



Fusion of technology management and financing management - Amazon's transformative endeavor by orchestrating techno-financing systems

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ABSTRACT

Amazon became the world R&D leader in 2017 by rapidly increasing R&D investment. Its R&D investment in 2017 was double that of 2015, 5 times that of 2012, and 10 times that of 2011. This rapid increase continued in 2018, and Amazon accomplished a skyrocketing increase in its market capitalization, closing to being the world's biggest company.

Such a rapid increase in R&D and subsequent market value has raised questions about how to conduct R&D and secure a large amount of funds needed for high-risk investments. Amazon has provided hypothetical answers to both of these questions.

Amazon has been conducting innovative R&D to transform routine or periodic alterations into significant improvements during the R&D process and claiming huge expenses for such transformation activities as expenses for R&D.

The company's ample free cash flow generated by sophisticated cash conversion cycle (CCC) management endorsed a large amount of investment for such a high-risk strategy.

Increased R&D induced business advancement and lean cost structure construction leading to a further increase in cash flow has stimulated interactions between vendors, customers, and Amazon via the Amazon marketplace. Activated interaction-accelerated CCC advancement, a subsequent free cash flow increase, and user-driven innovation have thus simultaneously accelerated R&D transformation.

All of these components - R&D transformation and technopreneurial strategy consisting of technology management, as well as marketplace development and CCC-driven cash flow generation consisting of financing management - function together as a consolidated sophisticated machine. Thus, Amazon has succeeded in fusing technology management and financing management by orchestrating all techno-financing systems.

In light of increasing concerns regarding R&D expansion without the dilemma of a productivity decline that most digital economies are now confronting, this paper demonstrates the above hypothetical answers.

Following the authors' preceding analysis of Amazon's unique technology management toward a new concept of R&D in the digital economy, an intensive empirical analysis focusing on the development trajectory of Amazon's techno-financing system over the last two decades was conducted.

An insightful suggestion as to neo-open innovation that fuses technology management and financing management is thus provided.

1. Introduction

Contrary to the decisive role of research and development (R&D) in the digital economy, the dilemma between its expansion and productivity decline has become worldwide concerns, as most digital economies are now confronting [1,2].

Notwithstanding such dilemma, Amazon demonstrated a conspicuous increase in its R&D and became the world's top R&D firm in 2017 with a skyrocketing increase in its market capitalization closing to being the world's biggest company [3].

Such a rapid increase in R&D and subsequent market value has raised the questions of ways in conducting R&D and also securing a large

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amount of funds for such high-risk investment.

The authors in their preceding analysis elucidated a dynamism leading Amazon to such a rapid jump in R&D within a short period of time [4–6].

They identified that Amazon, based on R&D as a culture, has been promoting company-wide experimentation that enabled it to deploy an architecture for participation, 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 inducing supra-functionality beyond an economic value that satisfies a shift in customers' preferences. Such a sophisticated management system has operated well because of the strong inertia induced by the strong customer-centric visionary leadership of Jeff Bezos, founder and CEO of Amazon, together with motivated, brilliant, and consistently innovative employees equipped with self-assessment and disruption analysis systems. These efforts function as a virtuous cycle, leading to the transformation of routine or periodic alterations to significant improvements during the R&D process.

While these findings have highlighted a notable transformative direction that global information and communication technology (ICT) leaders should attempt, such a miraculous model has shed light on the financing system that supported and endorsed such a reckless challenge to risky investment in R&D that incorporates such nature as uncertainty, long lead-time, and successive huge amount of fund without interruption.

This paper attempts to elucidate the interacting role of the financing system that endorsed such a reckless investment while being enabled by the miraculous R&D model.

In light of its notable business performance, to date, a significant number of studies have analyzed Amazon's business model enabling such performance (e.g., Refs. [7–9]). It is widely appreciated that Amazon's success can largely be attributed to its cash flow, particularly free cash flow management based on sophisticated cash conversion cycle (CCC) management [10–12].

However, none has provided a convincing bridge between such CCC-driven cash flow management and a unique R&D system leading Amazon to being the world R&D leader without the dilemma.

Following the authors' preceding analysis [4–6], this paper attempted to provide a convincing bridge between Amazon's mysteries of CCC-driven cash flow management and the transformation of the R&D concept.

An empirical analysis focusing on Amazon's techno-financing development trajectory over the last two decades was conducted.

It was identified that all functions involved marketplace dynamism inducing CCC advancement, CCC-driven cash flow management, and R&D transformation from routine or periodic alterations to significant improvements during the R&D process and were well-orchestrated as a consolidated sophisticated machine, as illustrated in Fig. 1.

Thus, Amazon succeeded in fusing a unique R&D transformation system endorsed by its institutional system as an R&D-driven company and a sophisticated financing system centered on CCC-driven cash flow management - exquisitely combining this with debt financing and aiming at acquiring the fruit of growth, depending on the capital market conditions (Fig. 2).

Such a consolidated sophisticated machine can be attributed to a multi-virtuous cycle -which was constructed through the following phased efforts, as illustrated in Fig. 3.

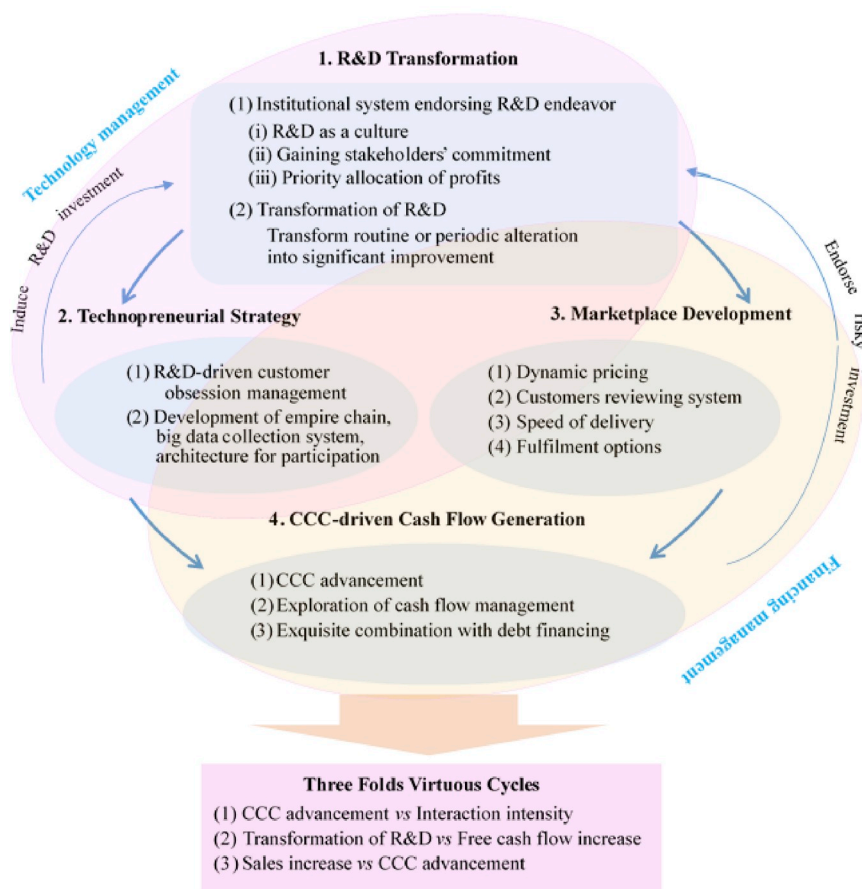


Fig. 1. Amazon's endeavor in orchestrating techno-financing systems.

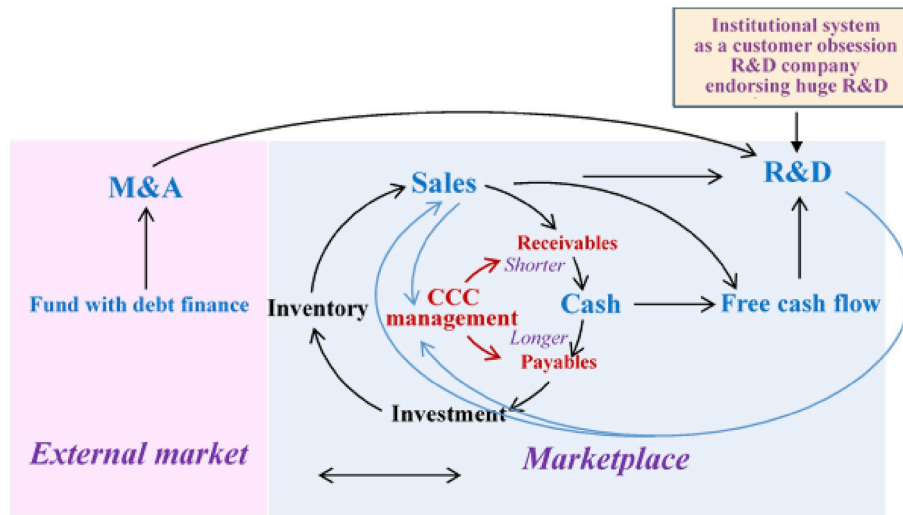


Fig. 2. Scheme of Amazon's cash flow management.

Phase I: Attempt mergers and acquisitions (M&As) by leveraging on the low interest rate market environment and raising funds with debt finance.

Phase II: Develop business activities by fully utilizing the fruits of the advancement of M&As and create CCC-oriented cash flow, thereby investing in R&D.

Phase III: Increase cash flow, particularly free cash flow, through the advancement of business and R&D; thereby, a virtuous cycle is constructed between them.

These findings give rise to insightful suggestions supportive of the transformation of an R&D model in the digital economy.

Section 2 reviews the dynamism of Amazon's R&D transformation. Section 3 summarizes a virtuous cycle between ample cash flow and active R&D investment. Dynamism enabling notable R&D investment is analyzed in Section 4. Section 5 demonstrates the optimal combination of acquisition and R&D. Section 6 summarizes the noteworthy findings, policy suggestions, and future research recommendations.

2. Transformation of R&D triggered by amazon: a review

The authors, in their preceding analysis, demonstrated the dynamism, triggered by Amazon, transforming R&D in the digital economy as follows [4-6].

2.1. R&D as a culture promoting company-wide experimentation

Amazon has been endeavoring to be an R&D-driven company since its inception in 1994 and promoting company-wide experimentation. This has founded a base for its institutional system enabling huge R&D investments as follows:

- (i) Stakeholders' commitment has been gained by appealing and demonstrating that establishing market leader status and raising shareholder value is an essential success.
- (ii) The resources allocation policy has been established as re-investing profits to R&D for further development, not to returns to shareholders (such as buybacks and dividends).

2.2. Architecture for participation inducing user-driven innovation

Amazon's business model and its endeavors have developed its empire chain, big data collection system, and the architecture for participation, harnessing the power of users and leading to user-driven innovation as illustrated in Fig. 4 [5].

2.3. Co-emergence of soft innovation resources

Such user-driven innovation accelerated a dramatic advancement of

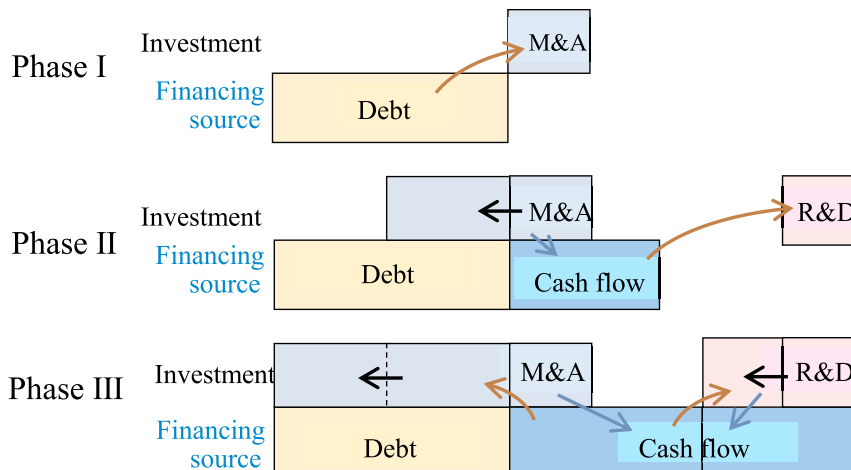


Fig. 3. Scheme of Amazon's Development Trajectory of R&D Financing. —>: Business/R&D emergence; —>: Cash flow creation; —>: Expansion.

