation, and exploitation. Building trust relationships between innovating partners for solving collective problems plays a decisive role (Kallio et al., 2010 [14]). Finland maintains superiority in creating a virtuous cycle based on trust (Hoyssa et al., 2004 [9]).

Table 6 demonstrates institutional sources of competence in industry's innovation capacity in Finland. The table supports the foregoing views and convinces us about their significant role as engines contributing to the emergence of ICT-induced new business models.

[3] Questionnaire survey "to what extent do ICTs enable new business models?"

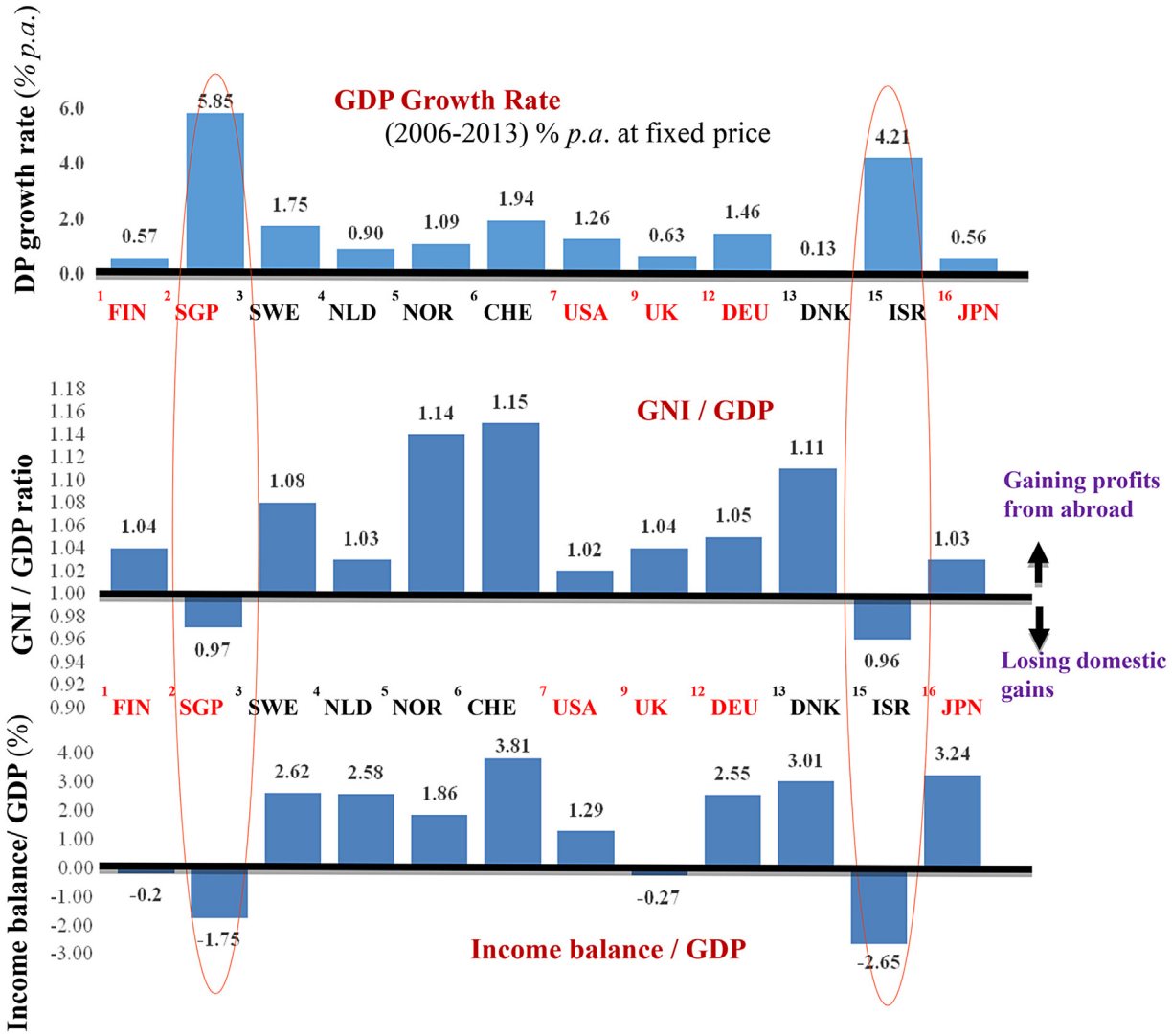


Fig. 22. Comparison of interactive return gain structure in 12 ICT-advanced countries *(2012, 2013 average)*. Figures on the country indicate the ICT competitiveness rank in 2013. Sources: World Economic Outlook Database (IMF 2013, 2014) [10], World Health Statistics 2014 (WHO 2014) [41], United Nations Statistics Division (2013, 2014), World Bank (2013, 2014).

Contrary to Finland, the biggest social innovation initiative in Singapore has long been provided by the Singapore government itself (Concern SG, 2015 [3]). This is the distinct government initiative in ICT usage demonstrated earlier. The government is actively engaged in shaping social institutions and practices through investment in human capital (Sherraden, 2015 [23]). What is unique about Singapore is not the nature of its social challenges in marginalized communities but that its ecosystem and economy are structured to be outward-facing and conductive to growth (Jacobs, 2013 [12]). Social policies are transformative rather than reactive, and institutional capacity is built to provide information which is accessible to researchers, service providers and policy planners.

