NOVEL R & D CAPABILITIES AS A RESPONSE TO ESG RISKS- LESSONS FROM AMAZON'S FUSION OF DIVERSE KNOWLEDGE

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ABSTRACT

Environmental, Social, and Governance (ESG) management is essential for transforming corporate financial performance-oriented business strategies into Finance (F) + ESG optimization strategies to achieve the Sustainable Development Goals (SDGs).

In this trend, the rise of ESG risks has divided firms into two categories. Former incorporates a growth-mindset that creates a passion for learning, and urges it to improve itself by endeavoring Research and development (R&D) -driven challenges, while the other category, characterized by risk aversion, avoids challenging highly uncertain R&D activities and seeks more manageable endeavors.

This duality underscores the complexity of corporate R&D strategies in addressing ESG risks and necessitates the development of novel R&D capabilities for corporate R&D transformation strategies towards F + ESG optimization.

Building on this premise, this paper conducts an empirical analysis, utilizing reliable firms data on ESG risk and brand value, with a focus on 100 global R&D leader firms. It analyzes R&D and actions for ESG risk mitigation, and assesses the development of new functions that fulfill F + ESG optimization through R&D. The analysis also highlights the significance of network externality effects, with a specific focus on Amazon, a leading R&D company, providing insights into the direction for transforming R&D strategies towards F + ESG optimization.

The dynamics of stakeholder engagement in F + ESG optimization are indicated with the example of amazon's activities. Through the analysis, it became evident that Amazon's capacity encompassing growth and scalability, specifically its ability to grow and expand, is accelerating high-level research and development by gaining the trust of stakeholders in the "synergy through R&D-driven ESG risk mitigation."

Finally, as examples of these initiatives, the paper discussed the Climate Pledge led by Amazon and the transformation of Japan's management system.

KEYWORDS

Decarbonization, Amazon, climate pledge, fusion of diverse knowledge

1. INTRODUCTION

1.1. Research focus

The escalation of environmental, societal, and governance (ESG) risks, including carbon neutrality, demands that firms consider the interests of all stakeholders beyond customers and shareholders, thereby effecting a transformation in corporate management strategies. Consequently, the strategies employed by R&D firms, which had leveraged R&D for competitive advantage, undergo fundamental alteration, necessitating an inevitable structural shift in the R&D model. Notably, many Japanese firms with strengths in manufacturing have witnessed a significant decline in their global competitiveness due to the convergence of changing notions of growth and R&D in the advancing digital economy (Tou et al. 2019b[18], Tou et al. 2020 [19], Watanabe et al. 2020 [21]).

In light of these trends, global firms actively implementing ESG initiatives recognize decarbonization as an opportunity for innovation, and it means that they operate under the common understanding that "ESG responses are no longer a cost." This has led to the formation of strategic collaborative frameworks aimed at implementing innovation through "collaboration with potential partners across borders and industries," harnessing diverse knowledge for this purpose. Effective management of environmental, societal, and governance factors is indispensable for achieving the Sustainable Development Goals (SDGs). The escalating demand for solutions to ESG issues, including carbon neutrality, is reshaping corporate management strategies from a perspective centered on financial performance (Corporate Financing Performance: CFP) to optimization that encompasses both CFP and ESG, thus fulfilling proper ESG management. Notably, the resolution of ESG challenges is regarded as a catalyst for new innovation, and the co-evolution between addressing ESG issues and stimulating R&D is considered key to achieving SDGs.

In the above trend, a firm's response to ESG depends on the allocation of management resources that can be effectively directed towards ESG (Fu et al. 2020 [7]). Growth-oriented firms typically exhibit a positive disposition towards active investment, while firms with a fixed mindset generally exercise restraint in investment (Watanabe et al. 2021[3]). This trend is distinctly manifested in their response to R&D, and even among the world's top 100 R&D firms, a dichotomy emerges beyond a certain threshold, categorizing them into "high R&D firms" (HRFs) and "low R&D firms" (LRFs) (see Figure 1).

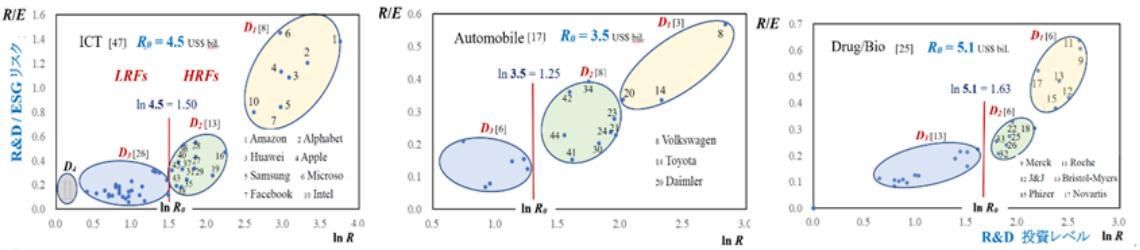


Figure 1 Correlation between R&D and R&D Inducibility by ESG Risk in Global R&D Leaders (2020).

1. R: R&D investment; R0: threshold (critical mass) of R&D; E: ESG risk ratings; D1*, D2* , D3* and D4: clusters.
2. The number in the circle corresponds to the number of 100 global R&D leaders tabulated.
3. D4 in ICT indicates 81 firms within the R&D rank 101-200 (PwC, 2018).

Fig. 1 shows a correlation between R&D and R&D inducibility due to increased ESG risk, R/E (R&D investment induced by an increase in 1 unit of ESG risk) in global R&D leaders in 2020.

This figures demonstrate that 100 R&D leaders can be classified into three clusters depending on their R&D level as D1: Supreme R&D firms (SRFs), D2: Medium R&D firms (MRFs), and D3: lower R&D firms (LRFs). In addition, Fig. 1 demonstrate a clear distinction of the R/E level between LFRs and higher R&D firms (HRFs) consisting of SRFs and MRFs.

HRFs ardently pursue R&D-driven solutions to ESG risks, whereas LRFs tend to evade R&D risks and explore non-R&D alternatives.

As a result, as shown in Figure 2, it is assumed that this has led to a dualization of synergies (virtuous cycle) and trade-offs (vicious cycle) between R&D and ESG risk response.

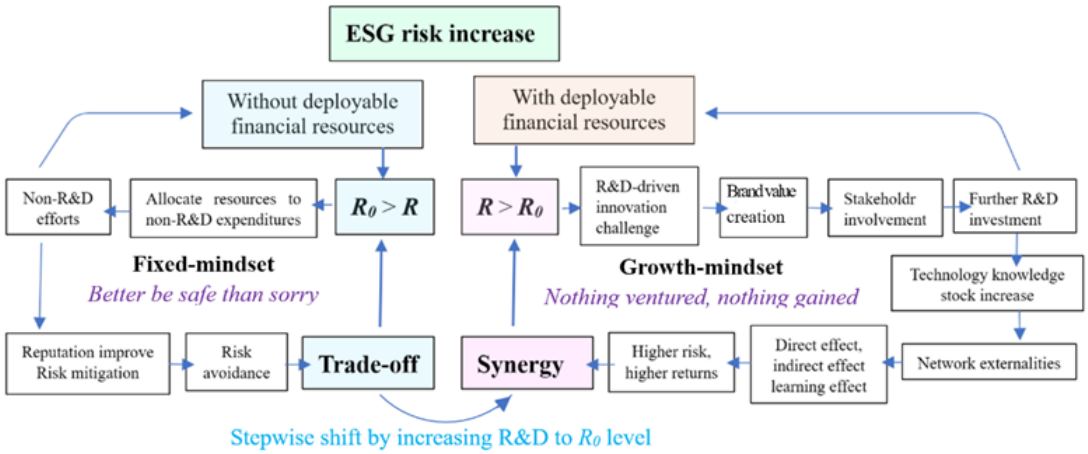


Figure 2. R&D responses to ESG risks – duality of synergies and trade-offs.