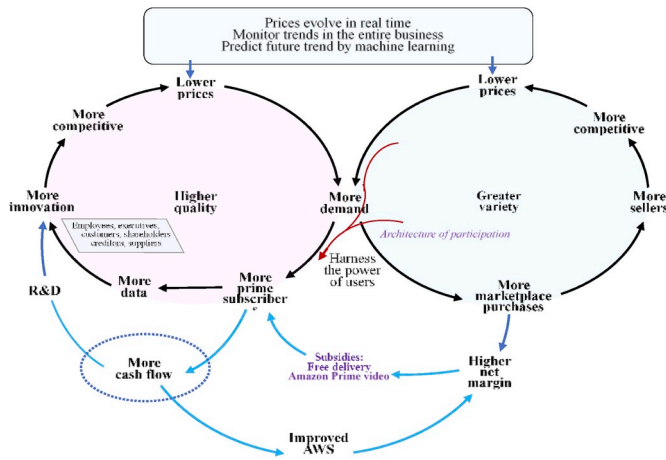


Fig. 4. The Dynamism of Amazon in Harnessing the Power of Users. Source: Authors' elaboration based on Colin's [13] study.

the Internet that, in turn, accelerated the co-emergence of soft innovation resources (SIRs) in the marketplace, as illustrated in Fig. 5. Here, SIRs are considered condensates and crystals of the advancement of the Internet and consist of the Internet-based resources that have been either sleeping or untapped or are results of multi-sided interactions in the markets where the consumer is looking for functionality beyond economic value. The common feature of SIRs is that they are not accountable in the traditional GDP terms [1,2].

Development trajectory of logistic growth within a dynamic carrying capacity (LGDC) incorporates a self-propagating function (NL(R)) that increases functionality during the process of development leading to inducing supra-functionality beyond an economic value.

Core function of this dynamism is to activate the latent self-propagating function through growth by means of increase in gross R&D increase consisting of indigenous R&D (R_i) and assimilated soft innovation resources centered on SIRs (z SIRs where z: assimilation capacity).

2.4. Self-propagating system

This emergence activated a self-propagating function inducing supra-functionality beyond economic value that satisfies a shift in customers' preferences, which Amazon has been treating as the highest priority. This shift, in turn, accelerates user-driven innovation and subsequent further advancement of the Internet leading to a virtuous cycle among SIRs emergence, supra-functionality beyond economic value, user-driven innovation and Internet advancement (see the details of this dynamism in Appendix 1).

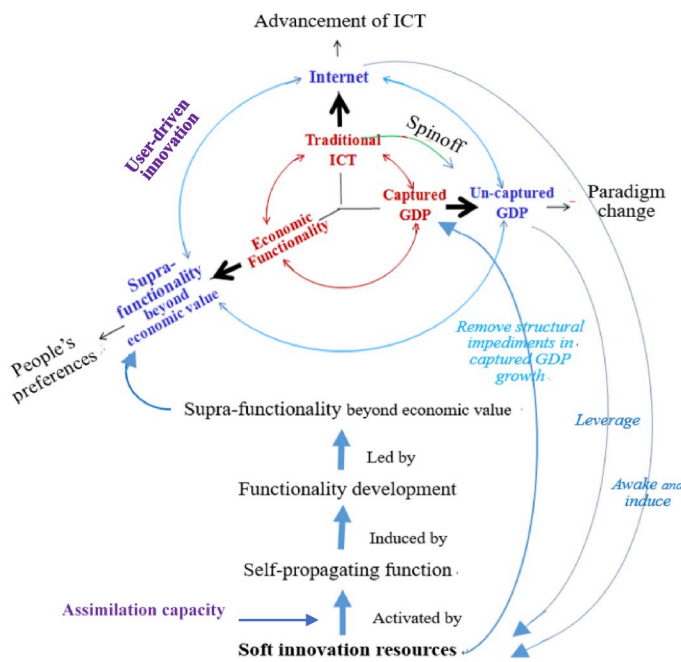
While this system depends on the assimilation capacity of SIRs, Amazon has developed a high level of capacity, supported by a rapid and notable increase in R&D investment.

Thus, leveraged by this activated latent digitalization function, development trajectory transforms from a captured GDP-based co-evolution cycle (inner circle indicated in pink color in the right column, which contains a function of routine or periodic alterations with respect to digital advancement) to an uncaptured GDP-driven co-evolution cycle (outer circle in the light blue section containing significant improvement function). This transformation can be attributed to the inertia of the shift of people's preferences and the Internet's function to create new functionality corresponding to such shift.

2.5. Sophisticated management system leading to the transformation

Such a sophisticated management system has operated well because of the strong inertia induced by the strong customer-centric visionary leadership of Jeff Bezos, together with motivated, brilliant, and consistently innovative employees equipped with self-assessment and disruption analysis systems. These efforts function as a virtuous cycle - leading to the transformation of routine or periodic alterations into significant improvements during the R&D process, as illustrated in Fig. 6 [5].

Such transformation led to Amazon becoming the world's top R&D leader in 2017. This conspicuous increase and subsequent increase in sales and market capitalization continued in 2018, as illustrated in Fig. 7 and Fig. 8.



Advancement of the Internet

Supra-functionality beyond an economic value

Logistic Growth within a Dynamic Carrying Capacity

Self-propagating function

$$N_L(R) = V_L(R) \left(\frac{1}{1 - \frac{1}{a} \frac{\Delta V_L(R)}{V_L(R)}} \right)$$

Growth

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

Gross R&D $R = R_i + z SIR_s$

Development trajectory of logistic growth within a dynamic carrying capacity (LGDC) incorporates a self-propagating function (N_L(R)) that increases functionality during the process of development leading to inducing supra-functionality beyond an economic value.

Core function of this dynamism is to activate the latent self-propagating function through growth by means of increase in gross R&D increase consisting of indigenous R&D (R_i) and assimilated soft innovation resources centered on SIRs (z SIRs where z: assimilation capacity).

Fig. 5. Dynamism in Co-Emerging Soft Innovation Resources in Amazon. Original source: Tou et al. [5].

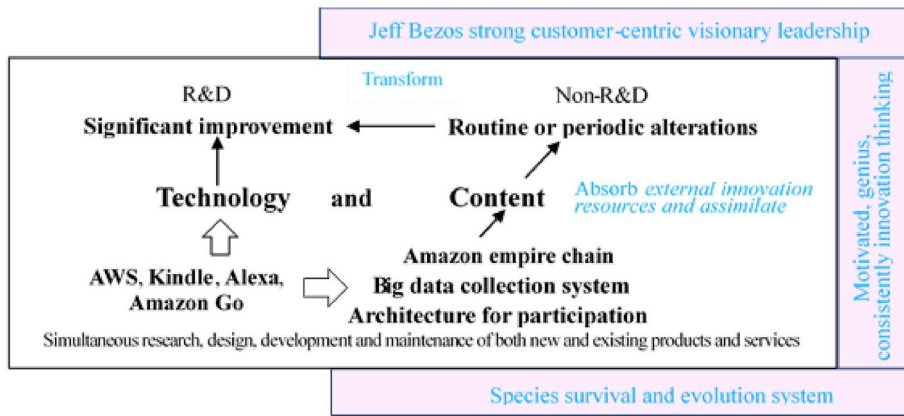


Fig. 6. Scheme of Amazon's unique R&D model.

3. Virtuous cycle between ample cash flow and active R&D

3.1. Amazon's financing structure

The above miraculous R&D investment dynamism leading to Amazon becoming the world R&D leader in a short period of time without confronting the dilemma has raised a question about how to secure a large amount of funds needed for such high-risk investment.

Fig. 9 overviews Amazon's financing structure in 2018 by integrating its statements of consolidated income and cashflow.

3.1.1. Top

The top table of Fig. 9 reviews the trend in Amazon's key managerial factors over the last five years - focusing on its business outcomes as revenues (sales), investment for the future as R&D investment, and consequent incomes as operating income and net income. It also overviews its business performances by reviewing its cash flow (CF) management, focusing on the management of operating CF and free CF, together with indebtedness by reviewing debt capital, focusing on long-term debt (see the details of these trends in Table A1 in Appendix 2).

The lower left table in Fig. 9 demonstrates Amazon's income statement in 2018, which presents the financial results of its business activities (see the details of these trends in Table A2 in Appendix 2).

This statement communicates how much revenue Amazon generated during the period and what cost it incurred in connection with

generating that revenue. This statement also explains the relationship between sales, operating income, R&D, and net income. Amazon describes expenses for R&D as those for "technology and content" [4,5].

Operating income (OI) measures the amount of profits realized from a business's operations after deducting operating expenses such as wages, depreciation, and cost of goods sold, including expenses for R&D (technology and product) from revenues (sales: S).

In Amazon these profits have been reinvested in its business and employees, not in dividends and buybacks. Amazon has not paid a dividend since its IPO in 1997, nor has it done any buybacks of its shares since 2012. That strategy is reflected in spending on R&D activities, which has led to Amazon becoming the world's top R&D firm over a short period of time [4,5], as demonstrated in Fig. 7.

Such R&D seeking resource allocation strategy is distinct. Amazon has been endeavoring to be an R&D-driven company since its inception in 1994. Consequently, Amazon maintains an extremely high ratio of R/OI (R&D investment and operating income ratio) and a subsequent extremely low ratio of OI/S (operating income and sales ratio), as demonstrated in Fig. 10.

Since R&D is such a high-risk investment that incorporates uncertainty, lengthy successive work with huge amounts of money without interruption, and long lead-time before commercialization, a lack of cash turns the return of all previous efforts to blisters. Therefore, intensive R&D investment can only be enabled by fueling ample and sustainable funding rich in mobility, which can be expected by net CF,

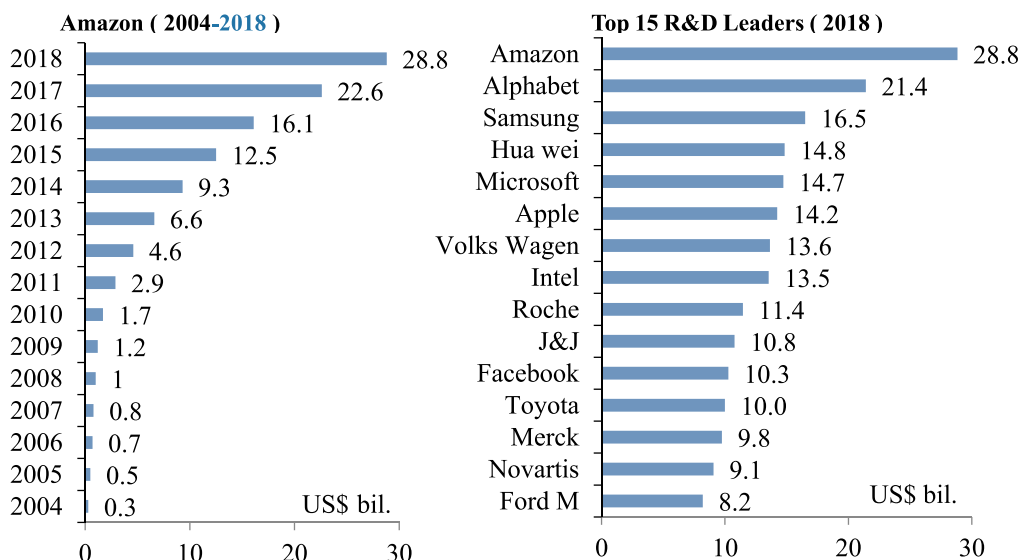


Fig. 7. Amazon's Conspicuous Jump to the World's Top R&D Leader: R&D Investment. Original sources: Bloomberg [14]; Amazon (annual issues)[16,45].

