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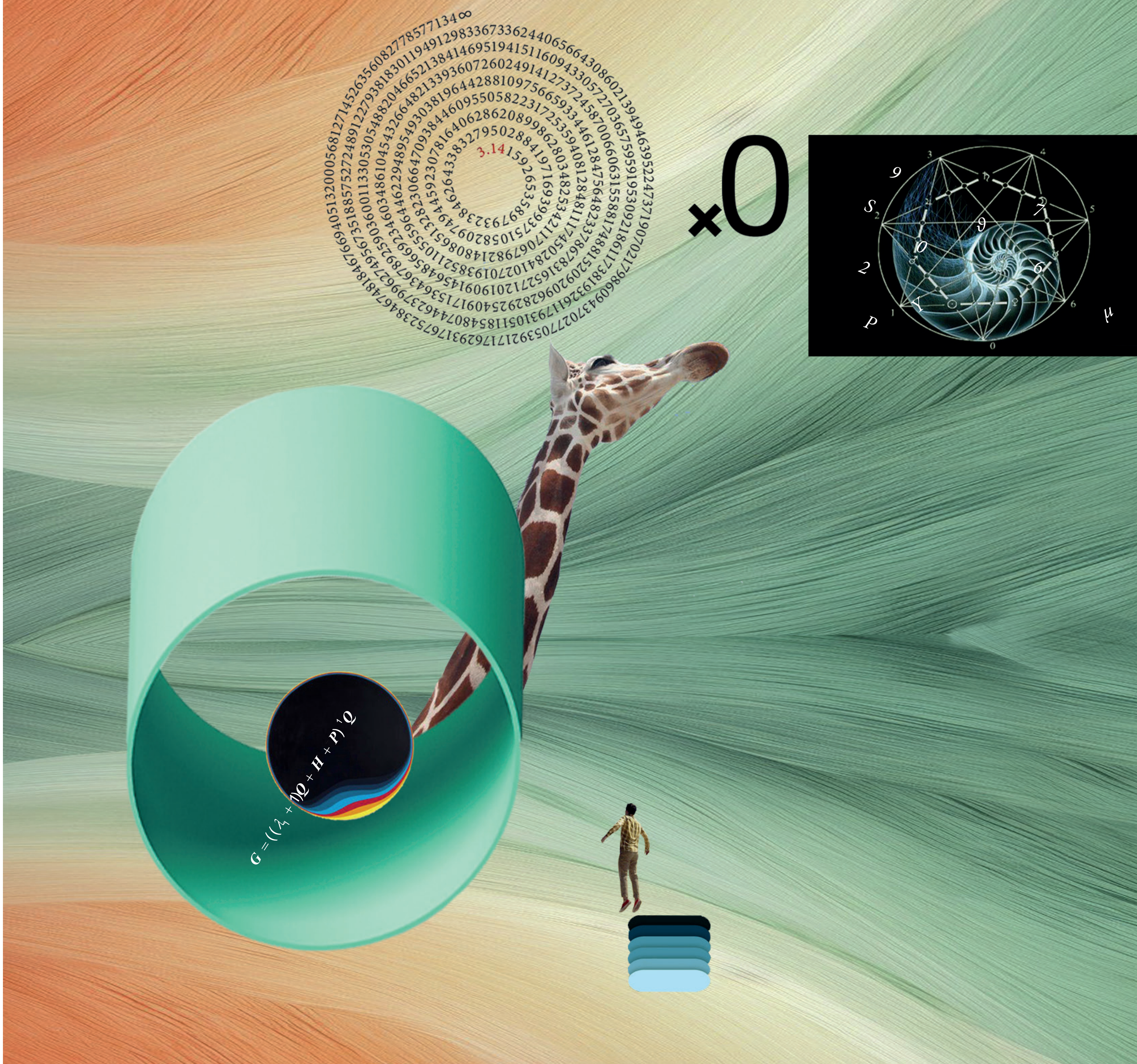

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CONTENTS

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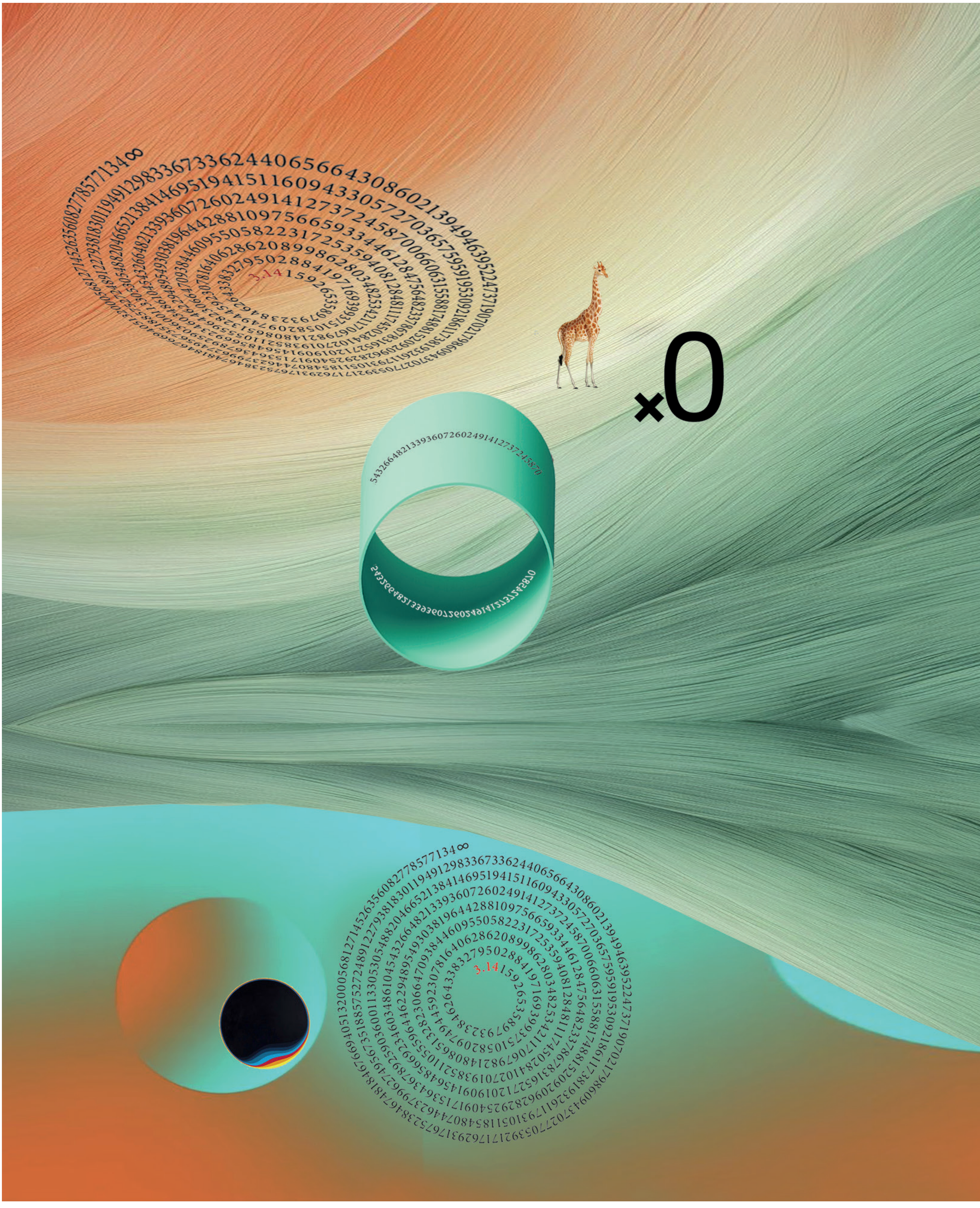
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Evaluating the Impact of Inward FDI & Economic Growth Upon the Carbon Emissions of South Korea

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Abstract

This study aims to evaluate the impact of inward foreign direct investment (FDI) and economic growth on carbon emissions in South Korea, a nation committed to achieving carbon neutrality by 2050. Given the dual role of inward FDI and economic growth in fostering economic development and potentially increasing carbon emissions, this study explored the complex relationships among these variables. This study uses annual time-series data from 1990 to 2021, including carbon emissions (CO_2) as the dependent variable and GDP, inward FDI, and renewable energy consumption as explanatory variables. An autoregressive distributed lag (ARDL) bounds test was employed to assess the long-term relationships between these variables. The empirical analysis confirms the long-run relationship among FDI, economic growth, renewable energy use, and carbon emissions in South Korea. This finding underscores the necessity of integrating sustainable investment practices and renewable energy solutions to mitigate the environmental impact of economic growth and FDI. Unlike previous studies, this study uniquely combines the effects of FDI, GDP, and renewable energy on carbon emissions within the context of South Korea's ambitious carbon neutrality commitment by 2050. Applying a robust ARDL model provides nuanced insights into the interactions between economic factors and sustainability efforts, offering actionable data to policymakers aiming to balance economic and environmental goals. These results highlight the importance of sustainable policies that balance economic growth and environmental preservation, especially in the context of South Korea's carbon neutrality goals.

Keywords: foreign direct investment; economic growth; carbon neutrality; South Korea

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Introduction

Public decision-makers and analysts have extensively recorded substantial trade transformations and their consequences on host economies, resulting from inbound FDI in many nations. The impact of FDI on natural environmental quality is becoming increasingly important and significant. The environmental implications of FDI can be categorized into several forms. First, there is widespread agreement on the adverse environmental repercussions of FDI. Second, FDI-induced development has been found to have negative consequences. Third, FDI often leads to the relocation of economic operations to areas with less stringent environmental laws. Finally, FDI can also drive innovation in cleaner technologies for pollution control (Wang, Luo, 2020). Globalization has significantly improved development, particularly financial globalization, and has led to an increase in the movement of money across borders, thus boosting the scale and frequency of international commercial transactions (Zameer et al., 2020).

Globalization has provided South Korea with significant opportunities, enabling it to compensate for its limited mineral and energy resources throughout its industrialization. This has led to the establishment of an export-driven economic growth model. Nevertheless, because of this tendency, Korea's industrial output constitutes a much larger proportion of the country's GDP than that of other industrialized nations (Lamb et al., 2021). The industrial sector, which plays a crucial role in driving national economic development, is also a large source of greenhouse gas emissions, and consumes a substantial amount of energy (He et al., 2022). To clarify, the economic prosperity of Korea in recent years has mostly been propelled by businesses that use large amounts of energy. These industries rely heavily on coal as their major source of fuel, resulting in a substantial national carbon footprint (Lee, Woo, 2020). Because FDI offers many advantages, including fostering economic development, building absorptive capacity, increasing exports, and encouraging productivity spillovers, its significance has grown dramatically in recent years. The need for South Korea to take on a greater share of responsibility for the conservation of energy and the reduction of emissions has also been brought about by changes in the country's international position. Korea made a commitment to raise the contributions that national governments are responsible for, including increasing financial investments in renewable energy, implementing stricter environmental policies, and actively participating in international agreements on climate change (Holmes, 2022).

It is predicted that by 2030, greenhouse gas emissions will be 40% lower than they were in 2018, while carbon neutrality is expected to be reached by 2050.[1] The industrial sector in Korea is the primary contributor to the pollution caused by carbon emissions. To achieve zero carbon emissions and sustainable development in a short amount of time, decisive action should be taken to complete the energy transformation (Oh et al., 2021). In 2020, Korea successfully reduced its greenhouse gas emissions by 7.3% compared to the previous year, resulting in a total of approximately 648.6 million tons. This marked the second year in a row, in which Korea successfully reduced its emissions. Additionally, the per capita emissions declined by 7.4% to 12.5 tons. According to the Greenhouse Gas Inventory and Research Centre, the manufacturing sector has achieved a year-on-year reduction of 7.8% and 7.1% in greenhouse gas emissions, respectively (Wang et al., 2023). The increased use of liquefied natural gas (LNG), nuclear power, and solar electricity has resulted in a reduction in the proportion of coal-fired power output from 43% to 39% as of 2020.[2]

The Korean electricity industry has achieved an unprecedented reduction in emissions intensity because of this transition. Nevertheless, the percentage of fossil fuels remains significant at 67%. Although it has seen double-digit growth over the last five years, the market share of the renewable energy sector is still just 6%. This is much lower than the market shares of the European Union, Japan, and the United States (Choo et al., 2024). Most countries have tried to reduce fossil fuel dependency by supporting the transition to clean energy (Kartal et al., 2023, 2024). Overall, Korea has experienced a decline in greenhouse gas emissions. However, the nation must continue to make significant efforts across all areas, particularly in the industrial sector, to achieve its emission-reduction targets. On the other hand, there is a limited amount of research currently accessible on the association between globalization and environmentally friendly economic growth on an industrial scale for the manufacturing sector in Korea. Different factors are responsible for the variations in the progress made toward being carbon-neutral. Among these are varying patterns of energy consumption. They also touch on energy source interchangeability. One factor is the differing degrees of strictness of the environmental rules.

The manufacturing industry in Korea has unique characteristics. These characteristics are attributed to differences in the reliance upon foreign direct investment (FDI) or international trade. The outcome is a varied and complex industrial landscape. Thus, policy suggestions derived from macro-level factors such as nations or sectors may have certain deficiencies.

Research gaps exist regarding the specific association between globalization, inbound FDI, and environmentally friendly growth in Korea's manufacturing sector. While many studies have discussed macro-level influ-

[1] https://www.opm.go.kr/en/policies/carbon-neutrality-scenarios.do, accessed 14.03.2025.

[2] https://world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea, accessed 14.03.2025.

ences, there is a lack of investigation into sector-specific dynamics, particularly regarding energy source interchangeability and environmental policy strictness. This study addresses these gaps by examining how inbound FDI and economic development influence carbon emissions in Korea's manufacturing industry. Focusing on this underexplored area, this study aims to provide targeted policy recommendations to guide sustainable industrial practices.

The following sections include an extensive review of the literature, an explanation of the data and methodology used, a discussion of the results, and finally, our conclusions.

Literature Review

Developing countries are aiming to become technologically advanced and achieve rapid industrialization (Aysan et al., 2020; Kayani 2021). FDI enhances domestic competitiveness and stimulates technical innovation among local firms, resulting in improved carbon emission efficiency and reduced environmental pollution. (Aysan et al., 2020; Kayani 2021). For developing nations, the transfer of sophisticated technology and expertise via inbound FDI has a positive impact on both the upstream and downstream sectors, leading to higher labor productivity and ultimately sustainable development (Negash et al., 2020). FDI can be considered one of the major driving forces behind GDP growth, and it also acts as a means of transferring the latest technologies to the host countries (Kayani, Sadiq, 2022; Kayani et al., 2024). Conversely, industrial operations situated at the lower end of the global value chain not only produce limited amounts of additional value but also have a more substantial negative impact on the environment. The inflow of FDI into an economy may lead to the establishment of polluting companies. This may result in the receiving country experiencing the pollution shelter effect, which in turn harms Gross Total Factor Productivity (GTFP) (Sun et al., 2023).

Several studies have examined the positive effects of FDI on promoting sustainable and environmentally friendly economic development, but have also investigated its influence on greenhouse gases, carbon emission efficiency, the destruction of the environment, and contaminants in the air. For example, Apergis et al. (2020) contend that green technology, trade, and FDI are the main factors responsible for the reduction of carbon emissions, based on panel data collected from 30 OECD nations from 1996 to 2013. FDI allows recipient nations to incorporate and develop cutting-edge technology as part of their local industrial procedures. FDI often leads to a rise in pollution in emerging nations, while simultaneously decreasing pollution levels in affluent nations (Xie et al., 2020). Nur Mozahid et al. (2022) examine the connection between FDI and emissions resulting from energy consumption in developing nations. The findings suggest a bilateral correlation between FDI and emissions resulting from energy use; however, this link is seen only in seven specific nations. Furthermore, a cause-and-effect relationship exists between the emissions resulting from energy usage and FDI. By contrast, FDI led to pollution across nine different countries.

Similarly, De Vita et al. (2021) argued that inbound FDI has the potential to introduce sophisticated technology and new products that may lower energy intensity and replace energy-intensive commodities with energy-efficient alternatives. This, in turn, can lead to a decrease in environmental pollution in the United States. More trade openness may lessen the increase in carbon emissions for ASEAN-5 countries, particularly in low- and high-emission countries, as shown by Guzel and Okumus (2020). FDI has a negative effect on carbon emissions. Khan et al. (2022) demonstrate that carbon emissions are positively influenced by economic policy uncertainty (EPU), commerce, and GDP. FDI inflows and sustainable energy enhance the environmental conditions of East Asian economies including China, Korea, and Singapore. However, several studies suggest no substantial correlation between inbound FDI and carbon emissions. For example, Cai et al. (2021) employed a simultaneous equation framework to analyze the influence of FDI on air pollution. They divided this impact into three components: size, composition, and method effects. These findings indicate that the impact of FDI on air pollution in Korea is not statistically significant. This is because the technique effect, which mitigates the negative effects of FDI, counterbalances the additional pollution resulting from the magnitude and composition of FDI.

