



The transformation of R&D into neo open innovation- a new concept in R&D endeavor triggered by amazon

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ABSTRACT

Amazon was the world's top Research and Development (R&D) firm in 2017. Its R&D investment was double that of 2015, five times that of 2012, and ten times that of 2011.

Such a rapid and notable increase in R&D investment has raised the question of a new R&D definition and focus in the digital economy, which Amazon insists includes both “routine or periodic alterations” (traditionally classified as non-R&D) and “significant improvement” (classified as R&D).

Using an empirical analysis of Amazon's R&D model as a system, this paper attempts to provide a convincing answer to this question.

It has been identified that Amazon, which is based on R&D as a culture, has been promoting companywide experimentation to cause customers obsessed with making purchase decisions. This obsession has enabled Amazon to deploy an architecture for participation that makes the most of digital technologies by harnessing the power of users. Such user-driven innovation has accelerated a dramatic advancement of the Internet that, in turn, has accelerated the co-emergence of soft innovation resources in the marketplace. This emergence has activated a self-propagating function that has induced functionality development, leading to supra-functionality beyond an economic value that satisfies a shift in customers' preferences. While this system depends on the assimilation capacity of soft innovation resources, Amazon has developed a high level of capacity supported by a rapid and notable increase in R&D investment. The above efforts function in a virtuous cycle leading to the transformation of “routine or periodic alterations” into “significant improvement.”

These findings give rise to insightful suggestions regarding a new concept of R&D in neo open innovation in the digital economy.

1. Introduction

There is a crucial dilemma when opting for R&D expansion as it can lead to productivity decline, caused by the two-faced nature of information and communication technology (ICT) centered on the advancement of the Internet. This has become a serious problem for ICT firms [1,2]. Despite this, global ICT leaders have exhibited a remarkable growth in R&D.

Fig. 1 illustrates the world's top 25 R&D leaders by their R&D expenditure in 2017, which demonstrates a notable R&D growth rate in software and Internet leaders in 2017 as 40.4% (Amazon), 12.7% (Alphabet), 8.8% (Microsoft), 28.5% (Huawei) and 24.5% (Apple) while

the growth rate in computer & electronics has been much lower, at –3.2% (Samsung) and 5.0% (Intel). Noteworthy is Amazon's conspicuous jump. It invested US\$ 22.6 billion R&D in 2017 and jumped up to the ranks of the world's top R&D firm, surpassing rival global ICT leaders. It is only in the last few years that Amazon's spending has ranked among that of the potential global leaders in R&D.

The rapid increase in R&D spending showed no signs of slowing down the pace in 2018. The amount spent by Amazon on R&D in 2018 is poised to surpass the GDP of Iceland, as demonstrated in Fig. 2 [5].

In corresponding to such a rapid and notable increase in R&D investment, Amazon has accomplished a skyrocketing increase in its market capitalization (MC), as demonstrated in Fig. 3. It hit the US\$ 1

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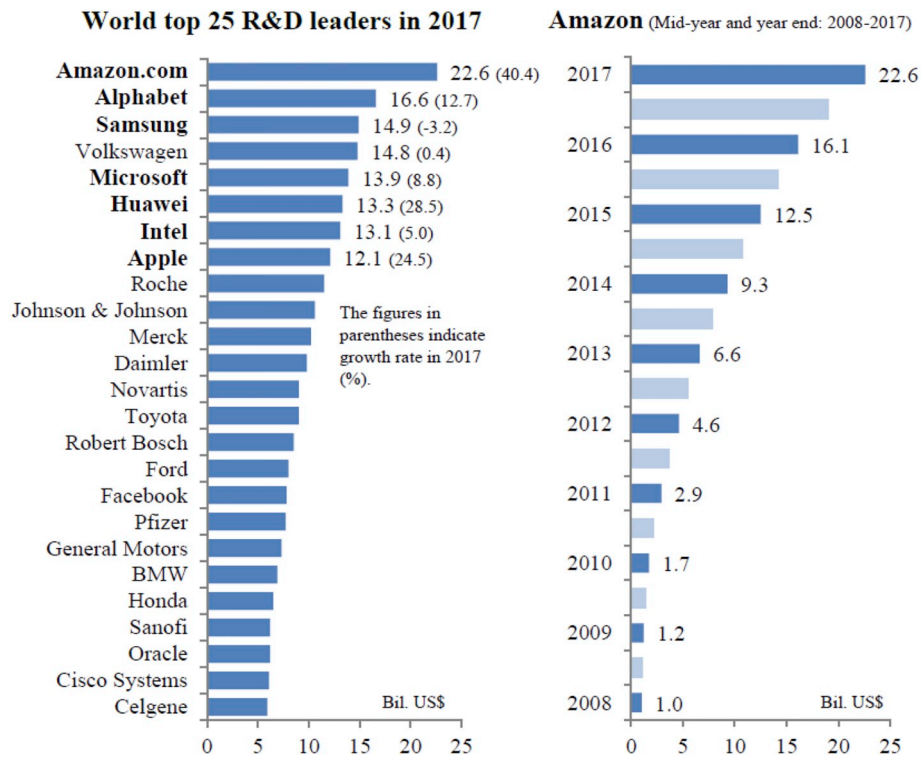


Fig. 1. Amazon's Conspicuous Jump into the Position of World's R&D Leader in 2017. Original sources: [3,4].

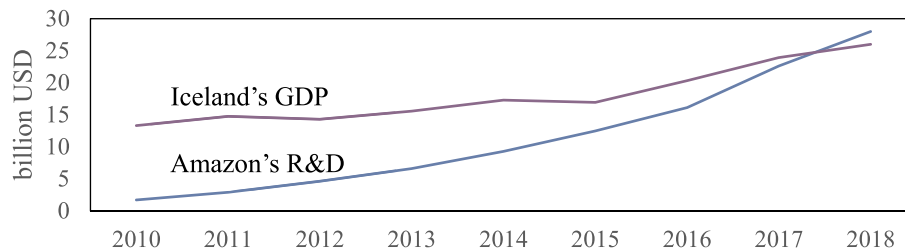


Fig. 2. Trends in Amazon's R&D investment and Iceland's GDP (2010-2018). Sources: [6]; and Quartz projection.



Fig. 3. Trend in Amazon's market capitalization (2006-2018). Source: [7].

trillion MC level in 2018. Consequently, Amazon was close to being the world's biggest Internet company in 2018, competing with Apple, as demonstrated in Fig. 4. It briefly exceeded the level of Apple in December 2018 and also in January 2019, as demonstrated in Figs. 4-2.

Recalling Amazon's conspicuous, rapid and notable increase in R&D investment, as reviewed in Fig. 1, it is naturally assumed that its skyrocketing increase in market capitalization can be attributed to its R&D investment.

However, Amazon's rapid and notable increase in R&D investment has raised two questions.

First, the definition of R&D in the digital economy. The authors have pointed out the structural change of the concept of output in the digital economy and revealed the limitation of GDP in measuring the output of the digital economy [9,10] by demonstrating the increasing dependence on uncaptured GDP [11–13]. Amazon's rapid and notable increase in its R&D investment amid the digital economy prompts the possibility of a structural change in the concept of R&D, similar to the output. Amazon insists on describing “technology and content,” not “R&D” as its “R&D investment” in its annual reports¹. This implies profound insights into the R&D model in the digital economy.

Second, there is the question of a disruptive business model that provides a reasonable solution to the dilemma between R&D expansion and productivity decline. Notwithstanding the fear of such a dilemma,

¹ In this paper comparative analysis was conducted using Amazon's expenditures for “technology and content” as its R&D investment first, and then assessed their performance for examining the validity of this treatment.

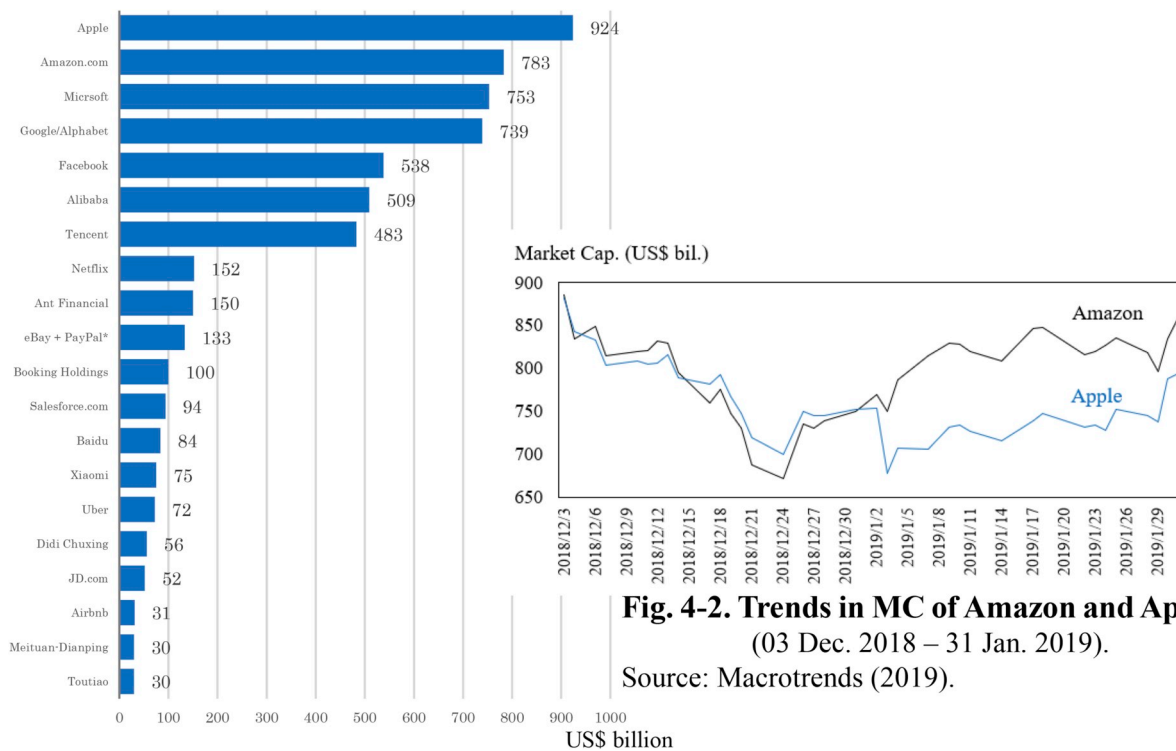


Fig. 4-2. Trends in MC of Amazon and Apple (03 Dec. 2018 – 31 Jan. 2019).
Source: Macrotrends (2019).

Fig. 4. Market capitalization of the top internet companies worldwide (as of May 2018) [68,69].
Source: [8].

Amazon has been accomplishing notable performance [14] by fully utilizing such a rapidly increasing R&D. Amazon has invested considerable resources into extremely innovative business areas, such as Amazon Web Services (AWS), Kindle, Alexa (Amazon Echo) and Amazon Go, which accelerate the exploration of the Amazon empire chain and big data collection system.

In parallel with such innovation challenges at the forefront, it endeavors to absorb soft innovation resources (SIRs)², such as sleeping and untapped resources [15], from external markets and assimilate them into its business model. This transforms “routine or periodic alterations” (classified as non-R&D in the traditional accounting standard) into “significant improvement” (similarly classified as R&D), leading to the company becoming the world’s top R&D firm.

The advancement of the Amazon empire chain and subsequent big data collection system contributes to the absorption of broad soft innovation resources. Rapid and notable R&D investment contributes to enhancing assimilation capacity.

Since these endeavors can be expected to trigger the new concept of R&D in neo open innovation, an empirical analysis of Amazon’s initiative may lead the way in revealing the significance of transformation of the R&D concept in the digital economy.

In light of Amazon’s notable business performance based on its unique business model, to date, a significant number of studies have attempted to analyze its notable performance and unique business model (e.g., [14,16,17]). In addition, given such a rapid and notable R&D increase leading Amazon to become the world’s top R&D firm in 2017 over such a short period of time, as reviewed above, a number of questions were raised about its R&D model, such as, is it really R&D or merely routine or periodic alterations (e.g., [4,18])? However, inside the black box of its unique model, much has remained unveiled. This can largely be attributed to Amazon’s secretiveness, which is part of its CEO Jeff Bezos’s policy [19]. As a matter of fact, he has himself confessed that “I have to be very choosy” [20].