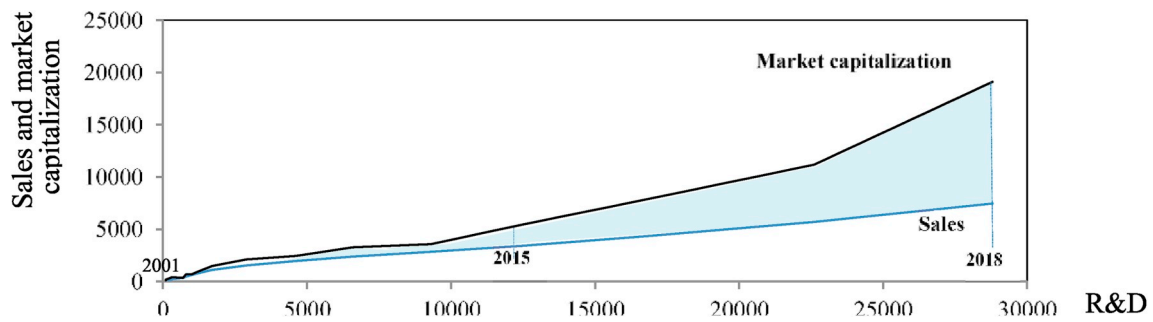


Fig. 8. The correlation between R&D investment and sales and market capitalization in amazon (2001–2018) – index: 2001 = 100. Source: Amazon [15].

Trend in Key Managerial Factors (2014–2018)– US\$ bil.

Year	Sales	Operating income	R&D	Net income	Operating CF	Free CF	Long-term debt
2014	89.0	0.2	9.3	-	6.8	1.9	8.3
2015	107.0	2.2	12.5	0.6	12.0	7.5	8.2
2016	136.0	4.2	16.1	2.4	17.2	10.5	7.7
2017	177.9	4.1	22.6	3.0	18.4	8.3	24.7
2018	232.9	12.4	28.8	10.1	30.7	19.4	23.5

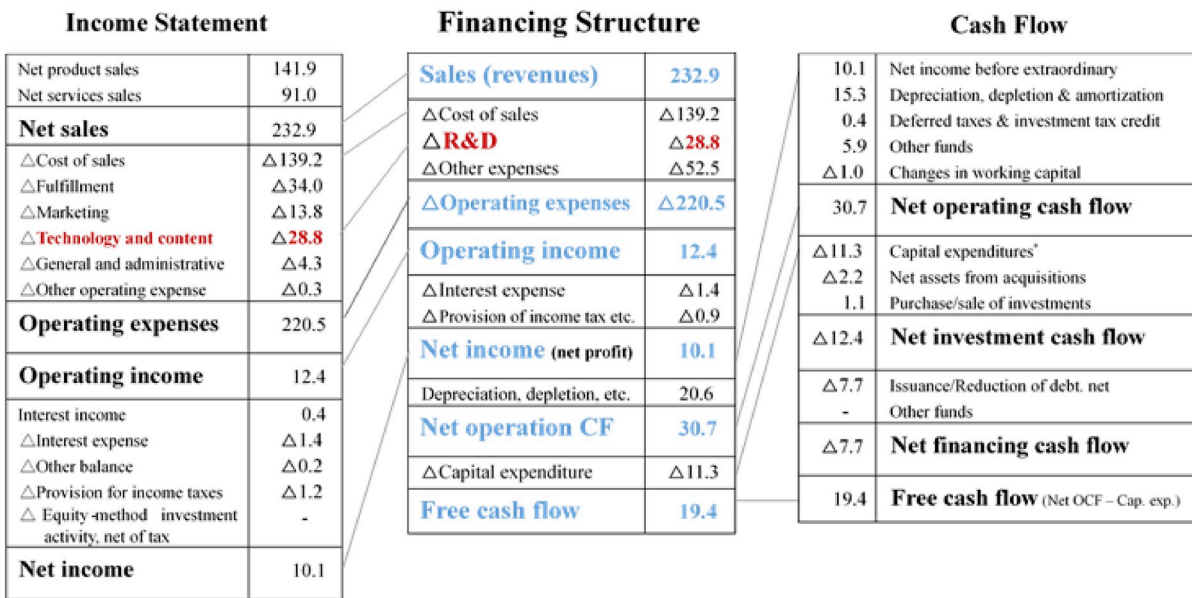


Fig. 9. Amazon’s Financial Structure in 2018 – US\$ bil. Sources: Amazon Consolidated Income Statement [16]; Amazon Cash Flow Statement [17].

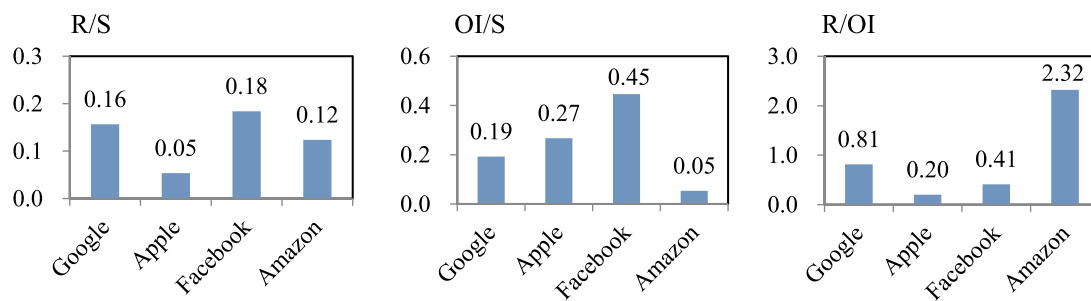


Fig. 10. Comparison of R/S, OI/S, and R/OI between google, apple, facebook and amazon (GAFA) (2018).

rather by net income (net profit).

While net income indicates revenues left over after all expenses have been paid for by adjusting for due income and expense from operating income, as explained in the lower-left table in Fig. 9, in conducting actual risky challenges, a timely ample fuel that endorses companies doing such challenge is indispensable. Net CF is the fuel that helps companies expand, develop new products, buy back stock, pay dividends, or reduce debt. It is what allows companies to conduct their day-to-day business, particularly a risk-heavy business, successively, as it includes all transactions that transfer cash [18].

Amazon as a world-leading R&D-driven company highly depends on this flow, as demonstrated in Fig. 11 [19].

3.2. Amazon's notable cash flow structure

Based on the analysis in the preceding section, which inspired the significance of CF management in fueling the company to conduct actual business, particularly risk-taking challenge as R&D investment without interruption, Amazon's CF structure is analyzed in this section.

As reviewed in the preceding section, net income (net profit) is the amount of total revenues after deducting total expenses (how much revenues are left over all expenses have been paid from sales). This is the amount of money that the company can use to pay off debt, invest in new projects, distribute to shareholders, or save.

However, in successively conducting a risk-heavy challenge as long-lasting big R&D without interruption, the endorsement of ample and sustainable funding rich in mobility is indispensable to avoid a fear of shortage of cash that may return all previous efforts to blisters. This can be expected by net CF. As demonstrated in the lower right table in Fig. 9 (see the details of these trends in Table A3 in Appendix 2), net CF is the sum of *operating CF* (net income plus or minus increases or decreases in the current assets, liabilities, and expenses), *investment CF* (increases or decreases in long- or fixed-term assets), and *financing CF* (increases or decreases in long-term liabilities/debt, capital or dividends). Cash for R&D investment is used from operating CF by deducting certain expenditures from investment CF.

Operating CF is measured by deducting the expenses for purchases from the sales or, in other means, adding such values as depreciation, depletion, and amortization to net income. This flow demonstrates how much cash is generated by the business. Amazon is consistently increasing this flow; thereby, its main business is securing ample cash.

Free CF is the value measured by deducting capital expenditure necessary for business expansion (included in investment CF) from operating CF. This is money reserved in the company after paying due payments as debt repayment, redemption of bonds, and dividends to shareholders. This is called free CF, as this is the money that companies can use freely.

Aiming at market leader status and raising shareholder value, Amazon has been paying special attention to free CF and reports the trend in this flow at the beginning of the company's quarterly report by defining it as follows: "Free cash flow is cash flow from operations reduced by 'purchases of property and equipment, including internal-use software and website development, net,' which is included in CF from investing activities."

Fig. 12 illustrates these trends in Amazon's free CF over the period 1996–2018.

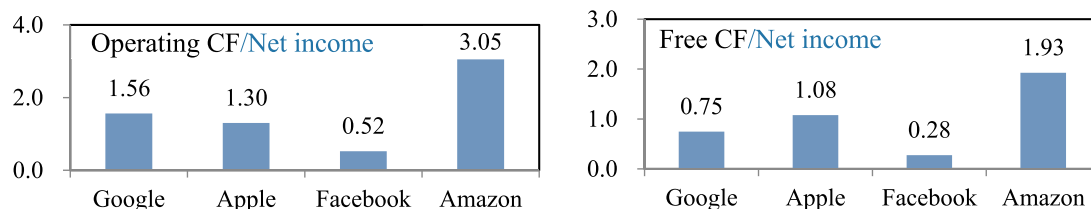


Fig. 11. Comparison of cash flow per income between GAFA (2018).

In the 2004 letter to stakeholders, Bezos reminded them that Amazon's financial focus is on long-term growth in free cash per share by stressing "Our ultimate financial measure, and the one we most want to drive over the long-term, is free cash flow per share." To accomplish this focus, he stressed, "Amazon's free cash flow is driven primarily by increasing operating profit and efficiently managing both working capital and capital expenditures. We work to increase operating profit by focusing on improving all aspects of the customer experience to grow sales and by maintaining a lean cost structure" [20].

As stressed by Bezos, Amazon's financial focus is on long-term growth in free cash per share for addressing to its targeting direction as an R&D-driven company. Fig. 13 illustrates the trend in Amazon's free cash per share over the period 1996–2018 - which corresponds to significant R&D inducement as demonstrated in Table 1.

RD: R&D investment; FCF/Share: Free cash flow per share; D: dummy variable (2012 = 1, Other = 0).

The figures in parentheses indicate t-statistics: all are significant at the 1% level.

3.3. Amazon's financing dynamism

Based on the analyses in the preceding sections, Fig. 14 summarizes Amazon's financing dynamism in 2018. Bezos repeatedly stressed to work to increase operating profit by focusing on improving all aspects of the customer experience to grow sales and by maintaining a lean cost structure. Table 2 demonstrates this postulate. Fig. 15 demonstrates a virtuous cycle between increases in free CF and R&D by optimizing free cash management and maximizing funding through a thorough improvement of business growth, lean cost structure construction, and CCC advancement.

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

4. Dynamism enabling notable R&D investment

4.1. Cash conversion cycle

(1) Strengths with "Payment before Goods Sold"

As a world leading R&D-driven company, to successively secure R&D funds without interruptions, Amazon highly depends on net CF, rather than net income (net profit), as reviewed earlier. This can be enabled by generating enough CF by promptly collecting payments from customers and then paying its vendors with relatively longer payment terms based on its sophisticated CCC management (e.g., Refs. [22–25]).

CCC is the timespan between disbursing and collecting cash by calculating the following period:

$$CCC = \text{Days inventory outstanding} + \text{Days sales outstanding} - \text{Days payables outstanding}.$$

Twelve days of CCC of the world's largest retail outlet Walmart indicates that it takes 12 days to collect the cash by selling inventories and new products. Typical CCC in the retail industry is 10–20 days, as demonstrated in Fig. 15. Due funds for this period should be provided by the company's own efforts. In case of manufacturing industry, this is much longer as 50–100 days or longer.