Musa et al. (2024) examined the co-integration link between FDI, economic development, industrial framework, sustainable and nuclear resources, urbanization, and Korean greenhouse gas emissions by employing the ARDL limits test. The findings show that FDI inflows result in an increase in greenhouse gas emissions, but the impact is minimal. Economic development has resulted in an increase in greenhouse gas emissions in the near term, but the use of renewable and nuclear energy tends to result in a reduction of greenhouse gas emissions. Both FDI and urban expansion have very little influence on the increase in greenhouse gas emissions. Habiba et al. (2021) suggest that FDI directly impacts economic development, however, it was not associated with an increase in carbon emissions in the G20 nations between 1971 and 2009. According to Cai et al. (2021), FDI has a favorable impact on carbon dioxide (CO_2) emissions over a prolonged period. Nevertheless, the magnitude of the favorable impact diminishes as income rises. Wang et al. (2023) analyzed a sample of around 20 developing countries and observed a noteworthy decline in energy intensity that coincided with an increase in FDI. This decline may be attributed to the use of modern technology combined with FDI, which marks a substantial shift from the outdated technologies used in other countries. This change has led to a decrease in ecologically detrimental emissions.

Recently, considerable debate has revolved around the relationship between FDI and environmental degradation. Hussain and Rehman (2021) examined the impact of foreign investments on greenhouse gas emissions. They propose several aspects and an intricate connection between FDI and CO2 emissions. Bhasin and Garg (2020) provided valuable insights into the impact of FDI on environmental conditions in emerging nations. Tang and Tan (2015) conducted a study that showcased the use of Granger causality analysis to examine the relationship between FDI and CO2 emissions. Nur Mozahid et al. (2022) looked at the effect that FDI has on CO2 pollution in nations that are oil exporters. Their study specifically focused on calculating emissions based on territory, rather than consumption. Their research suggested that FDI has the potential to reduce emissions when accompanied by suitable environmental measures. Ullah et al. (2022) showed that FDI in some industries has resulted in a significant increase in CO2 emissions. Nadeem et al. (2020) examined the impact of FDI on environmental degradation indicators, focusing specifically on CO2 emissions. Their research revealed that FDI had an initial detrimental impact on the environment. FDI has a beneficial impact on the improvement of environmental conditions through the expansion and development of the host nation's economy.

Naseem et al. (2021) explored whether there was a correlation between the BRIC countries' progress in terms of their economic growth and the degradation of the natural environment. This study found a direct relationship between higher levels of FDI and improved environmental standards, even in cases where economic growth initially leads to greater pollution levels, including CO2 emissions. This trend may be attributed to the use of more environmentally friendly technologies. Udemba and Keleş (2022) primarily focus on the impact of FDI on environmental conditions, with a particular emphasis on Turkey. After conducting the research, it was discovered that FDI had a negative impact on the environment in the short term but a positive impact in the long run. This indicates a period of transition in which there was a rapid rise in industrialization, resulting in an initial growth in emissions, followed by gradual improvements. The importance of sustainability and the environment cannot be ignored.

Several studies have been conducted on the potential correlation between pollution, economic development, and trade integration owing to the interconnectedness of countries in economic activities and commerce. In 1995, Holtz-Eakin and Selden performed a fundamental investigation into the correlation between the Carbon Index and its influence on economic advancement. The authors developed their hypotheses under the assumption that lowering trade barriers and encouraging economic activity would have an impact on the environment. This study aimed to provide empirical evidence for evaluating the relative magnitude of these three consequences of the implementation of market deregulation in Mexico. Aslam et al. (2022) used the ARDL approach and the Johansen co-integration process to explore the long-term correlation between economic growth and the environment. The findings of this investigation indicate a temporary correlation between company activities and CO2 emissions.

Bekun et al. (2021) used the Kuznets curve paradigm to examine the correlation between GDP and CO2 emissions in E7 countries. The findings suggest that institutional misalignments throughout the energy development process have a detrimental impact on sustainable development in economies. According to these findings, the Kuznets curve hypothesis is correct. Additionally, the research demonstrated that the utilization of alternative sources of energy and the expansion of economic growth led to a reduction in pollution. To evaluate the correlation between FDI and energy use intensity, Cao et al. (2018) conducted research that included a selection of developing nations as participants. The results indicated a notable decline in energy concentration as the level of FDI increased. This decrease may be ascribed to the use of contemporary technology in conjunction with FDI, indicating a significant improvement in comparison with the antiquated technologies that are utilized in other nations. This transformation led to a decrease in the number of ecologically detrimental pollutants.

Research Methodology

Data

The ARDL approach over the period 0f 1990-2021 was employed to investigate the effects of inward foreign direct investment and economic growth on carbon emissions in South Korea. In this study, carbon emissions were used as the dependent variable, and FDI, GDP (economic growth), and renewable energy were used as independent variables. These independent variables were selected because of their significant influence on environmental outcomes. FDI is a critical driver of economic growth and technological transfer, which can either exacerbate or mitigate environmental degradation depending on the nature of the investments (Wang, Luo, 2020). GDP is a direct measure of economic activity and growth and is often associated with increased energy consumption and emissions, highlighting its relevance in analyzing carbon emissions (Zameer et al., 2020). Renewable energy consumption was chosen because of its potential to reduce dependency on fossil fuels, thereby contributing to sustainable energy transitions (Kartal et al., 2024). By examining these variables, this study seeks to uncover the nuanced relationships between economic activities and environmental sustainability. Details of the dependent and independent variables are presented in Table 1.

Methods

This study examined the impact of inward foreign direct investment, and economic growth on carbon emissions. We use the Autoregressive Distributed Lag

Table 1. List of Variables

Variables	Symbols	Description & Measurement Scale
Carbon Emissions	CO_2	Metric tons per capita
Foreign Direct Investment	FDI	Foreign Direct Investment, net inflows (% of GDP)
Economic Growth	GDP	GDP growth (annual %)
Renewable Energy Consumption	REW	Renewable Energy Consumption (% of total final energy consumption)
Source: World Development Indicators, 2024 (https://databank.worldbank.org/source/world-development-indicators, accessed 07.03.2025).		

Bounds test for the analysis. Furthermore, we used Equation 1 to check the relationships among the variables.

$$CO_2\,emissions = f(FDI, GDP, REW) \quad (1)$$

Representation in regression form,

$$Y\,(CO_{2\ emissions}) = \alpha + \beta_1(FDI) + \beta_2(GDP) + \beta_3(REW) + e, \quad (2)$$

Where, β_1, β_2 & β_3 refer to the coefficients of the respective independent variables, α is the intercept of the regression model, *FDI* represents the foreign direct investment, *GDP* is the gross domestic product growth, *REW* is renewable energy consumption and *e* reflects the residuals.

To check the stationarity of the variables, we employ the ADF test, which is given below in equation 3.

$$\Delta x_t = \varphi x_{t-1} + \Sigma_{i=1}^{m} \delta \Delta x_{t-i} + e_t \quad (3)$$

Where Δ is the difference operator, *t* refers to time, φ is the symbol of the coefficient showing the process root, δ refers to the time trend coefficient, *m* shows the number of lags autoregressive model, and e_t is the random error term.

Empirical Results & Discussion

Descriptive Statistics

Initially, we ran descriptive statistics, and the results are presented in Table 2. The data were normal and did not have any outliers. The mean value of CO2 was 9.93, with a minimum value of 5.77 and a maximum of 12.21. This finding suggests substantial variability in carbon emissions across the years studied, which is indicative of shifts in energy policy and industrial output. Inward FDI exhibited a mean value of 0.85, minimum value of 0.21, and maximum value of 2.15, indicating moderate variability that may be associated with fluctuations in economic openness and foreign investment attractiveness. The GDP growth rate, with a mean value of 4.99 and a standard deviation of 5.12, reflects economic volatility due to global and domestic factors, including economic crises and recoveries. Finally, the mean value of Renewable Energy Consumption (REW) is 1.41, with a range of 0.40 to 3.60, indicating the gradual yet steady integration of renewables into Korea's energy portfolio. The findings underscore the multifaceted trends in the independent variables and their potential ramifications for carbon emissions, reinforcing the significance of this analytical investigation for the formulation of policies and the promotion of sustainable development.

Augmented Dicky Fuller (ADF) Unit Root Test

To check the stationarity of the variables, we applied the augmented Dickey–Fuller (ADF) unit root test proposed by Dickey and Fuller (1979). We find that our variables are stationary at I(0) and I(1). The findings presented in Table 3 reveal that carbon emissions (CO2) and renewable energy consumption (REW) reach a state of stationarity after the implementation of the first differencing, indicating their integration of order one I(1). Conversely, inward FDI and GDP growth are stationary at Level I(0), indicating the absence of a unit root issue at the original level. These findings corroborate the efficacy of the ARDL approach for further analysis, as it can accommodate variables with mixed integration orders. This ensures robust results when analyzing long- and short-term relationships among the variables.

ARDL Bounds Test

The ARDL Bounds Test helps estimate the long-run relationships among the variables of a model. Table 4 presents the results of the ARDL bound test. The F-statistic value of 12.83301 exceeded the upper critical bound values across all significance levels, confirming the presence of co-integration in the model. This indicates a long-term equilibrium relationship between carbon emissions, FDI, GDP, and renewable energy consumption.

Table 2. Summary Statistics for the Selected Variables

Var	Mean	Median	Max	Min	StDev
CO_2	9.939809	10.07126	12.21646	5.777465	1.840736
FDI	0.854976	0.779788	2.155979	0.211961	0.494646
GDP	4.993311	4.852400	11.46694	–5.129448	3.565381
REW	1.416129	1.000000	3.6000000	0.400000	0.943786
Source: authors.					

Table 3. ADF Unit Root Test for Stationarity

Variables	Symbol	ADF (Level)	ADF (1st Difference)
Carbon Emissions	CO_2	Non-Stationary	Stationary
Inward Foreign Direct Investment	FDI	Stationary	N/A
GDP Growth	GDP	Stationary	N/A
Renewable Energy	REW	Non-Stationary	Stationary
Source: authors.			

Table 4. **ARDL Bounds Test Results**

Test Statistics	Value	K
F	12.83301	3
Critical Value Bounds		
Significance level	**I(0)**	**I(1)**
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Source: authors.

Table 5. **ARDL Long-Term Estimate Results**

Variables	Coefficient	Standard Error	T-statistics	P-value
FDI	0.783249	0.966417	0.810467	0.4256
GDP	–1.160617	0.514524	–2.255709	0.0335
REW	0.966291	0.606921	1.592121	0.1244

Note: Dependent variable = CO2 & Independent variables = FDI, GDP, and REW.
Source: authors.

The results in Table 4 show that the F-statistic value (12.83301) was higher than the upper critical bound (I(1)) at all significance levels, including 10%, 5%, 2.5%, and 1%. This indicates a strong cointegration relationship among the variables in the model, suggesting that carbon emissions, inward FDI, economic growth (GDP), and renewable energy consumption share a long-term equilibrium relationship. The critical value bounds define the thresholds for determining co-integration, and surpassing the upper bound confirms this relationship. These findings validate the use of the ARDL approach to examine both the short- and long-term dynamics of the model.

ARDL Long-Term Estimates

The long-term ARDL estimates are presented in Table 5. The results indicate that GDP has a significant negative impact on carbon emissions, as evidenced by its coefficient of -1.160617 and p-value of 0.0335, which is below the 5% significance threshold. This suggests that economic growth in South Korea may lead to reduced carbon emissions, potentially due to increased efficiency or a shift toward sustainable practices. Conversely, FDI and renewable energy consumption (REW) do not exhibit statistically significant impacts on carbon emissions in the long run, as their p-values (0.4256 and 0.1244, respectively) exceed the common significance thresholds. The positive coefficient of FDI (0.783249) implies a potential increase in emissions associated with foreign investment, but the lack of significance suggests that the relationship is weak or inconsistent. Similarly, the positive coefficient for REW (0.966291) indicates that renewable energy consumption alone may not be sufficient to significantly reduce carbon emissions, possibly because of its relatively low share in South Korea's energy mix.

These findings illustrate the complex dynamics among economic growth, foreign direct investment, renewable energy, and carbon emissions in South Korea. While GDP appears to play a significant role in reducing emissions, further investigation is needed to understand why FDI and renewable energy consumption lack statistical significance and how their potential contributions can be enhanced in the future.

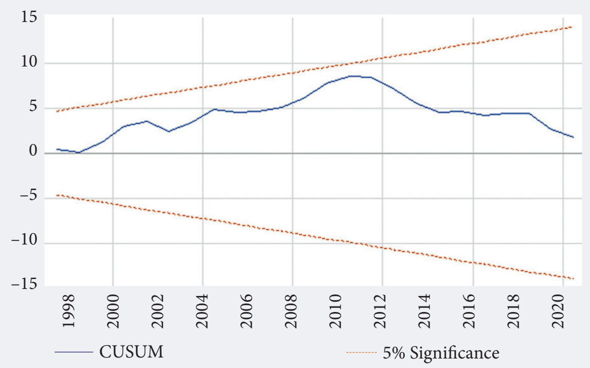
Stability Diagnostic Test

To evaluate the stability of the long-term coefficients, we employed Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests of recursive residuals. Figures 1 and 2 show the results of the tests. Figure 1 demonstrates that the CUSUM statistic remains within the 5% significance bounds throughout the sample period, indicating that the model's coefficients are stable over time. Similarly, Figure 2 shows that the CUSUMSQ statistic also lies within the 5% significance bound, further confirming the stability of the model's parameters. These stability diagnostic tests suggest that the model is robust and reliable for making inferences about the relationships between the variables.

Granger Causality Test

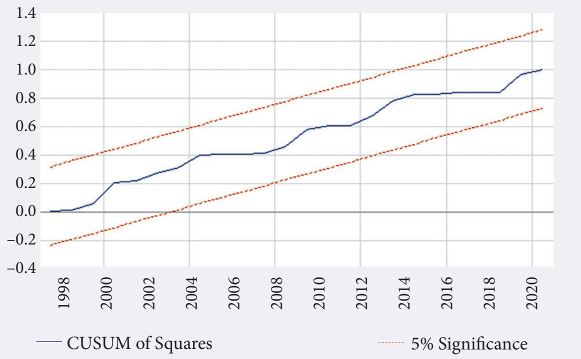
A Granger causality test was conducted to determine the direction of causality between the variables. The results presented in Table 6 reveal that carbon emissions (CO2) unidirectionally impact GDP and renewable energy consumption (REW). Additionally, renewable energy consumption unidirectionally affects GDP, suggesting that the expansion of renewable energy contributes to economic growth. The results indicate that, while FDI does not exhibit causality with any other variable, CO2 and REW demonstrate significant unidirectional causal relationships with GDP. These findings emphasize the importance of controlling renewable energy and carbon emissions when fostering economic growth in South Korea. Further exploration

Figure 1. **Cumulative Sum of Recursive Residuals**



Source: authors.

Figure 2. **Cumulative Sum of Squares of Recursive Residuals**



Source: authors.

of these causal links may offer insights for optimizing environmental and economic policies.

Discussion

The relationship between FDI, economic growth, and environmental quality, particularly carbon emissions, has generated considerable interest and debate among policymakers, economists, and environmental scientists such as (Wang, Luo, 2020; Oh et al., 2021; Holmes, 2022). This study examines this relationship in South Korea's manufacturing sector, where the dual forces of economic growth and FDI interact with South Korea's commitment to carbon neutrality by 2050. This sector, which is essential to the country's economic success, also represents a substantial source of greenhouse gas emissions due to its reliance on coal and other fossil fuels (He et al., 2022). As nations such as South Korea strive to balance economic prosperity with environmental responsibility, understanding the nuanced effects of FDI on carbon emissions is crucial.

The Dual Role of FDI in Economic Development and Environmental Degradation

FDI can significantly influence a host country's economy by promoting industrial competitiveness, advancing technological innovation, and spurring economic growth (Wang, Luo, 2020). However, FDI's environmental impacts are complex, and sometimes contradictory. Although FDI can introduce cleaner technologies, it may also lead to the establishment of carbon-intensive industries, especially if environmental regulations are lax. The results of this study align with previous literature indicating that FDI, when concentrated in high-emission sectors, such as manufacturing, tends to increase greenhouse gas emissions if stringent environmental standards are not enforced (Negash et al., 2020; Kayani, Sadiq, 2022).

Table 6. **Granger Causality Test Results**

Variables	F-statistics	P-value	Causality
FDI — CO2	0.68218	0.4161	No
CO2 — FDI	0.08549	0.7722	No
GDP — CO2	0.22477	0.6392	No
CO2 — GDP	19.4141	0.0002	Yes
REW — CO2	0.10449	0.7490	No
CO2 — REW	20.4590	0.0001	Yes
GDP — FDI	2.34815	0.1371	No
FDI — GDP	0.35106	0.5584	No
REW — FDI	0.84662	0.3657	No
FDI — REW	0.67730	0.4177	No
REW — GDP	4.55710	0.0420	Yes
GDP — REW	1.52883	0.2269	No

Source: authors

The findings underscore the "pollution haven hypothesis," where FDI flows into countries with relatively lenient environmental regulations, potentially increasing emissions and exacerbating environmental degradation (Sun et al., 2023). As South Korea attracts FDI, it simultaneously faces the challenge of managing emissions. This phenomenon suggests the need for policies that promote "green FDI," which involves investment in sectors that prioritize sustainability and environmental responsibility. This approach aligns with the arguments presented by Apergis et al. (2020), who found that environmentally focused FDI can play a crucial role in reducing emissions if regulations incentivize the adoption of clean technologies.

Economic Growth and its Environmental Trade-offs

Economic growth, as seen in South Korea, often results in increased energy consumption and greenhouse gas emissions, particularly in rapidly industrialized nations. Korea's economic model, heavily reliant on its manufacturing sector, has significantly contributed to its carbon footprint because of its dependence on coal (Lee, Woo, 2020). While the initial stages of economic growth typically lead to higher emissions, the Environmental Kuznets Curve (EKC) hypothesis posits that beyond a certain point, economic growth may reduce environmental degradation through increased investments in green technologies and improved energy efficiency (Lamb et al., 2021).