Source: Watanabe et al. (2022)[25]

As per the foregoing, this paper undertakes a quantitative analysis employing statistical data regarding the engagement of various firms with ESG and their accomplishments in surmounting associated challenges. The paper's primary focus lies in the transformation of R&D models within the context of the digital economy, with an emphasis on corporate management strategies that prioritize ESG. The aim is to elucidate the direction of R&D model transformation through this approach, targeting the world's leading R&D firms.

1.2. Existing research - Corporate response strategies to ESG risks

Existing research highlights the escalation of ESG risks, including carbon neutrality, and underscores how they are transforming corporate management strategies from a CFP-centered perspective to Neo Corporate Performance (NCP), optimizing both financial (F) and ESG aspects (Henisz, 2019 [9], Husted, 2017 [10]).

In particular, Fu et al. (2020) [7] point out that corporate engagement with ESG issues is intrinsically linked to the allocation of managerial resources. They emphasize that these choices are motivated by profit-enhancing reasons rather than being purely philanthropic.

Furthermore, Dweck et al. (1988) [4] reveal that firms grounded in growth-oriented management philosophies tend to exhibit a favorable disposition towards ESG investments. In contrast, firms adhering to fixed mindsets tend to display a more passive attitude towards such financial endeavors.

Regarding corporate engagement with ESG issues, studies on the financial performance of firms concerning ESG risks indicate a positive relationship between ESG engagement and financial performance. For instance, NYU Stern's Center for Sustainable Business reviewed over 1,000 studies published between 2015 and 2020 and confirmed a positive correlation between ESG engagement and financial performance. NYU Stern also highlight how corporate sustainability initiatives contribute to the enhancement of financial performance through improved risk management and increased innovation (NYU Stern, 2021 [13]).

Furthermore, Atz et al. (2019) [2] indicated that SDGs strategies implemented at the corporate level can enhance better financial performance through mediating factors. In other words, they emphasized that more innovation, higher operational efficiency, and improved risk management, among other aspects, serve as sustainability drivers for better financial performance.
Additionally, Vishwanathan et al. (2019) [20]reviewed 344 studies, demonstrating that four mediating factors play a central role: the enhancement of corporate reputation, strengthened collaboration with stakeholders, reduced corporate risks, and enhanced innovation capabilities.
Moreover, McWilliams et al. (2000) [11] and Henisz et al. (2019)[9] argue that a shift toward strategies aiming for comprehensive goals, including F+ESG optimization, is necessary. They emphasize that this transformation requires synergy rather than a trade-off with financial objectives, and that research and development play a critical role in addressing this contrast. In essence, firms that achieve synergy in the face of growing ESG risks can anticipate substantial research and development investments by combining a high level of research and development intensity (research and development per unit of revenue) to increase earnings. Watanabe et al. demonstrated this dynamic by reviewing the growth trajectories of 500 leaders in the global Information and Communication Technology (ICT) sector from 2005 to 2016 (Watanabe et al., 2018[21]; Naveed et al., 2018[12]; Tou et al., 2019a[17]).

Furthermore, Watanabe et al. (2020) [21]conducted an analysis of the institutional sources of Amazon's substantial R&D investments from the perspective of stakeholder support. Against the backdrop of expectations for Amazon's innovation and growth, they demonstrated a shift in stakeholder attitudes from cautious investments to higher-risk investments.

Moreover, Tou et al. (2019a) [17] provided evidence that highly research and development-intensive global ICT firms are attempting to activate potential self-propagation based on network externalities proportional to the increase in research and development. This enables them to incorporate resources from open innovation and lead to an expansion in available financial resources.

An illustrative case is Amazon's Climate Pledge initiative, where the global front-runner in research and development, Amazon, has embarked on a climate change commitment initiative aimed at leveraging diverse expertise from stakeholders worldwide to pursue decarbonization. Subsequently, these cases are categorized within the upper echelons of the world's top 100 research and development firms, comprising 53 firms in the ICT sector, 19 in the automotive sector, and 28 in the pharmaceutical sector.

While numerous studies have previously analyzed corporate responses to ESG risks, a significant portion of these have predominantly focused on specific ESG indicators and their correlation with ESG or financial performance. Consequently, research that underscores the role of research and

development as an energy source for transforming ESG risks into a springboard for new innovations remains scarce.

Inspired by the existing research outlined above, this paper aims to identify the contrasting dynamics between the virtuous cycle of increased ESG risks, increased research and development, efforts to tackle challenging risks, and the further induction of R&D in high research and development-intensive leaders. It also investigates the vicious cycle of increased ESG risks and increased research and development in risk-prone firms. To accomplish this, a new practical model was developed to determine the threshold of research and development levels for each firm and the elasticity of research and development concerning ESG risks by combining Arrow's learning theory (Arrow, 1962 [1]) and Dweck's growth theory and fixed mindset theory (Dweck, 2006 [5]).

By elucidating the dynamics of virtuous and vicious cycles and empirically demonstrating their significance, this paper provides evidence of the impact of network externalities in reconciling sustainable research and development growth with ESG risk reduction.
This paper is structured as follows: In Section 2, the framework of the analysis is presented. Section 3 discusses the response of Global R&D leaders to ESG risks, while Section 4 introduces the initiatives of R&D leaders. Section 5 showcases the case of Amazon-led Climate Pledge and Japan’s management system against this paper's implications. Finally, in Section 6, summary and achievements of this paper and future research directions are summarized.

2. ANALYSIS FRAMEWORK

2.1. 100 Global R&D Companies

Utilizing the understanding that R&D plays a crucial role in showcasing the synergistic impact of F + ESG, instances are sought from leaders in global R&D. These instances are subsequently categorized within the world's uppermost echelon of 100 R&D corporations (comprising 53 from the ICT sector, 19 from the automotive sector, and 28 from the pharmaceutical sector).

2.2. ESG risks and brand value

In this study, data of high credibility from esteemed institutions is employed to address both ESG risks and brand value.

(1) ESG risks

This study draws upon the Company ESG Risk Ratings (Sustainalytics, 2021[16]), which assesses the manner in which companies confront industry-specific ESG risks and their adeptness in mitigating these risks. Sustainalytics’ Companies ESG Risk Ratings measure a company’s exposure to industry-specific material ESG risks and how well a company is managing those risks. This multi-dimensional way of measuring ESG risk combines the concepts of management and exposure to arrive at an absolute assessment of ESG risk. The ratings provide a comprehensive analysis of a company’s exposure to and management of ESG risks, making it a valuable resource for investors, banks, lenders, and corporations.

(2) Brand value

This study employs data derived from the “Global Brand Value Report” published by Brand Finance, a leading independent brand valuation consultancy (Brand Finance, 2020 [3]). This

report provides a comprehensive analysis of brand value, incorporating data from over 5000 of the world's most prominent brands across various sectors and geographies. The data contained in the report is rigorously analyzed and calculated using internationally recognized standards, making it a valuable resource for this research.