While Singapore addresses the challenges of its evolving social landscape, there is a need for both short-term policy reviews and a mindset shift for the long term (Mathi and Mohamed, 2011 [19]).

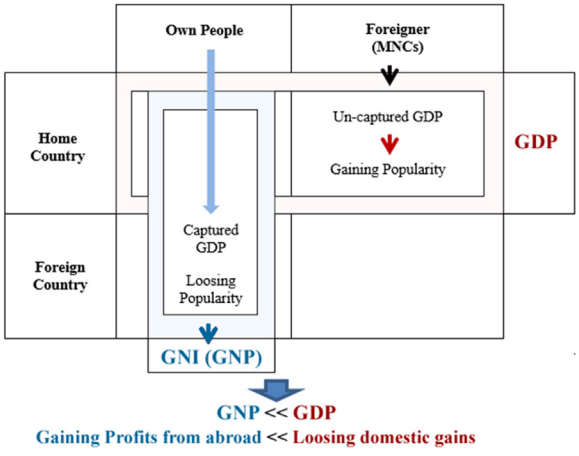


Fig. 23. Structural sources for losing domestic gains (The case of Singapore).

Table 5
Comparison of ICT Induced New Business Models in 12 ICT-Advanced Countries *(2013)*. - Rank in world 143 countries.[a]

1	3	6	6	10	11	14	15	17	19	25	32
FIN	SWE	NLD	UK	SGP	NOR	DEU	USA	CHE	JPN	ISR	DNK

[a] Questionnaire survey "to what extent do ICTs enable new business models?" Source: The Global Innovation Index 2014 (WEF, 2014).

Table 6
Institutional Sources of Competence in Industry's Innovation Capacity in 12 ICT-Advanced Countries *(2013)* - Rank in world 148 countries.

	FIN	SGP	SWE	NLD	NOR	CHE	USA	UK	DEU	DNK	ISR	JPN	
ICT[1]	**1**	2	3	4	5	6	7	9	12	13	15	16	Networked Readiness Index
Innovation capacity[2]	**2**	18	7	9	12	1	5	8	3	13	4	6	Companies capacity to innovate
R&D expenditure[2]	**3**	8	7	18	19	1	5	12	4	10	6	2	Companies R&D spending
Collaboration[2]	**2**	4	10	12	14	1	3	5	9	22	8	17	University-industry collaboration in R&D
Absorptive capacity[1]	**7**	13	1	22	8	3	9	24	16	20	5	6	Firm level technology absorption
Trust[2]	**4**	23	2	5	3	8	9	14	16	1	33	30	Willingness to delegate authority

Sources: 1. The Global Information Technology Report 2014 (WEF, 2014). 2. The Global Competitiveness Report 2013–2014 (WEF, 2014).