The ARDL bounds test results suggest the potential for Korea's economic growth to decouple from carbon emissions over the long term, contingent upon proactive policy measures. For instance, government interventions promoting renewable energy adoption, energy-efficient technologies, and emission regulations could help reduce the environmental impact of growth (Holmes, 2022). By implementing such measures, South Korea can manage its environmental footprint even as it continues to grow economically. However, as Choo et al. (2024) highlight, although renewable energy represents a promising solution, the share of renewables in Korea's energy mix remains low. Consequently, Korea's transition toward cleaner energy infrastructure requires substantial policy support and investment.

Renewable Energy as an Underutilized Resource

The role of renewable energy is critical for reducing carbon emissions, however, its current usage remains limited in South Korea. The findings reveal that, while renewable energy adoption shows potential, its short-term impact on emissions reduction is statistically insignificant. This is due to the relatively low share of renewables in South Korea's energy portfolio—currently only around 6%—compared to more mature markets such as the EU, Japan, and the US. (Wang et al., 2023). These findings align with those of (Kartal et al., 2023, 2024), who found that the transition from fossil fuels to renewable energy requires robust policy interventions, including subsidies and investment incentives, to achieve meaningful emission reductions.

Despite its slow progress, South Korea has made notable advances in the use of liquefied natural gas (LNG) and solar energy, which have helped reduce the proportion of coal-fired power (Oh et al., 2021). The findings underscore the need for a broader, long-term strategy to significantly boost renewable energy adoption, especially in the manufacturing sector, which remains one of the largest sources of emissions. By integrating renewables into industrial processes, South Korea can reduce its carbon footprint while maintaining its economic competitiveness.

Directional Influence on Economic and Environmental Dynamics

The results of the Granger causality test provide insights into the directionality between carbon emissions, economic growth, and renewable energy consumption. The test reveals unidirectional causality from carbon emissions to GDP growth, suggesting that environmental degradation may drive economic responses such as increased production to compensate for environmental losses. This finding is consistent with research indicating that environmental challenges often prompt economic diversification and innovation (Guzel, Okumus, 2020).

In addition, the causality between renewable energy and GDP highlights the economic growth potential of clean energy sources. As renewable energy adoption increases, so does economic output, supporting the argument that renewable energy is a viable pathway for sustainable economic growth. This finding aligns with studies such as that by De Vita et al. (2021), who argue that clean energy adoption has a compounding effect, reducing emissions while simultaneously boosting GDP. These insights emphasize the need for preemptive and forward-looking policies that mitigate emissions through sustainable growth strategies rather than reactive measures after environmental degradation occurs.

Conclusion

This study examines the long-run relationship between FDI, economic growth, and carbon emissions in South Korea. We employed the most effective ARDL Bounds test for the period ranging from 1990 to 2021. The empirical relationship revealed the existence of a long-run relationship between the variables in our model, and the results are consistent with those of previous empirical studies. Furthermore, we also found that CO2 emissions impacted GDP and renewable energy unidirectionally, and renewable energy affected GDP unidirectionally. The only limitation of this study is that it is restricted to the South Korean economy, and future studies can apply the panel methodology to other East Asian economies. Based on the findings of this study, several policy recommendations have emerged. First, South Korea should enhance regulatory frameworks governing FDI to ensure that incoming investments align with environmental standards. Encouraging FDI in sectors that prioritize sustainability and green technology could help offset the environmental costs associated with industrialization. The government could establish tax breaks, subsidies, or other incentives for foreign companies to invest in clean technologies and low-carbon industries.

Second, South Korea's energy policy must prioritize the development of renewable energy. Increasing the share of renewables beyond the current 6% would significantly contribute to emission reduction, particularly in the manufacturing sector. Policymakers may consider implementing stricter regulations on coal usage while simultaneously increasing investments in solar, wind, and nuclear energy. Such initiatives would contribute to reducing the country's carbon dependency and position Korea as a leader in the global green economy.

Finally, fostering innovation and technological transfer through FDI can reduce emissions. By promoting partnerships between local firms and foreign investors specializing in green technologies, Korea can leverage FDI to achieve sustainable industrialization. These partnerships would facilitate technology transfer, improve carbon efficiency, and support Korea's transition to a low-carbon economy.

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Systematic Review of Open Innovation Approaches for Industrialisation in Developing Economies

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Abstract

Industrialisation remains a cornerstone of economic transformation in developing countries, yet progress is often constrained by fragmented innovation systems, resource limitations, and institutional barriers. Open innovation offers an alternative paradigm by promoting knowledge flows across organisational and sectoral boundaries. This systematic literature review critically examines how open innovation partnership models are conceptualised, implemented, and adapted to support industrialisation in low- and middle-income countries. The results demonstrate a progressive shift from linear innovation approaches to more networked, ecosystem-based configurations, with inbound, outbound, and coupled innovation strategies increasingly evident. University-industry-government (UIG) partnerships, intermediary-facilitated collaborations, and digital platforms emerge as dominant mechanisms. SMEs are pivotal actors but encounter persistent capability and resource constraints. Key enablers include institutional trust, leadership commitment, absorptive capacity, and digital infrastructure. Conversely, barriers such as weak policy coherence, infrastructural deficits, and fragmented coordination inhibit innovation outcomes. The analysis also identifies emerging trajectories, notably the integration of AI and digital technologies in innovation ecosystems and the evolving role of intermediaries. This review highlights critical research gaps, particularly the need for empirically validated frameworks and SME-centric strategies and offers insights to inform policy design and the development of inclusive, adaptive innovation systems aligned with sustainable industrialisation objectives.

Keywords: open innovation; industrialization; developing countries; innovation partnerships; SMEs; innovation ecosystems; digital transformation; systematic literature review; Triple Helix; innovation policy

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Introduction

Industrialisation is an important strategy for fostering long-term economic development in underdeveloped countries. In the midst of global transformations in production dynamics and technological advances, open innovation has emerged as a strategic model with the potential to reshape how nations in the Global South seek industrial success. Rather than depending primarily on internal R&D, the open innovation paradigm encourages organisations to work beyond institutional boundaries, leveraging external ideas, technologies, and capabilities to co-create value and accelerate advancement. Open innovation fundamentally undermines the notion of closed, private innovation processes. It promotes the creation of inclusive ecosystems in which government, industry, academia, and civil society actively participate in mutual knowledge exchange and issue solutions. This paradigm is particularly well suited to the needs of developing nations, where resource restrictions and fragmented innovation systems frequently impede technological growth. This systematic review investigates the relationship between open innovation and industrialisation in low- and middle-income countries, specifically how partnership-driven innovation strategies might stimulate structural transformation. It draws on a wide range of literature to evaluate theoretical models, practical frameworks, and empirical evidence on the adoption, benefits, and restrictions of open innovation in different settings. This study is based on the idea that successful industrialisation is no longer simply about increasing output but also about developing innovation capacity through dynamic networks and shared capabilities.

The primary goal of this review is to investigate how open innovation partnership models contribute to industrial development in developing countries. To accomplish this, the paper analyses the theoretical foundations of open innovation and evaluates their relevance to industrial policy in resource-constrained contexts. It categorises and critically examines key open innovation practices and partnership models relevant to the Global South, with an emphasis on inbound, outbound, and coupled approaches. The review presents insights on the evolution of partnership approaches, stakeholder roles, enabling factors, and barriers to effective collaboration, with particular attention to the role of small and medium-sized enterprises (SMEs). It also explores the integration of digital technologies and the strategic function of intermediaries in contributing to innovation ecosystems. The study synthesises emerging trends and identifies gaps in empirical evidence, SME-specific frameworks, and innovation measurement. Finally, the review aims to provide actionable policy insights and strategic recommendations to support inclusive and sustainable industrial transformation through dynamic and networked innovation systems.

Methodology

Literature search and selection

This study uses a systematic literature review (SLR) technique to conduct a thorough and transparent analysis of scholarly work on open innovation and industrialisation in poor countries. The review uses specific search phrases such as "open innovation," "industrialisation," "developing countries," "innovation systems," and "SMEs" to locate publications in major academic databases such as Scopus, Web of Science, Google Scholar, and ScienceDirect. To ensure quality and relevance, only peer-reviewed journal articles, conference papers, and policy reports from 2000 to 2024 were evaluated. The literature was thematically coded to find repeating patterns, categorise open innovation approaches, and connect them to conceptual models like the Triple Helix, Innovation Systems Theory, and Resource-Based View. The review also highlights gaps in the research and draws conclusions that are directly relevant to policy and practice in developing nations.

The initial search identified approximately 1000 documents spanning journal articles, conference papers, and policy reports. Studies were screened in three stages: title review, abstract review, and full-text assessment. Inclusion criteria focused on studies that addressed open innovation models, practices, or partnerships with direct relevance to industrialisation in developing countries. Exclusion criteria included studies focused solely on advanced economies, those lacking a theoretical or empirical contribution, and publications not available in English. Following this process, 112 high-relevance sources were selected for in-depth analysis (See Appendix A). The final set reflects a diverse body of literature encompassing theoretical frameworks, empirical studies, and policy-focused analyses.

Open innovation impact mechanisms analysis

The selected studies were analysed using a thematic synthesis approach to identify key mechanisms through which open innovation contributes to industrialisation in developing contexts. The literature was coded iteratively to extract patterns related to innovation partnership models, actor roles, enabling factors, barriers, and policy implications. Special attention was given to the mechanisms by which knowledge flows are facilitated across organisational and sectoral boundaries, and how these processes impact SME participation, innovation performance, and ecosystem development. The analysis also examined the role of intermediaries, digital platforms, and emerging technologies in shaping open innovation outcomes.

Mechanisms were identified through an inductive thematic coding process. After full-text review of the selected studies, key concepts and recurring themes related to open innovation practices and their role in industrialisation were systematically extracted and categorised. An initial set of thematic codes was developed based on established conceptual models such as the Triple Helix, Innovation Systems Theory, and the Resource-Based View. Additional codes were added iteratively to capture emerging themes from the literature, including digital transformation, intermediary roles, and SME-specific dynamics. Cross-comparison of coded material allowed for the identification of mechanisms that facilitate or hinder knowledge flows, collaborative innovation, and industrial upgrading. The resulting synthesis informed the structure of the Results and Policy Recommendations sections of this review.

Conceptual and Theoretical Foundations

Definition of open innovation

The concept of open innovation represents a transition from the old model of closed, internalised research and development (R&D) to a more outward-looking, collaborative approach to innovation. Open innovation, first coined by Henry Chesbrough, is defined as the strategic utilisation of both internal capabilities and external knowledge flows to improve innovation processes (Chesbrough, 2003). It reflects an awareness that significant insights, ideas, and technological breakthroughs frequently exist outside of a single organization's borders and that enterprises can gain a competitive advantage by harnessing this external knowledge through purposeful collaboration.

In practice, the use of OI involves forming dynamic relationships with a wide range of stakeholders, including customers, suppliers, startups, institutions, and even competitors. Such partnerships, based on joint value creation, are formed with the aim of finding solutions, accelerating product development, and gaining access to new knowledge, skills, and technologies. Companies that implement OI create more flexible, adaptive innovation ecosystems, which is especially important in rapidly changing and resource-constrained contexts. This involves moving away from the principle of closed innovation and promotes adaptability, co-creation, and ecosystem thinking.

The OI model encourages companies to create open systems in which ideas and technologies can "flow in" and "flow out," blurring their boundaries. This allows companies to attract a wider range of partners, including customers, research institutions, other companies, and even competitors, which accelerates problem solving and expands access to markets. Three modes are commonly used to classify OI: inbound, outbound, and combined. "Inbound OI" refers to the acquisition of external ideas and technologies and their integration into a company's own innovation activities. This activity often takes the form of technology scouting, licensing, or joint development (Saebi, Foss, 2015). In turn, "outgoing OI" refers to the transfer (including on a commercial basis) of innovations created by the company to external partners in order to enhance their effect or obtain new sources of income (Michelino et al., 2014). The combined mode combines the two above: sharing existing innovation results and creating new ones jointly with partners. By leveraging skills distributed across the innovation landscape, this network approach enables companies, especially in developing countries, to overcome resource constraints and accelerate industrial and technological modernization. For a detailed overview of each mode of IP creation, see Table 1.

Theoretical perspectives

An underlying basis in an array of linked theoretical frameworks that describe how innovation arises, spreads, and boosts competitiveness is necessary for understanding open innovation in the setting of developing nations. This review is based on three prominent viewpoints: the Resource-Based View (RBV), the Triple Helix Model, and Innovation Systems Theory.

Innovation System Theory. According to the Innovation Systems Theory, innovation results from interactions between a variety of players within a larger institutional and policy framework, including businesses, research institutes, governmental entities, and intermediaries (Watkins, 2015). This idea emphasises how innovation is a systemic process that is influenced by infrastructure, financial mechanisms, education systems, and legislation rather than being a linear or firm-centric process. Innovation systems can be sectoral, technological, national, or regional, and they work best when information is openly shared among participants, encouraging experimentation, dissemination, and adaptation.

Triple Helix of University-industry-government relations. The Triple Helix Model, which emphasises the changing dynamics between government, business, and academics (Etzkowitz, Leydesdorff, 2000), is a useful addition to this systems concept. According to the concept, ongoing, co-evolutionary cooperation across these three domains increases the likelihood of sustained innovation outputs. In developing nations, where fragmented innovation ecosystems and institutional silos are prevalent, the Triple Helix provides a framework for knowledge co-production, resource sharing, and gap-closing. It also emphasises how crucial it is to establish hybrid organisations that are at the nexus of these three fields, like university incubators or public-private Research and Development platforms.

Resource-Based View. Providing an internal perspective, the Resource-Based View (RBV) asserts that businesses can obtain a competitive edge by creating and using special resources and talents that are valu-

Table 1. **Practices of Open Innovation, by type**

Practice	Summary Definition
Outside-In	
Licensing-In	Acquiring IP or tech rights from external entities
Customer Involvement	Engaging customers in product or process innovation
Consulting	Using external experts to solve innovation challenges
Technology Scouting	Searching for emerging external technologies
Outsourcing (Contract R&D)	Delegating R&D or innovation tasks to external firms
Crowdsourcing	Seeking ideas or solutions from an open online community
Reverse Engineering	Extracting insights from competitors' products
Sharing Facilities	Using or co-locating infrastructure with external partners
Inside-Out	
Licensing-Out	Selling or leasing internal IP to external firms
Spin-Off	Creating a new company using internal knowledge or assets
Open Source	Sharing internal tech openly for indirect strategic gains
Divesting	Selling internal units or technologies
Coupled	
Joint Research	Collaborative R&D with academia or other firms
Joint Development	Co-creating innovations with external partners
Joint Manufacturing	Sharing production of goods or services
External Participation	Attending fairs, consortiums, or conferences for knowledge exchange
Source: adapted from (Candi, Kahn, 2025).	

able, rare, inimitable, and non-substitutable (VRIN) (Talaja, 2012). RBV aids in the explanation of why certain businesses are more suited to gain from co-operative agreements in the context of open innovation. These businesses usually possess the strategic vision to match alliances with core strengths as well as the absorptive capacity, or the ability to recognise, absorb, and utilise outside information for competitive advantage.

Significance of industrialization in developing countries

Industrialisation has historically been a cornerstone of national growth, allowing governments to diversify their economies, increase productivity, and create jobs. For developing countries, industrial transformation is frequently considered as a crucial step towards long-term economic growth and higher living standards. Industrial sectors, particularly manufacturing, can absorb surplus labour from agriculture, boost export profits, and catalyse technical advancement. Despite its significance, industrialisation has not always followed the conventional, linear path observed in previously industrialised states in many low- and middle-income countries (Araujo et al., 2021). Manufacturing is a crucial step in the development and industrialization process, however some patterns indicate that some nations are eschewing industrialisation entirely and instead transitioning straight from agricultural into low-productivity service industries a process known as "premature deindustrialisation." (Rodrik, 2016).

For example, the issues in sub-Saharan Africa are complex. Industrial expansion has been hampered by a combination of structural constraints, poor institutions, inadequate infrastructure, and a lack of skilled labour. However, new data suggests that the industry is reviving, especially through micro and small-scale manufacturing businesses (Edobor, Sambo-Magaji, 2025), this research demonstrates how exchange rate policies, human capital, and geographical differences affect industrial success in African countries. Others have also emphasised how crucial it is to combine industrial strategy with more comprehensive innovation and employment plans, especially in economies with young populations and significant levels of informality. Developing nations have both possibilities and challenges because of the global fall in manufacturing's GDP share, the advent of automation, and changing global trade patterns. New models that integrate industrialisation with innovation, digital transformation, and inclusive growth are becoming more popular, even though classic export-led industrialisation may no longer ensure widespread prosperity (Delechat et al., 2024). Therefore, industrialisation is still relevant, but it needs to be rethought to consider the changing dynamics of the twenty-first century.

Rationale for Open Innovation in Industrialization

In developing nations, with their limited internal resources and fragmented innovation ecosystems, open innovation is best understood as a systematic strategy that brings together a variety of actors, including startups, government agencies, academic institutions, and businesses, to work together towards common industrial goals (Ogink et al., 2023; Rabelo et al., 2015). Several enablers are necessary for effective implementation, including building internal capacity to learn and apply new information, creating transparent intellectual property frameworks, collaborating to share operational and financial risks, and incorporating feedback loops for ongoing learning and adaptation (Santos, 2024). Monitoring important parameters including partnership activity, time-to-market, and information flow helps improve innovation success. Leadership that encourages a culture of transparency, experimentation, and mutual value creation is essential to this process. Open innovation transforms from a collection of methods into a comprehensive development approach that synchronises innovation with the objectives of sustainable and inclusive industrialization (Ghobakhloo et al., 2021).