Under such constraints, analyses of Amazon’s unique R&D model from the viewpoint of providing a solution to the dilemma between R&D expansion and productivity decline that the majority of global ICT firms have been confronting in the digital economy [1,2] are limited.

Some exceptions can be seen in the analyses from the viewpoints of co-emergence of innovation with its counterparts [21] demonstrated the significant effects of the collaboration with its competitors, known as co-competition. They demonstrated that, by collaborating with its competitors, Amazon has succeeded in building new capabilities, gaining better leverages and boosting its brand and technologies [22] also identified that, by making itself indispensable to e-commerce, Amazon has enjoyed receiving business from its rivals. [23]; based on O’Reilly’s postulation of the “architecture of participation” [24], demonstrated that Amazon has succeeded in deploying this architecture and has been making most of the digital technologies by harnessing the power of its users.

The authors, in their preceding studies, demonstrated the significance of the co-competition strategy in the conspicuous performance accomplished by Canon (Japan’s leading multinational corporation specializing in the manufacturing of optical products, similar to Amazon) [25,26]. Also, based on this finding, they postulated the significance of neo open innovation in the digital economy as a promising solution to such a dilemma [1,2]. Examination of this postulation, by analyzing Amazon’s R&D model as a system, is expected to shed light on the transformative direction towards a new concept of R&D in the digital economy.

Utilizing a techno-metrics approach, together with intensive literature reviews, this paper attempts to elucidate this dynamism. An empirical analysis was conducted, focusing on Amazon’s R&D performance by absorbing external innovation resources, particularly soft innovation resources, and assimilating them into its business.

Based on R&D as a culture of the company, Amazon has been encouraging companywide experimentation to make customers obsessed with making purchase decisions. This endeavor has enabled Amazon to deploy architecture for participation, which has made the most of

² See 4.3 the detailed concept of SIRs.

digital technologies by harnessing the power of its users. Such user-driven innovation accelerated the dramatic advancement of the Internet, which, in turn, accelerated co-emergence, awakening, and the inducement of soft innovation resources in the marketplace. Emerged soft innovation resources activated a self-propagating function, which induced functionality development, leading to supra-functionality beyond an economic value that satisfies a shift in customers' preferences. While this system depends on the assimilation capacity of soft innovation resources, Amazon has developed this capacity to a high level, supported by a rapid and notable increase in R&D investment. The above efforts functioned as a virtuous cycle, leading to transforming "routine or periodic alterations" into "significant improvement" during the R&D process.

These findings give rise to insightful suggestions about the new concept of R&D in neo open innovation in the digital economy.

The structure of this paper is as follows: Section 2 reviews Amazon's unique R&D model. Amazon's R&D, scope, definition, and methods of implementation are discussed in Section 3. Section 4 elucidates Amazon's R&D inducement dynamism. Section 5 summarizes the noteworthy findings, policy suggestions, and future research.

2. Amazon's unique R&D model

2.1. Amazon: R&D as a culture

Amazon has been endeavoring to be an R&D-driven company since its inception in 1994, as demonstrated in Table 1.

With such an R&D-driven innovation-seeking strategy, Amazon offered customers a lot more choice, speed, reliability and superior customer service, thereby proving its resilience against the bursting of the dotcom bubble in 2000 [27].

To better understand the origin of Amazon's R&D strategy, we can look at its founder and CEO Jeffery (Jeff) [28] letter to shareholders [28]. In the letter he stressed that:

"All the effort we put into technology might not matter that much if we kept technology off to the side in some sort of R&D department, but we don't take that approach. Technology infuses all of our teams, all of our processes, our decision-making, and our approach to innovation in each of our businesses. It is deeply integrated into everything we do." He added, *"these techniques are not idly pursued they lead directly to free cash flow."*

This quote explains the importance of R&D activities while at the same time highlighting aspects of Amazon's culture: innovation and growth are built into every segment of the company, not just R&D.

2.2. Fundamental business principle

This culture has led to Amazon establishing its fundamental business principle characterized by (i) Amazon doctrine, (ii) leadership principles, (iii) customer service philosophies, and (iv) experimentation.

Table 1

Brief chronology of Amazon's major steps to becoming an innovation giant.

1994	Founded
1997	IPO
2002	AWS envisioned
2005	Amazon Prime
2006	AWS opened to outside customers
	Amazon Elastic Computer Cloud (Amazon EC2)
2007	Amazon Kindle
2010	Migrated retail web services to AWS
2011	Kindle Fire
2014	Amazon Echo (Alexa Voice Service)
2016	Amazon Go store

2.2.1. Amazon doctrine

Amazon's business management has been conducted in a consistent and systematic way as a system for improving customer experience based on the Amazon doctrine, as was explained by Bezos in 2012 as: *"Above all else, align with customers. Win when they win. Win only when they win"* [29].

2.2.2. Leadership principles

Amazon has a unique culture of hiring and developing leaders with a focus on the following 14 leadership principles that have guided and shaped the company's decisions and its distinctive entrepreneurial culture. These Amazon leadership principles were set in stone to build a strong entrepreneurial and highly execution-based culture. Every employee is expected to adhere to these principles, and the firm tests all future hires on the same criteria (Bharti, 2015).

- (i) customer obsession; (ii) ownership; (iii) invent and simplify; (iv) be right a lot; (v) learn and be curious; (vi) hire and develop the best; (vii) insist on the highest standards; (viii) think big; (ix) bias for action; (x) frugality; (xi) earn trust; (xii) dive deep; (xiii) have backbone, disagree and commit; and (xiv) deliver results [30].

2.2.3. Customer service philosophies

As has been clearly explained in his doctrine and also stressed in the top 14 of leadership principles, Amazon is eager to receive consumer feedback, and Bezos has spread customers' focus as a mantra throughout the organization [27]. He has taken the philosophy of truly caring for the customer and ushered it into the digital era. He has built a company from the ground up purely based on the unbending, unyielding philosophy of serving the customer across all departments.

Such customer service philosophies have been realized in the top ranking of customer satisfaction, as demonstrated in Table 2.

Table 2 compares trends in customer satisfaction with Internet retail business in the US over the period from 2000 to 2017. Looking at Table 2 we note that Amazon's Internet retail maintains the top customer satisfaction level over the whole period (except in 2004 and 2006, when book-selling company Barnes & Noble slightly exceeded Amazon's satisfaction level).

2.2.4. Experimentation

Experimentation has been playing a crucial role in Amazon's business deployment. Bezos has encouraged experimentation by stressing that, *"Experiments are key to innovation because they rarely turn out as you expect and you learn so much."* Innovators like Bezos see the world as a laboratory [32].

At Amazon, experimentation is always occurring, initiated by employees in broad fields throughout the company, and ideas are constantly being presented to Bezos, leading to satisfying the first leadership principle: *Customer obsession*. Motivated employees understand that these ideas are going to be altered in many ways [33].

Bezos, in his 2013 letter to shareholders [34], stressed that:

"Innovation comes from distributed decision-making. Top-down teams are effective at optimizing existing processes and enforcing the completion of work, but only decentralized, bottom-up teams can consistently generate new ideas."

He realizes that, *"We don't make money when we sell things. We make money when we help customers make purchase decisions"* [20]. Amazon's CEO is always attempting experiments to make customers to be obsessed with making the purchase decision.

2.3. Resource allocation strategy

Most of Amazon's profits come from its high-tech division, such as its cloud computing operation and AWS. These profits have been reinvested in its business and employees, not in dividends and buybacks. Amazon has not paid a dividend since its initial public offering (IPO) in

Table 2
Amazon's position in customer satisfaction in the US (2000-2017).
 Source: American Customer Satisfaction Index [31].

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Amazon	84	84	88	88	84	87	87	88	86	86	87	86	85	88	86	83	86	85
Newegg	-	-	-	-	-	-	-	87	88	86	84	85	84	83	81	79	83	83
Internet Retail	78	77	83	84	80	81	83	83	82	83	80	81	82	78	82	80	83	82
Overstock	-	-	-	-	-	-	-	80	82	82	83	83	81	79	77	73	79	81
eBay	80	82	82	84	80	81	80	81	78	79	81	81	83	80	79	75	81	81
All Others	77	75	82	83	79	80	82	82	82	83	78	80	82	75	81	80	82	81
barnesandnoble.com	77	82	87	86	87	87	88	-	-	-	-	-	-	-	-	-	-	-
1-800-flowers.com	69	76	78	76	79	77	77	-	-	-	-	-	-	-	-	-	-	-
uBid.com	67	69	70	73	73	73	74	-	-	-	-	-	-	-	-	-	-	-
Netflix	-	-	-	-	-	-	-	84	85	87	86	74	75	79	81	76	79	-

Note: Figures in the table indicate scores of customer satisfaction: - indicates not measured; All Others represents the remainder of the total industry market share, less the market shares of the ACSI-measured companies.

1997, nor has it done any buybacks of its shares since 2012. That strategy is reflected in spending on research and development activities, which has led to Amazon becoming the world's top R&D firm over a short period of time.

2.4. Basic model for R&D

Notwithstanding a rapid and notable increase in expenses for business activities generally described as “R&D,” based on its basic principle for customer service, Amazon insists on describing them as “technology and content” in its annual report [35].

Amazon has invested considerable resources in extremely innovative business areas such as AWS, Kindle, Alexa and Amazon Go.

In parallel with such forefront innovation, Amazon is endeavoring to absorb soft innovation resources (SIRs) from external markets and assimilate them into its business model, which transforms “routine or periodic alterations” business activities into “significant improvement” ones as reviewed earlier.

This transformation depends on its high level of assimilation capacity, which can be attributed to the rapid and notable increase in its R&D investment, and also to the absorption of broad soft innovation resources based on the Amazon empire chain and big data collection system, together with the deployment of architecture for participation that harnesses the power of its users [23].

2.5. R&D structure

2.5.1. Scope

Amazon has been encompassing a broad area of activities such as research, design, development, and maintenance of both new and existing products and services in its “technology and content” business activities. It accomplishes these activities in such broad scope simultaneously with the principle that its business should not be managed by separating activities by type, as classified in the traditional accounting standard.

2.5.2. Costs

Costs for “technology and content” activities consist primarily of expenses for employees and infrastructure costs as follows:

(i) Expenses for employees

Payroll and expenses for employees involved in the research and development of new and existing products and services, development, design, and maintenance of its websites, curation, and display of products and services made available on its websites.

(ii) Infrastructure costs

Servers, networking equipment, and data center-related depreciation, rent, utilities, and other expenses necessary to support AWS, as well as other efforts.

2.5.3. Management policy

Its management has been conducted in a consistent and systematic way by improving customer experience based on the Amazon doctrine, explained by Bezos in 2012, as described earlier.

(i) Basic philosophy

Manage these costs for “technology and content” activities collectively, as investments being made on behalf of its customers to improve their experiences.

(ii) Operation policy

Manage the total investment in its employees and infrastructure across all its products and services, not separating activities by type as classified in the traditional accounting standard, as mentioned above.

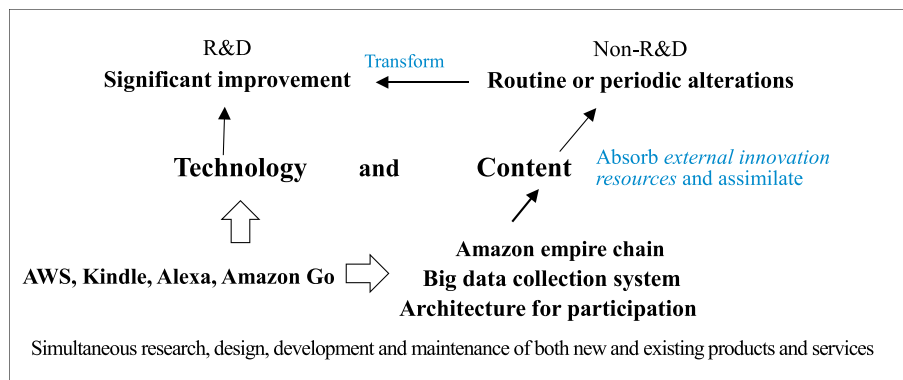


Fig. 5. Scheme of Amazon's unique R&D model.