The government's initiative has functioned efficiently in attaining its short-term policy target through GDP growth and by securing more job opportunities. Given the increasing shift from co-evolution initiated by traditional captured GDP to co-evolution initiated by un-captured GDP, it is essential to enhance industry's innovation capacity to improve the structure for gaining interaction returns. Thus, it would be a matter of urgency to transfer government competence to industry and create a muscular economic environment.

In endeavoring such transfer, Singapore's indigenous strength and cooperation in labor-employer relations cultivated by a long-lasting strong government initiative, as demonstrated in Table 7, should be fully utilized. The table demonstrates Singapore's exceptional strength in these relations, comparable to Nordic countries except Finland, and in distinct contrast with Israel.

Finland's ranking among Nordic countries in these relations is exceptionally low. Singapore's institutional knowhow has sustained its high ranking in these relations which are also essential for Finland for its social innovation quality.

5.3.2. Implication of engine and brake

These observations suggest the following contrast with respect to the engine and brake for improving the structure of interactive return gain in the context of service innovation in both countries, as shown through comparisons in Table 8.

The table suggests that Finland's advancement in shifting from traditional co-evolution to new co-evolution leveraged by the advancement of ICT, un-captured GDP, and supra-functionality beyond economic value as demonstrated in the preceding section can largely be attributed to business initiative with advanced innovation capacity, association capacity, collaborative practices, absorptive capacity, trusting relationship and increased number of women in labor force. All have contributed to the powerful engine to improve the structure of interactive return gain.

Contrary to such powerful engine in Finland by business initiative, while Singapore's strong government initiatives for accelerating its ICT advancement have played a significant role as an engine for the nation aspiring to the position of the world's ICT leader, these strong government initiatives have resulted in the delay of transferring business initiative which is essential in shifting from traditional co-evolution to new co-evolution.

Singapore has accomplished a broad-based "quantitative" social uplift over the last 5 decades as "*jobs for all, rising incomes for all, homes for all, quality schools and public healthcare for all, and neighborhoods and parks shared by all.*" Transferring the government's strong engine to business aiming at increasing the capacities of innovation, association and absorption would be an urgent task toward the next decade. Singapore's exceptional strength in labor-employer relations should be fully utilized for accomplishing these tasks.

Through such transferring efforts, a "muscular"[4] economic environment can be created. Shaking out indigenous home companies (HCs) with low production capacities would enable highly competitive HCs to explore global markets. This would lead to increasing returns on foreign investment and improve the terms of trade. Ultimately, this would increase the "muscularity" of HCs, which in turn would create a "muscular" economic environment, thus constructing a virtuous cycle expected in the service innovation environment. This is illustrated in Fig. 24.

Table 7
Cooperation in Labor-Employers Relations in 12 ICT-Advanced Countries *(2013)*. - Rank in world 143 countries.

1	2	3	4	5	6	9	18	21	26	42	58
CIE	SGP	DNM	NOR	NLD	SWE	JPN	DEU	FIN	UK	USA	ISR

Source: The Global Competitiveness Report 2013–2014 (WEF, 2014).

6. Conclusion

With the understanding that current ICT-driven global development depends on the shifting trend from traditional co-evolution of computer-initiated ICT, captured GDP, and economic functionality to new co-evolution of the dramatic advancement of the Internet, un-captured GDP, and supra-functionality beyond economic value, the following hypothetical view was postulated:

The noting the disparity in the world's ICT leader countries, Finland and Singapore, with respect to happiness/welfare during the great stagnation in Finland and conspicuous economic growth in a choking society of Singapore can be attributed to the difference in the state in the above shifting trends.