2.3. Analysis frame

Recognizing that companies generating synergy display characteristics aligned with growth-oriented perspectives and a strong inclination toward learning, and that they manifest synergies upon surpassing the R&D threshold (Fig. 1), R&D leaders encountering ESG risks, as depicted in Fig. 2, embarked on an endeavor. Their objective was to construct an R&D framework capable of articulating strategic alternatives that encapsulate the dual nature of synergies and trade-offs.
This undertaking was rooted in several theoretical foundations: (i) learning theory (Arrow, 1962 [1]), (ii) the theory of growth and fixed mindsets (Dweck, 1988, 2006 [7, 20]), and (iii) network externality theory (Rogers, 2003 [15], Fanti, 2016 [6]), among others. The leaders pursued the formulation of mathematical advancements as part of this initiative, effectively demonstrating its utility and broad applicability through an empirical analysis conducted on the top 100 R&D companies in the year 2020.

$L = \Gamma(K) = vK^{-\lambda}$ (L: labor, K: capital, λ, v: coefficient) [1](1)

$Y = uK\left[1 - \left(1 - \frac{L}{wK^{1-\lambda}}\right)^{\frac{1}{1-\lambda}}\right] (\lambda \neq 1)$(2) ($Y$: production, u: coefficient, $w = \frac{v}{1-\lambda}$)

$Y = uK(1 - e^{-L/v})$ $(\lambda = 1)$ (3)

$\frac{uK}{uK-Y} = e^{L/v}$ (Taking a case of λ =1)(4)

$L = g_1 + g_2 \ln E \times (R - R_0)$ (5)

$Z \equiv e^{L/v} = A \cdot E^{k(R-R_0)}$(6)

$W \equiv \frac{uK}{uK-Y} = \frac{1}{1-\frac{Y}{uk}} = B \cdot R$(7)

$B \cdot R = A \cdot E^{k(R-R_0)}$

$R = \frac{A}{B}E^{k(R-R_0)} = \boldsymbol{A'E^{k(R-R_0)}} = \boldsymbol{R_0 E^{k(R-R_0)}}$(9)

Elasticity of ESG risk to R&D investment (10)

Equation (10) embodies the duality of synergy and trade-off (Fig. 4).

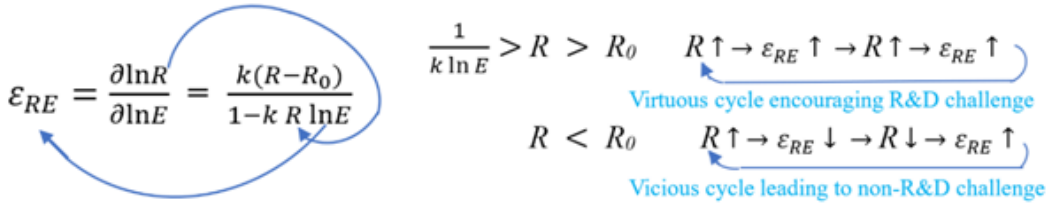


Figure 3. Dynamism of R&D-induced dualization in response to increasing ESG risks.

〖 k=k_0 (R lnE)〗^(n)n< 0, k0: constant, n: multiplier.(Endeavor to enhance R&D ceiling)

(11)

Dynamic elasticity of ESG risk to R&D

$$\varepsilon_{RE} = \frac{\partial \ln R}{\partial \ln E} = \frac{k_0 (n+1) R^n (R - R_0)(\ln E)^n}{\left[1 - k_0 (\ln E)^{n+1} \left[(n+1)R^{n+1} - nR_0 R^n\right]\right]} \quad (12)$$

(11) and (12) embody the R&D – ESG risk response strategy trajectory of each company.

3. Global R&D Leader's Response to ESG Risks

3.1. Dualization of ESG risk response by R&D

Obtained R0, k0, and n values for 100 firms through equation (11), and scrutinized R&D prompted by ESG risks. To achieve this, εRE was quantified employing equation (12), enabling the delineation of the R&D - εRE trajectory (as illustrated in Fig. 4).

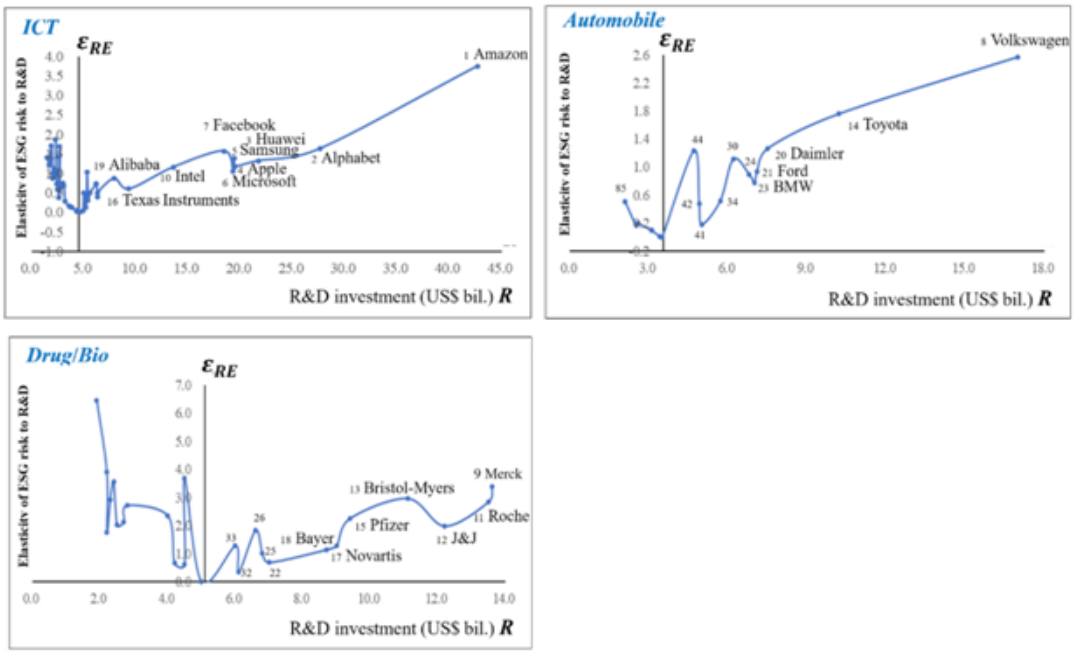


Figure 4. R&D elasticity of 100 companies' R&D and ESG risks (2020).

R: R&D, εRE: R&D elasticity of ESG risk.

High R&D Firms (HRFs) exceeding the R&D threshold R0 (ICT 4.5, Automobile 3.55, Drug/bio5.1)

Demonstrates a virtuous cycle as . $R\uparrow \rightarrow \varepsilon_{RE}\uparrow \rightarrow R\uparrow \rightarrow \varepsilon_{RE}\uparrow$

Low R&D firms (LRFs) that fall short of it shows a vicious circle. Thus, Figure 4 demonstrates embodying the dual dynamism as illustrated in Figure 2.

HRFs demonstrate network externalities as . $\frac{d\varepsilon_{RE}}{dR} > 0$

3.2. Encouraging R&D investment by stakeholders

For Low R&D Firms (LRFs), a paramount strategy involves initially assimilating the spillover technology emanating from High R&D Firms (HRFs). Concurrently, they should nurture their R&D resources in tandem with demand responsiveness, subsequently aiming for a trajectory shift to HRF status upon attaining the R0 threshold (recognized as the Tipping Point(Gladwell, 2000 [8])s' success lies in the sustainable accumulation of substantial R&D endeavors. To achieve this objective, a concerted effort will be directed toward augmenting brand value through R&D activities, thereby mitigating ESG risks. This will foster the confidence that their initiatives align with stakeholders' interests, while actively engaging with a wide spectrum of global stakeholders). Central to this approach is the establishment of a strategic framework (as illustrated in Figure 5) that promotes heightened R&D investment. This, in turn, is anticipated to foster the amalgamation of diverse knowledge spanning geographical and industrial boundaries. The Climate Pledge plays a pivotal role in facilitating the realization of this strategic construct.