Table 3
Comparison of R&D investment description between Amazon and Apple (2017).

Category	Description
Amazon	Technology and content
Apple	Research and development

2.6. R&D inducement dynamism

Amazon's business model and its endeavors to be at the frontier of innovation challenge, such as AWS, Kindle, Alexa and Amazon Go, have developed its growing empire, and also the subsequent big data collection system, as well as the architecture for participation.

These chain, system, and the architecture have enabled Amazon to absorb external innovation resources extensively and assimilate them into its indigenous business model. This assimilation has transformed "routine or periodic alterations" activities into "significant improvement" activities, as illustrated in Fig. 5.

3. Amazon's R&D

3.1. Description of R&D investment

Amazon has been pursuing identical innovation endeavor by insisting on describing its business activities, which are generally considered to be R&D investment, as "technology and content." Table 3 compares this concept with R&D conducted by Apple.

Sources: Amazon.Com, Inc. 2017 annual report (2018a) [35]. Apple Inc. 2017 annual report (2018) [67].

Similar to other ICT leaders, while Apple has been stressing the significance of continued R&D, licensing and mergers and acquisitions (M&A) for ensuring a continual and timely flow of competitive products, services and technologies to the marketplace, Amazon has been insisting on collective securement and management of costs for broad areas of employees (involved in the research and development of new and existing products and services, development, design, and maintenance of AWS, curation and display of products and services made available on AWS) and infrastructure (including servers, networking equipment, and data center-related depreciation, rent, utilities, and other expenses necessary to support AWS) for offering a wide variety of products and services to its customers.

3.2. The significance of technology and product concept – debate with the Securities and Exchange Commission

Amazon's profound implications on its unique R&D model is unveiled by a series of letters that the US Securities and Exchange Commission (SEC) sent to Amazon executives during the fall and winter of 2017-18 and released to the public in April 2018, the SEC urged Amazon to disclose its R&D spending as other companies do [15] ³.

3.2.1. SEC (27 Sep. 2017)

Tell us and disclose in future filings the total amount of research and development costs charged to expense for each year presented in the consolidated statements of operations as required by ASC (Accounting Standards Codification).

3.2.2. Amazon (26 Oct. 2017)

Our business model encourages simultaneous research, design, development, and maintenance of both new and existing products and services. For example, our teams are constantly working to build new Alexa skills and simultaneously maintain current skills, and these activities are within a continuum of those described in ASC 730-10-55-1 and 2 (see below) and are not easily distinguishable operationally.

3.2.3. SEC (24 Nov. 2017)

Disclose the total amount of research and development costs charged to expense for each year presented in the consolidated statements of operations as required by ASC 730-10-55-1.

3.2.4. Amazon (21 Dec. 2017)

Because of our relentless focus on innovation and customer obsession, we do not manage our business by separating activities of the type that under ASC 730-10-55-1 are "typically ... considered" research and

³In light of the vast amounts of money coming and going from particular segments of ICT giants such as Google's YouTube and Amazon's AWS and Alexa, the SEC has paid special attention to Amazon's allocation of R&D spending.

development from our other activities that are directed at ongoing innovation and enhancements to our innovations. Instead, we manage the total investment in our employees and infrastructure across all our product and service offerings, rather than viewing it as related to a particular product or service; we view and manage these costs collectively as investments being made on behalf of our customers to improve the customer experience. We believe this approach to managing our business is different from the concept of planned and focused projects with specific objectives that were contemplated when the accounting standards for research and development were developed under FAS 2 (Financial Accounting Standards). Given the significant breadth of projects and improvements that we have underway, our employees routinely work concurrently on multiple projects, including projects that could be defined as research and development in nature and also more routine, ongoing activities to refine, enrich, or otherwise improve or adapt our existing products and services. Similarly, our activities may focus on developing new products and services, but these activities often result, in whole or in part, in enhancements to existing products and services.

3.2.5. SEC (22 Jan. 2018)

If you are unable to identify or estimate research and development costs, explain in detail the reasons for your inability.

3.2.6. Amazon (16 Feb. 2018)

In reassessing this conclusion in response to your comment, we discussed with our investor relations department whether quantifying traditional research and development costs within the scope of ASC 730-10-55-1 would be meaningful or useful for investors, and we also reviewed our earnings call transcripts for the past three years to see whether investors ask questions about research and development costs within the scope of ASC 730-10-55-1. These discussions and review reaffirmed that such costs are not material for two reasons. First, as discussed above, because of the range of innovation activities we undertake to support the hundreds of millions of different products and services that we offer, aggregate research and development cost data would not indicate any particular area of activity and would not reveal trends with regard to development efforts that are material to an understanding of our business. Second, we believe that distinguishing between costs attributable to activities of the type described in ASC 730-10-55-1 and those attributable to activities described in ASC 730-10-55-2 would be confusing and misleading to investors, as the resulting disclosures would not fairly present the investments we make in order to offer a wide variety of products and services to our customers.

3.2.7. SEC (9 Mar. 2018)

We have completed our review of your filing. We remind you that the company and its management are responsible for the accuracy and adequacy of their disclosures, notwithstanding any review, comments, action or absence of action by the staff.

3.3. Amazon's claims to the traditional R&D definition

The US generally accepted accounting principles (GAAP) provided by FASB-ASC⁴ illustrates activities typically included and excluded from R&D by defining Research & Development [36].⁵ While the former

⁴The Accounting Standards Codification (ASC) of the Financial Accounting Standards Board (FASB).

⁵**Research** is a planned search or critical investigation aimed at discovery of new knowledge with the hope that such knowledge will be useful in developing a new product or service (hereinafter "product") or a new process or technique (hereinafter "process") or in bringing about a significant improvement to an existing product or process. **Development** is the translation of research findings or other knowledge into a plan or design for a new product or process or for a significant improvement to an existing product or process, whether intended for sale or use. It includes the conceptual formulation, design, and testing of product alternatives, construction of prototypes, and operation of pilot plants.

activities correspond to those of contributing to significant improvement, the latter activities contribute only to routine or periodic alterations (see the details of the illustration in Appendix 1).

Amazon claims that the boundary between the two types of activities has been blurring in the digital economy, and also that it is difficult to separate them, as its R&D activities are implemented in such a way as simultaneous research, design, development, and maintenance of both new and existing products and services occur in a holistic business operation. Also, Amazon's R&D has been conducted in transforming routine or periodic alterations into significant improvement during the R&D process as it absorbs soft innovation resources from external environments and assimilates them into its routine or periodic alterations activities, leading to the transformation of these activities into activities that lead to significant improvement.

4. Amazon's R&D inducement dynamism

4.1. Exponential increase in R&D triggered by AWS-based services

Amazon's business model and endeavors to be at the frontier of innovation challenge in AWS, Kindle, Alexa and Amazon Go develop its growing empire, fusing the physical and the digital toward "selling anything that can be sold online" and also the subsequent big data collection system, as demonstrated in Fig. 6.

It should not be overlooked that the smooth establishment of such a system can also be attributed to its intensive lobbying efforts, as the Amazon empire has been enabled by breaking through traditional regulations and the protection of existing industries. This breakthrough accelerates the blurring of the boundary between the two types of activities reviewed in the preceding section. Fig. 7 demonstrates trends in lobbying intensity to White House offices, legislative entity, and other executive entities in the period 2000-2017. Fig. 7 demonstrates clearly how Amazon deployed intensive lobbying efforts in undertaking new services, such as AmazonFresh grocery delivery in 2007, Sunday delivery in partnership with the Postal Service in 2012, drone delivery in 2013, and cloud services procurement with military significance in 2016.

Expenditure for such lobbying efforts has increased dramatically from the beginning of the second decade of this century, amounting to more than double the similar expenditure initiated by Apple, as demonstrated in Fig. 8.

From November 2010 all Amazon's retail web services have been transformed into AWS-based services by migrating to AWS [38]. This transformation has leveraged a dramatic increase in R&D (expenses on technology and content) aiming at offering a wide variety of products and services to its customers. Its R&D exceeded that of Apple from 2011 and triggered its lead, as demonstrated in Fig. 9. Since then Amazon has transformed into a highly R&D-intensive firm, as demonstrated by the notable increase in its R&D intensity (ratio between R&D and sales), as demonstrated in Fig. 10. While an increase in R&D contributes to an increase in sales, which increases profits, Amazon reinvests such profits to R&D based on its resource allocation strategy, as reviewed earlier.

Consequently, Amazon's R&D intensity has continued to increase since 2010, whereas this intensity was not time-dependent before 2009, as demonstrated in Table 4.

where t : time trend, D_1 : 2000-2009 = 1, other years = 0; D_2 : 2010-2017 = 1, other years = 0).

The figures in parentheses indicate t-statistics: All are significant at the 1% level, except * is not significant.

Table 4 demonstrates that R/S has increased exponentially since 2010, whereas this intensity was not time-dependent before 2009.

Consequently, above transformation into AWS-based services in 2010 has triggered extremely high-level R&D intensity (higher than double that of Apple's intensity level), as compared in Table 5.

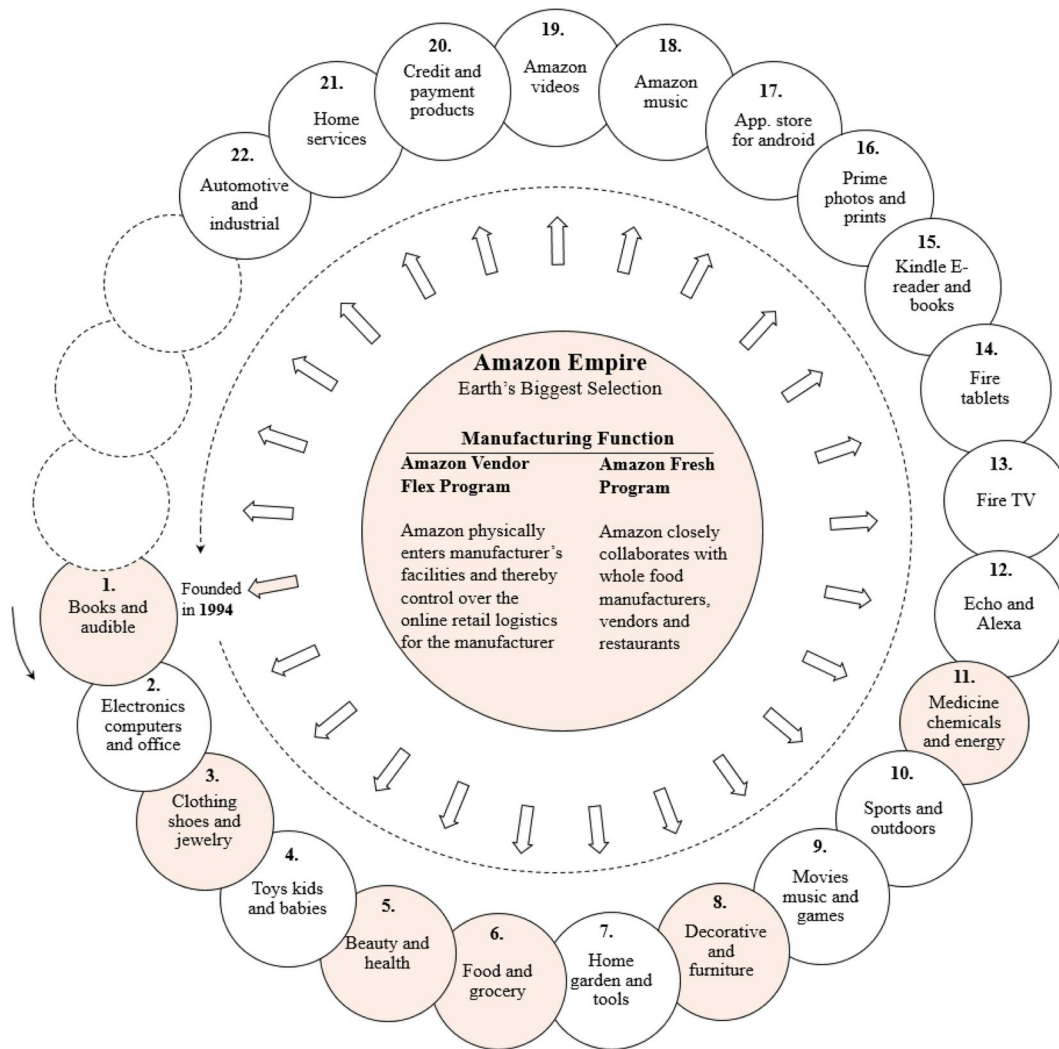


Fig. 6. Amazon's growing empire by final product category. Source: Watanabe et al. (2018a) [70].