On the basis of an empirical analysis measuring dependency on un-captured GDP, which is a key factor identifying the state of the shifting trend and based on the comprehensive review of the consequence of 3 mega-trends that lead respective co-evolution and also development of trajectories relevant to these mega-trends, the foregoing hypothetical view was demonstrated.

Noteworthy findings include:

(i) The divergence of development trajectories in ICT-advanced countries depends on the shift in the co-evolution of 3 mega-trends,
(ii) Emergence of un-captured GDP is typical to new co-evolution. It stems from the identical nature of online intermediaries which provide platforms for the exchange of goods, services or information over the Internet,
(iii) While Finland has shifted from traditional computer-initiated ICT and captured GDP co-evolution to the Internet and new co-evolution initiated by un-captured GDP from 2002, Singapore has still retained its traditional co-evolution,

[4] Structure with slim, efficient, strong, competitive and resilient performance.

Table 8
Engine and brake in the context of service innovation in Finland and Singapore *(2013)*.

Institutional factors	Finland	Singapore	References
Small income disparity			
Inequality (GINI index: 2010)	**19**	45	Distribution of Household Income by Source (ILO, 2012)
Capacity for innovation			
Capacity for industry innovation	**2**	18	The Global Information Technology Report 2014 (WEF, 2014)
Association capacity and collaborative practices			
University-industry collaboration in R&D	**2**	4	The Global Competitiveness Report 2013–2014 (WEF, 2014)
Absorptive capacity			
Firm-level technology absorption	**7**	13	The Global Information Technology Report 2014 (WEF, 2014)
Trusting relationship			
Willingness to delegate authority	**4**	23	The Global Competitiveness Report 2013–2014 (WEF, 2014)
Generosity (score)	**0.33**	0.19	World Happiness Report (The Earth Institute, Columbia Univ. et al., 2013)
Freedom to make life choices (score)	**0.52**	0.43	*idem*
Women in working life			
Women in labor force	**12**	76	The Global Competitiveness Report 2013–2014 (WEF, 2014)
Government ICT usage			
Importance of ICT to government vision	16	**3**	The Global Information Technology Report 2014 (WEF, 2014)
Government online service	7	**1**	*idem*
Government success in ICT promotion	16	**4**	*idem*
Labor-employer relations			
Cooperation in labor-employer relations	21	**2**	The Global Competitiveness Report 2013–2014 (WEF, 2014)

Figures indicate world rank otherwise indicated.

(iv) Difference in the stage of the shift results in the difference in the structure of the interactive return gain,

(v) Among ICT-advanced countries, both Singapore and Israel, contrary to their notable GDP growth, are losing their domestic gains. Other ICT-advanced countries are gaining profits from abroad, notwithstanding being afflicted by the great stagnation,

(vi) This can be attributed to a world-wide shift from captured GDP to un-captured GDP. Multi-national companies (MNCs) in Singapore have been developing knowledge and skills for un-captured GDP, and this has led to their products gaining popularity in the global market. On the other hand, Singapore's indigenous home companies (HCs) have relied on captured GDP for GDP growth. As a result, their products have been losing popularity in the global market. Consequently, rather than gaining profits from the global market, Singapore has been losing domestic gains while maintaining GDP growth on a conspicuously higher level than other ICT-advanced countries.

(vii) From the new innovation stream, typically service innovation, new business models emerge. Advancement of ICT accelerates this as ICT leverages interaction between stakeholders who are essential for service innovation. Finland, one of the world's leaders in ICT, holds the top position also in ICT-induced new business models. Singapore, another country among the world's ICT leaders, holds the 10th position in the ranking, notwithstanding its top position in ICT. This contrast suggests a need for further elaboration of the engine and brake to improve the structure of interactive return gain in the context of service innovation.

These findings give rise to the following policy suggestions:

(i) Un-captured GDP should be developed on a priority basis as it corresponds to people's preferences in the global market and leads to improvements in the structure of interactive return gain.