By filling in important gaps in resources, competencies, and market responsiveness, open innovation provides a measured method for reviving industrialisation initiatives in poor nations (Anshari, Almunawar, 2022). Open innovation promotes businesses to work with external partners, including startups, universities, and other industries, to co-develop solutions, share risks, and access complementary skills (Berchicci, 2013). The collaborative concept has several benefits. First, it makes specialised expertise and technologies more accessible, which enables businesses especially SMEs to get beyond internal barriers and quicken innovation cycles. Second, it makes innovation more financially feasible by sharing costs across partners, which lessens the financial strain of R&D. Third, by allowing businesses to use pre-existing technology or co-develop solutions with knowledgeable partners, open innovation reduces time-to-market (Lee et al., 2010). Open innovation strengthens supply chains, promotes cross-sectoral learning, and increases overall industrial resilience by integrating businesses into larger innovation ecosystems. This flexibility is essential in marketplaces that are changing quickly (Smith, 2007). Together, our capacity for innovation, learning, and adaptation puts businesses and the industries they serve in a better position to react to changing technological trends and economic conditions (Dolata, 2009).

Thus, open innovation is essential for developing nations hoping to industrialise under challenging and resource-constrained circumstances. It offers a structure for cooperation, testing, and ecosystem building that fits the requirements of sustainable and equitable industrial growth (Oliveira-Duarte et al., 2021).

Conceptualising Open Innovation process in developing countries

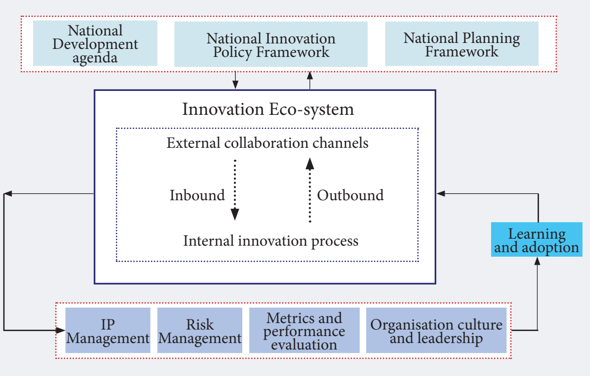
In developing countries, open innovation can be institutionalised within a larger national development strategy, as shown by the conceptual model (Figure 1). The National Development Agenda, the National Innovation Policy Framework, and the National Planning Framework serve as the model's three main policy pillars. These frameworks offer the strategic direction and legal underpinnings for innovation-driven industrialisation. The Innovation Ecosystem, which promotes an ongoing flow of concepts, technologies, and skills via external channels of collaboration, is at the heart of the paradigm. These channels provide both outbound flows, where internal ideas are disseminated or commercialised externally, and inbound flows, where external technology and knowledge are incorporated into internal innovation operations.

Four operational enablers underpin this ecosystem: IP management, which controls knowledge ownership and transfer; risk management, which reduces uncertainty and resource constraints; metrics and performance evaluation, which gauges the efficacy of innovation; and organisational culture and leadership, which promote transparency, flexibility, and teamwork within businesses. The Learning and Adoption loop, a key component of the framework, makes sure that input from innovation initiatives guides the improvement of policies and the building of capacity. These interrelated elements work together to provide a strong, flexible framework that supports inclusive and sustainable industrial transformation by coordinating institutional capacities with national development objectives.

Results of Thematic Synthesis

Building on the mechanism analysis described previously, the findings are organised around key patterns and mechanisms through which open innovation partnerships are shaping industrialisation processes in developing countries. The results highlight the evolution of partnership models, stakeholder roles, enabling factors, barriers, and emerging trends that influence the development of dynamic innovation ecosystems.

Figure 1. **Open Innovation Conceptual Framework**



Source: authors.

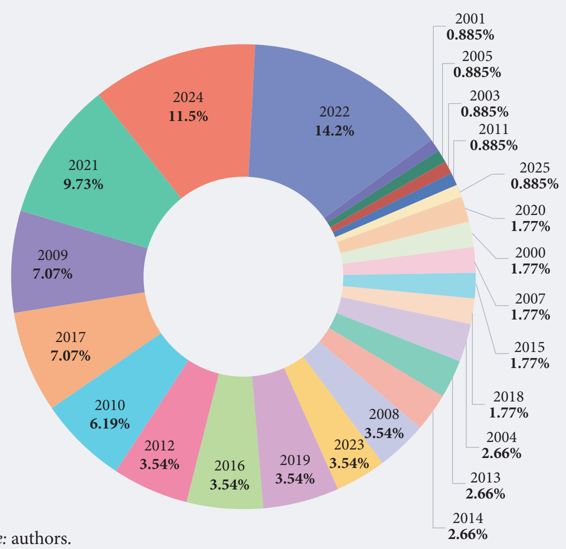
Descriptive Characteristics of the Reviewed Studies

This subsection provides an overview of the descriptive characteristics of the reviewed studies, including publication trends, geographical distribution, methodological approaches, industrial sectors covered, and theoretical foundations.

Temporal Distribution of Publications. The reviewed literature shows a clear increase in scholarly attention to open innovation and its role in industrialisation in developing countries over the past two decades. Early publications in this area were limited and fragmented, with only a small number of conceptual and policy-oriented papers appearing prior to 2010. From approximately 2015 onwards, there has been a marked growth in both the volume and diversity of publications, reflecting the increasing relevance of open innovation frameworks in development policy and practice. This growth corresponds with broader global shifts toward innovation-driven development agendas and digital transformation initiatives. The upward trend is particularly evident in the last five years (2019–2024), where a surge of empirical studies, systematic reviews, and analyses of innovation ecosystems has emerged. This indicates that open innovation has moved from a niche topic to a recognised area of inquiry within the field of industrialisation in developing contexts. This upward trajectory in publication activity provides a rich and evolving evidence base for the subsequent thematic synthesis presented in this review. Refer to figure 2.

Geographical Distribution. The geographical distribution of the reviewed literature shows that African contexts are the most extensively studied, reflecting both the growing interest of scholars and policy actors in leveraging open innovation to address industrialisation challenges across the continent. Studies focusing on African countries account for the largest share of the reviewed sample, with notable contributions covering Sub-Saharan Africa and country-level analyses from South Africa, Nigeria, Kenya, and other nations. Asia is also represented, though to a lesser extent, with studies covering emerging economies such as China, India, and selected Southeast Asian countries. European-based scholars contribute to the literature primarily through conceptual and comparative studies, often in collaboration with researchers and institutions in developing regions. South America appears less frequently in the reviewed literature, with some studies addressing Brazil, Mexico, and cross-regional innovation networks. This uneven distribution highlights both opportunities and challenges for building a comprehensive understanding of open innovation partnerships in diverse industrial contexts. The predominance of studies from low to middle-income countries suggests that open innovation is more advanced in contexts with relatively stronger innovation systems and institutional capacity. The synthesis that follows therefore draws attention to both common patterns across regions and context-specific variations that reflect differing stages of industrial development. Refer to figure 3.

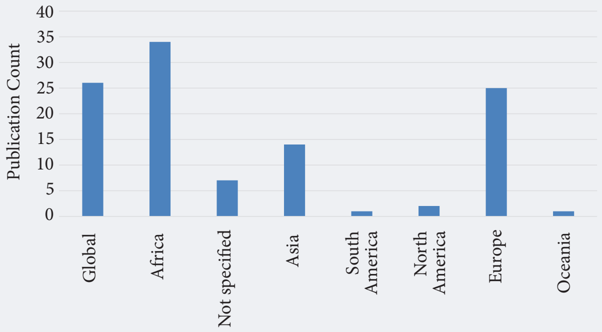
Figure 2. **Temporal Distribution of Publications**



Source: authors.

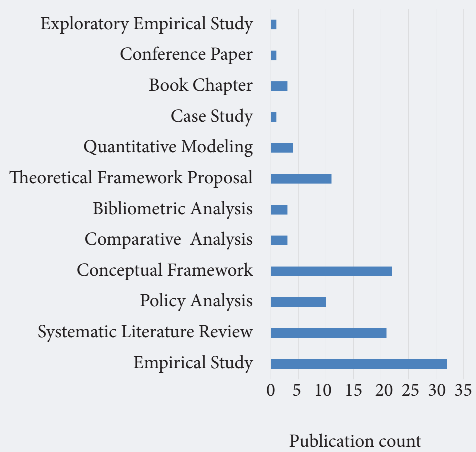
Types of Studies and Methodological Approaches. The reviewed literature encompasses a wide range of study types and methodological approaches, reflecting the multidisciplinary nature of research on open innovation and industrialisation. Conceptual and literature-based studies represent approximately 38% of the total sample, including theoretical frameworks, conceptual syntheses, and normative policy proposals. Systematic literature reviews (SLRs) and bibliometric analyses account for roughly 21%, providing structured insights into the evolution of open innovation scholarship. Empirical research forms a significant portion of the evidence base at 28%. Quantitative studies, primarily surveys employing structural equation modelling (SEM), regression analyses, canonical correlation, and other statistical techniques constitute about 3.6%, with a strong focus on SME adoption of open innovation practices. Qualitative approaches, including case studies, thematic analyses, and policy evaluations, represent approximately 10% and contribute rich contextual insights. A smaller subset of studies 1% employs econometric modelling and network analysis to explore macro-level patterns in innovation ecosystems. The methodological diversity observed here enhances the robustness of the evidence base but also reveals certain limitations. While survey-based and conceptual research are dominant, there is a relative scarcity of longitudinal studies and in-depth qualitative research that can capture the dynamic and context-specific nature of open innovation partnerships. The findings from this varied body of work provide a strong foundation for the thematic synthesis presented in the subsequent sections. Refer to figure 4.

Figure 3. **Geographical Distribution**



Source: authors.

Figure 4. **Types of Studies and Methodological Approaches**



Source: authors.

Figure 5. **Industrial Sectors Covered**

Source: authors.

Industrial sectors covered. A large proportion of the reviewed literature focuses on open innovation practices among small and medium-sized enterprises (SMEs), often across multiple sectors. Studies addressing open innovation in SMEs represent approximately 34.5% of the sample, frequently exploring cross-sectoral dynamics and the role of SMEs as innovation adopters and ecosystem participants. As such, many papers do not explicitly focus on one industrial sector but instead examine innovation behaviours, partnership models, and policy frameworks applicable to SMEs operating across diverse economic activities. Where sectoral focus is evident, manufacturing remains the most studied industry, reflecting its traditional role in industrialisation. Approximately 4% of studies address manufacturing, including both high-tech and low-tech subsectors. The agri-food sector features in a smaller subset of studies (1%), often linked to rural development and SME innovation in value chains. The ICT and digital services sector is also represented (11%), particularly in relation to digital platforms and knowledge exchange. Overall, the sectoral distribution highlights the prominence of SME-focused and cross-sectoral studies, with relatively limited coverage of sector-specific innovation dynamics in industries such as healthcare, energy, and construction. This pattern reflects both the research emphasis on SMEs as key actors in developing country innovation ecosystems and the cross-cutting nature of many open innovation initiatives. Refer to figure 5.

*Theoretical Basis***.** The reviewed literature draws upon a wide range of theoretical frameworks to examine open innovation and its relationship to industrialisation in developing countries. The most used perspectives are those associated with open innovation models and related business frameworks, which appear in approximately 50% of the studies. These include the Open Innovation Framework, co-creation models, and business model innovation, particularly in the context of SME development. Innovation Systems Theory, including National Innovation Systems (NIS) and Sectoral/Regional Innovation Systems, is another prominent foundation ([20%), often used to analyse the structural and institutional factors shaping innovation ecosystems. Dynamic Capabilities and Resource-Based View (RBV) perspectives are applied in 15% of the studies, particularly those examining how firms develop strategic capabilities to engage in open innovation partnerships. The Triple Helix Model and related ecosystem-based approaches appear in 10%, highlighting the role of university-industry-government interactions in fostering collaborative innovation. Smaller but growing subset of studies (5%) incorporates frameworks from technology adoption, digital economy theories, and economic complexity perspectives to explore how digital transformation is reshaping innovation dynamics. The diverse theoretical base reflects the multidisciplinary nature of the field but also points to opportunities for greater theoretical integration. While many studies adopt single-framework approaches, there is a need for more holistic models that can better capture the complex, multi-actor nature of open innovation partnerships in developing contexts.

Focus Area. The reviewed studies address a range of focus areas related to the adoption and impact of open innovation in developing countries. The most prominent area of focus is open innovation in SMEs, which accounts for approximately 30% of the sample. These studies explore how SMEs adopt and implement open innovation practices, the barriers they face, and the enabling factors that influence their participation in innovation ecosystems. This strong emphasis reflects the central role that SMEs play in the industrialisation processes of many developing economies. University-industry-government (UIG) partnerships represent another key focus area (25%), with studies examining the dynamics of collaboration between academic institutions, firms, and public sector actors. Innovation policy and systems-oriented research (20%) addresses how national and regional innovation frameworks can support open innovation and industrial upgrading. Technology and digital transformation is a rapidly growing focus area ([15%), with studies highlighting the role of digital platforms, ICT tools, and Industry 4.0 technologies in facilitating open innovation practices. Research on innovation ecosystems and collaboration (5%) examines how multi-actor networks, intermediaries, and collaborative platforms shape innovation outcomes. Inbound and international open innovation is a smaller but emerging area (5%), focusing on knowledge sourcing and cross-border collaboration by firms in developing contexts. The dominance of SME-focused and cross-sectoral studies, alongside increasing attention to digitalisation and ecosystem collaboration, reflects both current policy priorities and practical challenges in fostering innovation-driven industrialisation.

Changes in partnership approaches

The reviewed literature highlights significant changes in how open innovation partnerships are structured and operationalised in developing contexts. Early studies focused predominantly on formal university-industry-government (UIG) collaborations and public-private partnerships, often driven by donor funding and government policy initiatives. Donor-driven models, while instrumental in catalysing early innovation partnerships, have sometimes resulted in fragmented or short-term initiatives that struggle with long-term sustainability and local ownership, 90% of the papers reviewed do not recommend these models. Over time, there has been a notable shift toward more diverse and flexible partnership models. Informal collaborations and intermediated networks such as innovation hubs, incubators, and living labs are increasingly prevalent, enabling more agile forms of knowledge exchange and co-creation.

Cross-sectoral and multi-stakeholder approaches now feature prominently, with horizontal and vertical alliances involving actors from the private sector, academia, government, civil society, and international partners. This reflects a growing recognition that open innovation requires ecosystem-wide engagement, particularly in resource-constrained settings. International and cross-border collaborations are also gaining traction, enabling firms and innovation networks in developing countries to access global knowledge flows and market opportunities. Digital platforms and ecosystem-based collaborations represent a further evolution, facilitating distributed innovation and crowd-based engagement. These developments indicate a move away from linear and centrally coordinated partnership models toward more dynamic, networked approaches that are better suited to the complexities of industrialisation in the Global South.

Models of Open Innovation Partnerships

The reviewed literature reveals a wide variety of models and typologies used to conceptualise and structure open innovation partnerships in developing countries. At the national and regional level, National Innovation Systems (NIS) and Regional Innovation Systems (RIS) remain foundational frameworks, providing a systemic view of how innovation capabilities are built across institutional actors. These models are particularly useful for identifying gaps in policy coherence and institutional capacity in developing contexts. Open innovation-specific models such as inbound, outbound, and coupled innovation frameworks are widely applied at the firm and network level. Several studies also propose integrative models that combine innovation processes with business model innovation and ecosystem thinking, recognising the dynamic and distributed nature of innovation in resource-constrained environments. The Triple Helix and its extended versions (Quadruple and Quintuple Helix) feature prominently, reflecting the centrality of university-industry-government collaboration and the increasing inclusion of civil society and environmental considerations in innovation partnerships.

These models are frequently used to analyse both formal and informal collaboration mechanisms and the evolving roles of different actors in innovation ecosystems. Ecosystem and network-based models, including Living Labs, intermediated networks, and platform-based collaborations, are increasingly visible in recent studies. These models emphasise flexibility, user-centred innovation, and the role of intermediaries in orchestrating cross-sectoral collaboration. Dynamic capabilities frameworks are also employed to explain how firms particularly SMEs, develop the capacity to engage effectively in open innovation partnerships. The literature demonstrates a rich but fragmented landscape of models, with considerable variation in how they are operationalised across contexts. While existing models provide valuable conceptual tools, there is a growing need for more context-sensitive and integrated frameworks that better reflect the complex, multi-actor realities of open innovation in developing countries.

Key actors and stakeholder roles

The literature consistently highlights the multi-actor nature of open innovation ecosystems in developing countries, with distinct roles played by government, academia, private firms, civil society, intermediaries, and SMEs. Government actors are typically positioned as key enablers, providing the policy frameworks, infrastructure, and financial support needed to foster innovation. Governments also play an increasingly proactive role in facilitating innovation ecosystems through the creation of incubators, digital infrastructure, and incentives for cross-sectoral collaboration. Academic and research institutions serve as critical generators of knowledge, though their engagement with industry remains uneven across contexts. Universities and research centres contribute to skills development, knowledge creation, and collaborative research, but often face institutional and cultural barriers that limit their participation in dynamic innovation partnerships.