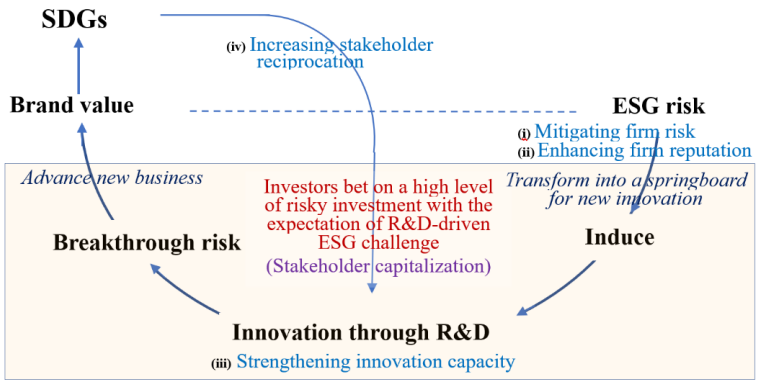


Figure 5. ESG risks, R&D, and the dynamism of brand value creation.

Source: Watanabe, 2021 [24]

In light of this viewpoint, Table 1 offers a comparative analysis of the R&D-driven framework revolving around ESG risks, R&D endeavors, and the generation of brand value dynamism within the top 10 R&D corporations. Evident from Figure 6, the constructed framework for four entities (AAAM), namely Amazon, Alphabet, Apple, and Microsoft, emerges prominently.

These four corporations exhibit distinctive incentive structures characterized by elevated R/E (R&D/ESG), B/R (Brand Value/R&D), and B/E (Brand Value/ESG) ratios. These structures are marked by a distinctive strategic orientation that effectively addresses ESG risks through R&D initiatives, fosters brand value augmentation, engenders stakeholder engagement, and promotes the stimulation of further R&D undertakings.

Table 1. R&D incentive structure of top 10 R&D companies (2020)

	R&D (R)	Sales (S)	Brand value (B)	ESG risk (E)	ε_{RE}	MIER	R/E	B/R	B/E
1 **Amazon**	42.7	386.1	220.8	30.9	3.75	5.18	1.38	5.17	7.15
2 **Alphabet**	27.6	182.5	159.7	22.9	1.63	1.97	1.21	5.79	6.97
3 **Huawei**	21.7	136.4	65.1	20.0	1.32	1.44	1.09	3.00	3.26
4 **Apple**	19.5	274.5	140.5	17.2	1.18	1.34	1.13	7.21	8.17
5 **Samsung**	19.4	218.1	94.5	23.0	1.38	1.17	0.84	4.87	4.11
6 **Microsoft**	19.3	143	117.1	13.3	1.06	1.54	1.45	6.07	8.80
7 **Facebook**	18.4	86	79.8	28.0	1.57	1.03	0.66	4.34	2.85
8 **Volkswagen**	17.0	272.3	44.9	29.9	2.56	1.46	0.57	2.64	1.50
9 **Merck**	13.6	48.0	11.8*	22.4	3.38	2.05	0.61	1.15	0.53
10 **Intel**	13.6	77.9	27.5	17.0	1.17	0.93	0.80	2.02	1.62

* MIER: Marginal R&D Induction Rate of ESG Risks.

Source: Firms' annual reports and Brand Finance (2020).

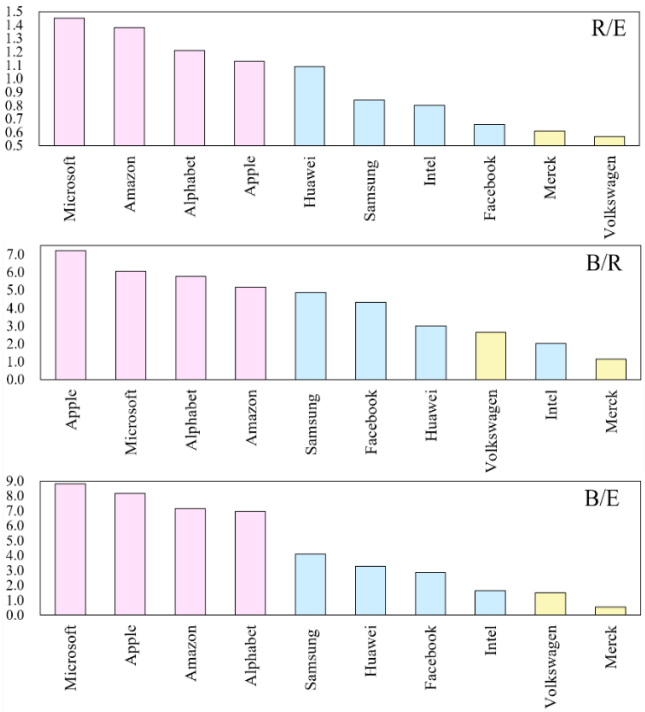


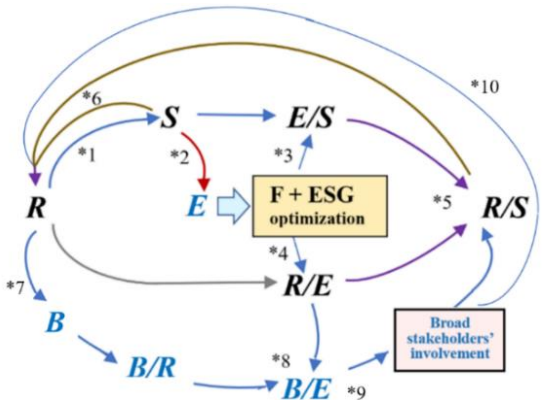
Figure 6. Induced Structure of Top 10 R&D firms (2020).

Source: Firms' annual reports and Brand Finance (2020).

4. INITIATIVES OF GLOBAL R&D LEADERS

Based on the aforementioned validation, the dynamics of stakeholder engagement in F+ ESG optimization are depicted in Figure 7, with a focus on four companies denoted as AAAM.

As illustrated in Figure 8 and detailed in Tables 2-7, the R&D-centered ESG risk response strategies of these four companies align with the dynamics represented in Figure 7, albeit with certain deviations.



*1 Table 2, Fig. 4
*2 Fig. 8
*3 Fig. 8, Table 3
*4 Fig. 1, Table 4
*5 R/S = E/S x R/E
*6 R =R/S x S
R: R&D investment, S: revenue (sales), E: ESG risk, F: finance.

Figure 7. Dynamism of stakeholder participation in F+ ESG optimization.