4.2. User-driven innovation induced by R&D-driven business model

Such a spiraling increase in Amazon's R&D has enabled Amazon to offer a wide variety of products and services to its customers, corresponding to its very first leadership principle: *Customer obsession* as reviewed in 3.1.

This accomplishment is evidenced by the high level of its stock prices, as demonstrated in Fig. 11 and Table 6. This high level of prices has led to the skyrocketing increase in Amazon's market capitalization, as reviewed earlier in Figs. 3 and 4. where *ST*: stock prices, *S*: sales, *OI*: operating income, *R*: R&D expenditure, *OCF*: operating cash flow.

Translog (transcendental logarithmic) expansion on the first term:

$$\ln ST = A + a \ln S + b \ln OI + c \ln R + d \ln OCF$$

Regression analysis by backward elimination method at 20% significance level identifies.

$\ln ST = A + b \ln OI + c \ln R$ in both firms examined as the affluence of *OCF* can be appraised by *OI* and future prospects of these firms can be demonstrated by *R*, rather than *S* growth.

Table 6 demonstrates that Amazon largely depends on R&D for offering a wide variety of products and services to its customers, but not

significantly on operating income (*OI*) in its stock prices formation, while Apple depends on both *OI* and R&D aiming at improving its developed hardware and software every year. This analysis supports the postulation that Amazon has provided qualified multi-functional products and services to its customers, corresponding to its first leadership principle (*customer obsession*), using an R&D-driven business model.

The offering of such a wide variety of products and services, in turn, has induced user-driven innovation, typically observed in the invention of the Kindle [41]. The Kindle tablet came into existence defined purely by customers' desires rather than engineers' preferences (Baldacci, 2014).

Above contrast in R&D model between Amazon and Apple can be highlighted by comparing their development trajectories of focal inventions as AWS – Kindle – Alexa -Amazon Echo in Amazon, and PC – iPod – iPhone – iPad - HomePod in Apple. Fig. 12 compares development trajectories of these core inventions in two firms.

Fig. 12 highlights identity of Amazon's R&D-driven business model by contrasting with that of Apple focusing on their core inventions as summarized in Table 7.

Such multi-functional products/services for new experiences to customers oriented business model has enabled Amazon to absorb

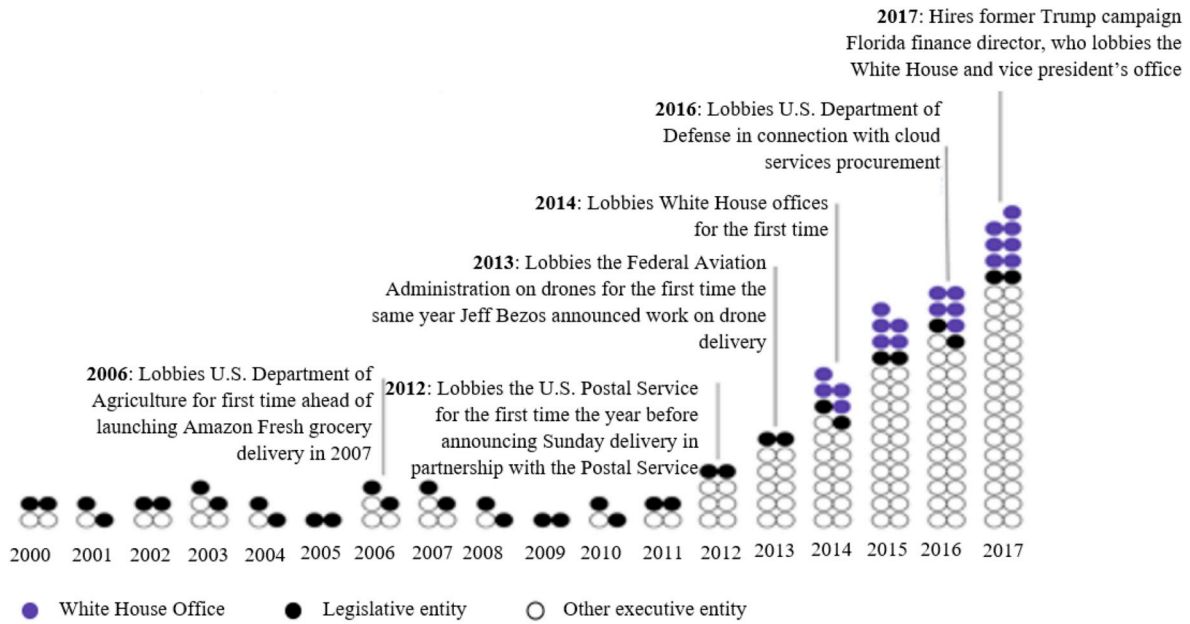


Fig. 7. Trend in Amazon's lobbying intensity (2000-2017). Source: [37].

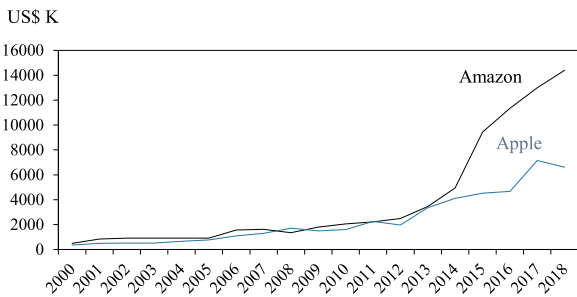


Fig. 8. The trend in expenditure for lobbying at amazon and apple (2000-2017). Source: [37].

external resources extensively and assimilate them into its indigenous business. Amazon has deployed the “architecture of participation,” thus making the most of digital technologies by harnessing the power of its users to create even more value [23], as illustrated in Fig. 13. “Architecture of participation” was postulated by [24]; and implies that users help to extend the platform.

Amazon's deployment of this strategy is quite similar to that of Canon, known as a cooptation strategy [42]. This strategy harnesses

the vigor of mobile phone development in the consumer market leveraged by users, based on cooptation between Canon's printers, developed based on its own learning, and personal computers (PCs) developed by its rival firms [26], as illustrated in Fig. 14.

[21] demonstrated the significant effects of Amazon's cooptation. They demonstrated that, by collaborating with its competitors, Amazon has succeeded in building new capabilities, gaining better levers and boosting its brand and technologies.

[43] also demonstrated Amazon's strategic action for cooptation. They stressed that Amazon seized the strategic opportunities presented by the successive wave of disruption, ruthlessly cannibalizing its own business where necessary.

e-books were inevitable, so Amazon launched the Kindle, to which customer information and scale in data processing are critical, so it sold cloud services to its competitors. Unlike many of his rivals, Bezos saw business architecture as strategically valuable, not a given. He did not harness technology to the imperatives of his business model; rather, he adapted his business model to the possibilities of technology.

Like its willingness to sustain losses, this feature of Amazon's power largely confounds contemporary antitrust analysis, which assumes that rational firms seek to drive their rivals out of business. Amazon's game is more sophisticated. By making itself indispensable to e-commerce, Amazon enjoys receiving business from its rivals, even as it competes with them [22].

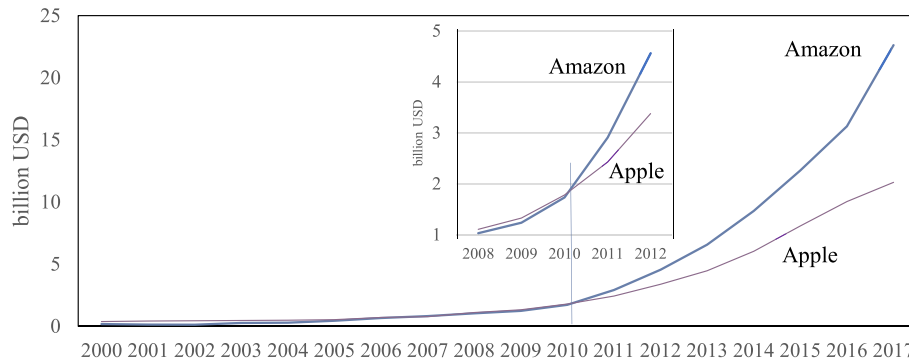


Fig. 9. The trends in R&D investment at amazon and apple (2008-2017). Sources: Amazon.Com, Inc. 2017 annual report (2018a) [35]. Apple Inc. 2017 annual report (2018) [67].

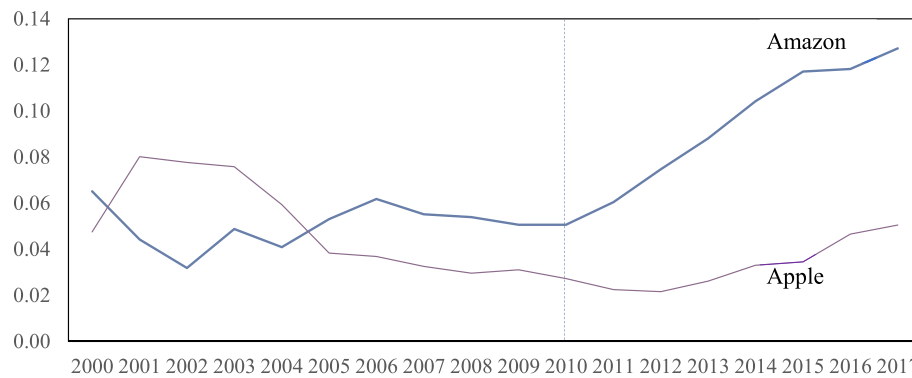


Fig. 10. The trends in R&D intensity at amazon and apple (2000-2017).

Sources: Amazon.Com, Inc. 2017 annual report (2018a) [35]. Apple Inc. 2017 annual report (2018) [67].

Table 4
Time dependency on Amazon's R&D intensity (2000-2017).

$\ln R/S = -273.47 + 0.017 D_1 t + 0.135 D_2 t + 236.38 D_1$				adj. R^2 0.846	DW 1.51
(-5.13)	(0.90)*	(5.09)	(3.62)		

Table 5
Comparison of trends in key managerial factors between amazon and apple (2000-2017).

Sources: Amazon.Com, Inc. 2017 annual report (2018a) [35]. Apple Inc. 2017 annual report (2018) [67].