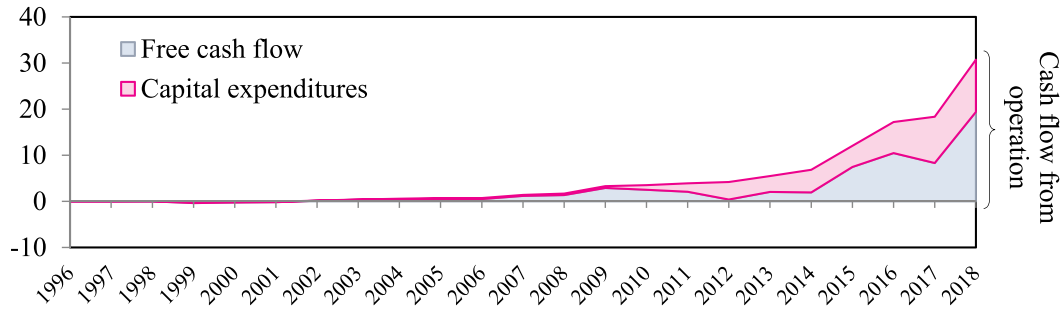


Fig. 12. Trend in Amazon’s Free Cash Flow (1996–2018) – US\$ bil.

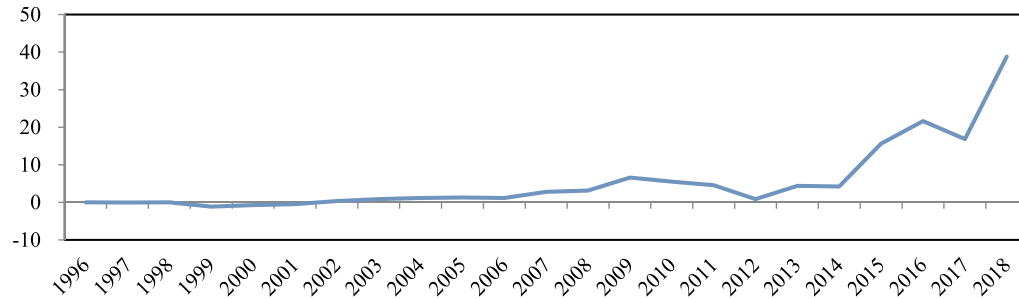


Fig. 13. Trend in Amazon’s Free Cash Flow per Share (1996–2018) – US\$. bil.

Table 1

Correlation between free cash flow per share and R&D in amazon (2002–2018).

$$\ln RD = 5.92 + 1.25 \ln FCF/Share + 2.67D \quad \text{adj. } R^2 \text{ } 0.848 \quad DW \text{ } 1.15 \text{ } (24.27) \text{ } (9.50) \text{ } (3.78)$$

Contrary to such a burden, Amazon demonstrates negative CCC (–20 to –30 days), as demonstrated in Fig. 16. This implies that the product in the distribution chain is already cashed 20–30 days before it is sold. This level can be considered a sweet spot taking into optimal balance with vendors and customers. Such a significant negative CCC is the source enabling Amazon to develop huge investments and new businesses one after another as illustrated in Fig. 3.

(2) “Deal Deposit” that Can Be Operated without Interest

While the inside the black-box of Amazon’s negative CCC scheme has been unveiled, it can definitely be attributed to its unique marketplace function. Marketplace is a mechanism that allows non-Amazon vendors to sell their goods and services. In this marketplace, payments from customers are collectively received by Amazon. The sales are returned to the vendors a few weeks later after deducting a small percentage of the commission.

The point is that the entire sales in the marketplace are deposited in Amazon first and then returned to the vendors certain days later as illustrated in Fig. 2. This temporary deposit is called “deal deposit.” Amazon’s negative CCC can largely be attributed to this deposit magic. Amazon incorporates unique specific functions in its marketplace

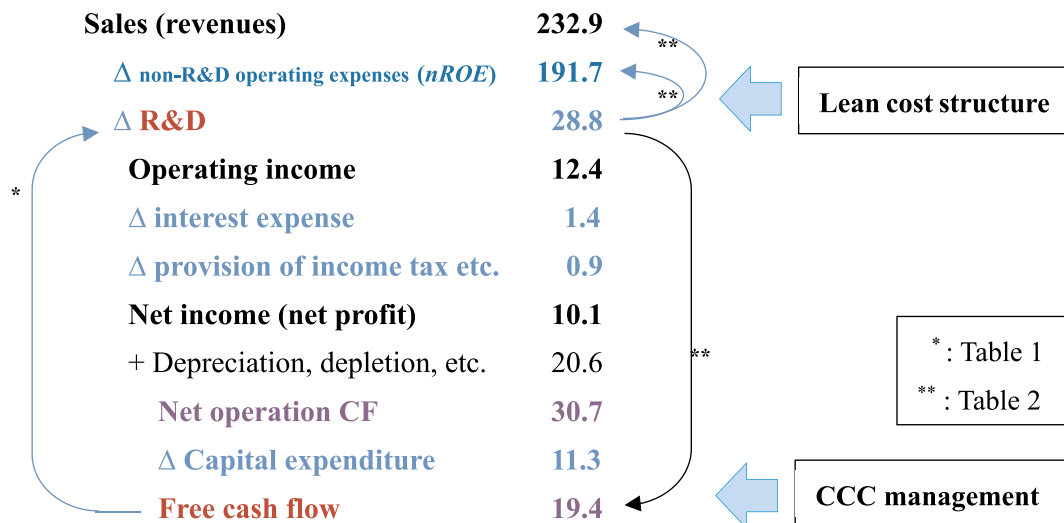


Fig. 14. Amazon’s Financing Dynamism toward R&D-Driven Company (2018) – US\$ bil.

Table 2
Correlation between R&D and sales, operating expenses and free cash flow in amazon (1997–2018).

$\ln RD + 0.89D_2 \ln RD + 0.66 D_3 \ln RD - 1.83D_2 \text{ adj.}R^2 0.997 DW 2.17$
<small>(12.82) (20.35) (-8.32)</small>
$\ln ROE = 5.57 + 0.99D_1 \ln RD + 0.89 D_2 \ln RD + 0.63D_3 \ln RD - 29D_1 - 2.03D_2 \text{ adj.}R^2 0.998 DW 1.91$
<small>(23.03)(29.30) (15.23) (23.26) (-10.21)(-4.70)</small>
$\ln FCF = 2.86 + 1.11 D_2 \ln RD + 0.64 D_3 \ln RD - 3.43D_2 - 1.70 D_3 \text{ adj.}R^2 0.870 DW 1.82$
<small>(2.08*)(3.38) (4.16) (-1.40**)(-4.34)</small>

S: sales; RD: R&D investment; nROE: non-R&D operating expenses; FCF: Free cash flow; D: dummy variables (D_1 : 1997–2001 = 1, others = 0; D_2 : 2002–2008 = 1, others = 0; D_3 : 2009–2018 = 1, others = 0; D: 2012 = 1, others = 0).

enabling the practice of this magic (see 4.2). Three folds virtuous cycle (see 4.3) maximizes this function.

4.2. Unique function in Amazon’s marketplace

CCC management is a management strategy for attaining shorter receivables (days of outstanding of inventory and sales) and longer days of payables. This management is deployed by leveraging such functions of the marketplace as (i) dynamic pricing and (ii) review systems, systems promoting customer purchase by enabling the customer to review goods and services that satisfy such requirements as (iii) speed of delivery and (iv) fulfillment options.

(1) Dynamic Pricing

Amazon, which is based on R&D as a culture, has been promoting company-wide experimentation to make 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 [4,5].

Such user-driven innovation enabled Amazon to offer lower prices of goods and services - which satisfied customers leading to a virtuous cycle between them. However, Amazon’s pricing strategies are much more complex in that it does not always offer the lowest prices but changes millions of prices daily based on learning customers’ behaviors via big data collection, as illustrated in Fig. 16 [21].

Through such pricing strategy that enables learning users’ reactions further to understanding (i) the supply-demand relation, (ii)

competitors’ prices, (iii) seasonal effects, (iv) the perception among consumers, (v) discounts’ effect, and (vi) the feedback to algorithmic pricing, Amazon has been enjoying the effect of data network externality.

This effect increases exponentially as interactions with users increases, leading to gaining overwhelming power in the CCC game in the marketplace. This power can be considered one of the significant sources of Amazon, enabling it to generate CF and increase high dependence on it.

Fig. 17 and Table 3 demonstrate this hypothetical view by analyzing the correlation between sales increase (which represents interaction increase) and corresponding exponential increase (which represents network externality effect, see the details of this effect in Fig. A1 in Appendix 1) in operating CF in Amazon over the period 2002–2018.

The figures in parentheses indicate t-statistics: all are significant at the 1% level.

These analyses demonstrate operating CF increases exponentially, corresponding to interaction increase. A sharp increase with high learning coefficient (λ in Table 3) changed to moderate increase after 2009. This suggests that Amazon developed a high level of operating CF dependent structure in 2009 as demonstrated in Fig. 18, which supports the above hypothetical view.

Operating CF/Sales.

(2) Review System

A review system that attempts to promote customers purchase by enabling them to review goods and services is one of the most important

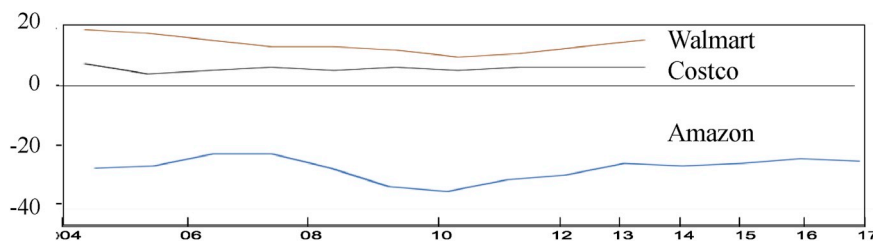


Fig. 15. Cash Conversion Cycle in Walmart, Costco, and Amazon (2004–2013) – in days. Sources: Fox [11] and Uenlue [21].

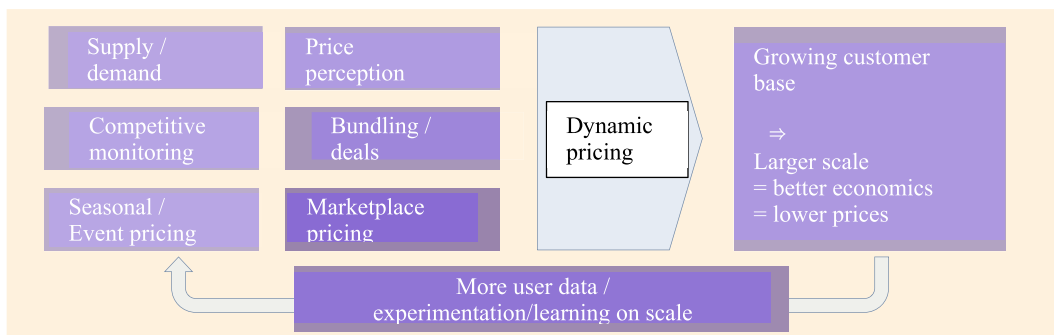


Fig. 16. Amazon’s Virtuous Cycle of Pricing Leading to Data Network Externality. Original source: Uenlue [21].

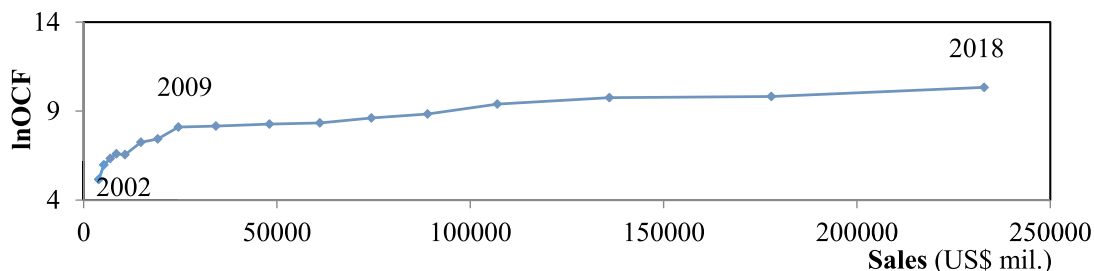


Fig. 17. Correlation between sales and logistic value of operating cash flow in amazon (2002–2018).