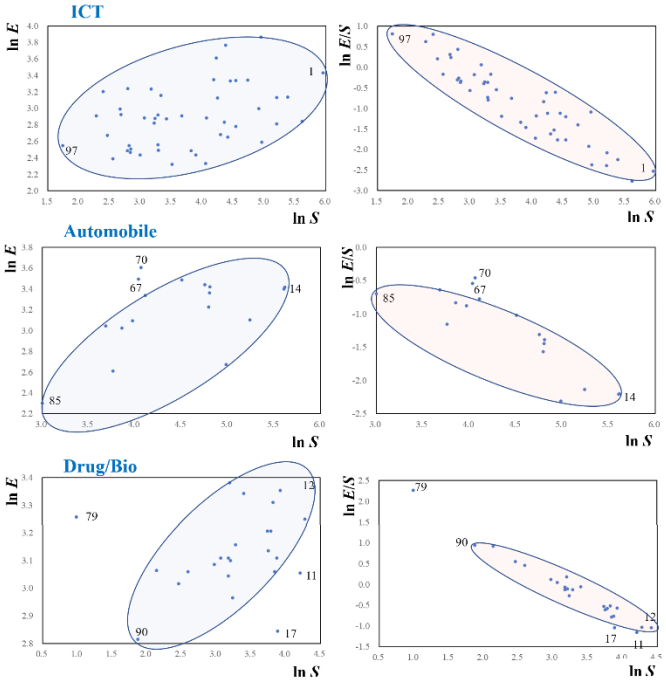


Figure 8. ESG Risk Increase Corresponding to Sales Increase and Subsequent Increase in Mitigation Efforts.

While R&D investment contributes to finance by increasing revenues (sales), as in the case of "higher risk, higher returns," an increase in ESG risk is unavoidable as demonstrated in the left-side of Fig. 8 which shows ESG risks increase as sales increase.

Against such ESG risks increase, aiming at the synergy between finance and ESG risk mitigation, F + ESG optimization strategy is undertaken by

A: Improving company's reputation and mitigating its risk by not necessarily relying on increased R&D, as demonstrated in the right-side of Fig. 8 and Table 3, and

B: Strengthening innovation capacity with increased R&D through increasing stakeholder reciprocation, as demonstrated in Fig. 1 and Table 4.

Table 2. Induction of sales by R&D - Top 100 R&D companies (2020)

$S = e^{p} R^{q}$ $\quad \ln S = p + q_1 D_1 \ln R + q_2 D_2 \ln R + q_3 D_3 \ln R + r D_4$

	p	q_1	q_2	q_3	r	$adj.R^2$	*Dummy*
ICT [47]	1.9835 (5.63)	1.0192 (8.00)	1.0167 (4.81)	1.0138 (2.90)	1.6683 (7.07)	0.740	D_1:1, 2, 3, 4, 5, 6, 7, 10 D_2:16, 19, 27, 28, 29, 31, 35, 36, 37, 38, 40, 43, 4 D_3:48, 49, 52, 53, 54, 57, 58, 60, 63, 64, 65, 66, 6 71, 72, 76, 77, 78, 81, 82, 84, 88, 89, 92, 97, 9 D_4: 57, 58, 68, 71, 76, 99
Automobile [17]	3.1504 (10.52)	1.0695 (8.56)	0.8728 (5.19)	0.8384 (2.99)*	-0.6358 (-7.36)	0.953	D_1:8, 14, 20 D_2: 21, 23, 24, 30, 34, 41, 42, 44 D_3: 55, 56, 59, 67, 70, 85 D_4: 42, 44, 59, 85
Drug/bio [25]	0.8952 (2.03) *	1.2680 (6.52)	1.4332 (5.83)	1.5353 (4.13)	1.4894 (4.38)	0.720	D_1: 9, 11, 12, 13, 15, 17 D_2: 18, 22, 25, 26, 32, 33 D_3: 39, 46, 47, 50, 51, 61, 62, 69, 74, 75 79, 83, 9 D_4: 69, 75

Table 3. Correlation between sales and ESG risk intensity - R&D top 100 companies (2020)

$\ln (E/S) = a + b_1 D_1 \ln S + b_2 D_2 \ln S + b_3 D_3 \ln S + c_1 D_4$

	a	b_1	b_2	b_3	c_1	$adj.R^2$	*Dummy*
ICT [47]	2.1903 (9.39)	-0.8671 (-16.58)	-0.8415 (-13.03)	-0.7997 (-11.64)	0.4352 (2.79)	0.923	D_1:1, 2, 3, 4, 5, 6, 7, 10 D_2:16, 19, 27, 28, 29, 31, 35, 36, 37, 38, 40, 43, 45 D_3:48, 49, 52, 53, 54, 57, 58, 60, 63, 64, 65, 66, 68, 71, 72, 76, 77, 78, 81, 82, 84, 88, 89, 92, 97, 99 D_4:1, 5, 7, 16, 19, 48
Automobile [17]	2.4700 (2.97)*	-0.8167 (-5.57)	-0.8070 (-4.64)	-0.7957 (-3.73)	-0.5287 (-3.26)	0.905	D_1:8, 14, 20 D_2: 21, 23, 24, 30, 34, 41, 42, 44 D_3: 55, 56, 59, 67, 70, 85 D_4: 20, 34, 42, 44, 85
Drug/bio [25]	2.9982 (21.52)	-0.9435 (-24.88)	-0.9388 (-22.20)	-0.9655 (-20.19)	-0.2402 (-2.09)*	0.968	D_1: 9, 11, 12, 13, 15, 17 D_2: 18, 22, 25, 26, 32, 33 D_3: 39, 46, 47, 50, 51, 61, 62, 69, 74, 75 79, 83, 90 D_4: 9, 17

Table 4. Correlation between R&D and R&D induction rate of ESG risks - Top 100 R&D companies (2020)

$$R/E = a + b_1 D_1 \ln R + b_2 D_2 \ln R + b_3 D_3 \ln R + c_1 D_3 + c_2 D_4$$

	a	b_1	b_2	b_3	c_1	c_2	$adj.R^2$	*Dummy*
ICT [47]	-0.7391 (-3.08)	0.6207 (7.56)	0.6374 (4.63)	0.1853 (2.51)*	0.7336 (3.00)	-0.2571 (-4.54)	0.923	D_1:1, 2, 3, 4, 5, 6, 7, 10 D_2:16, 19, 27, 28, 29, 31, 35, 36, 37, 38, 40, 43, 45 D_3:48, 49, 52, 53, 54, 57, 58, 60, 63, 64, 65, 66, 68 71, 72, 76, 77, 78, 81, 82, 84, 88, 89, 92, 97, 99 D_4:1, 5, 7, 16, 19, 48
Automobile [17]	-0.6425 (-4.11)	0.4176 (6.69)	0.4700 (5.59)	0.2434 (2.45)*	0.4894 (3.13)	0.1877 (6.16)	0.905	D_1:8, 14, 20 D_2: 21, 23, 24, 30, 34, 41, 42, 44 D_3: 55, 56, 59, 67, 70, 85 D_4: 20, 34, 42, 44, 85
Drug/bio [25]	-0.6354 (-3.29)	0.4534 (5.62)	0.4797 (4.63)	0.1378 (4.01)	0.6275 (3.18)	0.1109 (3.31)	0.940	D_1: 9, 11, 12, 13, 15, 17 D_2: 18, 22, 25, 26, 32, 33 D_3: 39, 46, 47, 50, 51, 61, 62, 69, 74, 75 79, 83, 90 D_4: 9, 17

Table 5. Correlation between R&D and brand value - 25 representative R&D companies (2020)

$$\ln B = a + b_1 D_1 \ln R + b_2 D_2 \ln R + b_3 D_3 \ln R + b_4 D_4 \ln R + b_5 D_4$$

a	b_1	b_2	b_3	b_4	b_5	$adj.R^2$	*Dummy*
2.663 (15.02)	0.727 (9.89)	0.739 (8.40)	0.482 (5.69)	0.750 (2.10)*	-1.137 (-1.78)**	0.889	D_1:1, 2, D_2: 4, 6 D_3: 3, 5, 7, 8, 10, 14, 23, 24, 27, 28, 31, 35, 68, 70, 88, 94 D_4: 19, 21, 38, 41, 60