Amazon							Apple						
year	Sales	OI	R	OI/S	R/S	OI/R	Sales	OI	R	OI/S	R/S	OI/R	
2000	2762	-864	180	-0.31	0.07	-4.80	7983	522	380	0.07	0.05	1.37	
2001	3122	-412	138	-0.13	0.04	-2.98	5363	-344	430	-0.06	0.08	-0.80	
2002	3933	64	125	0.02	0.03	0.51	5742	17	446	0.00	0.08	0.04	
2003	5264	270	257	0.05	0.05	1.05	6207	-1	471	0.00	0.08	0.00	
2004	6921	440	283	0.06	0.04	1.55	8279	326	491	0.04	0.06	0.66	
2005	8490	432	451	0.05	0.05	0.96	13931	1643	535	0.12	0.04	3.07	
2006	10711	389	662	0.04	0.06	0.59	19315	2453	712	0.13	0.04	3.45	
2007	14835	655	818	0.04	0.06	0.80	24006	4409	782	0.18	0.03	5.64	
2008	19166	842	1033	0.04	0.05	0.82	37491	8327	1109	0.22	0.03	7.51	
2009	24509	1129	1240	0.05	0.05	0.91	42905	11740	1333	0.27	0.03	8.81	
2010	34204	1406	1734	0.04	0.05	0.81	65225	18385	1782	0.28	0.03	10.32	
2011	48077	862	2909	0.02	0.06	0.30	108249	33790	2429	0.31	0.02	13.91	
2012	61093	676	4564	0.01	0.07	0.15	156508	55241	3381	0.35	0.02	16.34	
2013	74452	745	6565	0.01	0.09	0.11	170910	48999	4475	0.29	0.03	10.95	
2014	88988	178	9275	0.00	0.10	0.02	182795	52503	6041	0.29	0.03	8.69	
2015	107006	2233	12540	0.02	0.12	0.18	233715	71230	8067	0.30	0.03	8.83	
2016	135987	4186	16085	0.03	0.12	0.26	215639	60024	10045	0.28	0.05	5.98	
2017	177866	4106	22620	0.02	0.13	0.18	229234	61344	11581	0.27	0.05	5.30	

S: Sales, OI: Operating income, R: R&D expenditure. All US\$ billion at current prices.

4.3. Neo open innovation activating a self-propagating function

User-driven innovation based on architecture of participation accelerates the dramatic advancement of the Internet, as O-Reilly's postulate of architecture of participation is a Web 2.0 concept in which a community of users contributes to the content or to the design and development process. Advancement of the Internet, in turn, accelerates co-emergence, awakening and inducement of soft innovation resources (SIRs) in the marketplace as illustrated in Fig. 15 [2,45]. Thus, co-evolutionary co-emergence of user-driven innovation and emergence of SIRs can be expected. Here, SIRs are considered as a condensate and crystal of the advancement of the Internet and consist of the Internet based resources that have been either sleeping or untapped or are results of multisided interaction in the markets where consumer is looking for functionality beyond an economic value. The common feature of SIRs is that they are not accountable in the traditional GDP terms [1,2].

The authors in previous studies stressed the significance of

increasing dependence on uncaptured GDP⁶ by postulating that the Internet promotes a free culture that provides utility and happiness to people but cannot be captured through GDP. This added value of providing people with utility and happiness, which extends beyond economic value, is defined as uncaptured GDP [11,12].

The shift in people's preferences from the economic value to the

supra-functionality beyond an economic value (encompassing social, cultural, and emotional values)⁷ induces the further advancement of the Internet, which intensifies the increasing dependence on uncaptured GDP. User-driven innovation further accelerates this inducement.

Thus, spinoff from co-evolution among traditional ICT, captured GDP, and economic functionality to new co-evolution among the

⁶ The Internet promotes a free culture that provides utility (satisfaction of consumption) and happiness to people through its consumption but this culture cannot be captured through GDP data which measure revenue. Such utility and happiness constituted uncaptured GDP. This can be defined as added value that provides utility and happiness beyond economic value to people but cannot be measured by traditional GDP accounts (captured GDP) which measure economic value.

⁷ Supra-functionality beyond economic value illustrates peoples' shifting preferences which encompass 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., perception value, five senses) values [66].

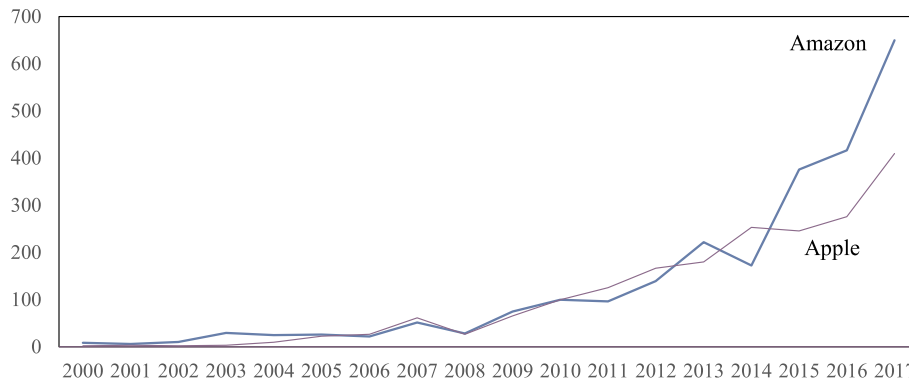


Fig. 11. The Trend in Stock Prices in Amazon and Apple (2000-2017) - Index: 2010 = 100. * Stock prices indicate the closing price of each year. Sources: [39,40].

Table 6
Governing factors of stock prices in amazon and apple (2000-2017).

	$\ln ST = A + b \ln OI + c \ln R$				
	A	b	c	adj. R ²	DW
Amazon	-1.035 (-2.22)**	0.161 (1.63)***	0.657 (9.77)*	0.942	2.13
Apple	-4.503 (-5.10)*	0.433 (4.37)*	0.501 (2.49)**	0.917	1.61

The figures in parentheses indicate t-statistics. *, ** and *** are significant at the 1%, 5% and 10% level, respectively.

Note: $ST = F(S, OI, R, OCF)$.

advancement of the Internet, the increasing dependence on uncaptured GDP, and people's shifting preferences to beyond an economic value has been accelerated as illustrated in the upper double circle in Fig. 15 [11-13,46].

Under such a transforming circumstance, highly R&D intensive economies have been confronting a dilemma [2,9,10,45]. While they are satisfying people's shifting preferences of supra-functionality beyond an economic value, their economic productivity has been declining as R&D (centered on the advancement of the Internet) increases which is essential to satisfy economic functionality. Amazon cannot be an exception.

Solution to this critical dilemma can be expected by the hybrid role of SIRs [1,2].

Use of SIRs is a novel innovation mode applied in the highly

digitalized ICT firms. The authors in previous studies described this hypothetical view [46] and identified that while such a transformative circumstance in the digital economy results in productivity decline, global ICT firms endeavor to survive by spontaneous creation of uncaptured GDP by harnessing the vigor of SIRs [10]. Amazon's endeavor is one of the typical case.

One more finding from the authors' previous study is important background to the analysis described in this paper. It has been demonstrated that SIRs function to the removal of structural impediments of GDP growth such as conflict between public, employers and labor union, disparity of gender, and also increasing discrepancy toward an aging society. Thus, spontaneous creation of uncaptured GDP through effective utilization of SIRs contributes to resurgence of captured GDP growth by its hybrid function as illustrated in the lower part of Fig. 14 [10,47].

Fig. 15 demonstrates that SIRs awake and activate latent self-propagating function indigenous to ICT (see the detailed dynamism in Fig. A1 in the Appendix 2). This activation induces functionality development leading to supra-functionality beyond an economic value that corresponds to people's shift in preferences. Furthermore, SIRs contribute to resurge captured GDP growth by removing structural impediments in this growth. Since supra-functionality accelerates co-evolutionary innovation among this functionality, the advancement of the Internet, and uncaptured GDP dependence, SIRs function hybrid role in balanced advancement of both captured and uncaptured GDP.

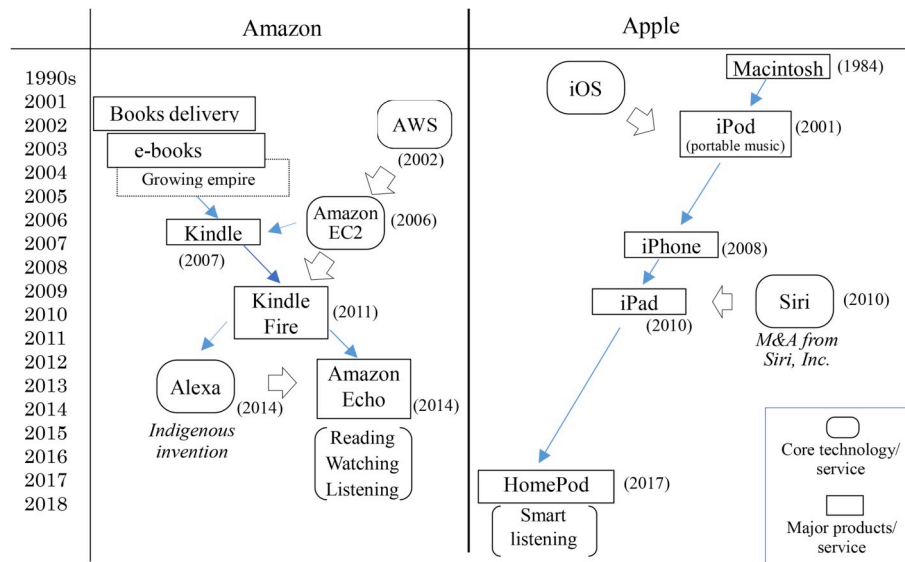


Fig. 12. Comparison of Development Trajectories in Amazon and Apple focusing on Core Inventions.

Table 7
Identity of Business Model in Amazon and Apple focusing on R&D.

Amazon	Apple
Multi-functional products/services	High-functional products/services
Not fixated on a tightly designed ecosystem of interlocking apps and services	Tightly designed ecosystem
Provide new experiences to customers	Provide best experiences to customers
Hardware/software are less capable but the most suitable/fastest services	Improve hardware/software every year
Much more attainable	More expensive
Explore new types of customers via AWS	Rely on creating additional value from existing customers

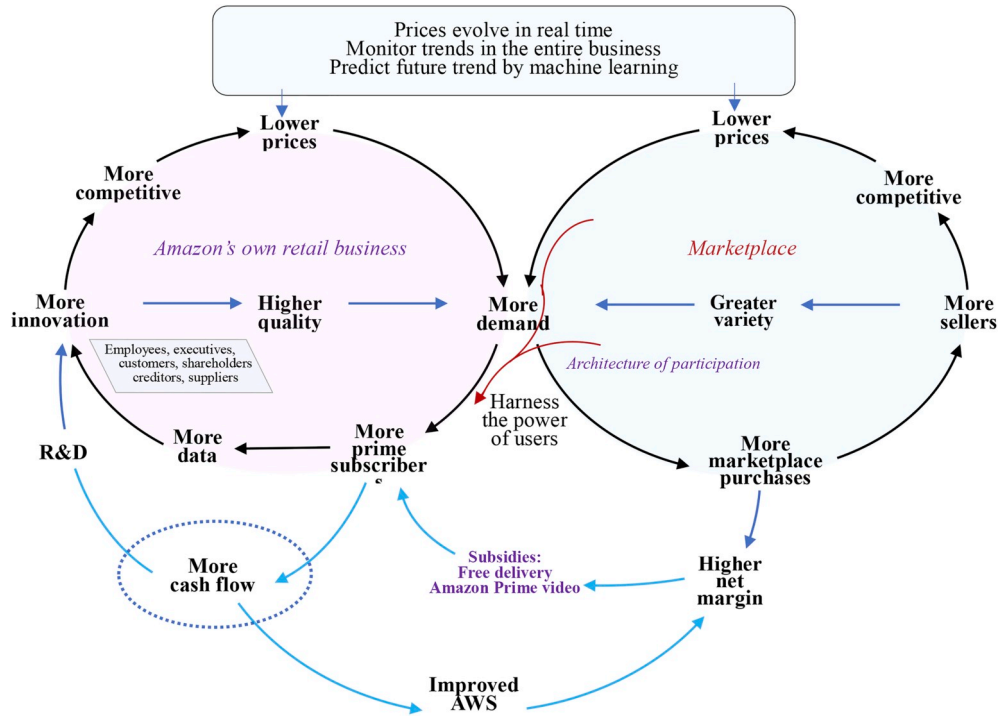


Fig. 13. The dynamism of amazon in harnessing the power of users.
Source: Authors' elaboration based on [23].