Private sector firms, particularly large enterprises and multinational corporations, focus primarily on the commercialisation and scaling of innovations. They contribute essential resources, market access, and technological capabilities to innovation ecosystems. SMEs, meanwhile, are central actors in the open innovation landscape. They are both adopters and implementers of open innovation practices, often benefiting from intermediary facilitation and partnerships with larger firms, academia, and government actors. However, SMEs face significant barriers related to absorptive capacity, access to finance, and limited resources. Civil society actors and intermediaries play increasingly important roles in bridging institutional gaps, facilitating trust-building, and supporting user-centred innovation. Intermediaries such as innovation hubs, incubators, and network brokers enable knowledge flows and help orchestrate collaboration across fragmented ecosystems.

Enablers of Effective Open Innovation Partnerships

Trust and social capital emerge as foundational enablers of effective open innovation partnerships. The literature highlights the importance of trust-based networks, transparent intellectual property (IP) regimes, shared goals, and informal interactions in facilitating knowledge exchange and collaborative innovation. In contexts where formal institutions may be weak, relational trust is often the glue that holds innovation partnerships together.

Leadership and strategic alignment within organisations also play a critical role. Strong top management support, a clear strategic vision for innovation, and cultural alignment with open innovation principles are consistently associated with more successful partnerships. Organisational leadership that fosters a learning orientation and openness to external collaboration is particularly important for SMEs engaging in innovation ecosystems. Digital infrastructure and readiness are increasingly recognised as essential enablers. Access to ICT tools, digital platforms, and interoperable systems facilitates distributed innovation and enables SMEs and other actors to participate more fully in innovation networks. Digital inclusion policies and investments in ICT capacity building are seen as critical to levelling the playing field for smaller and less-resourced actors.

A supportive policy and institutional environment is another key enabler. Effective policies, infrastructure investment, access to finance, and skilled labour development all contribute to the strength of national and regional innovation ecosystems. The alignment of policy frameworks with local contexts and the promotion of cross-institutional trust are particularly important in resource-constrained settings. At the organisational level, dynamic capabilities such as absorptive capacity, learning orientation, and the ability to integrate external knowledge are central to successful open innovation engagement. Networks, ecosystems, and intermediary organisations also play a vital enabling role by facilitating interactions, building social capital, and providing access to knowledge, resources, and markets.

Barriers and Challenges

Institutional and policy weaknesses are among the most pervasive barriers to open innovation partnerships. Inadequate infrastructure, underfunded innovation systems, low levels of skills development, and fragmented or incoherent policy frameworks frequently undermine the effectiveness of innovation ecosystems. Weak enforcement of intellectual property (IP) rights and limited absorptive capacity within institutions further constrain knowledge flows and collaboration. Infrastructure and resource constraints are a recurring theme, particularly for SMEs and less-resourced actors. Limited access to finance, inadequate digital infrastructure, and high costs associated with IP protection and advanced technologies create substantial barriers to participation in open innovation ecosystems.

Cultural and organisational resistance also poses significant challenges. Many organisations especially in contexts with limited prior experience of open innovation exhibit cultural inertia, a lack of absorptive capacity, and internal resistance to knowledge sharing. Over-reliance on internal incentives and leadership gaps further inhibit the adoption of open innovation practices. Knowledge and capability gaps represent another critical constraint. Many firms lack the dynamic capabilities needed to engage effectively in open innovation partnerships.

Fragmentation and coordination issues across ecosystems further inhibit collaboration. Siloed departments, fragmented support structures, and power imbalances among actors often result in inefficient or unsustainable partnerships. A lack of trust and unclear value distribution between actors can exacerbate these problems. Finally, legal, IP, and data barriers complicate knowledge sharing and collaboration. Legal uncertainties, high costs of technology adoption, concerns over data privacy, and poorly harmonised regulatory frameworks hinder both domestic and cross-border innovation partnerships.

Thematic Synthesis of Literature

A multidimensional view of innovation systems and contextualisation emerges strongly from the literature. Effective open innovation partnerships in developing contexts require tailoring to local institutional, cultural, and market conditions. Informal and formal linkages, as well as hybrid innovation models, are particularly important in fragmented innovation ecosystems. There is a clear need for integrated and context-sensitive innovation systems that align with national development priorities and industrial strategies. Open innovation and collaboration represent a core mechanism for fostering industrialisation. The literature documents a clear shift from closed innovation models to more open, collaborative approaches that leverage external knowledge flows. Business model innovation and co-creation strategies are increasingly used to enable SMEs and other actors to participate in innovation ecosystems and drive value creation.

Digital transformation and infrastructure are rapidly reshaping innovation dynamics. Digital platforms, ICT tools, and open digital ecosystems enable more inclusive participation in innovation partnerships and facilitate knowledge exchange across traditional sectoral and geographic boundaries. However, disparities in digital readiness remain a critical constraint. Dynamic capabilities and organisational learning are essential enablers of effective open innovation. Firms that develop strong absorptive capacity, strategic agility, and learning orientation are better positioned to leverage external knowledge and collaborate effectively. Organisational enablers must be supported by ecosystem-level interventions to enhance these capabilities across the innovation system.

Policy and institutional support is widely recognised as a critical success factor. Tailored innovation policies, intermediary organisations, and cross-sectoral collaboration platforms are needed to foster sustainable open innovation partnerships. Policy coherence, stakeholder alignment, and adaptive governance are especially important in dynamic and resource-constrained contexts. Finally, intermediaries and networks play a pivotal role in making open innovation viable in developing countries. Intermediaries facilitate trust-building, knowledge flows, and cross-sectoral collaboration. Strong network ties and multilevel innovation networks are key to overcoming fragmentation and enabling the emergence of more resilient and inclusive innovation ecosystems.

Future Reserch Avenues

Despite significant progress in the literature on open innovation and industrialisation in developing countries, important gaps remain in research, policy, and practice. Building on the thematic synthesis of the reviewed literature, this section identifies key gaps and emerging issues that define future research priorities in the field of open innovation and industrialisation in developing countries.

Gaps in research, policy and practice

A major gap in the literature relates to empirical validation and the long-term impact of open innovation partnerships. Many studies remain conceptual or cross-sectional; few provide robust empirical evidence on how different partnership models affect industrial upgrading over time. There is a clear need for longitudinal studies, comparative analyses, and mixed-methods research that can capture the dynamic and evolving nature of innovation ecosystems in developing contexts. SME-specific gaps are particularly prominent. While SMEs are central actors in open innovation ecosystems, there is a lack of SME-specific frameworks, toolkits, and metrics tailored to the unique constraints and opportunities they face in low- and middle-income countries. The development of practical, scalable models to support SME engagement in open innovation remains a priority for both research and policy.

Policy and institutional gaps also persist. Many national innovation strategies do not adequately incorporate open innovation principles or support ecosystem development. There is limited understanding of how intermediary organisations can be effectively leveraged within policy frameworks, and a need for more context-specific, adaptive policy instruments aligned with local innovation dynamics. Measurement and indicators represent another critical gap. Current innovation metrics are often poorly harmonised, insufficiently granular, or fail to capture key dimensions of open innovation such as absorptive capacity, network dynamics, and cross-sectoral knowledge flows. Developing better indicators is essential for both academic analysis and policy evaluation.

Sectoral and regional gaps are evident as well. Much of the existing literature focuses on middle-income countries and a limited set of sectors (primarily manufacturing and ICT). More research is needed on open innovation in under-researched sectors (e.g. healthcare, energy, construction) and in low-income and fragile contexts where innovation ecosystems face distinct challenges. Finally, innovation system and collaboration gaps persist. The informal sector is frequently neglected in innovation studies, despite its importance in many developing economies. There is also a need to better understand how collaborative platforms can be sustained over time and how strategic reconfiguration can be operationalised to enhance ecosystem resilience.

Emerging issues of interest in open innovation

Several emerging issues are shaping the evolving landscape of open innovation partnerships in developing country contexts. Digital transformation and the integration of advanced digital tools are among the most prominent trends. The literature highlights growing interest in how digital platforms, ICT tools, and Industry 4.0 technologies can enable more inclusive and dynamic innovation ecosystems. Digital innovation platforms not only facilitate cross-sectoral knowledge exchange but also offer new pathways for SMEs to access markets, partners, and technical resources. However, disparities in digital readiness and the risk of deepening digital divides remain critical concerns.

The development and application of new open innovation models and approaches is another key area of interest. Researchers and practitioners are increasingly exploring open innovation as a service model, as well as its integration with business model innovation and internationalisation strategies. Educational applications of open innovation are also gaining attention, particularly in relation to building innovation capabilities and entrepreneurial skills in developing contexts. SMEs and dynamic capabilities remain a focal point for emerging research. There is a growing emphasis on understanding how SMEs can develop the dynamic capabilities required to engage effectively in open innovation, and on designing SME-specific readiness frameworks and pathways for innovation-driven growth.

Intermediaries and collaboration mechanisms continue to evolve. The strategic use of intermediaries—both physical and digital—is seen as vital for facilitating knowledge flows, building trust, and enabling SMEs to participate in complex innovation ecosystems. The literature also highlights the importance of designing intermediary roles that are context-sensitive and adaptive to changing innovation dynamics. Finally, the intersection of open innovation with AI, platform ecosystems, and emerging technologies is a

Table 2. **Policy Recommendations**

Theme	Representative Policy Recommendations
Support for SMEs and Capability Building	• Provide targeted training to enhance SMEs' learning capabilities and absorptive capacity for open innovation. • Support SMEs in developing dynamic capabilities for innovation, adaptability, and problem-solving. • Facilitate SME access to market intelligence, digital tools, and collaborative platforms. • Develop tailored SME-focused frameworks and toolkits for open innovation adoption in resource-constrained environments. • Introduce innovation vouchers and financial incentives to promote SME participation in innovation ecosystems.
Infrastructure and Digital Transformation	• Expand digital infrastructure and interoperability to enable broader SME participation in innovation networks. • Establish national open innovation hubs to support SME–intermediary partnerships. • Promote digital inclusion policies and cross-border ecosystem integration. • Strengthen STI incubator networks with a focus on SDG-aligned and green innovation.
Policy and Strategic Frameworks	• Embed open innovation principles in national SME development plans and industrial strategies. • Design adaptive innovation policies aligned with country-specific development priorities. • Develop SME-focused Fourth Industrial Revolution (4IR) policy instruments linked to innovation strategies. • Institutionalise platforms for experimental industrial policy and multi-stakeholder engagement.
Partnerships and Ecosystem Development	• Promote multi-actor collaboration across firms, institutions, and intermediaries to strengthen innovation networks. • Institutionalise UIG partnerships and expand industry involvement in academic and innovation initiatives. • Develop intermediary networks to facilitate SME integration into innovation ecosystems. • Support innovation ecosystems through investments in collaborative infrastructure and trust-building initiatives.
Knowledge Sharing and Intermediaries	• Facilitate structured knowledge transfer mechanisms between SMEs and external partners, including academia. • Establish university–industry liaison centres and intermediary platforms to support continuous collaboration. • Develop legal and technical standards for sustainable open government data (OGD) collaboration. • Promote balanced public-private collaborations in open-source and platform-based innovation ecosystems.

Source: authors.

rapidly evolving frontier. AI-driven tools for knowledge exchange, innovation monitoring, and cross-functional integration are beginning to reshape how open innovation partnerships are designed and managed. At the same time, concerns around governance, ethics, and inclusivity are prompting calls for new frameworks to guide the responsible integration of AI into innovation ecosystems.

Summary tables of the analysis results and directions for further research are presented in Appendix B.[2]

Policy Recommendations

Drawing on the thematic synthesis and identified research and practice gaps, this section presents key policy recommendations to strengthen open innovation partnerships for industrialisation in developing countries. These recommendations aim to inform policymakers, practitioners, and ecosystem stakeholders seeking to foster more inclusive, dynamic, and sustainable innovation ecosystems. Refer to table 2.

Conclusion and Future Direction

This systematic review presents the critical role of open innovation partnerships in advancing industrialisation efforts in developing countries. The findings reveal that the evolution of open innovation practices encompassing inbound, outbound, and coupled approaches is reshaping how firms, particularly SMEs, engage with broader innovation ecosystems. University-industry-government collaborations, intermediary-facilitated networks, and digital platforms are emerging as central mechanisms for fostering innovation-driven industrial upgrading. However, effective implementation remains contingent on several enabling factors, including institutional trust, leadership commitment, digital readiness, and absorptive capacity within firms. Persistent barriers such as fragmented policy frameworks, infrastructure deficits, capability gaps, and weak coordination continue to constrain innovation outcomes. The strategic role of intermediaries in bridging knowledge flows and facilitating collaboration is increasingly evident, particularly in contexts where SMEs lack the internal resources to engage fully in open innovation.

The review also highlights key gaps in the literature, notably the need for SME-focused models, empirically validated frameworks, and improved indicators for assessing innovation impact in developing contexts. Furthermore, emerging trends such as the integration of AI and advanced digital technologies offer new opportunities but also introduce fresh challenges related to governance, inclusivity, and capacity building. To harness the full potential of open innovation for sustainable industrialisation, policymakers and practitioners must adopt tailored, context-sensitive strategies that strengthen innovation systems, foster cross-sectoral collaboration, and build the dynamic capabilities of firms and ecosystems alike. Future research should deepen empirical analysis, explore sector-specific dynamics, and develop actionable frameworks to support inclusive and adaptive innovation-driven industrial transformation.

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[1] The materials in the Appendix are available on the article's online page.: https://foresight-journal.hse.ru/article/view/27979

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Appendix A. **Literary sources that have been the subject of in-depth analysis**

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Spawning Butterflies — Value Flow across Startup Lifecycle Stages

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Abstract

Startup firms are dynamic entities that undergo fundamental transformations over their lifecycle. Such transformations are the result of value flow to newer firm related factors. However, startup valuation factors are often used fluidly in multi-stage empirical studies resulting in confounding results. The objective of this study is to disentangle determinants of startup valuation across the early-stages and late-stages of a startup's lifecycle. By doing so, the study identifies valuation factors that increase, decrease or maintain relevance across lifecycle stages. We conducted literature survey of entrepreneurship studies that analyzed startup valuation and its determinants and carefully classified these into early-stage and late-stage factors. By seeking stagewise interpretations, we introduce the 'relevance hierarchy' for valuation factors across lifecycle stages. We uncover persistent and volatile factors, i.e. some factors persistently affect firm valuation while others exhibit volatility in its effects. For practitioners, we derive a meta-model of startup valuation that is unique to the two lifecycle stages – early-stage and late-stage. The main contribution of this study is in conducting the literature review on startup valuation through the 'looking glass' of lifecycle stage and this vantage point will allow practitioners to develop focused models of valuation that avoid confounding effects.

Keywords: startup valuation; venture capital decision making; entrepreneurial firm performance; IPO valuation; new firm growth

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Introduction

As compared to public firms, investments in start-ups pose the most difficult challenges in valuation (Damodaran, 2009). The need to look beyond mainstream finance theories was observed in the study of venture capitalists' decision-making process by Silva (2004) and over time, this has led to huge diversity in explanatory constructs of firm performance (Bromiley, Rau, 2016). Such diversity in valuation factors and its varying influence across valuation rounds has motivated the need for further studies exploring comparative relevance and role of valuation factors across time (Colombo et al., 2023, Köhn, 2018).

Hand (2005) undertook one of the first studies in this millennium to assess how valuation factors vary in relevance across lifecycle stages of a startup. He empirically explored value relevance of 2 broad types of factors - financial and non-financial information of startup firms in pre-IPO and post-IPO periods

This seminal study established that financial and non-financial information are information substitutes in valuation, not complements. Figure 1 shows R2 for value relevance unique to non-financial information and financial information from Series A till post-IPO stages. The two factors demonstrate steep slopes of opposing polarity indicating information substitution when examining different funding rounds across a startup's lifecycle. Such inferences were reinforced by later studies too. Gompers et al. (2020) noted that 31% of early-stage VCs do not forecast company financials at all when they make an investment. Whereas, McCoy (2022) finds that financial factors such as revenue and revenue growth are highly relevant to valuation of late-stage Software-as-a-Service (SaaS) firms.

The purpose of this study, therefore, is to disentangle determinants of startup valuation across early-stages and late-stages of a startup's lifecycle. By doing so, the study broadens the study of valuation factors beyond the 2 broad types of factors - financial and non-financial information used by Hand (2005) in an attempt to identify valuation factors that increase, decrease or maintain relevance across lifecycle stages.

Problems of overlooking lifecycle stage in valuation studies

The problems of overlooking stage-wise-relevance of valuation factors are manifold. We use stage-wise-relevance to refer to the relevance of valuation factors across lifecycle stages. Firstly, academic studies that omit controlling for firm stage can often report confounding or oversized effects. Koenig & Tennert (2022) illustrated this with a direct comparison of regression coefficients with and without lifecycle stage fixed effects and found that effect sizes were consistently overestimated when not controlling for stage.

Secondly, valuation factors are frequently applied in different ways across multi-stage empirical studies. We find that across three studies examining venture valuation, Tumasjan et al. (2021) used social media sentiment, firm factors and VC factors to study effects, while controlling for deal, venture and market factors. Moghaddam et al. (2016) evaluated the effects of network factors controlling for firm-specific, transaction-specific and context-specific features. In Barick & Aithal (2023), we find firm factors and funding rounds information were used to examine venture valuation. This indicates variance in explanatory constructs and control variables used that requires a deeper investigation.

Finally, overlooking the stage-wise-relevance of valuation factors is related to the explosion in explanatory constructs, especially in the form of control variables. This can make data analysis cumbersome, unwieldy and confounding. The use of firm stage as a control variable in a large proportion of start-up valuation studies lends credence to the assertion that the relevance and role of valuation factors of start-ups vary by firm stage.