Table 6. Stakeholder Capitalism Induction of Brand Value - AAAM (2020)

$$\ln PFCR = a + b \ln B + c \ln FCF + d D$$

	a	b	c	d	$adj.R^2$	DW	*Dummy*
Amazon	1.926 (6.05)	0.827 (7.25)	-0.781 (-7.27)		0.814	2.80	
Alphabet	1.511 (6.24)	0.877 (11.19)	-0.753 (-10.31)	0.453 (3.75)	0.915	2.37	2007, 2009, 2010, 2012 2013, 2020=1
Apple	3.200 (5.71)	0.117 $(0.28)^+$	-0.279 $(-0.64)^+$		0.000	1.63	
Microsoft	1.228 (1.96)**	1.057 (3.78)	-0.752 (-2.01)**	-0.481 (-4.04)	0.827	2.27	2008, 2010-2016=1

Table 7. R&D Induction of Stakeholder Capitalism - AAAM (2020)

$$\ln R = a + b \ln PFCR + c \ln FCF + d D$$

	a	b	c	d	$adj.R^2$	DW	*Dummy*
Amazon	-4.080 (-6.76)	1.175 (8.12)	1.037 (13.11)		0.936	2.07	
Alphabet	-3.548 (-4.11)	0.716 (3.63)	1.267 (12.77)	0.853 (4.09)	0.944	1.88	2008, 2012=1
Apple	-4.257 (-5.63)	0.648 (3.10)*	1.147 (11.01)	0.490 (1.94)**	0.915	1.30	2016, 2018=1
Microsoft	-0.465 (-2.75)*	0.302 (6.92)	0.633 (10.62)	-0.158 (-3.10)*	0.955	1.95	2007, 2020=1

Building upon the aforementioned insights, Table 8 offers a comparative examination of the ESG risk framework among the four corporations.

Among these, Amazon, with its pronounced R&D orientation and the highest R&D elasticity pertaining to ESG risks, emerges prominently when contrasted with CCC and Cloud. Amazon's stance also positions it at the forefront of stakeholder capitalism, a role supported by references [10, 11, 13].

Table 8. Anti-ESG risk structure of four companies (2020)

	R&D (*R*)	ESG risk (*E*)	Brand value (*B*)	ε_{RE} Elasticity of ESG to R&D	MIER Marginal inducibility of ESG to R&D	MC Market Capitalization	Sales (*S*)	Net income	TRR Total return ratio (%)	SC Stakeholder capitalization	CCC Cash conversion cycle (Days)	Cloud Infra market share (%)
Amazon	**42.7**	30.9	220.8	**3.75**	5.18	1634.0	386.1	21.3	**0**	**52.7**	**-38**	**33**
Alphabet	27.6	22.9	159.7	1.63	1.97	1154.0	182.5	40.3	76.9	26.9	40	9
Apple	19.5	17.2	140.5	1.18	1.34	2255.0	274.5	57.4	151.0	30.7	-30	0
Microsoft	19.3	13.3	117.1	1.06	1.54	1681.0	143.0	44.3	72.0	37.2	8	18

5. Combining Diverse Knowledge following the Amazon-Led Climate Pledge

5.1. ESG-oriented stakeholder capitalism

Harnessing its notable Comprehensive Corporate Competence (CCC), Amazon has established a multifaceted feedback loop encompassing CCC, R&D, sales, and market capitalization, as elaborated in references [1, 24]. This intricate feedback mechanism has been further evolved into a co-evolutionary architecture involving R&D, Amazon Web Services (AWS), and brand value, as visually depicted in Figure 9 and detailed in Table 9.

Notably, AWS emerges as a product of R&D endeavors, contributing to the generation of brand value and concurrently fostering an impetus for additional R&D pursuits. Amazon's marked resilience in the domain of ESG risk-centered R&D is substantially underpinned by this co-evolutionary framework.

Figure 9. Co-advancement of Amazon

R&D, AWS, and brands.

Table 9. Co-advancement of Amazon R&D, AWS, and brands (2008 - 2020) .

$\ln Y = a + b \ln X + c\, D$ where X, Y: R&D, *AWS*, and *BW*; D: Dummy variable.

X to Y	a	b	c	$adj.R^2$	DW	Dummy
R&D to AWS	-4.64 (-56.78)	1.44 (159.46)		0.999	2.53	
AWS to BV	-1.20 (-6.12)	0.60 (26.00)		0.983	1.53	
BW to R&D	-2.28 (-21.96)	1.16 (41.10)	-0.27 (-3.35)	0.993	2.18	2008, 2019, 2020 = 1, others = 0.

Figures in parentheses are t-statistics: all are significant at the 1% level.

Via this process of coevolution, AWS accrues machine learning capabilities, consequently giving rise to the development of novel functionalities (Fig. 10, Table 10).

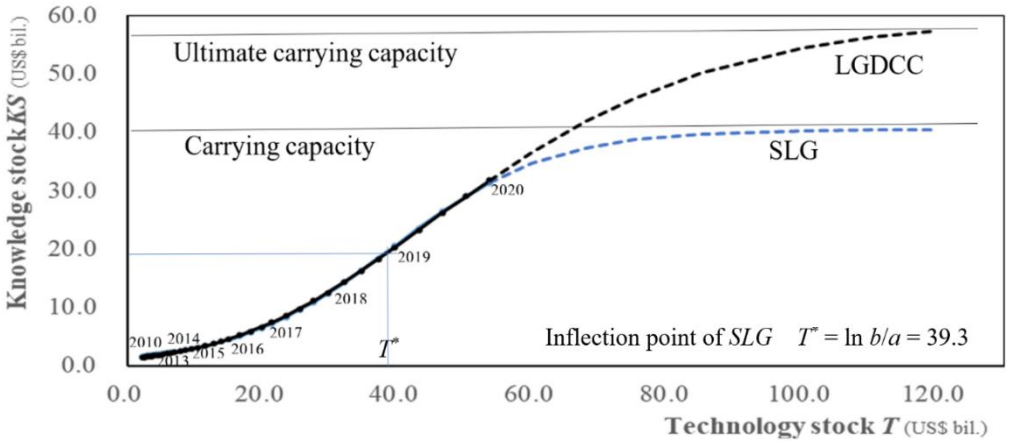


Figure 10. Amazon R&D-led AWS stock accumulation trajectory (2010-2020).
Source: Watanabe et al. (2021) [23]

Table 10. R&D Driven AWS Stock Accumulation Trajectory (2010-2020: Quarterly)

$$KS(T) = \frac{N}{1+be^{-aT}} \quad \textit{(SLG)} \qquad KS(T) = \frac{N_k}{1 + be^{-aT} + \frac{b_k}{1-a_k/a}e^{-a_kT}} \quad \textit{(LGDCC)}$$

	N	a	b	a_k	b_k	$adj.\ R^2$
SLG	40467	8.65×10^{-5}	28.85			0.998
	(65.52)	(83.25)	(55.09)			
LGDCC	59557	1.18×10^{-4}	40.42	4.58×10^{-5}	5.41	0.999
	(7.31)	(17.87)	(4.69)	(4.91)	(6.58)	

$KS(T)$: knowledge stock of AWS corresponding to T; T: technology knowledge stock; N and N_k; carrying capacity; a, b, a_k, b_k; coefficients.