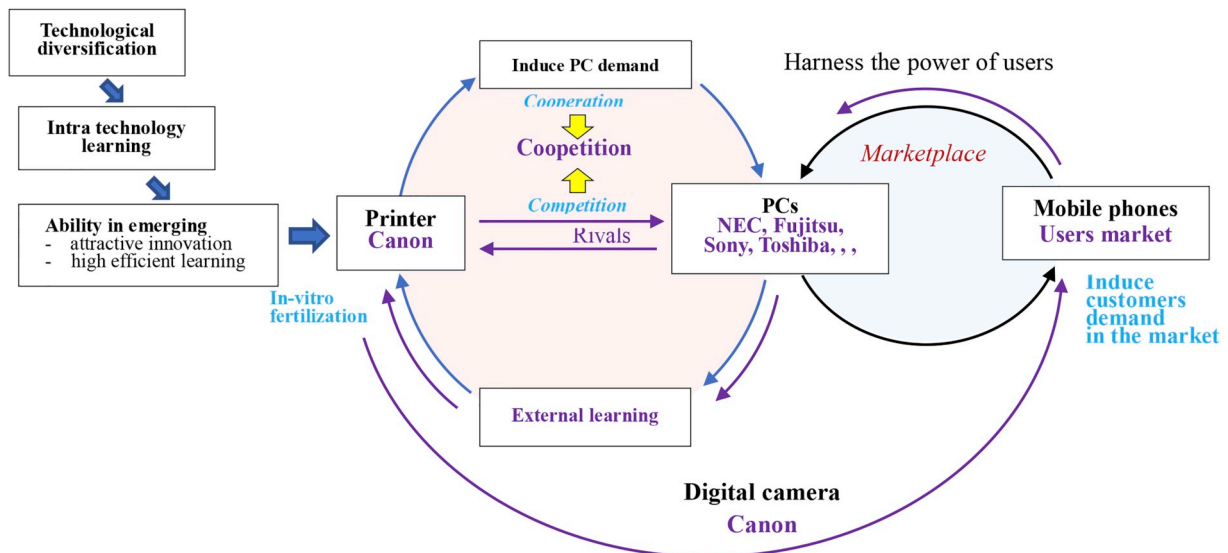


Fig. 14. The dynamism of canon in Co-emerging innovation by harnessing the power of users.
Source: Watanabe (2011).

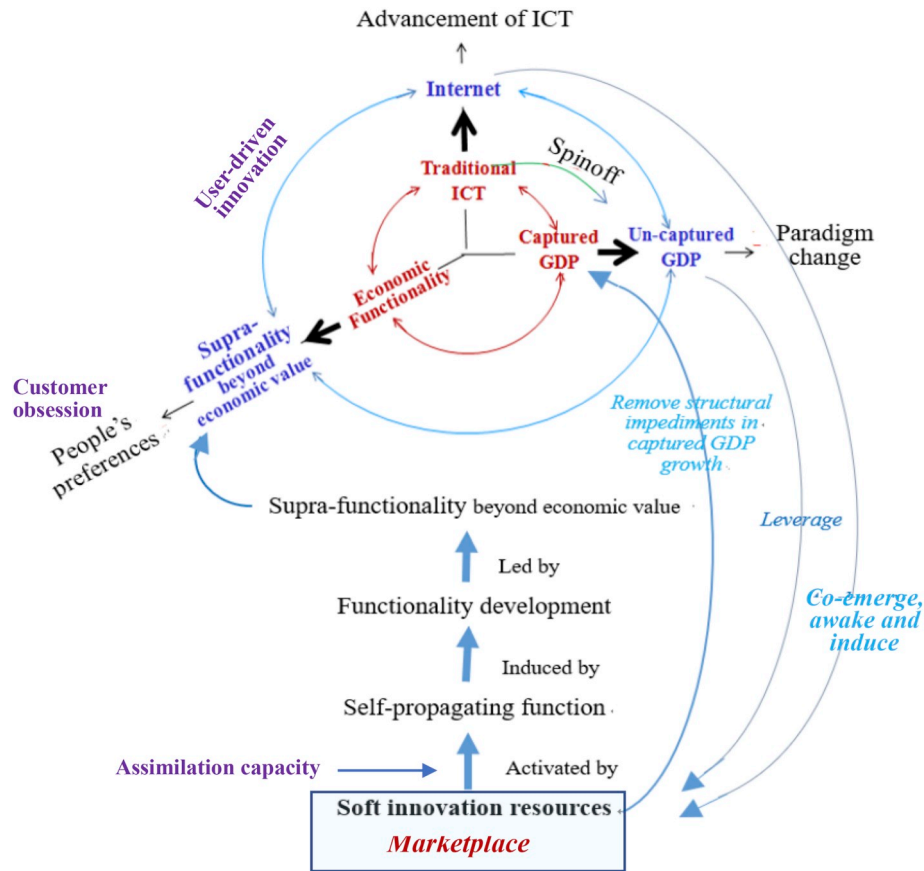


Fig. 15. Dynamism in Transforming Amazon into an R&D-driven Business Model. Original source: [44].

4.4. Assimilation of soft innovation resources

Given that emerged SIRs can be well assimilated in the business, these resources activate a self-propagating function which induces functionality development leading to supra-functionality beyond an economic value that satisfies customer's preferences shift without confronting the dilemma between R&D expansion and productivity decline (see the details of this dynamism in Appendix 2).

Therefore, assimilation capacity of SIRs plays a critical role in corresponding to customer's demand: customer obsession for Amazon. Amazon has developed a high level of this capacity as demonstrated in Fig. 16.

Fig. 17 outlines a scheme of measuring dynamic assimilation capacity which demonstrates that Amazon's high level of assimilation

capacity largely depends on its rapid and notable increase in R&D investment (high level of $\frac{\Delta T_i}{T_i}$ much higher than $\frac{\Delta T_s}{T_s}$ and subsequent high level of $\frac{T_i}{T_s}$).

Recalling SIRs unique role in removing structural impediments in growth as reviewed earlier, Amazon has effectively utilizes SIRs for transforming “routine or periodic alterations” into “significant improvement” during the R&D process by removing structural impediments in the former's transformation.

4.5. Enablers of transformation

The above business model has enabled Amazon to absorb external resources extensively through the Amazon empire chain, big data

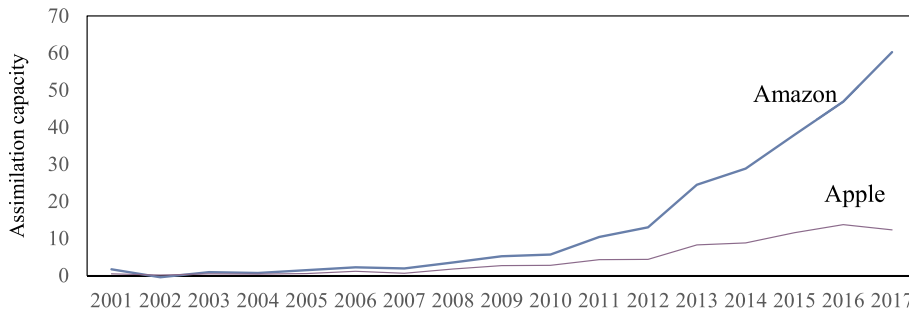
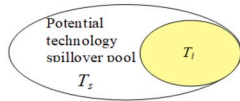


Fig. 16. The trend in assimilation capacity in amazon and apple (2001-2017).

Note: Based on the measurement scheme, illustrated as below, where T_i and T_s are used by R and Internet dependence (ID) in the US as proxies, respectively. R and ID are index (2000 = 100).

Assimilation capacity

$$z = \frac{1}{1 + \frac{\Delta T_s}{T_s} / \frac{\Delta T_i}{T_i}} \cdot \frac{T_i}{T_s}$$



$$T_i \approx \frac{R_i}{\rho + g} \approx \frac{R_i}{H}$$

R_i: R&D
ρ: rate of obsolescence of technology (Watanabe et al., 2018b)
g: R&D at initial stage
H: constant

$$T_s = F(ID)$$

ID: Internet dependence (Tou et al., 2018)

$$T_s = \sum_{j=i}^n T_j$$

T_i: indigenous technology stock

T_s: Technology spillover pool

Fig. 17. Scheme of measuring dynamic carrying capacity. Source: [48].

collection system and architecture for participation, and assimilate them into its business.

Given that this model deploys a full-fledged function, it may transform “routine or periodic alterations” (traditionally classified as non-R&D) into “significant improvement” (classified as R&D). Amazon declares that its activities may focus on developing new products and services, but these activities often result, in whole or in part, in enhancements to existing products and services. Web service has imposed a virtuous pressure that has incentivized everyone to improve reliability and performance [23].

Such a pressure leverages Amazon to maintain its strong points, such as having excellent customer service and ensuring complete customer satisfaction through such “Species survival and evolution systems” as. (i) Consistent innovation by means of (a) a peer review system, (b) easy checkouts, (c) user-tailored suggested products, (d) making changes proactively, and (ii) Performing disruption analysis on existing customer data for business changes [49].

A holistic management policy, rather than separate activities contributes to the broad dissemination of this transformation effect. Such transformation exercises are similar to experiments, which Bezos has been encouraging, by stressing that “It’s not an experiment if you know in advance it’s going to work. If you want to be inventive, you have to experiment a lot, which means you will fail a lot.” He has advised shareholders that “You need to select people who tend to be dissatisfied by a lot of the current ways. As they go about their daily experiences, they notice that little things are broken in the world and they want to fix them. Inventors have a divine discontent.” Thus, Bezos has characterized the company as an “invention machine” and inspired its workers to invent and continue to come up with innovative ideas [50]. The staff within Amazon are geniuses in their respective fields [51]. Bezos proudly notes that, “We

have the good fortune of a large, inventive team and a patient, pioneering, customer-obsessed culture—great innovations, large and small, are happening every day on behalf of customers, and at all levels throughout the company. This decentralized distribution of invention throughout the company not limited to the company’s senior leaders is the only way to get robust, high-throughput innovation” [34].

The value created is distributed among various stakeholders: shareholders, employees, executives, customers, creditors, and suppliers.

Under such a distinct CEO’s policy and strong leadership thereof, at Amazon, experimentation is always occurring, initiated by employees in broad fields throughout the company, and ideas are constantly being presented to Bezos, leading to the satisfying of the first leadership principle: *Customer obsession*. Motivated employees understand that these ideas are going to be altered in many ways [33]. Consistent innovative thinking is another resource that Amazon has exploited advantageously [51,52].

This transformation is illustrated in Fig. 18.

It has been popularized the following mathematical formula that *Cash + Willingness to experiment + Stable leadership = Success* (Levinson, 2007). It is evident that the company’s unique team of employees and Jeff Bezos’ visionary leadership have been instrumental in Amazon’s success [51].

Unlike Apple, Google, and Microsoft, Amazon is not fixated on a tightly designed ecosystem of interlocking apps and services as demonstrated in Table 7. Bezos instead emphasizes platforms, each of which serves its customers in the best and fastest possible way. “Our customers are loyal to us right up until the second somebody offers them a better service,” he says. “And I love that. It’s super-motivating for us.” That impulse has spawned an awesome stream of creative firsts [53] as if firing from the top right corner of Fig. 17.



Fig. 18. Illustration of Amazon’s R&D.

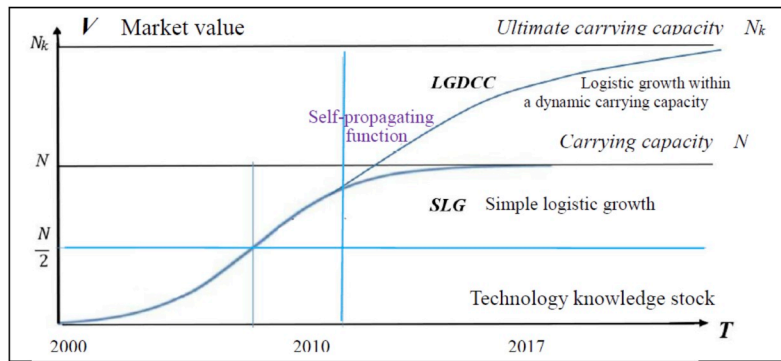


Fig. 19. Amazon's R&D-driven development trajectory.

$$V_L(T) = \frac{N_k}{1 + be^{-aT} + \frac{b_k}{1 - a_k/a} e^{-a_k T}}$$

$$V_S(T) = \frac{N}{1 + be^{-aT}}$$

a, a_k : Coefficients governing the velocity of diffusion,

b, b_k : Coefficients governing the initial level of diffusion

Given this impulse, Amazon may explore a newer R&D model that also transforms “routine or periodic alterations” into “significant improvement” by deploying the full-fledged function of its sophisticated management system to absorb external resources extensively and assimilate them into its business.