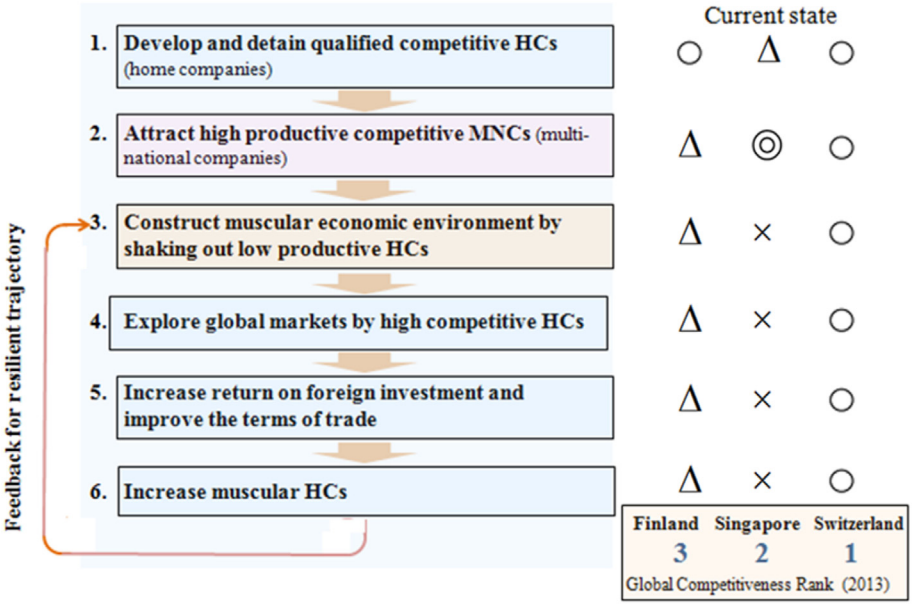


Fig. 24. Strategic Actions for Attaining the targeted trajectory.

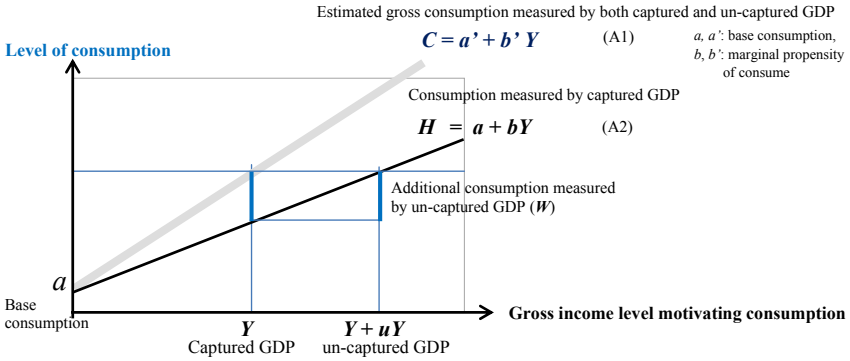


Fig. A1. Concept of Consumption Function with Un-captured GDP.

(ii) Therefore, shifting from traditional co-evolution to new co-evolution leveraged with the advancement of the Internet, un-captured GDP and supra-functionality beyond economic value should be accelerated.
(iii) Business initiative with advanced innovation, association and absorptive capacity, together with collaborative practices, trusting relationship and increase in the number of women in labor force should all be further developed.
(iv) While strong government initiatives to accelerate a country's ICT advancement play a significant role as an engine for the nation's aspirations to global ICT leadership, they may cause delays in the transfer of business initiative, which is essential for shifting from traditional co-evolution to new co-evolution.
(v) Transferring that strong engine possessed by the government to business, which aims at increasing its capacities in innovation, association and absorption, is thus important.
(vi) The exceptional strength of labor-employer relations in Singapore should be fully utilized for accomplishing these tasks. In this respect, Finland should learn from Singapore's institutional know-how.
(vii) Creating "muscular" economic environment by shaking out home companies with low production capacities should be encouraged. As a result, highly competitive home companies would engage in exploring global markets. This would lead to increasing returns on foreign investment and to improving terms of trade.
(viii) Construction of a virtuous cycle between increase in "muscularity" of home companies and development of a "muscular" economic environment should become priorities.