Table 3
Effect of network externality in inducing operating cash flow in amazon (2002–2018).

$$OCF = A e^{aS} \Rightarrow \ln OCF = \ln A + \lambda_1 D_1 S + \lambda_2 D_2 S + dD_1 \ln OCF = 7.81 + 0.13D_1 S + 0.01D_2 S - 2.62D_1 \quad adj.R^2 \ 0.969 \ DW \ 1.29(51.59) \ (6.71) \ (9.06) \ (-9.96)$$

OCF: operating cash flow; S: sales; λ : learning coefficient; A: scale factor; D: dummy variables (D_1 : 2002–2008 = 1, others = 0; D_2 : 2009–2018 = 1, others = 0).

decision and ranking tools for customers [26]. It is not only of significant value to Amazon but also third-party sellers in Amazon’s marketplace. Therefore, Amazon has been encouraging customer- and vendor-intensive reviews by providing them the following review system:

- (i) Review guideline,
- (ii) Early reviewers’ program,
- (iii) Voting opportunity on helpful review,
- (iv) List of top reviewers based on the helpful votes, and
- (v) Filters and machine learning tools to weed out fake reviews.

4.3. CCC’s role in Accelerating the Transformation of R&D

Amazon has been endeavoring to be an R&D-driven company since its inception in 1994. This culture has led to Amazon establishing its fundamental business principle.

Most of Amazon’s profits come from its high-tech division - which have been reinvested in its business and employees, not in dividends and buybacks. That strategy is reflected in spending on R&D activities, which has led to Amazon becoming the world’s top R&D firm over a short period of time.

Notwithstanding such an increase in expenses for business activities generally described as R&D, Amazon insists on describing them as “technology and content.” While the former focuses on business activities for “significant improvement,” the latter encompasses those for “routine or periodic alterations.”

Amazon has invested considerable resources in extremely innovative business areas - such as Amazon Web Service (AWS), Kindle, Alexa, and Amazon Go - regarding the former type of improvement. In parallel with such forefront innovation, it is endeavoring to absorb external

innovation resources, particularly SIRs [4,5], from external markets and assimilate them into its business model, which transforms the latter business activities into the former during its R&D process. The scheme of this unique R&D model was illustrated earlier in Fig. 6.

Such a world-leading R&D investment can be attributed to its ample free CF enabled by sophisticated CCC management. This management enabled Amazon to acquire ample funds that can be managed without interests for a certain period (as reviewed earlier), leading to a decrease in average interest rates of operating funds. This decrease enabled Amazon to decrease prices of goods and services, as illustrated in Fig. 19, which induced interactions with customers.

Marginal productivity of technology = $\frac{\partial S}{\partial T} = (1 + mr)(r + \rho) \approx p_r, r = (1 - \alpha)r_0$ where m : lead-time between R&D and commercialization, r : interest rate, ρ : rate of obsolescence of technology, p_r : relative price of technology, α : interaction intensity ($0 < \alpha < 1$), r_0 : interest rate in the market ($m = 3$ years, $\rho = 0.2, r_0 = 0.05$: [5]).

Induced interactions, in turn, further advanced CCC (as reviewed earlier) - leading to constructing the **first virtuous cycle**, as illustrated in the upper part of Fig. 20.

Since increased fund through this CCC advancement can be considered as “invisible fund” unexpectedly obtained from the balance of interest free deal, such fund can be utilized for high-risk investment, as it could be excused even if the investment results in no returns [27,28]. Thus, induced interactions accelerated the transformation of R&D: transformation of activities in routine or periodic alterations into significant improvements endorsed and supported by free CF. This acceleration increased in qualified technology stock. Increased stock contributed to sales increase and the construction of a lean cost structure: both contributed to an increase in operation profits. This increase contributed to an increase in free CF, thus constructing the **second virtuous cycle**. Sales increase contributed to the further advancement of CCC management, leading to the construction of the **third virtuous cycle**.

Thus, three virtuous cycles can be constructed from Amazon’s CCC management model, as demonstrated in Fig. 20.

5. Optimal combination of acquisition and R&D

5.1. Exquisite combination of own cash and debt financing

In addition to the foregoing notable CF management, it is also

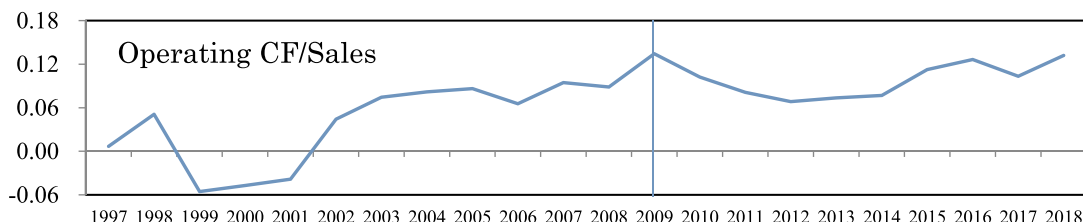


Fig. 18. Dependence on operating CF per sales in amazon (1997–2018). Source: Amazon [15].

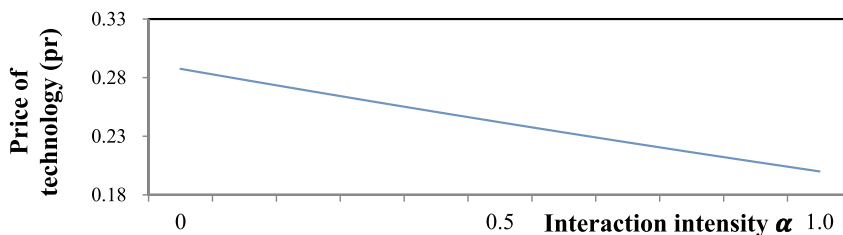


Fig. 19. Correlation between interactions with customers and price decrease in amazon.

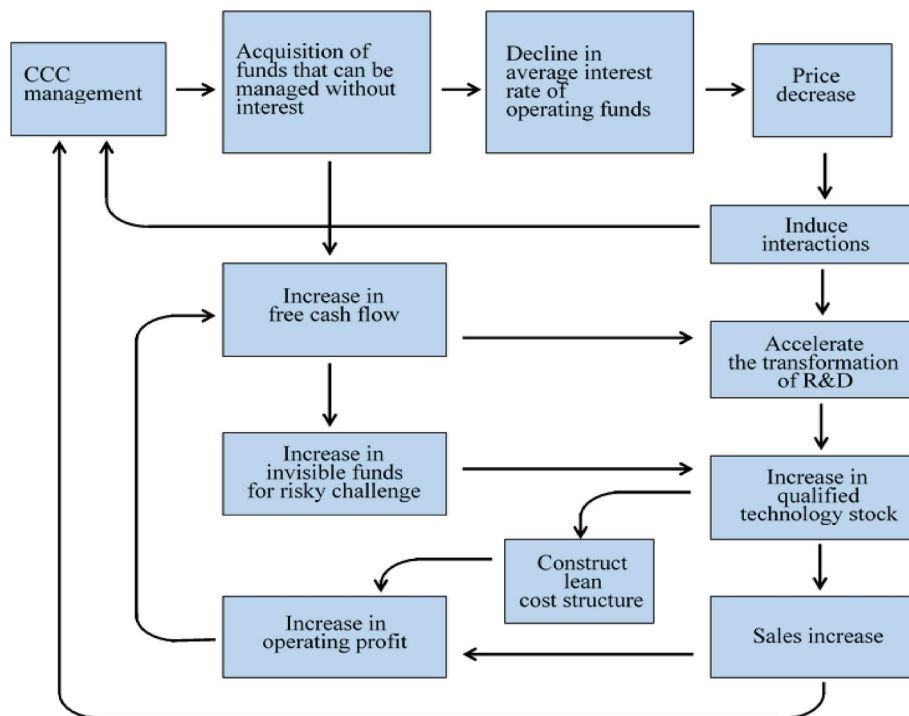


Fig. 20. Dynamics of CCC in accelerating the transformation of R&D.

distinctive that Amazon uses different methods of financing for business acquisitions and investments, taking into account the capital market conditions [29].

Debt capital refers to the value of bonds, notes, term loans, and other credit sources that are used to finance business operations. Amazon carried a long-term debt of US\$ 8.2 billion as of December 2015, and no short-term debt. This debt consisted primarily of notes with interest rates ranging from 1.2% to 4.95%, and maturity dates ranging from 2017 to 2044. Amazon’s total debt was largely unchanged in 2016, as US \$ 7.7 billion., but the company’s indebtedness increased sharply in 2017 and 2018 as US\$ 24.7 and 23.5 billion, respectively.

Amazon acquired US\$ 16 billion in debt financing for the acquisition of Whole Foods for US\$ 13.7 billion in 2017. At that time, Amazon had over US\$ 21 billion cash on hand and was able to fully prepare the funds needed for the acquisition without issuing bonds. However, taking advantage of the low interest rate market environment, Amazon succeeded in raising cost and flexible funds. As Amazon continued to invest in R&D in parallel with the acquisition of Whole Foods, it was considered that its own cash should be devoted to R&D and the acquisition of Whole Foods could be covered by low interest rates, as it was expected to generate CF through its continued growth.

Contrary to such financing decision regarding the acquisition of Whole Foods, Amazon utilized abundant cash generated through its CCC management as reviewed in the preceding section for investments in its new engine - AWS, Amazon Prime, Kindle, Amazon Echo, and Amazon

Go. Such investments enabled Amazon to hold broader financing possibilities. All financing strategies and R&D-driven business development strategies thereon have been deployed as a consolidated machine.

5.2. Three periods of M&A

Amazon’s M&A trend can be classified into three periods, as summarized in Table 4.

The first period - from 1998 to 2000 - can be considered as the active acquisition period. During this period the acquisition was aimed at the beyond book and US markets, including Bookpages (1998, UK) and Alexa Internet (1999).

Alexa Internet was acquired for US\$ 250 million, and it developed into one of Amazon’s core businesses - Amazon Echo (Alexa Voice Service), which started in 2014 [5].

The second period - from 2001 to 2008 - can be considered cautious against M&As, primarily due to the burst of the net bubble. During this period, strengthening the indigenous R&D base was the focus.

The third period - from 2009 to 2018 - can be considered re-active acquisition involving Amazon’s own cash flow - driven R&D - including Zappos (2009), Kiva Systems (2012), Twitch Interactive (2014), and Whole Foods Market (2017).

Table 4
Trend in number of acquisitions by amazon (1998–2018).

Year	Number	Cumulative number	Noteworthy acquisitions and trend	
1998	5	5	Bookpages	
1999	9	14	Alexa Internet	
2000	0	14	Beyond book, US market	
2001	2	16		
2002	0	16		
2003	0	16		
2004	1	17		
2005	4	21	Cautions against the effects of the net bubble bursting, Established a business culture to create by itself by shifting from M&A to R&D.	
2006	2	23		
2007	2	25		
2008	5	30		
2009	5	35	Zappos	
2010	6	41	Strengthened new infra-structure, digital contents toward fusing net and real. Established well comple-mented system between free cash flow and long-term debt,	
2011	5	46		
2012	5	51		Kiva Systems
2013	4	55		
2014	4	59		Twitch Interactive
2015	9	68	Whole Foods Market	
2016	7	75		
2017	12	87		
2018	4	91		

Source: Amazon (2019a).

5.3. Strategy for acquiring the fruit of growth

The acquisition of Whole Foods Market for US\$ 13.7 billion was the biggest and most impressive acquisition. This acquisition is not merely quantitatively impressive but provides significant implications for Amazon’s development trajectory management.