4.6. Leading to self-propagating R&D initiatives

The above analysis leads us to expect that Amazon's R&D model may provide a solution to a critical problem that the majority of ICT leaders have been confronting within the digital economy: the dilemma between R&D expansion and productivity decline [1,2]. This solution can be anticipated by activating a self-propagating function indigenous to ICT development [54]. This activation can be enabled by assimilating SIRs, as illustrated in Fig. 15, rather than depending on R&D expansion.

Thus, provided that Amazon's above business model: (*Absorption of external resources + assimilation in own business + impulse towards customer obsession* → *Transform “routine or periodic alterations” into “significant improvement”*) functioned as designed, investment used for this R&D model (investment of technology and the content of its annual report, as summarized in Table 3) should have duly emerged as a self-propagating function.

In order to demonstrate this hypothetical view, a comparative analysis of technology-driven development trajectories between Amazon and Apple over a period from 2000 to 2017 was conducted.⁸

As far as the development trajectory depends on the simple logistic growth (SLG) trajectory, its market value ($V_s(T)$) saturates with a fixed upper limit (N). However, once the trajectory shifts to logistic growth within a dynamic carrying capacity (LGDCC) trajectory that incorporates a self-propagating function, the upper limit dynamically enhances as growth proceeds, thereby its digital value ($V_L(T)$) can continue to increase supported by this function [54].

Recalling particular innovation that creates new carrying capacity during the process of diffusion (e.g., Internet, functional mobile phones, and smartphones), transforming endeavor against the preceding dilemma corresponds to shifting from SLG to LGDCC trajectory [2] as illustrated in Fig. 19.

Fig. 20 and Table 8 examine the development trajectories in Amazon and Apple over the period from 2000 to 2017 by comparing SLG and LGDCC.⁹

Looking at Fig. 20 we note that, while Apple attempted to shift from a SLG to a LGDCC trajectory, it has not entirely transformed into LGDCC, as its LGDCC trajectory is not necessarily statistically

Table 8

Comparison of R&D-driven development trajectory between amazon and apple (2000-2017).

		N	a	b	a_k	b_k	adj. R^2
Amazon	SLG	310.153 (17.96)	0.484 (6.76)	11.739 (3.56)			0.954
	LGDCC	733.090 (3.28)	0.166 (27.94)	11.384 (2.55)*	0.039 (12.93)	0.140 (3.10)	0.999
Apple	SLG	539.796 (30.16)	1.053 (9.66)	94.632 (11.67)			0.980
	LGDCC	652.458 (5.33)	1.534 (8.77)	403.500 (1.21)**	0.164 (2.44)*	1.100 (3.19)	0.996

The figures in parentheses indicate t-statistics: all are significant at the 1% level except *5% and **25% level, respectively.

significant, as demonstrated in Table 8, and the magnitude of its self-propagating function has been limited, as demonstrated in Fig. 20. Consequently, its market value has been accessing a plateau. Contrary to such a trajectory in Apple, Amazon has continued to increase its market value depending on the LGDCC trajectory, with a notable magnitude of self-propagating function, as demonstrated in Fig. 20.

The contrast in this market value trajectory between Apple and Amazon, while the former has been accessing a plateau and the latter has been continued to increase, can be endorsed by the trend in their number of patent applications, as demonstrated in Fig. 21. Since market value (V) increase induces R&D investment, leading to technology knowledge stock (T) increase, which is proportional to the number of patent applications (P), as demonstrated in Table 9 in R&D-driven firms like Apple and Amazon, trends in their P have close relevance to their V trends (see the details of P trends in GAF A in Table A3 in Appendix 3).

Table 8 demonstrates that, contrary to Apple, which incorporates a certain statistical insignificance in its LGDCC trajectory, Amazon has developed an explicit technology-driven self-propagating function, as the LGDCC is statistically more significant than the SLG. This can be attributed to its unique R&D model. While investment used for this R&D model is described in its annual report as investment of technology (centered on expenses for employees and infrastructure costs directly linked to significant improvement) and content (including those for routine or periodic alterations), as summarized in Table 3, technology knowledge stock constructed by both investments demonstrated a duly emerged self-propagating function essential for overcoming the crucial problem in the digital economy.

This fact demonstrates that Amazon successfully transformed “routine or periodic alterations” into “significant improvement” sufficiently enough to overcome the critical problem in the digital economy.

In addition, Table 9 endorses the fact that Amazon's technology

⁸ See the details of the numerical analysis and data construction for the analysis in Table A2 in Appendix 3.

⁹ Estimation of LGDCC depended on the three-steps approximation approach [15].

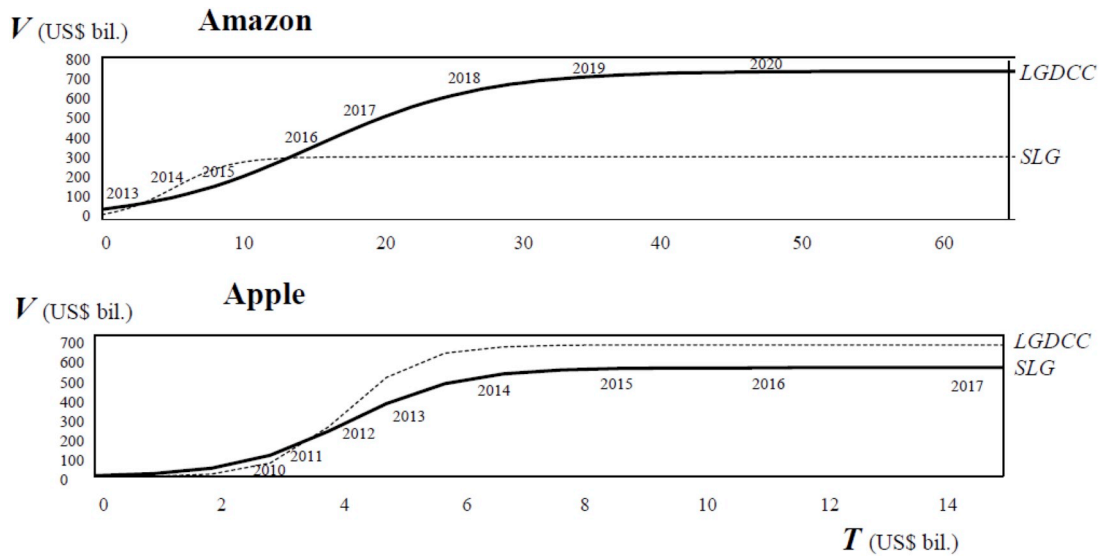


Fig. 20. Trends in technology-driven market value growth trajectory .in amazon and apple (2000-2017).

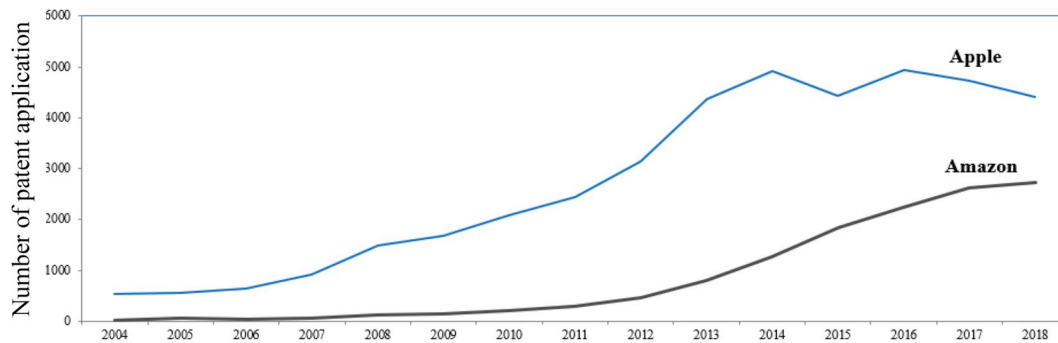


Fig. 21. Trend in number of patent applications in amazon and apple (2004-2018). Source: [55].

Table 9

Correlation between technology knowledge stock and number of patent applications in amazon and apple (2004-2018).

Amazon	$\ln P = 4.25 + 1.38 \ln T - 0.90 D$ (41.06) (19.77)	(-2.71)*	adj. R^2 0.970	DW 1.62	$D: 2018 = 1, \text{ other years} = 0$
Apple	$\ln P = 6.56 + 0.88 \ln T - 0.85 D$ (38.06) (9.02)	(-5.48)	adj. R^2 0.901	DW 1.25	$D: 2004-2006, 2018 = 1, \text{ other years} = 0$

P: number of patent applications; T: technology knowledge stock; and D: dummy variables. The figures in parentheses indicate t-statistics; a; are significant at the 1% level except * 2%.

knowledge stock, constructed by both investments of technology and content, demonstrates similar performance to Amazon's technology stock by generating patent applications, which are generally considered as outcomes of innovation.

Thus, we could conclude that Amazon's unique R&D model and subsequent unique R&D investment convince us of the significance of the transformation of the R&D concept in the digital economy.

5. Conclusion

In light of a rapid conspicuous increase in Amazon's R&D elevated it to the position of world's top R&D firm in 2017 based on its unique R&D model, and subsequent debate on the new concept of R&D in the digital economy, the transformative direction of R&D was examined.

By an empirical analysis focusing on Amazon's R&D-driven disruptive business model, a new concept of R&D in neo open innovation that harnesses the vigor of soft innovation resources was investigated.

It was identified that Amazon, which is based on R&D as a culture,

has been promoting companywide experimentation to cause customers obsessed with making purchase decisions. This has enabled Amazon to deploy an architecture for participation that makes the most of digital technologies by harnessing the power of users. Such user-driven innovation accelerated a dramatic advancement of the Internet that, in turn, accelerated the co-emergence of soft innovation resources in the marketplace. This emergence activated a self-propagating function that induced functionality development, leading to supra-functionality beyond an economic value that satisfies a shift in customers' preferences, which Amazon has been treating as the highest priority. While this system depends on the assimilation capacity of soft innovation resources, Amazon has developed a high level of capacity, supported by a rapid and notable increase in R&D investment. Such a sophisticated management system has operated well because of strong inertia induced by the strongly customer-centric visionary leadership of Jeff Bezos (founder and CEO of Amazon), together with motivated, brilliant and consistently innovative employees equipped with species survival and an evolution system that watches for the necessity of disruptive

business change. These efforts function as a virtuous cycle, leading to the transformation of “routine or periodic alterations” into “significant improvement.”

This virtuous cycle was demonstrated by a numerical empirical analysis showing that technological knowledge stock consisting of investment for both activities has duly emerged as a self-propagating function essential for overcoming the critical problem in the digital economy.

These findings give rise to the following insightful suggestions for reconstructing the R&D model in the digital economy, which incorporates a two-faced nature and a subsequent dilemma between R&D expansion and productivity decline:

- (i) The system of neo open innovation should be specified more on the basis of priority.
- (ii) The role of assimilated soft innovation resources in transforming “routine or periodic alteration” into “significant improvement” should be further analyzed.
- (iii) Dynamism in increasing assimilation capacity via user-driven innovation, M&A and big data collection systems should be elucidated.
- (iv) The development of assimilation capacity should be explored further.
- (v) The accounting principle of R&D in the digital economy should be reviewed.
- (vi) The sophistication of Amazon's R&D-driven business model against

the “new monopoly” in the digital economy should be further generalized.

This analysis provides new insights for shedding light on exploring a practical solution to the dilemma between R&D expansion and productivity decline in the digital economy.

Future works should focus on further elucidation of the micro-dynamism of transformation of “routine or periodic alteration” into “significant improvement.” Further identification of systems effects of R&D between Amazon's R&D model and models initiated by other network firms should also be focused on.