Future studies should focus on the new phase of digital innovation including IoT corresponding to shifting trends from traditional co-evolution to new co-evolution. A new phase of possible co-evolution stimulated by the new phase of digital innovation would also be an important subject to pursue.

In this context, typical features of current leading global platform ecosystem architectures initiated by ICT driven disruptive business model, and their impact on national economy, particularly on un-captured GDP should be analyzed.

Appendix. Measurement of the Magnitude of Un-captured GDP

(1) Analytical framework

Inspired by the conceptual image in Figs. 13 and 14, the magnitude of un-captured GDP was computed based on the following analytical framework:

1) Consumption function

2) Discrepancy between two consumption functions

$$W = C - H = (a' + b'Y) - (a + bY) = (a' - a) + (b - -b)$$
$$Y = (a' - a) + buY \tag{A3}$$

(i) ICT advancement stimulation. Attributed to the internet (J) with secondary impacts of consumer's preferences (E)

$$buY = H \cdot J^{\phi} \cdot e^{\kappa E^m} + \delta \tag{A4}$$

where ϕ, κ: coefficients, m: power factor, and δ: adjusting factor ($= a'$- a).
(see Note).

(ii) Consumer's preferences inducement. Represented by elasticity of utility to consumption (ε_{cu}: E) with the secondary impacts of the Internet (J),

$$buY = A \cdot E^{\alpha} \cdot e^{\lambda J^n} + \delta \tag{A5}$$

where A, λ: coefficients, n: power factor.

3) Identification of un-captured GDP

Since (A4) and (A5) maintain equilibrium, leading to lifting power.

$$buY = H \cdot J^{\phi} \cdot e^{\kappa E^m} = A \cdot E^{\alpha} \cdot e^{\lambda J^n} \tag{A6}$$

$$H = A \cdot E^{\alpha} \cdot e^{\lambda J^n} \cdot \frac{1}{J^{\phi} \cdot e^{\kappa^m}} = A \cdot E^{\alpha} \cdot J^{-\phi} \cdot e^{\lambda J^n} \cdot e^{-\kappa E^m} \tag{A7}$$

$$\ln H = \ln A + \alpha \ln E - \phi \ln J + \lambda J^n - \kappa E^m \tag{A8}$$

Using an empirical regression analysis, coefficients A, α, ϕ, λ, κ can be identified. Power factors m and n can be identified by comparing statistical significance among possible m and n combinations.

By utilizing identified coefficients and power factors, un-captured GDP uY can be measured as follows:

$$uY = \frac{e^{\ln A} \cdot E^{\alpha} \cdot e^{\lambda J^n}}{b} + \frac{\delta}{b} \tag{A9}$$

Provided that the Internet-driven un-captured GDP has emerged triggered by the commercialization of the Internet in 1991, uY at the initial years of its commercialization can be negligibly small. The adjusting factor δ/b can be fixed by applying the

fact that magnitude of un-captured GDP in 1994 was assumed negligibly small.

Un-captured GDP ratio is depicted as follows:

$$\eta = \frac{uY}{Y} \tag{A10}$$

Note.

Un-captured GDP stimulated by ICT advancement

$$\text{Un}-\text{captured GDP} \quad buY = \frac{\partial H}{\partial Y}\cdot uY = \frac{H}{Y}\cdot\frac{\partial H}{\partial Y}\cdot\frac{Y}{H}\cdot uY = H\cdot\gamma\cdot\eta$$

where γ : the elasticity of Y to H, and η : un-captured GDP ratio.