Figures in parentheses are t-statistics: all are significant at the 1% level.

The novel functionality permeates into peer enterprises, thereby fostering their advancement. Through the assimilation and accumulation of such acquired knowledge, AWS is poised to undergo further enhancement and expansion, as illustrated in Figure 11.

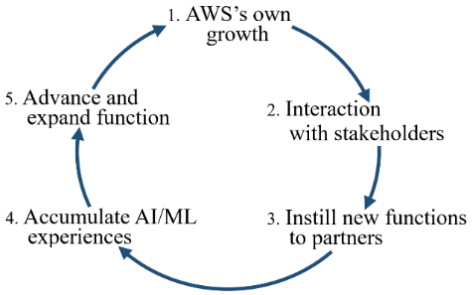


Figure 11. Co-evolutionary structure of R&D, AWS, and brand value.

Source: Watanabe et al. (2021)[23]

In such a manner, Amazon swiftly expanded its R&D endeavors by imbibing knowledge and harmonizing with the progress achieved by its peer firms, as illustrated in Figure 12.

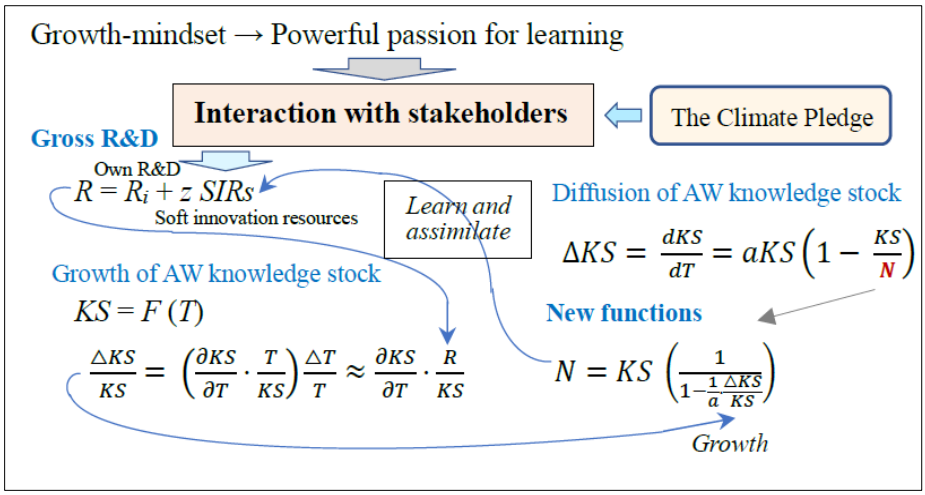


Figure 12. Mutual enlightenment with stakeholders embodied in R&D.

According to the above, Amazon exemplifies remarkable ESG risk R&D elasticity and notable inducement of R&D marginal elasticity, thereby showcasing a virtuous cycle that surpasses the dynamics outlined in Figure 3.

This self-perpetuating mechanism, encompassing the growth and scalability of AWS, engenders a heightened trust among stakeholders in tandem with ESG risk mitigation through R&D initiatives. Consequently, this trust augments the participation of a diverse array of stakeholders who place their confidence in this synergy. Moreover, it stimulates the advancement of substantial R&D activities (as illustrated in Figure 13 and detailed in Table 11).

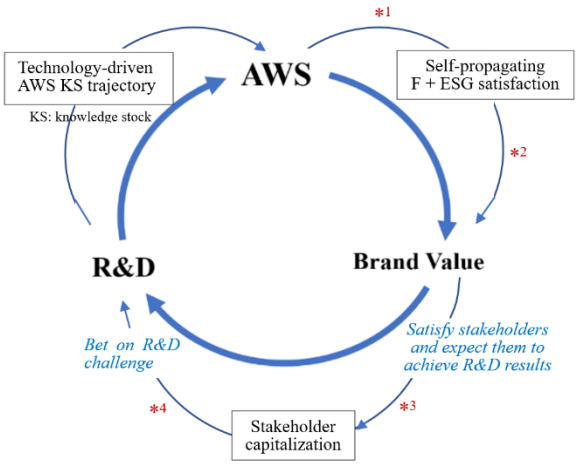


Figure 13. Co-advancing structure of R&D, AWS, and brand value that acceleratesstakeholder capitalism.

Table 11 Co-advancement of R&D, AWS, and brand value to accelerate stakeholder capitalism (2007-2020)

*1 $\ln AS = a + b \ln KS + c\,D$

a	b	c	$adj.R^2$	DW
0.904	1.030	0.613	0.944	1.26
(6.90)	(14.72)	(3.87)	D: 2012-2015, 2017=1	

*2 $\ln BV = a + b \ln AS$

a	b	$adj.R^2$	DW
1.236	1.015	0.978	1.69
(11.25)	(24.19)		

*3 $\ln PFCR = a + b \ln BV + c \ln FCF$

a	b	c	$adj.R^2$	DW
1.624	0.904	-0.837	0.944	2.33
(9.10)	(14.13)	(-13.89)		

*4 $\ln R = a + b \ln PFCR + c \ln FCF + d\,D$

a	b	c	d	$adj.R^2$	DW
-3.530	1.009	1.059	0.440	0.986	2.42
(-11.35)	(11.67)	(28.35)	(3.51)	D: 2012-2015, 2017=1	

AS: apparel sales; KS: Knowledge stock of AWS; BV: brand value; PFCR: price free cash ratio; FCF: free cash flow; R: R&D; D: dummy variables.
Figure in parentheses are t-statistics: all are significant at the 1% level.

Drawing from the comprehensive embrace of a diverse array of stakeholders as elucidated previously, the optimization of F + ESG generates an emerging impact of innovation that transcends the scope of network externalities, as outlined in Table 11.

A coalition of 417 companies across 39 nations collaborates in confronting decarbonization, viewing it as a "convergence of multifaceted systemic phenomena". This collaborative pursuit serves as an inspiration. The amalgamation of diverse knowledge is indispensable for perpetuating a virtuous cycle interlinking R&D and ESG considerations. This approach is envisaged to yield efficacy beyond the confines of confidentiality and competition, due to its status as a "universal challenge of global magnitude".

5.2. Combining Diverse Knowledge Inspired by the Climate Pledge Initiative

(1) Combining Diverse Knowledge Across Borders and Industries - An Example of Synergy Acceleration through Co-Progress between Amazon, the Digital Leader, and UPM, the Finnish Forest Leader

Amazon, renowned for its advanced technological capabilities and digital innovation, has positioned itself as a global leader in the digital landscape. In contrast, UPM, a significant player in the forest industry, engages in a spectrum of activities encompassing sustainable forestry, wood products, pulp, paper, and biorefining.

In recent times, these seemingly divergent entities have converged to explore and harness synergies emerging from their complementary proficiencies. UPM's expertise in sustainable forestry and unwavering commitment to environmental preservation resonates harmoniously with Amazon's aspiration to mitigate its ecological impact. This convergence has spurred collaborative ventures that bridge the domains of digitalization and environmental stewardshipas illustrated in Figure 15.

For example, given Amazon's status as a major consumer of cardboard packaging due to its extensive e-commerce operations, there's a substantial demand for packaging materials. UPM, being a stalwart in the forest industry, excels in producing sustainable and renewable resources, including pulp and paper. Through their collaborative efforts, Amazon can procure ecologically friendly packaging materials from UPM, thus reducing its dependence on non-renewable resources and furthering its Environmental, Social, and Governance (ESG) objectives.