Whole Foods was a high-end supermarket, with 450 stores in the US, focusing on organic foods and maintained sustainable growth with a strong brand and popularity as an eco-friendly firm. It was included in Fortune’s illustrious “100 best companies to work for” list 20 years in a row. However, this company was not necessary digitally advanced and, was, thus, running short of online shift capability and fulfillment power essential to the digital economy, as demonstrated in Fig. 21. Consequently, it started losing market share and online shift capability, peaking in 2013, while sustaining net sales increase as US\$ 9 billion in 2010 to 10.1 billion, 11.7 billion, 12.9 billion, 14.2 billion, 15.4 billion, 15.7 billion and 16.0 billion in 2017.

Grocery spend made online: % of all US. take-home grocery retail spend that is made online.

Sources: Global Data [30]; and Yahoo!Finance [31].

The acquisition of Whole Foods was expected to provide Amazon the knowhow of delivery management and quality control of fresh foods and

pave the way to Amazon’s entry into real stores and sales. Furthermore, capturing the engine of growth that Whole Foods had been constructing for many years could play a significant role in Amazon’s development trajectory. CNBC estimated that, Amazon’s goodwill accounted for US\$ 9 billion of the US\$ 13.7 billion acquisition price. That means 70% of the price Amazon paid was for the future growth it expected to get from Whole Foods, while a mere 30% was based on the value of Whole Foods current business and assets. Amazon’s goodwill balance was US\$ 13.4 billion as of the end of 2017. Furthermore, this acquisition was expected to transfer Whole Food’s knowhow for its digital solution.

Taking these implications into consideration, and following up on Amazon’s transformative direction into a new R&D model, as reviewed in Section 2, Fig. 22 illustrates the implication of the acquisition of Whole Foods to Amazon’s transformative direction with respect to a new R&D model in the digital economy (see the details of the mathematical analysis of this dynamism in Appendix 1).

Amazon has been endeavoring to induce supra-functionality beyond an economic value -as it satisfies a shift in customers’ preferences, which it has been treating as the highest priority. This inducement depends on the activation of the latent self-propagating function indigenous to ICT [46], as illustrated in Fig. 23.

Since the incorporation of growth power is the key to activating this

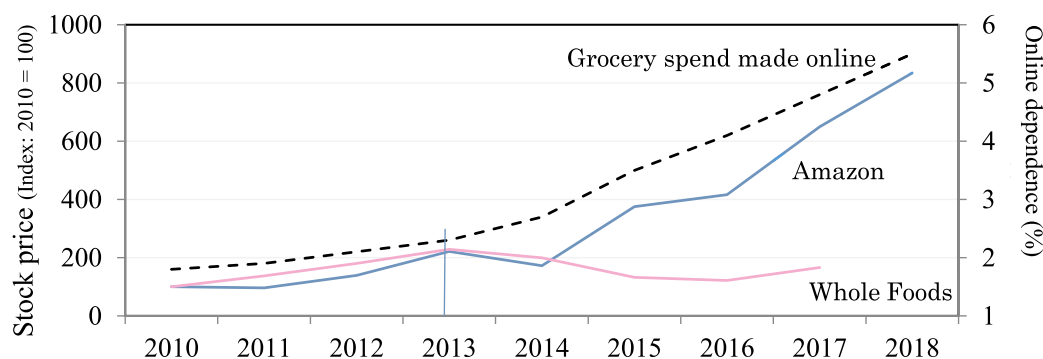


Fig. 21. Trends in stock price and online dependence in amazon and whole foods. (2010–2018).

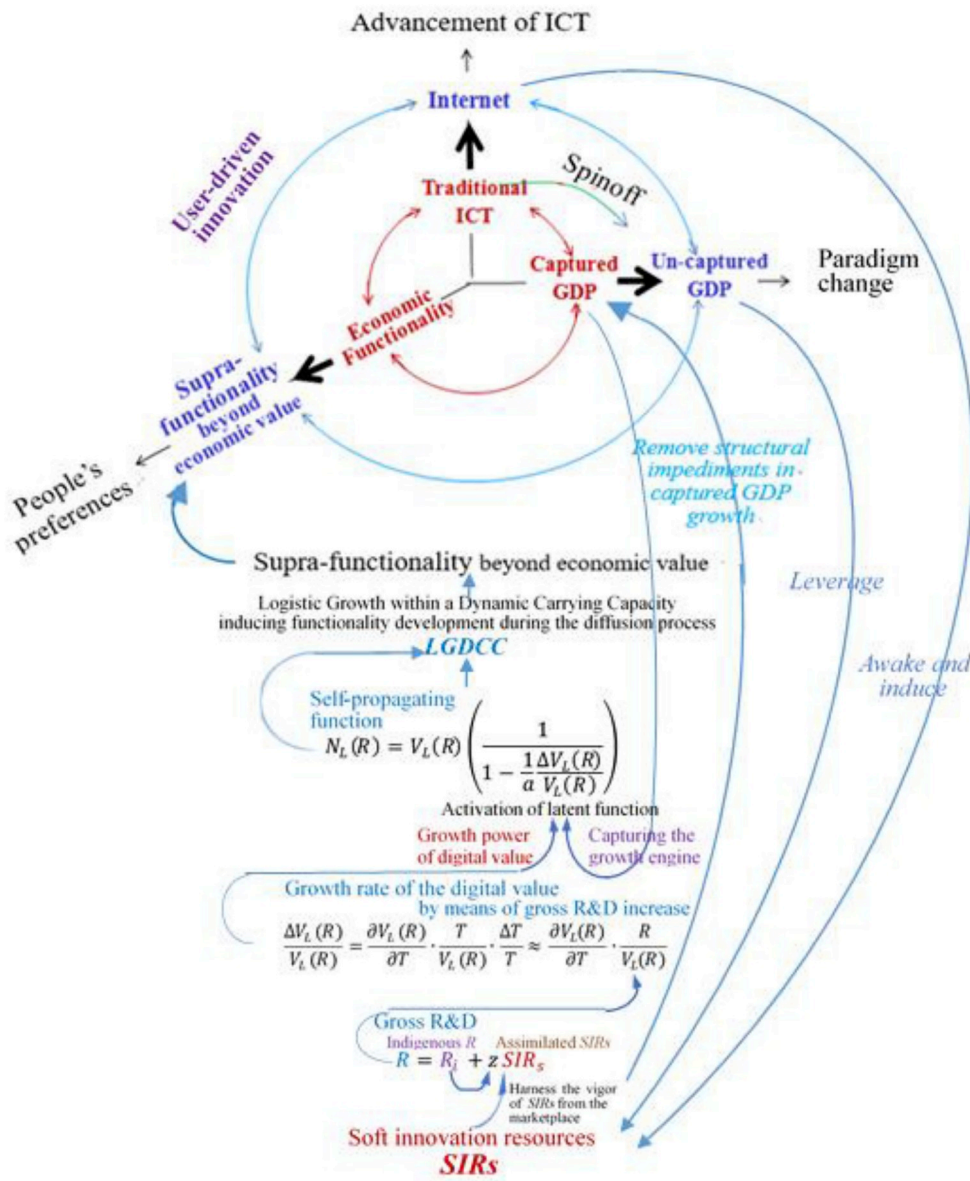


Fig. 22. Dynamism in capturing the growth engine for ensuring. And accelerating the transformation of R&D.

latent function, as demonstrated in Fig. 5 and Fig. A1, Amazon has been endeavoring to incorporate the growth power of digital value through gross R&D increase consisting of increases in indigenous R&D and assimilated external innovation resources centered on SIRs as reviewed in Section 2. The transformation of R&D by assimilating SIRs, from the marketplace corresponds to this theory [33] and contributes to constructing a virtuous cycle between supra-functionality inducement, the acceleration of user-driven innovation, the advancement of the Internet, and the emergence of SIRs, as illustrated in Fig. 22.

While Amazon has succeeded in constructing this virtuous cycle, this cycle contains fragility, particularly of sustainable incorporation of the growth power of digital value without any interruption, as the creation of this value incorporates technological and financial risks and uncertainties.

To reinforce this fragility, Amazon has attempted to supplement the incorporation of growth power. Given its sustainable growth with an established strong brand and popularity, the acquisition of Whole Foods is strongly expected to play the function of capturing the growth engine, as illustrated in Fig. 22. Since this expectation could be realized by assimilating new businesses as real stores and sales in organic foods into

Amazon's digital business without deteriorating original sustainable growth, Amazon has been endeavoring to remove Whole Foods's "structural impediments" as a non-digital firm running short of an online shift capability and fulfillment power. In addition, intensive continued efforts in assimilating Whole Foods's business culture into Amazon empire chain continued.

Consequently, with a two-year learning exercise, contrary to an initial fear of a culture clash, this acquisition markedly expanded Amazon's reach offline and helped push the rest of the grocery industry to bolster its online and offline services [34]. This can be largely attributed to Amazon's intensive efforts for smooth assimilation through structured empowerment that enables to balance control and flexibility as the company grows [35].

5.4. Optimal combination of financial resources in inducing R&D

Fig. 24 illustrates trends in R&D, operating CF, long-term debt and the number of Amazon acquisitions over the period 1998 to 2018.

Based on these observations, Table 5 demonstrates financial sources that have induced Amazon's conspicuous R&D investment since its IPO

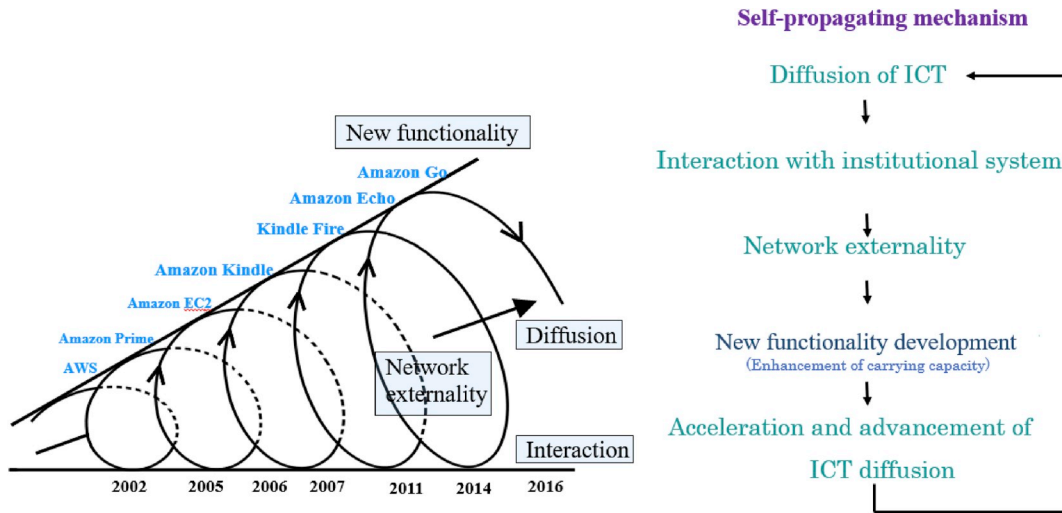


Fig. 23. Dynamism in activating the self-propagating function indigenous to ICT.