Since $\gamma = \gamma(J,\ E)$, $\eta = \eta(J,\ E)$ (Watanabe et al., 2015 [32]), $\gamma\cdot\eta$ can be depicted by the following equation:

$$\gamma\cdot\eta = J^{\phi}\cdot e^{\kappa E^m} \approx J^{\phi}\cdot e^{\kappa E^m} + \frac{\delta}{H} \quad \left(\because\ \frac{\delta}{H}\approx 0\right)$$

Thus, $$buY = H\cdot\gamma\cdot\eta = H\cdot J^{\phi}\cdot e^{\kappa E^m} + \delta$$

(2) Empirical result

Using Eq. (A8), coefficients governing un-captured GDP as depicted in Eq. (A9) were identified as demonstrated in Table A1. Marginal propensity to consume b was computed using the correlation between GDP and household consumption as demonstrated in Table A2.

The average marginal propensities to consume in Finland and Singapore over the whole period are 0.771 and 0.563, respectively.

Since the above regressions were conducted by using index (1994 = 100), marginal propensity to consume by actual values should be converted by multiplying H/Y ratio in 1994: 0.52 and 0.43 in Finland and Singapore, respectively leading to 0.401 and 0.242.

$$b_{Index} = \frac{\partial H_{Index}}{\partial Y_{Index}} = \frac{\partial_{\frac{H}{H_{1994}}}}{\partial_{\frac{Y}{Y_{1994}}}} = \frac{\partial H}{\partial Y}\cdot\frac{Y_{1994}}{H_{1994}} = \frac{b_{actual}}{\left(\frac{H}{Y}\right)_{1994}}$$

Figures in parenthesis indicate t-statistics (*1, *2 *3 means significant at the 1%, 5% and 10 level, respectively).

Table A3 summarizes the result of the analysis on a shift to new co-evolution using correlation between the Internet advancement and un-captured GDP shift in Finland and Singapore over the period 1996–2013.

Table A1
Governing Factors of Household Consumption in Finland and Singapore *(1994–2013)*

Finland	**S**	$\ln H = 6.435 + 1.185\ln E - 0.208\ln J + 1.03\times10^{-4}J^{1.6} + 0.917E^{2.0}$	$adj.R^2$ 0.998	DW 1.58	AIC −191			
		(7.24*)	(2.23*2)	(-3.10*)	(1.60*4)	(0.69*5)		
	H	$\ln H = 6.520 + 1.230\ln E - 0.214\ln J + 1.70\times10^{-4}J^{1.5} + 0.887E^{2.2}$	$adj.R^2$ 0.998	DW 1.61	AIC −190			
		(7.52*)	(2.35*2)	(-3.29*)	(1.58*4)	(0.64*5)		
	L	$\ln H = 6.380 + 1.158\ln E - 0.209\ln J + 1.03\times10^{-4}J^{1.6} + 0.939E^{1.8}$	$adj.R^2$ 0.998	DW 1.60	AIC −190			
		(6.69*)	(2.10*2)	(-3.63*)	(1.61*4)	(0.69*5)		
Singapore	**S**	$\ln H = 3.721 + 0.740\ln E - 0.198\ln J + 1.00\times10^{-2}J^{1.00} + 1.575E^{-0.22}$	$adj.R^2$ 0.982	DW 1.63	AIC −122			
		(3.28*)	(2.14*2)	(-3.32*)	(5.41*)	(1.37*4)		
	H	$\ln H = 3.856 + 0.735\ln E - 0.229\ln J + 1.70\times10^{-2}J^{0.90} + 1.484E^{-0.22}$	$adj.R^2$ 0.981	DW 1.63	AIC −121			
		(3.27*)	(2.08*2)	(-3.64*)	(5.31*)	(1.25*4)		
	L	$\ln H = 3.593 + 0.745\ln E - 0.172\ln J + 0.60\times10^{-2}J^{1.10} + 1.658E^{-0.22}$	$adj.R^2$ 0.982	DW 1.62	AIC −122			
		(3.27*)	(2.18*2)	(-2.99*)	(5.49*)	(1.48*4)		

S: standard estimate, **H:** higher possible estimate, **L:** lower possible estimate. S, H and L are chosen statistically for most significant 3 cases. Among the three, S demonstrates middle level and is statistically not inferior to H and L.
H: Household consumption (Index: 1994 = 100), E: Elasticity of utility to consumption, J: Internet dependency.
Figures in parenthesis indicate t-statistics (*, *2, *4, *5 means significant at the 1%, 5%, 20% and 50% level, respectively).