Conversely, UPM stands to benefit from Amazon's digital acumen. As the drive toward digitalization intensifies, UPM can leverage Amazon's technological expertise to bolster its supply chain management, optimize operations, and streamline its processes.

The synergy between Amazon and UPM serves as an embodiment of the concept of co-progress, wherein their distinct strengths and areas of specialization intertwine harmoniously to yield outcomes mutually advantageous. Beyond promoting sustainable practices, this collaboration underscores the potential of cross-industry partnerships to catalyze innovation and expedite progress towards shared environmental and business objectives.

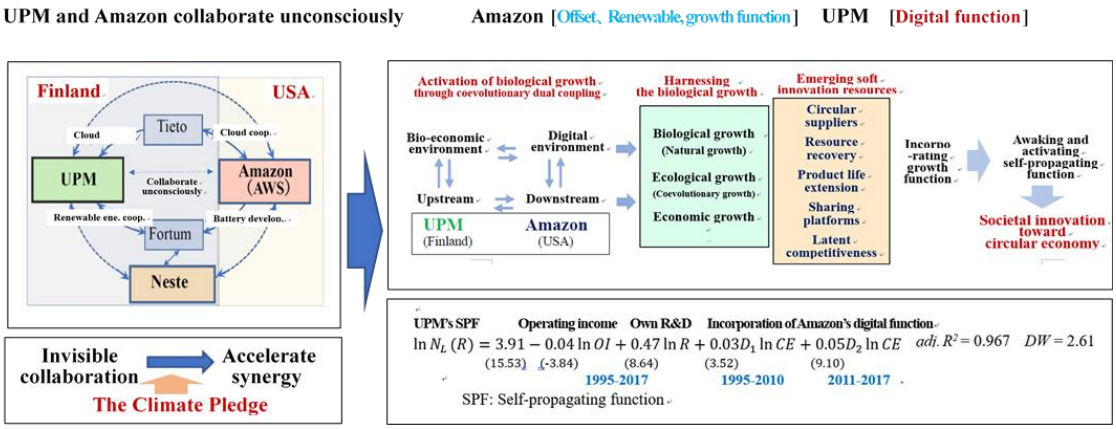


Figure 15. Collaboration between Amazon and UPM under the Climate Pledge Initiative - Accelerating synergies by combining diverse knowledge .

(2) Renewal of Japanese management system

In this section, an overview of ESG responsiveness in Japan within the context of the aforementioned trends will be provided. The evolution of the innovation ecosystem that once underpinned Japan's historical growth will be examined.

Historically, Japanese corporate value was defined by the ability to provide high-quality products at the lowest possible cost, which has, in turn, made course corrections challenging. Conversely, the ongoing digitization of the economy enables effective, efficient, and flexible responses to customer needs, prompting a transformation of established frameworks.

These transformations also affect the Japanese management system, often referred to as the system that supported post-war high economic growth. Rooted in the concept of growing stronger with each crisis, this system used the energy crises of 1973 and 1979 as springboards for energy substitution through technology. This ultimately led to the emergence of high-tech miracles in the 1980s, pioneering a virtuous cycle of energy efficiency, CO2 reduction, and sustainable growth, setting a global example. However, the advent of the information society with the development of IT since the 1990s has necessitated change in the Japanese model. Especially in recent years, the innovation imperative in response to ESG risks has shifted from conventional product development and external collaborations to a focus on self-replicating new functionality harnessing the characteristics of the internet, mindset cultivation to enable such innovation, and the utilization of software resources, all emphasizing the importance of SDGs.

As previously described, Japanese-style innovation relied on the intricate system built by companies, employees, and capital owners, which originated from the Japanese management paradigm up to the 1980s. This system can be considered a system enabled by technological alternatives supported by the scarce resource of innovation. However, since the 1990s, this system has undergone transformation and currently finds itself in a state of ongoing metamorphosis, where the remnants of the past intersect with the new management paradigm in the digital economy.

Amid the urgency of cross-border, cross-industry collaboration with an ESG focus, the renewal of Japanese-style innovation toward decarbonization, based on the Japanese management model up to the 1980s, is of paramount importance. The possible configurations of this renewal are summarized in Table 12.

Table 12. Direction of Japanese management system reform

Age	Attributing	Innovation resources	Bearer	Resources for growth	Return	Current state → Renewal
1980s –	Lifetime affiliation	Invisible investment	Lower wages for younger generation	Productivity surplus over low wages	Higher wages beyond productivity for aged generation	Cursed by the inertia of experiences of success
– 2040s	Region/Earth	Invisible coevolution beyond borders and industries	Breakthrough of ESG risk towards synergy	Coordinating global challenges and invisible coevolution through the cloud	Synergy of *F + ESG*	Collaboration with invisible partners beyond borders and industries

In response to the evolving challenges listed in Table 12, global innovation companies are taking action, exemplified by initiatives such as the Climate Pledge. Japanese's fimrs must expand those

horizons and recognize the crucial stakeholders in the pursuit of decarbonization, and they are required to strive for cross-border, cross-industry collaborations.

6. CONCLUSION

This paper aimed to analyze the "R&D - ESG Risk Response Strategy Trajectory" of the top 100 R&D companies, derive a mathematical model representing duality, and employed these models to elucidate the synergy acceleration effect resulting from the diverse integration of knowledge encompassing stakeholders.

While numerous studies have analyzed corporate responses to ESG risks, many of these studies have primarily focused on specific ESG indicators and their correlation with ESG or financial performance. As a result, research emphasizing the role of R&D as an energy source for transforming ESG risks into a springboard for new innovations is rare. Therefore, this paper holds academic significance.

The synergy resulting from the active involvement of global stakeholders was shown to be rooted in the network externality effects, supported by the strong learning appetite of growth-oriented companies. Through modeling, a comparative verification of the F + ESG optimization strategies of R&D leaders was conducted, revealing the dynamics that align with the aforementioned objectives and proposing various strategies for the integration of diverse knowledge.
In this context, the acknowledgment that R&D was indispensable for the manifestation of F + ESG synergy is fundamental. Examples among global R&D leaders ware sought to establish this recognition. A comparative empirical analysis of the dual structure of synergy and trade-offs in R&D responses to ESG risks within the top 100 R&D companies worldwide was performed, analyzing the inducement of R&D due to ESG risks.

The results indicated that R&D-led ESG risk response hinges on the sustainable assurance of R&D. To achieve this, it was vital to establish a scheme that encouraged proactive R&D investments from a wide range of global stakeholders by creating brand value through ESG risk mitigation by R&D. This trust should align with the interests of stakeholders.

The dynamics of stakeholder engagement in F + ESG optimization are presented, with Amazon as a prominent example in the realm of R&D, excelling in cash conversion cycles, and cloud technology while leading management with a strong stakeholder focus. The "self-replicating capabilities encompassing the growth and scalability of AWS" accelerated high R&D by gaining the trust of stakeholders in "synergy through R&D-driven ESG risk mitigation."

Finally, as examples of these initiatives, the paper discussed the Climate Pledge led by Amazon and the transformation of Japan's management system. Particularly concerning Japan's case, it was recognized that Japanese companies needed to broaden their horizons, acknowledging the need to recognize vital stakeholders in their pursuit of decarbonization and striving for cooperation beyond borders and industries.

As the future works, further analysis should need to deepen understanding of the "R&D - ESG Risk Response Strategy Trajectory." This involves examining the transformation and strategy trajectories resulting from the digitalization of manufacturing technology, primarily in Asia and the Global South, where firms will be strongly affected by ESG risks.

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