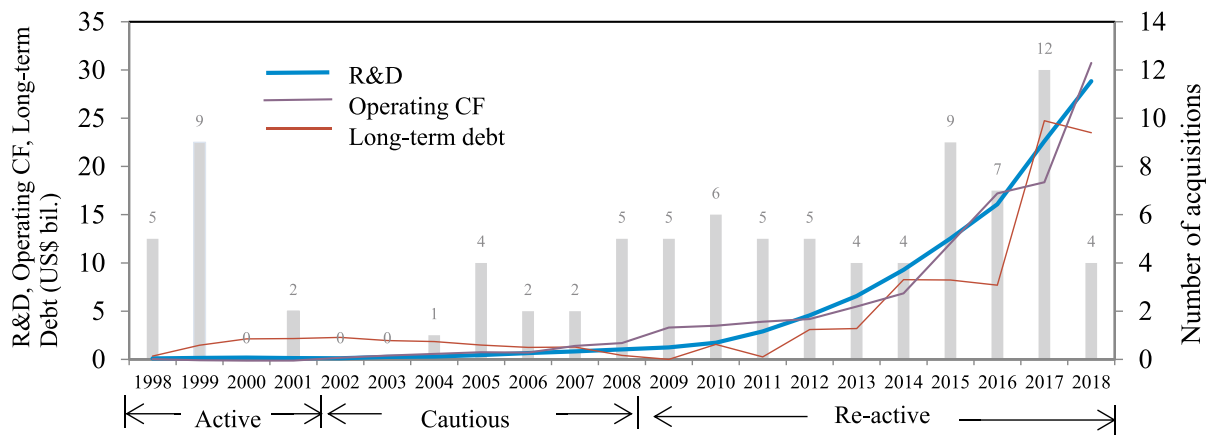


Fig. 24. Trend in R&D, operating cash flow, long-term debt and number of acquisitions by amazon (1998–2018).

in 1997.

The figures in parentheses indicate t-statistics: all are significant at the 1% level except * 5% and ** 15%.

Based on this result, Amazon’s development trajectory focusing on R&D financing as an R&D-driven company can be summarized in Table 6.

Table 6 demonstrates the distinct focus of financial resources for R&D-driven development depending on the three phases of development as follows:

Phase I (1997–2001).

Founded in 1994 as a book-based e-commerce company, focal efforts were devoted to establishing financial and own R&D bases beyond books and the US market.

During this period, operating income was minus, the same as operating CF. Consequently, active M&A attempted largely depended on

long-term debt.

Phase II (2002–2008).

Developed business activities by fully utilizing the fruits of the advancement of M&A, leading to gaining operating income that enabled CCC-oriented CF creation; thereby, intensive R&D was promoted. This accelerated R&D substitution for M&A, leading to strengthening the indigenous R&D base and decreasing long-term debt dependence.

Phase III (2009–2018).

Increased CF, particularly free CF, through the advancement of business and the construction of a lean cost structure. This induced R&D significantly, which contributed to the further advancement of business and subsequent CCC management. Thus, a virtuous cycle between them was constructed - which re-activated M&A, including the acquisition of Whole Foods (which functioned as capturing the growth engine and reinforced the fragility of the virtuous cycle).

Table 5
Financial sources inducing Amazon’s R&D investment (1997–2018).

$\ln R = 1.12 + 0.33D_2 \ln OCF + 0.72D_3 \ln OCF + 0.89D_1 \ln LTD - 1.04D_2 + \ln LTD + 1.04D_3 \ln LTD$						
	(1.79***)	(2.90*)	(7.71)	(20.42)	(-5.63)	(3.80)
$-2.46D_1 + 10.42D_2 - 0.79D_{31} \quad adj.R^2 \quad 0.996 \quad DW \quad 1.86$						
	(-3.55)	5.53	(-6.42)			

R: R&D investment; OCF: operating CF; LTD: long-term debt; D: dummy variables (D₁: 1997–2001 = 1, others = 0; D₂: 2002–2008 = 1, others = 0; D₃: 2009–2018 = 1, others = 0; D₃₁: 2009, 2010 = 1, others = 0).

Table 6
Amazon's Development Trajectory focusing on R&D Financing.

Period	1997–2001	2002–2008	2009–2018
Elasticity of financing resources to R&D			
Operating CF	-	0.33	0.72
Long-term debt	0.89	-1.04	0.17
Operating CF	No function	Start its function	Full-fledged function
M&A Development phase	Active Phase I Attempt M&A by leveraging low interest rate market environment and raising fund with debt finance.	Cautious Phase II Develop business activities by fully utilizing the advantage of M&As and creating CCC-oriented cash flow, thereby investing in R&D.	Re-active Phase III Increase cash flow, particularly free cash flow, through the advancement of business and R&D; thereby a virtuous cycle between them is constructed.

Amazon accelerated its digitalization by migrating all retail web services to AWS in 2010, thereby shifting to an increasingly digital state.

On the basis of these phased efforts, three virtuous cycles - involving financing structures such as ample free CF creation in combination with debt financing and R&D transformation dynamism, as transforming routine or periodic alterations into significant improvement during R&D process - were constructed.

6. Conclusion

In line with an increasing concern and with respect to the new concept of the techno-management system in the digital economy, Amazon, based on its unique identical system, jumped up to being the world R&D leader in 2017, with a consequent skyrocketing increase in its market capitalization over a short period of time, and this paper attempted to elucidate this dynamism.

Following the authors' own preceding analysis that identified Amazon's unique R&D inducing system that transforms routine or periodic alteration activities into significantly improving activities during its R&D process by assimilating external resources of innovation based on an empire chain, a big data collection system, and also the architecture for participation, elucidation of inside the black box of its techno-management system that enabled to secure such a large amount of R&D investment were attempted.

It was identified that Amazon succeeded in fusing a unique R&D transformation system and a sophisticated financing system centered on CCC-driven CF management that induced the following dynamism:

- (i) With strong user-driven innovation, Amazon has constructed an overwhelming power to both customers and vendors in its marketplace.
- (ii) This power enabled the construction of an extremely advanced CCC as negative 20–30 days.
- (iii) Advanced CCC decreased average interest rates of operating funds leading to a decrease in prices of goods and services, and enabled Amazon to deploy dynamic pricing which induced interactions with customers while increasing free CF.
- (iv) Induced interactions, in turn, further advanced CCC, leading to the construction of the first virtuous cycle.
- (v) Endorsed and supported by increased free CF, induced interactions accelerated the transformation of R&D, leading to increasing qualified technology stock.
- (vi) Increased stock contributed to sales increase, as well as the construction of a lean cost structure.

- (vii) Both contributed to an increase in operating profits and a subsequent increase in free CF, thus constructing the second virtuous cycle.
- (viii) Sales increase contributed to further advancement of CCC management, leading to the third virtuous cycle.

Thus, three virtuous cycles have been constructed regarding Amazon's CCC management, enabling its notable CF management.

In addition to this cash flow-based financing, Amazon also uses a different method of financing for business acquisitions and investments for reinforcing the above virtuous cycles by capturing a growth engine and also stimulating new R&D, taking into account the capital market conditions and, thereby deploying an exquisite combination of own cash and debt financing.

All financing strategies and R&D-driven business development strategy thereon has been deployed as a sophisticated consolidated machine that was constructed through three phases of development after the IPO in 1997, consisting of:

(i) Phase I (1997–2001)

Focal efforts were devoted to establishing financial and R&D bases beyond books and the US market through active M&A largely dependent on long-term debt.

(ii) Phase II (2002–2008)

Developed business activities by fully utilizing fruits of the advancement of M&A, leading to gaining operating income that enabled CCC-oriented CF creation; thereby, R&D was promoted - which accelerated R&D substitution for M&A, leading to strengthening indigenous R&D base and decreasing long-term debt dependence.

(iii) Phase III (2009–2018)

Increased CF, particularly free CF through advancement of business and construction of lean cost structure which induced R&D significantly leading to contributing to further advancement of business and subsequent CCC management. Thus, a virtuous cycle between them was constructed which re-activated M&A including the biggest acquisition of Whole Foods which functioned as capturing the growth engine and reinforced the fragility of the virtuous cycle.

Noteworthy is all functions as marketplace dynamism inducing CCC advancement, CCC-driven CF management and R&D transformation from routine or periodic alteration to significant improvements during the R&D process are well-orchestrated as a consolidated sophisticated machine.

These findings give rise to the following insightful suggestions supportive of the transformation of the R&D model in the digital economy:

- (i) The fusion of an R&D transformation model in the digital economy and a CCC-seeking advanced financing system should be promoted.
- (ii) The orchestration of institutional system endorsing R&D endeavor, market dynamism inducing CCC advancement, CCC-driven CF management, and R&D transformation strategy should be accelerated.
- (iii) Amazon's identical platform consisting of empire chain, big data collection system, and the architecture for participation should be reviewed from the view point of above fusion and orchestration.
- (iv) Capturing the growth engine should be studied for co-evolutionary coupling between captured and uncaptured GDP cycles.

Future works should focus on the following points:

- (i) In-depth comparative analysis of a similar techno-financing system in global ICT leaders.
- (ii) Deployment of a similar analysis in ICT-leading nations.
- (iii) Development of an analytical approach identifying the optimal orchestration of key governing functions.
- (iv) Effects of co-evolutionary coupling between captured and uncaptured GDP cycles for resilient development trajectory.

Acknowledgement

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Appendix 1. Dynamism Inducing a Virtuous Cycle

1. Bi-Polarization Fatality of ICT-Driven Development

ICT in which network externalities function to alter the correlation between innovations and institutional systems - which creates new features of the innovation leading to exponential increase. Schelling [36] portrayed an array of logically developing and diffusing social mechanisms stimulated by these interactions. The advancement of the Internet further stimulates these interactions and accelerates ICT's logically developing and diffusing feature, which is typically traced by the sigmoid curve [32].

Digital value created by the Internet of things (IoT) can be depicted as follows [37,38]:

$$V = F(X, T) = F(X(T), T) \approx F(T) \text{ Growth rate: } \frac{\Delta V}{V} = \left(\frac{\partial V}{\partial T} \cdot \frac{T}{V} \right) \cdot \frac{\Delta T}{T} \approx \frac{\partial V}{\partial T} \cdot \frac{R}{V} \tag{A1}$$

where T : gross ICT stock; X : other production factors; and R : R&D investment ($\Delta T \approx R$)

In long run, since $T \approx \frac{R}{\rho+g}$, growth rate can be depicted as follows:

$$\frac{\Delta V}{V} = \left(\frac{\partial V}{\partial T} \cdot \frac{T}{V} \right) \cdot \frac{\Delta T}{T} \approx \frac{\partial V}{\partial T} \cdot \frac{R}{V} = \frac{\partial V}{\partial R} \cdot \frac{\partial R}{\partial T} \cdot \frac{R}{V} = (\rho + g) \frac{\partial V}{\partial R} \frac{R}{V} \tag{A2}$$

where ρ : rate of obsolescence of technology, g : R&D growth rate at the initial period.

Given the logistic growth nature of ICT, R&D-driven development trajectory $V_s(R)$ can be depicted by the following epidemic function that leads to a simple logistic growth function (SLG):

$$\frac{dV}{dR} \approx \frac{\partial V}{\partial R} = aV \left(1 - \frac{V}{N} \right) \tag{A3}$$

$$SLG = V_s(R) = \frac{N}{1 + b e^{-aR}} \tag{A4}$$

where N : carrying capacity; a : velocity of diffusion; b : coefficient indicating the initial level of diffusion.

Given the ICT-driven development, its growth follows a sigmoid trajectory that continues to grow until it reaches carrying capacity (upper limit of growth). In this trajectory, while growth rate continues to increase before reaching the inflection point corresponding to the half the level of the carrying capacity, it decreases after exceeding the inflection point. Thus, ICT-driven logistic growth incorporates bi-polarization fatality, with increase and decrease of marginal productivity between before and after the inflection point [5,6].

2. Dilemma between R&D Expansion and Productivity Decline

This causes the dilemma between R&D expansion and productivity decline, as R&D expansion exceeding the inflection point results in productivity decline and subsequent growth rate decrease [1].

Confronting such a dilemma, global ICT-leaders have been endeavoring to find a practical solution by transforming their traditional business models into new business models.

Given that this dilemma stems from the unique feature of ICT, logistic growth, this feature should be transformed.