Research problem and research objectives

Recent literature review articles on startup valuation factors have concurred that identifying stage-wise-relevance of valuation factors across time periods is a critical research gap (Köhn, 2018, Berre, Le Pendeven, 2023). This study contributes to this research gap by conducting a literature survey of entrepreneurship studies that analyzed startup firm valuation (as dependent variable) directly or indirectly and examined determinants of startup value (as independent variables). In order to maintain recency in findings, only articles published in the last 10 years were considered. By doing so, the study explores the large diversity in startup valuation factors that have emerged in the last 10 years and disentangles their relevance on startup valuation across a startup's lifecycle.

The below research questions will be evaluated in this study:

1. What is the role and relevance of valuation factors across a startups' lifecycle stages?
2. Do valuation factors increase, decrease or maintain relevance across lifecycle stages?
3. Does the meta model for startup valuation vary across lifecycle stages?

This study has the following objectives:

1. To identify stage-wise-relevance of valuation factors as startups advance in their lifecycle stages.
2. To understand the 'relevance hierarchy' of valuation factors across a startups' lifecycle stages.
3. To develop focused models of valuation by firm stage that avoid confounding effects.

This paper is organized as follows. In the following section, we provide a detailed description of the methodology adopted when conducting this literature review. The subsequent sections summarize the key findings from this study – What are the key determinants of startup valuation and what are its influences in early-stages and late-stages? What is the relevance of each valuation factor across lifecycle stages? What are the persistent and volatile factors influencing startup valuation across lifecycle stages? What are the theoretical contributions and future research directions identified in this study?

Methodology

Definition of startup lifecycle stages

Frameworks capturing a startups' lifecycle stages have been explored by academics and practitioners alike. One of the oldest is from Scott and Bruce (1987) who defined a five-stage model comprising of inception, survival, growth, expansion and maturity stages. A more recent model is the four-stage model comprising conception and gestation, infancy, adolescence and maturity (Detienne, 2010). Steve Blank, a serial entrepreneur-turned-academic and originator of the 'Lean Startup' movement, defines a 3-stage model comprising of search, build and grow.

For the purpose of this study, we follow the approach of Colombo et al. (2023) who used 2 stages namely – seed/start-up and scale-up/exit – to classify drivers of entrepreneurial venture valuations. Such a simplified two-stage model allows us to disentangle influence of valuation drivers across stages to the extent possible. The two-stages in this study are referred to as Early-stage and Late-stage. This is depicted in Table 1.

Study design

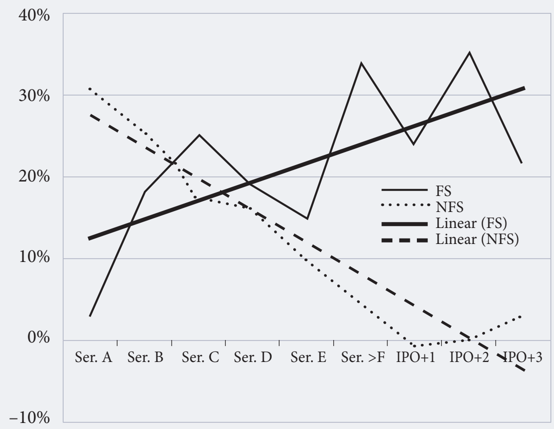
There is wide diversity in explanatory constructs used such as founder characteristics, investor characteristics, R&D investments, market conditions etc. This study reviewed articles published from 2015 – 2024 in peer-reviewed journals indexed in FT50, Web of Science, ABCD Journal List and Scopus. In order to maintain recency in findings, only articles published in the last 10 years were considered. Whitepaper publications from top VC houses such as Bessemer Venture Partners, Accel Partners were also considered to incorporate practitioner perspectives.

The review was conducted across three phases. Starting with 165 articles, the first phase carefully selected empirical studies that examined startup valuation (as dependent variable) directly or indirectly and evaluated determinants of startup valuation (as independent variables). At the end of first phase, 80 articles were taken forward to subsequent phases.

In the second phase, articles were classified into three groups based on lifecycle stage of firms selected for study. The three groups were categorized as early-stage studies, late-stage studies or mixed-stage studies. See Table 1 for early-stage and late-stage mapping.

In the third and final stage, all articles were read in detail to extract top determinants of startup valuation and to classify these determinants into early-stage valuation drivers and late-stage valuation drivers. This was quite straight-forward for articles grouped under early-stage studies and late-stage studies. For articles grouped under mixed-stage studies, we checked for key findings specific to firm stage. As firm stage is a commonly recurring control variable across many studies, authors report stage-specific findings whenever applicable, allowing us to classify these factor influences under early-stage valuation drivers or late-stage valuation drivers. However, we also find that many articles that dealt with mixed-stage studies did not report findings per stage. This may be due to similar factor influences across lifecycle stages. This aligns with the findings of this review too which show that value determinants across these two stages had overlaps. Finally, there were also studies where lifecycle stage was not used as a control variable and we omitted those studies from review. The study design is summarized in Figure 2.

Figure 1. **Value Relevance of Financial Statement Data (FS) and Nonfinancial Statement Information (NFS) in Investment Rounds in Pre-IPO and Post-IPO Periods**



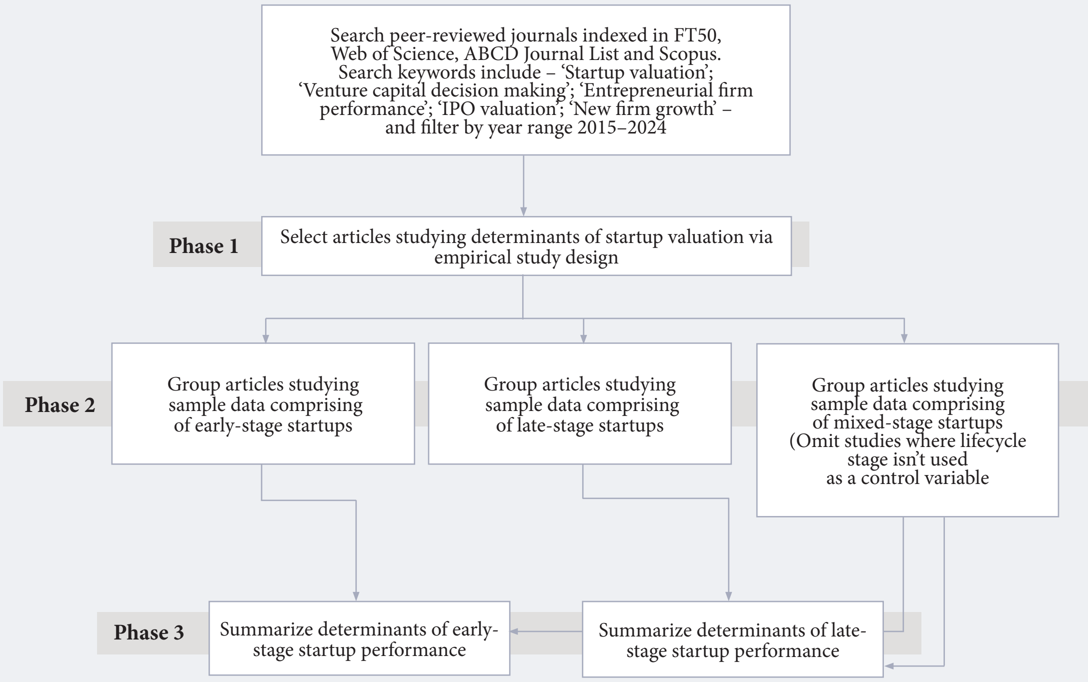
Source: authors.

Table 1. **Two-stage Lifecycle Model Used to Study Valuation Drivers of a Startup**

2-stage model used in this study	Mapping the popular 5-stage model (Scott and Bruce (1987))	Mapping valuation rounds observed in VC industry
Early stage	Inception	Pre-seed/Seed
	Survival	Series A
	Growth	Series B
Late stage	Expansion	Series C/D/E etc. (Pre-IPO)
	Maturity	IPO & post-IPO

Source: authors.

Figure 2. **Three-Phase Study Methodology**



Source: authors.

Thematic coding

This study closely follows literature survey studies by Berre & Le Pendeven (2023) and Colombo et al. (2023) and extends the observations based on lifecycle stage. During phase 3 of this study, we categorize empirical indicators of valuation drivers along 5 thematic lines; Entrepreneur Characteristics; Firm Characteristics; Market Conditions; Investor Characteristics; and Deal Conditions. This approach is similar to that followed by Berre & Le Pendeven (2023) for thematic categorization of startup valuation drivers. The Deal Conditions theme was expanded to include equity market conditions, regulations and institutional factors, following Colombo et al. (2023).

Figure 3 outlines the periodicity observed in early-stage and late-stage valuation drivers following this thematic coding. Periodicity indicates the frequency of that factor's significance in prior empirical studies, either as an independent variable or as a control variable. For example, in early-stage studies, Entrepreneur characteristics are most frequently found to be significant, indicating that it has a higher relevance to valuation than other factors in this stage. Thus Figure 3 gives us an early peek into the relative relevance of valuation factors which we will explore deeper in the *Discussion*.Section.

Not surprisingly, we find large diversity in empirical indicators categorized under the most recurring themes of - Entrepreneur characteristics, Firm characteristics and Investor characteristics. Hence, we further expand the five startup valuation themes into nine factors as shown in Table 2 - Founding team experience, Founding team traits, Management team experience, Firm's non-financial resources, Firm's financial resources, Market conditions, Venture Capital (VC) financing, Venture Capital's (VC) non-financial resources and Deal conditions. Such a classification allows us more flexibility in reporting the role and relevance of these valuation factors in subsequent section.

Key Determinants of Startup Valuation

We now delve into the role and relevance of each of these nine factors in detail.

Founding team experience

Role and relevance in early-stage valuation – Early-stage studies have used the following sub-factors to study founding team experience - Domain knowledge, Education and Social capital of founding team.

Domain knowledge represents tacit knowledge learned from prior working experiences. Tacit knowledge acquired by the team increases likelihood of discovering opportunities and acquiring resources required to address them. Hence entrepreneur experience has strong signaling effects to external stakeholders (Honoré, Ganco, 2023). Studies have found that such experience signals quality, commitment and legitimacy (Rocha, Grilli, 2024). Prior working

Table 2. **Map of Five Thematic Factors Found in Literature Review to an Expanded Set of 9 Factors for Detailed Discussions**

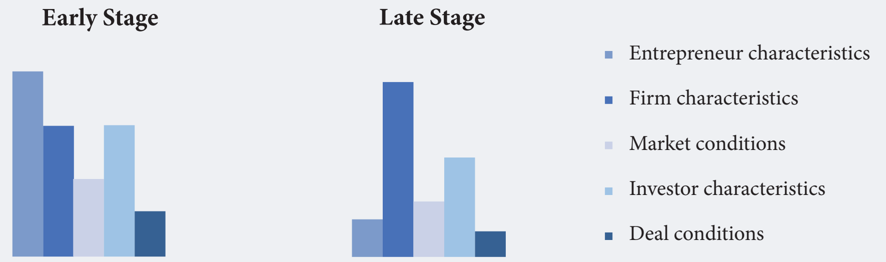
Expanded 9 factors used in this study for discussion	Empirical indicators
Entrepreneur characteristics	
Founding team experience (observable characteristics of founders)	Years of working experience, years of management experience, shared working experience of founding team, prior startup experience, multicultural experience of founders, highest level of education acquired, ranking of university attended, size of LinkedIn connections, multicultural experience of founders, City of birth/operation
Founding team traits (underlying characteristics of founders)	Openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism, risk-taking behavior, innovativeness, pro-activeness, autonomy, competitive aggressiveness, absorptive capacity (typically measured via surveys with Likert-scale responses)
Management team experience (observable characteristics of Top Management Team, excl Founders)	Completeness of management team, work experience and education qualifications of top management team, team size
Firm characteristics	
Firm's non-financial resources	Number/age of patents, Citation count, employee count, business model, number of external alliances such as business incubator membership, industry alliances, GTM partners, university partnership, city of operation
Firm's financial resources	Revenues, revenue growth rate, capital investments received, R&D expenditure, ratios such as R&D/Assets, SGA/Sales, ROA
Market conditions	
Market conditions	Industry growth rate, industry lifecycle stage, financial ratios such as R&D/Sales, SGA/Sales
Investor characteristics	
VC financing	Amount of financing, stage of financing, equity dilution, previous investors in cap table
VC's non-financial resources	Past experience intensity, diversity of IPO experiences, number of prior syndicated IPOs, human/social capital of partners, patent activity in VC home country, domain specialization
Deal conditions	
Deal conditions	Total venture capital investments, FDI inflows, Country level indices such as corruption index, innovation index, infrastructure quality, economic uncertainty
Source: authors.	

experience also has strong signaling effects to internal stakeholders resulting in lower management churn (Chahine, Zhang, 2020). Overall, relevant industry and managerial experience improves valuation of a new venture since tacit knowledge thus acquired is considered to be unique and transferable to future endeavors (Dhochak, Doliya, 2020).

Education represents codified knowledge. For highly specialized domains, higher levels of educational qualification may even be a pre-requisite. In addition to technical knowledge, soft skills acquired during formative years of the entrepreneur are highly valuable. Social networks built during this period help in attracting talent, making early customer connects and securing institutional investment (Bublitz et al., 2018). It has been observed that founders' academic association help attract quality management talent, following '*a matching of equals among equals*' and generates higher valuation than peers (Wasserman, 2017; Bublitz et al., 2018).

Social capital represents a network of resources gained by the founding team via their social networks. In early stages of a startup, signaling value of founders' social capital assists in bootstrapping resources. Such resources include human capital, investor connects or advisory board members (Rocha, Grilli, 2024). Social capital works by reducing information asymmetry (Gompers et al., 2021). In the absence of operating history, early-stage startups heavily rely on their social networks to build trust and confidence.

Figure 3. **Periodicity of Valuation Factors Based on Thematic Coding**



Source: authors.

Geographically diverse social networks are valuable as it allows founders to judiciously explore a broader set of opportunities (Szymanski et al., 2021).

Role and relevance in late-stage valuation – Late-stage studies have used the following sub-factors to study founding team experience - Domain knowledge and social capital of founding team.

In late-stages, prior domain knowledge drives founders to set more ambitious goals for rapid growth of the firm. Domain specific experiences create a network of contacts (Montanaro et al., 2022). In late-stages where growth creates demand for massive resources, founders with domain experience find that they have better access to financial and social capital (Cotei et al., 2022). Founders with prior entrepreneurship experience are more likely to retain CEO role and secure favorable contracts from VCs (Nahata, 2019). Founders continue to remain top decision makers and reference points in late stages of a startup and this increases the possibility of replicating previous best practices.

By tapping social networks, founders continue to attract executive hires well into its later stages (Wasserman, 2017). The startup has now established product-market-fit and is racing to scale its investments and resources. Hence its core competencies now expand beyond technology and products to include operations, governance structures and smart financing. Social network of the founders plays a key role in attracting human capital across functional domains. It is found that prior networks of the founding team inform hiring decisions and composition of management team in later stages (Chahine, Zhang, 2020). Social capital of founding team helps to mitigate risks as well as to diffuse new ideas and information. (Zhang et al., 2023).

Firm's non-financial resources

A firm's non-financial resources are broadly classified into internal and network resources. Internal resources comprise of R&D, products, processes and business model developed by the startup. Network resources represent the network of external resources that allows the startup access to complementary resources, such as industry alliances or incubator membership.

Role and relevance in early-stage valuation – R&D is found to be intrinsic to technology startups. R&D helps nascent firms handle the liability of newness and establish legitimacy (Tumasjan et al., 2021). In high-tech firms' patents and trademark applications have high complementarity to VC funding (Zhou et al., 2016) In a study of startups across lifecycle stages, (Singh, Subrahmanya, 2022) found that resources invested in acquiring research capital (RC) and innovation capital have a positive relationship with sales growth and competitive advantage in later stages. Innovation is not restricted to technology and products. Business model innovation is a critical value driver. Early-stage firms with fluid business models can thrive during volatility and disruption and hence attract higher valuations (Gompers et al., 2021).

External tie-ups help a new venture access new technology and/or markets and increase its growth prospects (Dhochak, Doliya, 2020). Many studies have explored the influence of university alliances and found that university alliances, specifically when initiated by founders with higher educational qualifications, can result in higher revenues than peers (Keogh, Johnson, 2021). Furthermore, strong connections to entrepreneurial ecosystems such as business incubators provide the network environment to acquire and transform knowledge into firm outcomes (Vincent, Zakkariya, 2021). Business accelerators reduce uncertainty around nascent ventures and convince early customers. Social impact accelerators can have a snowball effect on customers and positively influence revenues (Kher et al., 2023). Reinforcing the effect of entrepreneurial ecosystems assert that startups outside of traditional venture capital hubs may have higher entry barriers (Gompers et al., 2021).

Role and relevance in late-stage valuation – Investments in R&D continue to be valued in late-stages as seen by its influence on IPO evaluations. This is especially true for technology intensive startups where innovation input of firms as indicated by R&D expenditures lead to higher innovation outputs as indicated by patents (Chemmanur et al., 2018, Chahine et al., 2022). Future investors or acquirers value the growth potential signaled via intellectual property rights, research and development activity due to its long-term potential (Cotei et al., 2022). Patents and trademarks continue to positively influence valuation (Shi, Xu, 2018, Fisch et al., 2022). Additionally, startups that maintain flexible business models via the comprehensiveness of product workflows have a strong positive relation to setting a differentiated strategy for the firm (Lee et al., 2023). Such scalable firms thus have larger potential business opportunities and are rewarded with higher valuations.