A priority of the national innovation system in the digital economy should be to accumulate the lessons from the new concept of R&D initiated by Amazon and use them to establish a new concept of R&D in neo open innovation. A government-initiated R&D ecosystem should be developed to complement the possible deficits of this new concept, particularly in smaller firms. This, in turn, will induce further sophistication of the Amazon model as a comprehensive system.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.techsoc.2019.05.005>.

Appendix 1. Definition of Research and Development

Table A1
Activities Typically Included and Excluded from R&D

Activities typically included in R&D (730-10-55-1) b. Laboratory research aimed at discovery of new knowledge
 c. Searching for applications of new research findings or other knowledge
 d. Conceptual formulation and design of the possible product or process alternatives
 e. Testing in search for or evaluation of product or process alternatives
 f. Modification of the formulation or design of a product or process
 g. Design, construction, and testing of preproduction prototypes and models
 h. Design of tools, jigs, molds, and dies involving new technology
 i. Design, construction, and operation of a pilot plant that is not of a scale economically feasible to the entity for commercial production
 j. Engineering activity required to advance the design of a product to the point that it meets specific functional and economic requirements and is ready for manufacture
 k. Design and development of tools used to facilitate research and development or components of a product or process that are undergoing research and development activities.

Activities typically excluded from R&D (730-10-55-2) a. Engineering follow-through in an early phase of commercial production
 b. Quality control during commercial production including routine testing of products
 c. Trouble-shooting in connection with break-downs during commercial production
 d. Routine, ongoing efforts to refine, enrich, or otherwise improve upon the qualities of an existing product
 e. Adaptation of an existing capability to a particular requirement or customer's need as part of a continuing commercial activity
 f. Seasonal or other periodic design changes to existing products
 g. Routine design of tools, jigs, molds, and dies
 h. Activity, including design and construction engineering, related to the construction, relocation, rearrangement, or start-up of facilities or equipment other than the following:
 1. Pilot plants (see [h] in the preceding paragraph)
 2. Facilities or equipment whose sole use is for a particular R&D project i. Legal work in connection with patent applications or litigation, and the sale or licensing of patents.

Source: US generally accepted accounting principles (GAAP) in Definition of R&D by [56].

Appendix 2. Dynamism of the Solution to Dilemma

Digital value V created by an IoT society can be depicted as follows [9,57]:

$$V = F(X, T) \tag{1}$$

where T : gross ICT stock; X : other production factors.

Translog (transcendental logarithmic) expansion on the first term:

$$\ln V = p + q \ln X + r \ln T \tag{2}$$

where p , q , and r : coefficients.

T embodies into X in an IoT society as follows:

$$X = F(T) \ln X = p_x + r_x \ln T \tag{3}$$

where p_x and r_x : coefficients.

Synchronizing equations (2) and (3):

$$\ln V = p + q(p_x + r_x \ln T) + r \ln T = (p + qp_x) + (qr_x + r) \ln T \equiv \alpha + \beta \ln T \tag{4}$$

where $\alpha = p + qp_x, \beta = qr_x + r$.

This demonstrates that V is governed by T as follows under the above circumstances.

$$V = F(T) \tag{5}$$

Given the logistic growth nature of ICT, V can be developed by an T -driven logistic growth function.

$$V \approx F(T), \quad \frac{dV}{dT} = \frac{\partial V}{\partial T} \cdot \frac{dT}{dT} = \frac{\partial V}{\partial T} = aV \left(1 - \frac{V}{N}\right) \tag{6}$$

where N : carrying capacity; and a : velocity of diffusion.

Equation (6) develops the following simple logistic growth function (SLG):

$$V_s(T) = \frac{N}{1 + be^{-aT}} \tag{7}$$

where b : coefficient indicating the initial level of diffusion; $V_s(T)$: T -driven SLG-based development trajectory.

In particular innovation which creates new carrying capacity $N(T)$ during the process of diffusion, equation (6) is developed as follows:

$$\frac{dV(T)}{dT} = aV(T) \left(1 - \frac{V(T)}{N(T)}\right) \tag{8}$$

Equation (8) develops the following logistic growth within a dynamic carrying capacity function (LGDCC) as depicted in equation (9) which incorporates self-propagating function as carrying capacity ($N_L(T)$) increases corresponding to $V_L(T)$ (T -driven LGDCC-based development trajectory) increase as depicted in equation (10) [2,54]:

$$V_L(T) = \frac{N_k}{1 + be^{-aT} + \frac{bk}{1-a_k/a} e^{-a_k T}} \tag{9}$$

$$N_L(T) = V_L(T) \left(\frac{1}{1 - \frac{1}{a} \frac{\Delta V_L(T)}{V_L(T)}} \right) \Delta V_L(T) = \frac{dV_L(T)}{dT} \tag{10}$$

Equation (10) suggests that self-propagating function can be activated as growth rate of $V_L(T)$ increases.

From equation (5), this rate is depicted as follows:

$$\frac{\Delta V_L(T)}{V_L(T)} = \frac{\partial V_L(T)}{\partial T} \cdot \frac{T}{V_L(T)} \cdot \frac{\Delta T}{T} \approx \frac{\partial V_L(T)}{\partial T} \cdot \frac{R}{V_L(T)} \tag{11}$$

where R : R&D expenditure ($\approx \Delta T$).

Equation (11) suggests that activation of self-propagating function by increasing growth rate depends on increases in marginal productivity of technology ($\partial V/\partial T$) and R&D intensity (R/V).

Given the declining trend in marginal productivity of technology in the digital economy due to two-faced nature of ICT,¹⁰ growth rate increase can be expected by increasing R&D intensity. However, considering the dilemma between R&D expansion and productivity decline that R&D-intensive firms have been confronting, only a solution can be found through effective utilization of external innovation resources, centered on soft innovation resources (SIRs) from external market [2] as illustrated in Fig. A1.

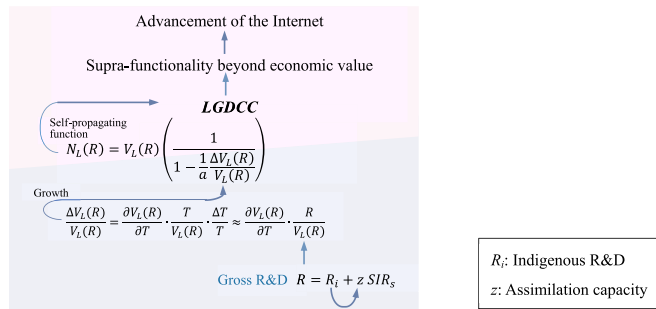


Fig. A1. Dynamism in Assimilating External Innovation Resources for Sustainable Growth.

¹⁰ While advancement of ICT generally contributes 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 and free replication, and mass standardization [11].

Amazon's endeavor in transforming resources for "routine or periodic alterations" activities into resources functioning "significant improvement" by absorbing soft innovation resources from the external market and assimilating them in its business can provide practical solution to this dilemma as illustrated in Fig. A2.

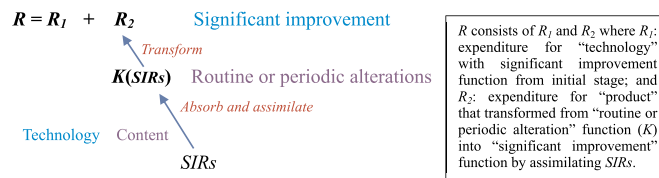


Fig. A2. Dynamism of Amazon's Transforming Routine or Periodic Alterations into Significant Improvement. R: R&D expenditure; K: tangible assets, SIRs: soft innovation resources.

Appendix 3. Statistics for the Analysis

Table A2

Trend in Sales, R&D, Market Value and Technology Knowledge Stock in Amazon and Apple (2000-2017) – US\$ billion at 2010 fixed prices (except indicated as nominal) [6,35,67].

Amazon				Apple									
Year	S_n (nominal)	R_n (nominal)	S_r (real)	R_r (real)	V	T	S_n (nominal)	R_n (nominal)	S_r (real)	R_r (real)	V	T	Deflator(2010 = 100)
2000	2.8	0.2	3.4	0.2	4.2	0.2	8.0	0.4	9.9	0.4	7.8	1.8	81
2001	3.1	0.1	3.8	0.2	6.7	0.4	5.4	0.4	6.5	0.5	11.9	1.8	83
2002	3.9	0.1	4.7	0.1	9.4	0.5	5.7	0.4	6.8	0.5	15.2	1.9	84
2003	5.3	0.3	6.1	0.3	12.7	0.6	6.2	0.5	7.2	0.6	17.9	2.0	86
2004	6.9	0.3	7.9	0.3	16.7	0.7	8.3	0.5	9.4	0.6	21.9	2.1	88
2005	8.5	0.5	9.3	0.5	21.1	0.7	13.9	0.5	15.3	0.6	30.7	2.2	91
2006	10.7	0.7	11.4	0.7	26.2	0.8	19.3	0.7	20.6	0.8	42.1	2.3	94
2007	14.8	0.8	15.4	0.9	33.8	1.0	24.0	0.8	25.0	0.8	54.4	2.4	96
2008	19.2	1.0	19.5	1.1	43.2	1.3	37.5	1.1	38.2	1.1	76.3	2.5	98
2009	24.5	1.2	24.8	1.3	55.0	1.7	42.9	1.3	43.4	1.3	96.9	2.8	99
2010	34.2	1.7	34.2	1.7	72.7	2.2	65.2	1.8	65.2	1.8	133.0	3.0	100
2011	48.1	2.9	47.1	2.9	98.0	2.8	108.2	2.4	106.1	2.4	199.2	3.6	102
2012	61.1	4.6	58.8	4.4	127.4	3.5	156.5	3.4	150.6	3.3	290.0	4.2	104
2013	74.5	6.6	70.5	6.2	159.7	4.6	170.9	4.5	161.8	4.2	364.9	5.1	106
2014	89.0	9.3	82.8	8.6	194.5	6.5	182.8	6.0	170.0	5.6	425.4	6.5	108
2015	107.0	12.5	98.4	11.5	234.6	9.6	233.7	8.1	215.0	7.4	512.8	8.4	109
2016	136.0	16.9	123.5	14.6	287.8	13.9	215.6	10.0	195.9	9.1	554.9	11.0	110
2017	177.9	22.6	158.7	20.2	360.2	19.7	229.2	11.6	204.6	10.3	593.0	14.4	112

S: Sales, R: R&D expenditure, V: Market value, T: Technology knowledge stock [58].

$$V_t = S_t + (1 - \delta)V_{t-1}, V_0 = \frac{S_1}{\delta + \kappa}, T_t = R_{t-m} + (1 - \rho)T_{t-1}, T_0 = \frac{R_{1-m}}{\rho + g}$$

where δ : Rate of depreciation of sold goods and services; ρ : Rate of obsolescence of technology; m : Leadtime between R&D and commercialization; κ : Growth rate of goods and services at initial stage; g : Growth rate of R&D at initial stage.

Based on the empirical reviews of typical goods, services and R&D in both companies over a period from 1995 to 2015, together with literature reviews, respective factors were estimated as follows [14,16,17,59–64]:

$\delta = 0.3, \rho = 0.2, m = 3$ years in both companies. $\kappa = 20\%$ p.a (Amazon) and 15% p.a (Apple). $g = 25\%$ p.a (Amazon) and 5% p.a (Apple).

Original sources: Amazon.Com, Inc., 2017 annual report (2018a). Apple Inc., 2017 annual report (2018). [65].

Table A3

The Trend in Number of Patent Application in GAFA (2004-2018)

Year	Google	Apple	Facebook	Amazon
2004	1783	534	186	24
2005	1587	565	188	55
2006	1813	645	209	46
2007	2202	925	221	60
2008	2003	1484	786	120
2009	1618	1685	236	143
2010	1791	2092	302	216
2011	1828	2451	333	306
2012	2980	3150	322	469
2013	4021	4368	749	806
2014	5338	4926	1055	1269
2015	6519	4429	933	1843
2016	5515	4935	1310	2249
2017	5237	4731	1780	2629
2018	4291	4407	1743	2732

Source: [55].

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