Table A2
Correlation between GDP and Household Consumption in Finland and Singapore (1994–2013) – Index (1994 = 100)

Finland	$H = 17.254 + 0.889D_1Y + 0.494D_2Y + 69.034D_2 + 5.238D$	$adj.R^2$ 0.986	DW 1.02			
	(3.42*[1])	(21.50*[1])	(1.84*[3])	(1.73*[3])	(2.84*[2])	
Singapore	$H = 87.127 + 0.648D_1Y + 0.365D_2Y - 79.47D_1 + 14.170D$	$adj.R^2$ 0.976	DW 1.12			
	(2.63*[2])	(17.07*[1])	(3.71*[3])	(−2.33*[2])	(2.15*[2])	

H: Household consumption index (1994 = 100), *Y*: GDP index (1994 = 100).
D1, *D2* and *D*: Dummy variable (1994–2007 = 1, 2008–2013 = 1, and 2007, 2012, 2013 = 1, other years = 0, respectively).

Table A3
Correlation between the Internet Advancement and Un-captured GDP Shift in Finland and Singapore *(1996–2013)*

Finland	$\ln\eta = 5.889 - 2.613D_{9401}\ln I/J + 0.316D_{0213}\ln I/J - 7.059D_{0213}$	$adj.R^2$ 0.948 DW 1.43
	(6.38 *[1]) (−7.50 *[1]) (3.62 *[1]) (−7.40 *[1])	
Singapore	$\ln\eta = -0.772 - 1.148D_{9603}\ln I/J - 0.133D_{0406}\ln I/J - 0.106D_{0713}\ln I/J + 2.173D_{9603}$	$adj.R^2$ 0.983 DW 1.64
	(−3.39 *[1]) (−23.13 *[1]) (−1.36 *[4]) (−1.29 *[4]) (−8.33 *[1])	

η: un-captured GDP ratio (2013 value was estimated by extending trend in 1994–2012), *I*: ICT stock, *J*: Internet dependency.
D_{mn}: dummy variable (period *m*-*n* = 1, other period = 0), *mn* reads as follows:9600 (1996–2000), 0113 (2001–2013), 9601 (1996–2001), 0213 (2002–2013), 9602 (1996–2002), 0313 (2003–2013), 9698 (1996–1998), 9913 (1999–2013), 9699 (11996–1999), 0013 (2000–2013), 9600 (1996–2000), 0113 (2001–2013).
Figures in parenthesis indicate t-statistics (*1 and *4 means significant at the 1% and 20% level, respectively).

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Chihiro Watanabe graduated from University of Tokyo, Japan and is currently Professor Emeritus of Tokyo Institute of Technology, Visiting Professor of National University of Singapore, Visiting Professor of University of Jyväskylä, Finland and also a Research Scholar, International Institute for Applied Systems Analysis (IIASA). (watanabe.c.pqr@gmail.com).

Kashif Naveed graduated with Bachelor's degree in Computer Science from Hamdard University Karachi, Pakistan, Master of Science in Economics and Business Administration from University of Jyväskylä, Finland, and currently doing his Ph.D. in Economics and Business Administration from University of Jyväskylä, Finland. (kanaveed@student.jyu.fi).

Pekka Neittaanmäki graduated from the University of Jyväskylä and is currently a Dean of the Faculty of Information Technology, University of Jyväskylä, Finland. (pekka.neittaanmaki@jyu.fi).

Yuji Tou graduated from Tokyo Institute of Technology, Japan and is currently an Associate Professor at Tokyo Institute of Technology, Japan. (tou.yuji@gmail.com).