Network resources continue to be a key value determinant in the startup's late stages. Access to external resources determines the pace of growth as firms struggle to scale organically. External partnerships boost the comprehensiveness of the startup's offerings (Lee et al., 2023). Investments in social capital, for example, affiliation with prestigious universities, have spillover effects on higher human capital of the firm (Colombo et al., 2019). This is also true in the case of service providers to startups – lawyers, investment bankers, VCs, and board directors. Service providers tend to congregate geographically, motivating the startup to expand its geographic presence in later stages (Li et al., 2023). Such geographic colocation improves firm performance due to imperfect information of spillover effects (Boschma, 2015) and improved IPO and M&A outcomes (Ahluwalia, Kassicieh, 2024). Interestingly, even non-core networks such as political affiliations serve to enhance the legitimacy and competitiveness of the firm, signaling that quantity of alliances matters (Gounopoulos et al., 2021, Moghaddam et al., 2016).

Firm's financial resources

The firm's financial resources are represented by assets reported in its financial statements. It includes tangible assets like revenue, physical assets, royalties, as well as intangible assets like R&D, and brand value.

Role and relevance in early-stage valuation - In the early stages, the firm's financial resources are insignificant and typically do not play a role in determining future valuation. In fact, Gompers et al. (2020) find that 31% of early-stage VCs reported that they do not forecast company financials at all when they make an investment. However, other studies have reported contradictory results. For example, Kalyanasundaram et al. (2021) argue that lack of revenue reduces life expectancy of survival stage startups and hence forms a key value determinant of the firm. In its early stages, a firm's financial resources are more often used as a proxy to assess market demand for its products and hence future potential. However, its use in traditional valuation methods like the Discounted Cash Flow (DCF) or Multiples method is generally avoided.

Role and relevance in late-stage valuation - By its later stages, the startup has sufficient operating history and a primary business model. The firm's financial resources become critical in its evaluations. Even though evaluation techniques as used for public firms may not be applied directly, the firm's financial resources take center stage in its valuations due to its influence on future growth and profits. Financial resources retain high levels of significance even when combined with other non-financial resources of the firm such as organizational reputation (Liu et al., 2020).

In this phase, leverage or debt is found to be negatively related to valuations (Somaya, You, 2024) while financial ratios such as Return on Assets (ROA) assume significance (Shi, Xu, 2018). Kalyanasundaram et al. (2021) note that a key result in growth stage is rapid scale-up and market expansion. Profitability metrics are often side-lined in this phase. However, as the firm matures, survival hinges on profitability. Attention is spent on volume growth to hit break-even level of operations. Industry practitioners have evolved various approaches to assess the quality of the firms' financial resources. An example is the Rule of 40 (and its extensions) – which emphasizes that the sum of revenue growth rate and profit margin should exceed 40% for credible SaaS startups (Bessemer Venture Partners, 2024).

Intangible resources are also valued highly especially in technology-based startups, even if it doesn't have a direct impact on revenue today (Chemmanur et al., 2018). As accounting methods have evolved to assign value to intangible resources, R&D expenditures and SGA are found to be value accretive, especially during IPOs.

VC Financing

VC Financing refers to external capital received from institutional investors. Due to the lack of operating history of the funded firm, venture capital is most often not backed by collateral. Instead, in return for capital, investors receive an equity stake in the firm.

Role and relevance in early-stage valuation – External financing aids the pace of innovation in early-stage. Information asymmetries are highest in the earliest stages due to limited track record and future uncertainties. Working with the liability of newness, the startup tries to move fast and deliver credible products as fast as possible. Studies have found that the earlier startups receive VC investment, the higher the performance achieved (Nahata, 2019, Chemmanur et al., 2016). VC investment keeps up the growth momentum and allows the firm to move faster than firms that haven't raised external financing.

Studies have also shown that the quantum of financing received also plays a role in future valuations. (Barick, Aithal, 2023) conducted a study of startups that have achieved unicorn status and found that technology-based startups achieve unicorn status faster than non-tech startups due to their higher valuations and funding amounts. Funding received gives them an edge on innovation and skilled labor. For early-stage startups, having a higher capital at startup allows them to invest ahead of the curve and perform better in the face of external uncertainties (Fracasso, Jiang, 2022). In addition to early investments facilitated, financing rounds also confer reputational capital on the nascent firm. (Kleinert et al., 2020) tested the hypothesis that ventures that have raised prior institutional financing will be valued favorably. The effect of prior funding is most significant for seed stage firms due to its signaling effects.

The presence of certain types of institutional investors in the financing rounds also plays a role in startup valuation. This effect is particularly pronounced in the early stages. For example, corporate venture capitalists bring technology know-how in addition to financial resources. Li et al. (2023) find that corporate venture capitalists can mitigate the negative impact of technological novelty on high-tech startups' alliance formation. Overall, the quantum of financing received and the type of early-stage investor onboarded influence the path adopted by the startup and its future outcomes.

Role and relevance in late-stage valuation – Financing requirements in late stages far outweigh those in early stages. This is because financial resources are particularly versatile and are critical for rapid growth (Piaskowska et al., 2021). External financing facilitates investments in human capital, social capital and research capital (Singh, Subrahmanya, 2022). In fast-paced industries, timing is everything. The initialization, pace and chronology of actions affect the likelihood of entrepreneurial actions (Wood et al., 2021). Financing requirements continue to increase in the firms' late stages so much so that unavailability of adequate financing may cause the firm to lose its competitive edge or reverse its growth momentum.

Demand for high levels of VC financing in late stages is often driven by the pursuit of venture scale. Scale opens up larger business opportunities for the firm and improves capital efficiency. In the face of limited internal cash flows, scale is often financed by external capital. Furthermore, regulatory and governance burdens increase in this phase which in turn leads firms to seek higher valuations and higher capital inflows (Somaya, You, 2024).

Sustainable differentiation is built by the firm based on future bets placed (Göttel et al., 2024). Higher funding serves to signal the size and scale of these future bets. Hence studies have reported that exit outcomes are influenced by funding amount and duration of investment (Shuwaikh et al., 2024). Higher funding also increases the likelihood of IPO exit as VCs assist firms through the IPO process (Gounopoulos et al., 2021).

VC's non-financial resources

VC non-financial resources represent the additional resources employed by the VC firm as they take a more active role in their portfolio companies. These resources mainly include human and social capital of VC partners as well as functional support services.

Role and relevance in early-stage valuation – In the early stages, non-financial contributions of VCs – such as domain experience, entrepreneurial experience and reputation – help startups acquire valuable resources. Media prominence of VC firms helps in attracting human capital (Vanacker, Forbes, 2016). Corporate VCs help the firm to acquire complementary technology resources (Röhm et al., 2018).

Future financing rounds are also favorably influenced by the domain experience of VC partners (Kleinert et al., 2020). Overall, VC backed companies grew faster than PL (participative loans) backed firms due to unique non-financing contribution of VCs (Quas et al., 2021.

Role and relevance in late-stage valuation – The paramount non-financial resource of interest to later-stage investee firms is the reputation transfer from association with highly experienced VCs. Such reputation transfer enhancers include past experience intensity, diversity of IPO experiences, number of prior syndicated IPOs (Chahine et al., 2022). Nanda et al. (2017) finds that each additional IPO experience in VC firms' first 10 investments predicts an 8% higher IPO rate. Even highly innovative firms command a price premium, contingent on the existence of venture capital ownership and reputable underwriter endorsements (Shi, Xu, 2018).

VC firms offer further value enhancing services such as managing human capital issues (Gompers et al., 2021), coaching and networking services (Chahine, Zhang, 2020) and access to tacit knowledge and networks (Joshi, 2018). Further, diversity in institutional investors such as CVC investors or VC syndicates also act as value enhancers (Bayar et al., 2020; Shuwaikh et al., 2024). These studies confirm the sociological approach to financial market behavior (Chahine et al, 2022).

Market conditions

Market condition refers to the industry lifecyle in which the startup operates. Market condition acts as an externality impacting startup valuation.

Role and relevance in early-stage valuation – Venture capital partners rank industry lifecycle a close second in factors influencing early-stage valuation, directly after the firm's internal resources (Gompers et al., 2021). This is because a startup operating in early stages of an industry transformation can achieve substitution effects where it replaces incumbents with its novel technology and gains a significant share of the market. Studies find that startups accomplishing early-stage entry and sustained differentiation remain independent and are more likely to exit via IPOs (Bowen et al., 2023). Even though being the first-mover can often be a liability, ventures operating in nascent markets categorize and balance between legitimation and differentiation (McDonald, Eisenhardt, 2020) to maintain steady progress.

Industry forces and startup positioning within the industry value chain can determine opportunity size, profitability and hence valuations. A large opportunity size lowers uncertainty risk (Dhochak et al., 2024). Industry-wide ratios such as the Industry-market-to-book ratio can often find significance in regression analysis of valuation (Nahata, 2019). As a second-order effect, the economic scope of the opportunity also has a positive impact on alliance formation and growing the network of partners (Li et al., 2023). Thus, startups addressing opportunities in an industry that is rapidly growing are highly valued. Gompers et al. (2021) conducted a study of investments post COVID-19. Researchers find that the importance placed on industry has only increased and some industries benefit non-linearly due to external conditions.

Role and relevance in late-stage valuation – Industry type continues to remain a control variable in valuation studies of firms in the late stages; however, the firms' unique assets such as patents or Software-as-a-Service (SaaS) distribution model could allow it to grow faster than rates prevalent in the industry. Deep focus on a specific industry helps the firm to rapidly expand its portfolio of products or services (Lee et al., 2023). In this phase, it is likely that firms expand their offerings across industry segments and reduce dependence on a single industry. The firm's technology can have complementary effects (incremental innovation) or substitution effects (disruptive innovation) (Bowen et al., 2023). Such effects are realized in the later stages via non-financial resources of the firm and determine its pace of growth within that industry.

Deal conditions

Deal conditions refer to the overall business environment in which the startup operates. This is conceptualized as an amalgamation of the social, cultural, economic, legal and political environments. However, studies have largely focused on the macroeconomic environment due to its first-order influence on valuation.

Role and relevance in early-stage valuation – Early-stage startups are sensitive to fluctuations in the macro environment, either positive or negative. High levels of capital inflows increase financing available to innovative, fast-paced firms. Foreign Direct Investment (FDI) also has spillover effects on entrepreneurial ventures via demand expansion, knowledge expansion and demand for intermediate inputs (Kim, 2019). Early-stage startups are particularly vulnerable to market shocks. Howell et al. (2020) find that early-stage VC activity declined by 38% in the first 2 months after COVID-19 reached the United States of America. This holds true for recessions overall, where VCs show unwillingness to finance innovation. It indicates cyclicality of VC and it is more pronounced in early-stage investments. Overall, entrepreneurial ecosystems thrive when stable macroeconomic environment prevails in the country of operation.

Role and relevance in late-stage valuation – During recessions, late-stage transactions do not see the steep fall that early-stage transactions do (Howell et al., 2020). This holds for dollar volume, number of deals or transaction size. Cotei et al. (2022) further confirm that startups that can build competitive advantage and can demonstrate innovative capabilities through the presence of intellectual property are more likely to have a successful exit, even in high policy uncertainty. However, due to the larger size of funding transactions in late stages, findings have been mixed with Shuwaikh et al. (2024) reporting that financial distress can impact late-stage valuations too.

Founding team traits

Role and relevance in early-stage valuation – Early-stage studies have used the following sub-factors to study founding team traits - Personality of the founding team, Entrepreneurial orientation and Absorptive capacity.

Entrepreneurship can be a lonely journey and personality traits such as extraversion help founders avoid social isolation in their early days. Founders who have more active interactions with peers, informal support networks, mentors and partners generally outperform their peers (Galloway, 2019). Openness as a personality trait contributes to rapid diffusion of new ideas (Zhang et al., 2023). Cultural experiences can also shape how entrepreneurs gather and process resources which can lead to wide variances in outcomes.

Another important factor in the establishment of startup firms is entrepreneurial orientation or motivation, which is supported by environment and business opportunities. Attitudes, behaviors, and unique processes differ from workers to managers to entrepreneurs (Murnieks et al., 2016; Santoso et al., 2022). Educational institutes have a key role in promoting entrepreneurial motivation (Yan et al., 2023). An entrepreneurially oriented individual who is able to explore and acquire knowledge creates entrepreneurial capital and improves innovation (Caputo et al., 2020). Gompers et al. (2021) noted that early-stage investors put more weight on the management team and assess soft information about founder traits via in-person meetings.

Finally, higher absorptive capacity in earlier stages allows firms to scale rapidly. VC investment in early stages helps firms gain and cement this capacity (Jeong et al., 2020). Management decisions that define the knowledge orientation of the firm change resource allocation and hence valuation of the firm. Management team sets processes to enable absorptive capacity and this dynamic capability allows the firm to excel differently as compared to firms receiving similar support (Vincent, Zakkariya, 2021). Startups that have corporate or university stakeholders strengthen their knowledge and resource base (Rocha, Grilli, 2024).

Role and relevance in late-stage valuation – In the late-stages, not many studies have explored founding team traits as an influencing factor. This could be because founder traits such as passion, tenacity, and customer orientation become ingrained in the culture of the firm as a whole (Murnieks et al., 2016) in its later stages and its influence can be observed via firm-level factors such as its processes, knowledge orientation or strategic decisions.

Management team experience

Role and relevance in early-stage valuation – In the early stages, the startup maintains a lean team with a fluid organizational structure. It is unlikely to have a strong management team outside of the founders. Hence this factor is not found relevant for early-stage assessments.

Role and relevance in late-stage valuation – In late-stages, team management consistently ranked high among all companies the VC firm would have liked to invest in. As a firm matures managerial capabilities evolve from addressing survival concerns to setting up complex organization systems. Relevant experience of management team has a direct impact on the productivity and growth of firms (Chahine, Zhang, 2020). Top management team receives close attention during IPO valuations (Wasserman, 2017). Firms with a broad experience team secure milestones faster – be it funding milestones or performance milestones. Hence it is generally found that funds allocated to acquiring quality human capital surge in late stages (Singh, Subrahmanya, 2022). The increased allocation also helps to counter human capital risk, i.e.; the likelihood of critical employees leaving the firm.

Discussion

In the prior section, we provided a map of nine valuation factors and their distinct influences on early-stage and late-stage startup valuation. We now try to derive relative relevance of these valuation factors in each stage. Figure 3 gave us an early peek into the relative relevance of valuation factors based on frequency of that factor's significance in empirical studies. We now extend the same approach to all nine valuation factors discussed above.

The approach to deriving the relative relevance of valuation factors is as follows - once the factors influencing startup valuation are attributed to early-stage, late-stage or both, we determine the frequency of that factor's significance in empirical studies, either as an independent variable or as a control variable. We then arrange these factors in descending order of frequency. As the focus is on determining relative relevance, instead of absolute relevance we move away from the frequency distribution chart format in Figure 3 to a simple hierarchy. This allows us to synthesize the findings of literature map into a *'relevance hierarchy'*.

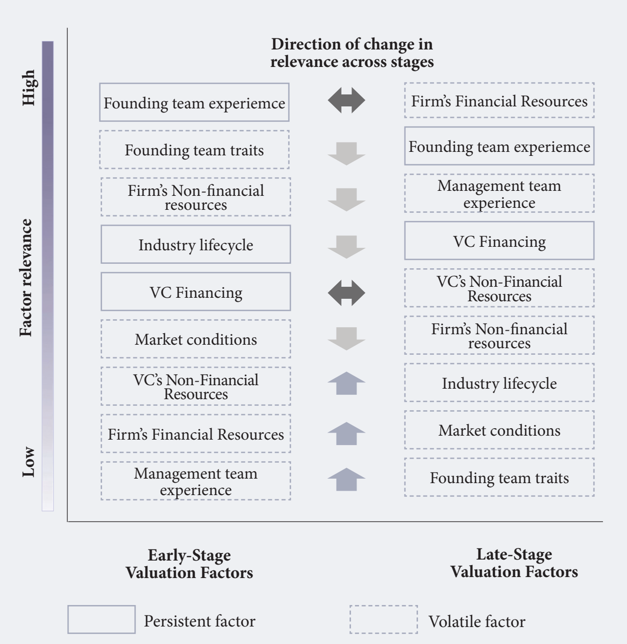
Relevance hierarchy of valuation factors

Relevance hierarchy offers an interesting dimension of relevance of valuation factors across lifecycle stage. Figure 4 shows the relevance hierarchy in early-stages followed by relevance hierarchy in late-stages to its right. The arrows in the middle against each box indicate the direction of change in relevance of that factor across lifecycle stages. An up/down arrow indicates that the factor has risen/dropped in relevance hierarchy by +2/-2 or more levels. A status-quo arrow indicates that the factor has retained its relevance within +1/-1 levels.

It should be emphasized that startups are highly dynamic entities with outliers observed frequently. Hence it would be impossible to attribute an absolute relevance value. Rather, the relevance hierarchy is an attempt to visualize the relative relevance of valuation factors that can inform empirical studies in this domain.

The key highlights of this literature review from a theoretical standpoint are summarized below –

Figure 4. **Relevance Hierarchy across Lifecycle Stages**



Source: authors.