3. Transformation of the Unique Feature of ICT: Self-Propagating Function

As far as the development trajectory depends on the SLG trajectory, its digital value, $V_s(R)$, saturates with the fixed upper limit which inevitably results in the above dilemma. However, once the trajectory shifts to logistic growth within a dynamic carrying capacity (LGDC), its digital value, $V_L(R)$ can continue to increase, as it creates a new carrying capacity during the process of development.

In particular innovation which creates new carrying capacity $N_L(R)$ during the diffusion process, equation (A3) is developed as follows:

$$\frac{dV(R)}{dR} = a V(R) \left(1 - \frac{V(R)}{N_L(R)} \right) \tag{A5}$$

Equation (A5) develops the following LGDC - which incorporates self-propagating function as carrying capacity increases corresponding to $V(R)$ increase as depicted in equation (A6) and (A7) [32]:

$$V_L(R) = \frac{N_k}{1 + b e^{-aR} + \frac{b_k}{1-a_k/a} e^{-a_k R}} \tag{A6}$$

where N_k : ultimate carrying capacity; a, b, a_k , and b_k : coefficients.

Dynamic carrying capacity $N_L(R)$ in this *LGDC* is depicted as follows:

$$N_L(R) = V_L(R) \left(R \left(\frac{1}{1 - \frac{1}{a} \frac{\Delta V_L(R)}{V_L(R)}} \right) \right) \quad \Delta V_L(R) = \frac{dV_L(R)}{dR} \tag{A7}$$

4. Assimilation of Soft Innovation Resources

Therefore, the key to sustainable growth in this trajectory is how to trigger $V_L(R)$ increase, without confronting the dilemma, for realizing such a virtuous cycle as $V_L(R)$ increase stimulating $N_L(R)$ enhances - which, in turn, leads to $V_L(R)$ growth.

Since ICT incorporates an indigenous self-propagating function utilizing network externality (see Fig. 25. [32], the point for sustainable growth corresponds to activating a latent self-propagating function indigenous to ICT. Amazon highly depends on network externality particularly data network externality as reviewed in Section 4.2.

Efforts to create a new carrying capacity are reflections of a repulsive power of price (marginal productivity) decrease as a consequence of the bipolarization fatality against the excessive R&D.

This repulsive power enforces ICT leaders to absorb resources for innovation particularly of SIRs from the external market that advances innovation without confronting the dilemma, and assimilate them to their business [4]. Here, SIRs are considered condensates and crystals of the advancement of the Internet [1,2] and consist of the Internet based resources that have been either sleeping or untapped or are results of multi-sided interaction in the markets where consumers are looking for functionality beyond an economic value [4].

5. Supra-functionality beyond Economic Value

Assimilated SIRs awake and activate latent a self-propagating function indigenous to ICT [1]. Activated a self-propagating function develops *LGDC* and induces functionality development leading to exploring supra-functionality beyond an economic value encompassing social, cultural, and emotional values [39].

Since this functionality corresponds to a shift in people’s preferences in the digital economy, this exploration further induces user-driven innovation and subsequent advancement of the Internet, which accelerates the awakening and inducement of further SIRs.

6. Core Function of the Disruptive Business Model

Core function of this disruptive business model that overcomes the dilemma between R&D expansion and productivity decline in the digital economy is to activate the latent self-propagating function through growth by means of an increase in gross R&D consisting of increases in indigenous R&D (R_i) and assimilated external innovation resources centered on SIRs, as illustrated in Fig. A1.

Increased digital value $V_L(R)$ generated by *LGDC* induces indigenous R&D R_i increase which contributes to increasing assimilation capacity z [40]. Both are the sources of R&D-driven growth on which the activation of a self-propagating function and consequent *LGDC* growth depends. Given the fragility of this feedback cycle due to technological and financing risks and uncertainty, the reinforcement of this cycle would be critical.

7. Co-Evolutionary Coupling between Captured and Uncaptured GDP Cycles

During the process of this sustainable growth endeavor, ICT leaders’ development trajectory is transformed from the traditional GDP-based co-evolution cycle (which seeks economic functionality) to the uncaptured GDP-driven co-evolution cycle (which seeks supra-functionality beyond economic value) [39,41,42].

The shift in people’s preferences from the economic functionality to the supra-functionality beyond an economic value as demonstrated in Fig. A2, induces the further advancement of the Internet, which intensifies the increasing dependence on uncaptured GDP.

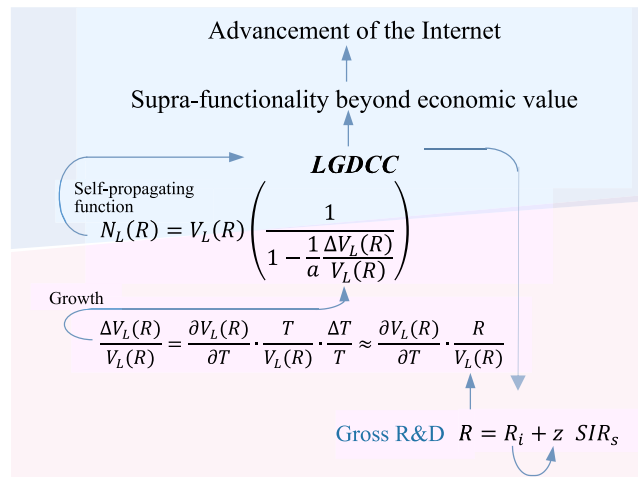


Fig. A1. Dynamism of a Core Function of the Disruptive Business Model.

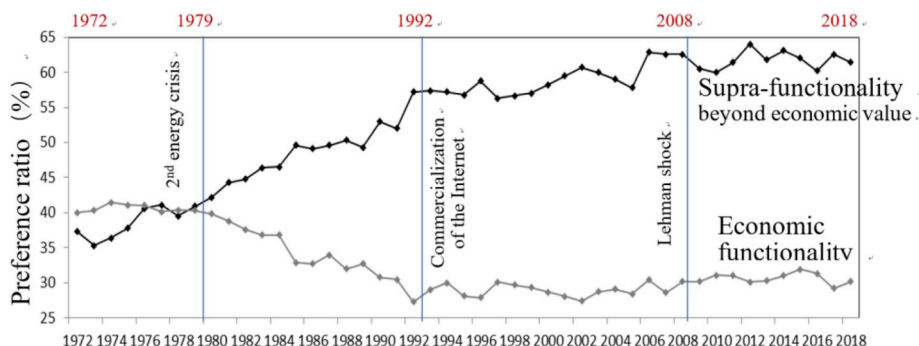


Fig. A2. Trend in the Shift in Peoples' Preferences in Japan (1972–2018). Source: Japan Cabinet Office [43].

The advancement of the Internet, at the same time, awakes and induces *SIRs* - which activate the latent self-propagating function leading to supra-functionality beyond economic value exploration - thus, uncaptured GDP-driven co-evolution cycle is accelerated. Induced *SIRs* also stimulate captured GDP by removing structural impediments in its growth [44].

Thus, the above disruptive business model toward overcoming the dilemma by inducing supra-functionality beyond an economic value leverages on co-evolutionary coupling between captured and uncaptured GDP cycles [33].

This coupling enables the capture of the growth power from captured GDP-based co-evolution and reinforces such a sophisticated and, at the same time fragile, virtuous cycle as *SIRs* assimilation; the activation of self-propagating function; the inducement of supra-functionality beyond an economic value; further advancement of the Internet; and the emergence of *SIRs*.

Appendix 2. Statistics for the analysis

Table A1
Trend in Amazon's Key Managerial Factors (1997–2018) – US\$ mil.

Year	Sales	Operating income	R&D	Net income	Operating CF	Free CF	Long-term debt
1997	148	-32	13	-30	1	-7	77
1998	609	-109	46	-125	31	3	348
1999	1640	-606	159	-720	-91	-378	1466
2000	2762	-864	269	-1411	-130	-265	2127
2001	3122	-412	241	-567	-120	-170	2156
2002	3933	64	216	-149	174	135	2277
2003	5264	270	257	35	392	346	1945
2004	6921	440	283	588	566	477	1855
2005	8490	432	451	359	733	529	1480
2006	10,711	389	662	190	702	486	1247
2007	14,835	655	818	476	1405	1181	1282
2008	19,166	842	1033	645	1697	1364	409
2009	24,509	1129	1240	902	3293	2920	0
2010	34,204	1406	1734	1152	3495	2516	1561
2011	48,077	862	2909	631	3903	2092	255
2012	61,093	676	4564	-39	4180	395	3084
2013	74,452	745	6565	274	5475	2031	3191
2014	88,988	178	9275	-241	6842	1949	8265
2015	107,006	2233	12,540	596	12,039	7450	8227
2016	135,987	4186	16,085	2371	17,203	10,466	7694
2017	177,866	4106	22,620	3033	18,365	8307	24,743
2018	232,887	12,421	28,837	10,073	30,723	19,400	23,495

Sources: Amazon [15].

Table A2
Amazon's Consolidated Income Statement (2014–2018) – US\$ mil.

	2014	2015	2016	2017	2018
Net product sales	70,080	79,268	94,665	118,573	141,915
Net services sales	18,908	27,738	41,322	59,293	90,972
Net sales	88,988	107,006	135,987	177,866	232,887
[Operating expenses]	[88,810]	[104,773]	[131,801]	[173,760]	[220,466]
(Cost of sales)	(62,752)	(71,651)	(88,265)	(111,934)	(139,156)
(Fulfillment)	(10,766)	(13,410)	(17,619)	(25,249)	(34,027)
(Marketing)	(4332)	(5254)	(7233)	(10,069)	(13,814)
(Technology and content)	(9275)	(12,540)	(16,085)	(22,620)	(28,837)
(General and administrative)	(1552)	(1747)	(2432)	(3674)	(4336)
(Other operating expense)	(133)	(171)	(167)	(214)	(296)

(continued on next page)

Table A2 (continued)

	2014	2015	2016	2017	2018
Operating income	178	2233	4186	4106	12,421
Interest income	39	50	100	202	440
(Interest expense)	(210)	(459)	(484)	(848)	(1417)
(Other balance)	(118)	(256)	90	346	(183)
(Provision for income taxes)	(167)	(950)	(1425)	(769)	(1197)
(Equity-method investment activity, net of tax)	37	(22)	(96)	(4)	9
Net income	(241)	596	2371	3033	10,073

Source: Amazon [15].

Table A3

Trend in Cash Flow in Amazon (2012–2018) – US\$ bil.

	2012	2013	2014	2015	2016	2017	2018
Net income before extraordinary	−0.04	0.27	−0.24	0.60	2.37	3.03	10.07
Depreciation, depletion & amortization	2.16	3.25	4.19	5.65	7.48	11.48	15.34
Deferred taxes & investment tax credit	–	–	−0.32	0.08	−0.25	−0.03	0.44
Other funds	0.54	1.19	2.24	3.15	3.68	4.13	5.91
Changes in working capital	1.52	0.77	0.97	2.56	3.92	−0.24	−1.04
Net operating cash flow	4.18	5.48	6.84	12.04	17.20	18.37	30.72
Capital expenditures*	−3.79	−3.44	−4.89	−4.59	−6.74	−10.06	−11.32
Net assets from acquisitions	−0.75	−0.31	−0.98	−0.80	−0.12	−13.97	−2.19
Purchase/sale of investments	0.94	−0.52	0.81	−1.07	−3.02	−3.05	1.14
Net investment cash flow	−3.60	−4.28	−5.07	−6.45	−9.88	−27.08	−12.37
Issuance/Reduction of debt. net	2.79	−0.62	4.42	−3.88	−3.74	9.93	−7.69
Other funds	−0.53	0.08	0.01	0.12	0.83	–	–
Net financing cash flow	2.26	−0.54	4.43	−3.76	−2.91	9.93	−7.69
Free cash flow (Net OCF – Cap. exp.)	0.40	2.03	1.95	7.45	10.47	8.31	19.40

Source: Amazon [15].

* Purchases of property and equipment, net of proceeds from property and equipment incentives.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.techsoc.2019.101219>.

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