- A critical determinant of firm valuation in its early-stage is its human capital, i.e.; Founding team experience and Founding team traits. Founding team experience continues to be a high determinant of firm valuation in its late-stages with its scope expanding beyond founders to its top management team.
- A significant jump in value relevance is seen in favor of the Firm's financial resources. This is consistent with prior studies that show that value moves from non-financial resources to financial resources across lifecycle stages.
- The quantum of VC financing received retains its relevance across stages, while the relevance of non-financial resources accrued from VC association increases substantially in the late-stages.
- External factors such as Industry lifecycle and Market conditions have a relatively higher value relevance in early-stages of a startup.

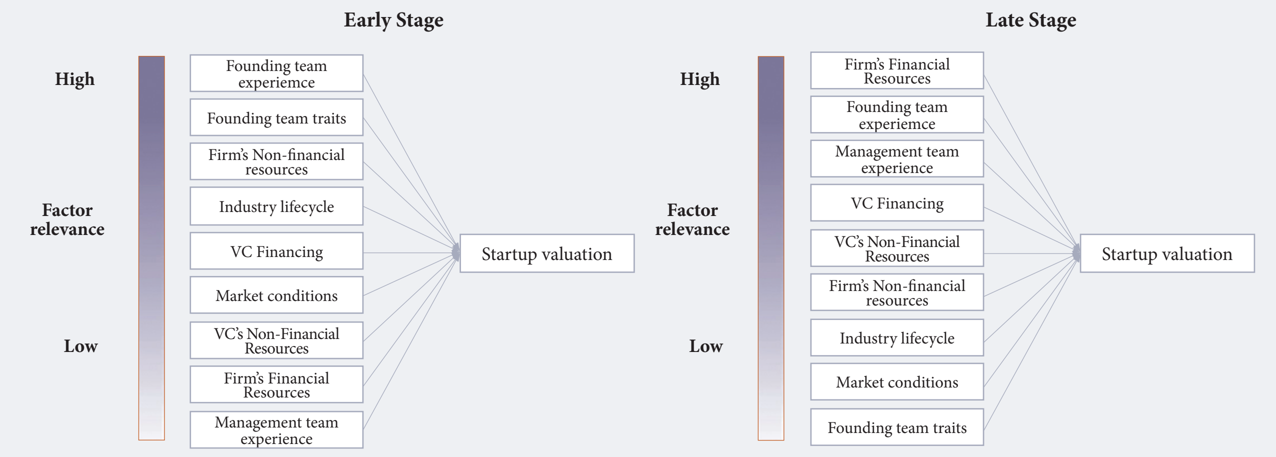
Persistent and volatile factors

The relevance hierarchy offers a sharper focus on variations in factor influences. This allows us to further uncover '*persistent*' and '*volatile*' factors.

The key highlights of this literature review from a theoretical standpoint are summarized below –

- Persistent factors retain their relevance levels across a startup's lifecycle stages. Hence such factors should be strongly considered in empirical studies.

Figure 5. **Meta-model of Early-stage and Late-stage Valuation**



Source: authors.

- Volatile factors vary in relevance levels across a startup's lifecycle stages. Inclusion and exclusion of these factors should be carefully considered based on lifecycle stage of the study.
- Founding team experience and VC financing were found to be persistent factors across lifecycle stages. This implies that its influence on startup valuation remains relevant throughout. Founding team experience also demonstrates the strongest influence on valuation.
- Volatile factors include Firm's non-financial resources, Firm's financial resources, VC's non-financial resources, Industry lifecycle, Market conditions, Management team experience and Founding team traits. This implies that its influence changes across lifecycle stages. Volatile factors can move up or down in relevance across lifecycle stages.

A meta-model of startup valuation based on relevance

We now present a meta-model model of startup valuation that is unique to each lifecycle stage in Figure 5. It includes the diversity of explanatory constructs we found in prior entrepreneurial studies assessing startup valuation and overlays it with the *relevance hierarchy*. In simple terms, the conceptual model is essentially a superset of all determinants of startup valuation. However, by overlaying the *relevance hierarchy* into the conceptual model, the revised model provides valuable guidance on the significance of each factor in that lifecycle stage.

While some of these determinants remain constant, some others wane and grow in importance across lifecycle stages. As more empirical studies are being taken up in emerging startup ecosystems such as India, South East Asia, and Latin America, such an understanding can help improve quality of data collected for these studies. It also reduces model complexity by dropping variables of lower relevance and thus improves quality of data analysis conducted.

To summarize, in stage-specific studies, the relevance hierarchy informs contraction of control variable set. Whereas in the case of mixed-stage studies, it informs expansion of control variable set.

Conclusion

Despite large pools of private money chasing startups, the successful evolution of a startup from its early-stages to late-stages is a slow process, often involving transformative changes, which motivated the title of this study – *Spawning Butterflies*. The process, while painful to entrepreneurs, has also been baffling to researchers due to dynamic capabilities and confounding effects. This study contributes to disentangling confounding effects in valuation factors by applying the '*looking glass*' of lifecycle stage. Closely following prior empirical studies in entrepreneurship domain, this study identifies valuation drivers and catalogues them based on their relevance to startup valuation into a '*relevance hierarchy*'. This presents a novel view to future researchers that can inform selection of independent and control variables in their study of startup valuation. The relevance hierarchy also allowed the study to uncover *persistent and volatile* valuation factors. The study finally distills overall findings into a refined meta-model for startup valuation unique to each lifecycle stage.

Venture capital industry has realized the need for stage-wise specialization, resulting in the rise of early-stage VCs, growth-stage VCs and late-stage VCs. Startup incubators too further sub-segment early-stage startups into idea-stage, pre-idea stage, etc. These developments signify the need to micro-target startup academic studies specific to the firm stage. The evolution of an egg into a butterfly is one of nature's most delightful mysteries. The intermediate transformations though almost unrecognizable, demystify our understanding of it.

Our study addresses the following existing gaps in literature. Firstly, by seeking stage-wise interpretations, we compare the role and relevance of valuation factors across stages. Such differences across stages have been acknowledged by prior literature surveys (Köhn, 2018; Berre, Le Pendeven, 2023; Colombo et al., 2023). Secondly, it expands our understanding of each of these valuation factors by *relevance*. Third, the *relevance hierarchy* allows us to introduce *persistent and volatile factors* in startup valuation. The ebb and flow of these factors directly addresses and informs existing gaps in selection of explanatory variables in multi-stage studies. Finally, the study distills overall findings and provides a meta-model for startup valuation. This view opens up future avenues of study into factors driving these movements.

Looking ahead, we see multiple avenues of future research. Volatile factors identified in this study warrant further contextualization studies. Understanding the 'why' and 'how' of volatility of factors via empirical studies is required. For example, exploring the volatility in VCs non-financial resources can help delve deeper into the capabilities of VC's involved in early-stage, growth-stage or late-stage investments. What are the evolving characteristics of micro-VCs (early-stage VCs) and how do they influence startup performance? Other volatile factors such as firm's non-financial resources, or market conditions also warrant deeper studies.

Another area that has remained under researched is the study into boundary conditions driving the ebb and flow of volatile factors. It is opportune to explore what drives the increase or decrease of relevance of volatile factors via interaction effects. There has been sustained interest in the exploration of interaction effects of valuation factors (Vincent, Zakkariya, 2021; Coad et al., 2016; Sethuram et al., 2021). For example, it would be interesting to investigate the interaction effects of founder risk propensity and firm stage or founder quality and VC financing. Such interaction studies can help explore boundary conditions of valuation factors or path dependencies that cause one effect to prevail over another.

Lastly, and this is the most unambiguous research direction from this study, we recommend entrepreneurial studies to have a narrow timeline of analysis – go "inch wide, mile deep". This points to the need to expand beyond cross-sectional factors-based analysis but rather delve deeper into iterative events that occur within a developmental stage of the firm.

The author(s) declare this paper is the result of original research. We have NO financial and/or business interests in any company that may be affected by the research reported in the enclosed paper. We have disclosed all interests fully.

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How to Radically Innovate in Emerging Defense Ecosystems?

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Abstract

Radical innovation is the most critical driver for latecomers' catch-up. In this regard, while scholars doubt the emergence of radical innovations in the South, various success stories prove otherwise. On the other hand, the intensification of geo-strategic and geo-economic competition between great powers and the occurrence of the global technological revolution promises a fundamental transformation in the nature and distribution of global power, with radical innovation as an urgent priority for the world's military powers. Accordingly, this article first develops a radical innovation framework for emerging defense ecosystems based on the content analysis of 27 interviews with defense innovation experts. The drivers and sub-dimensions of the framework are then prioritized with fuzzy AHP, according to a survey answered by 67 experts. Culture (radical innovation importance, organizational culture, and collaboration culture), governance (policy framework, institutional framework, and organizational structure), resources (infrastructure, human capital, and financial resources), and processes (knowledge management, project management, and open innovation) are the proposed drivers for radical innovation in emerging defense ecosystems. Also, innovation resources are identified as the most crucial driver, with human capital, financial resources, policy framework, and institutional structure as the most critical sub-dimensions, respectively.

Keywords: radical innovation; innovation ecosystem; defense industry; emerging context

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Introduction

As the most critical driver of developed economies, innovation covers a broad spectrum, from minor improvements in goods to new businesses based on technological breakthroughs. Meanwhile, radical innovation includes introducing new products or services that lead to developing large businesses and new industries by creating new values (Gaynor, 2002). These innovations develop new territories and paradigms, create a capacity for grand transformations and are a vital driver for the growth, success and wealth of firms and countries (Norman, Verganti, 2014). However, reviewing innovation literature, few scholars have addressed radical innovation in latecomer countries as they suggest that these innovations probably do not develop in such a context. On the other hand, although latecomers can start the catch-up journey by imitating the leaders, replicating existing products or technologies can only be fruitful in the short run, as developing new technological pathways is vital later on (Malerba, Lee, 2021). Several successful firms in India, South Korea, South Africa, and Mexico moved up the learning hierarchy and even got ahead of the leaders using an ambidextrous strategy while investing in radical innovation (Forbes, Wield, 2002).

However, the analytical frameworks presented for radical innovation are unsuitable for analyzing and explaining such trends and processes because they have paid less attention to historical, social, external, and internal factors and the internal relationships affecting the dynamics of the radical innovation process (Uachotikoon, Utsahajit, 2019). Therefore, new approaches (e.g., open innovation and innovation networks) have studied innovation as a multi-player and evolutionary phenomenon, with innovation ecosystems focusing on creating shared values (Gomes et al., 2016).

In the defense ecosystem, as a pioneer innovation ecosystem, the world is in the vortex of changes at the intersection of two transformative developments; intensified geostrategic and geoeconomic competition between the great powers - especially the United States and China - and the technological revolution promises a fundamental transformation in military power, resulting in global leaders prioritizing disruptive innovation (Cheung, 2021). Also, rapid development and convergence in robotics, information technology, and artificial intelligence will continue revolutionizing future battlefields (Billing et al., 2021). Technological innovations maintain armies' operational strength while reducing soldiers, thus transforming modern armies (Dyson, 2020). Furthermore, the relationship between technological innovations and military capacity dates back to the formation of the first armies, with various technological leaps resulting from military conflicts (Safdari Ranjbar, Fatemi, 2022). However, defense R&D has been widely criticized since the 1970s because of the opportunity cost, relative inefficiency compared to civilian R&D, and armies' focus on incremental innovations (Bellais, 2013). High-tech defense firms are eager to incrementally modify technologies they dominate to strengthen their position in the defense market, neglecting disruptive changes that compromise their technology portfolios or require additional investments. This conservative approach is also evident on the demand side, as armed forces promote established technologies, resisting new technologies that may alter their missions and organization (Bellais, 2009).

In addition, emerging defense ecosystems face more profound and multifaceted challenges. Emerging defense ecosystems are national defense innovation systems that are undergoing foundational development in institutional architecture, actor coordination, and policy coherence, typically marked by fragmented governance, underdeveloped innovation infrastructure, and limited experience in managing radical innovation processes within the defense sector.[1] These challenges are compounded by the sector's deep entanglement with national political and military agendas, where prioritizing defense innovation often diverts resources from other vital domains such as welfare. Moreover, international constraints severely restrict access to external expertise, as leading countries consistently refrain from transferring sensitive military technologies—even to close allies—forcing latecomers to rely primarily on domestic capacities for developing advanced capabilities (Lee, Park, 2019). In response, emerging defense ecosystems have historically pursued two divergent strategies: the "good enough" approach, which emphasizes affordable technologies tailored to regional threats, and the "golden" strategy, which aspires to match the technological sophistication of global powers through high-cost innovation initiatives (Cheung, 2014). Yet, the persistent dominance of traditional superpowers suggests the limited success of the latter approach, raising critical questions about the underlying barriers to radical innovation in the defense sectors of these countries.

As one of the emerging defense ecosystems, Iran's defense industry was founded by purchasing technology and importing production lines from foreign countries, especially Germany and the United States, before the 1979 revolution, within the framework of NATO's military doctrine. With foreign consultants as the primary knowledge workers, accumulated knowledge mainly included low learning and skill

[1] "Emerging defense ecosystems" is conceptually distinct from "emerging economies," which refers to a broader macroeconomic classification. For example, while countries like China and Russia are widely regarded as emerging economies, their defense innovation ecosystems are relatively mature.

capabilities. After the revolution, many foreign experts left Iran's defense industry, and the weak flow of defense innovations was interrupted by the start of the Iran-Iraq war and the resulting sanctions. As a result, the industry pursued a self-reliant approach, relying on domestic power, using limited opportunities for technological collaboration, and focusing on trial and error. Although defense R&D developed further in the post-war era, the technology gap with defense leaders is evident, especially in propulsion engines and advanced electronic systems (Ghazinoory, Vaziri, 2020).

Few scholars have studied radical innovation ecosystems, especially in the defense context, which has unique features. Also, as emerging defense ecosystems mostly have limited resources to invest, presenting a guideline for prioritizing required actions for developing radical innovation in their defense ecosystems is vital. Therefore, this article aims to develop a conceptual model for radical innovation in emerging defense ecosystems and then prioritizes its drivers and sub-dimensions with fuzzy AHP. Respectively, the research questions are: 1) What are the drivers and sub-dimensions of developing radical innovation in emerging defense ecosystems? and 2) Which drivers and sub-dimensions are most critical in developing radical innovation in emerging defense ecosystems? For this purpose, the article reviews radical innovation, innovation ecosystem, and innovation in the defense context to identify the research gap. Then, it discusses the qualitative-quantitative research methodology, presents the conceptual framework with the prioritization of drivers and sub-dimensions. Finally, the article discusses the findings while comparing them with previous studies, and concludes by presenting policy implications and possible research directions.

Literature review

Radical innovation

There are various dichotomies for categorizing innovation, including competence-developing versus competence-destroying innovation, modular innovation versus architectural innovation, and identity-challenging versus identity-sustaining innovation (Ansari, Krop, 2019). Among these dichotomies, administrative versus technical innovation, product versus process innovation, and radical versus incremental innovation are more beneficial (Costa, Monteiro, 2016).

Radical innovation is commercializing products and technologies that strongly impact the market and the firm through a simultaneous change in business model and technology, resulting in a fundamental transformation in the industry's competitive environment (Sarkar et al., 2018). Radical innovation is vital for the growth of firms and economies as it deals with creating new markets and integrating or destroying old markets. Therefore, it can push small followers toward the industry's leadership position when incumbents are locked in the current technological trajectory (Bao et al., 2019). Although scholars identify radical innovation as a strategic driver for firms' growth and renewal, empirical evidence indicates that they fail to develop strategies tailored to its complex and challenging nature (Hill, Rothaermel, 2003).

Innovation ecosystem

An innovation ecosystem is a network of actors producing or exploiting products and services focused on a shared value (Autio,Thomas, 2014). The approach combines open innovation, strategic management, organizational studies, evolutionary economics, and industrial ecology knowledge fields and has gained popularity among strategy and policy scholars (Rinkinen, Harmaakorpi, 2018). Various definitions and concepts are presented to analyze innovation ecosystems from different perspectives, the most important of which are focal (hub) ecosystems (Nambisan, Baron, 2013), open innovation ecosystems (Chesbrough, Bogers, 2014) platform ecosystems (Gawer, Cusumano, 2014), and innovation ecotones (Ghazinoory et al., 2021). While such conceptualizations indicate the flexibility of the concept, they can lead to conflicts and divergence. Also, the distinction between the innovation ecosystem and supply chain, network, and business model is vague, making knowledge integration difficult (Gomes et al., 2018). Finally, the culture, subsystems and institutions play a vital role in analyzing innovation ecosystems (Durst, Poutanen, 2013); therefore, developing a radical innovation ecosystem requires attention to the context.

Innovation in defense industries

Defense innovation varies from similar concepts, including military innovation and national security innovation. Defense innovation develops complex, high-value solutions by integrating multiple technologies and complementary skills (Barbaroux, 2019). While military innovation focuses on enhancing armies' capabilities, defense innovation also encompasses the civilian domain, particularly the dual industrial base (Cheung, 2021).

Defense innovation has unique characteristics compared to civilian innovation. Defense R&D has a lower rate of social return and higher uncertainty than civilian R&D projects. Also, defense programs are frequently postponed, their costs increase quickly, and the expected results are sometimes not obtained (Bellais, 2009). On the other hand, while commercial enterprises should pay special attention to financial efficiency, distribution and logistics, market studies, pricing and marketing to ensure their survival in the competitive environment, defense innovation focuses primarily on technical and operational efficiency (Safdari Ranjbar, Fatemi, 2022). Therefore, defense innovation requires a specific policy and management model.

Research gap

Emerging defense ecosystems face a strategic imperative to develop indigenous capabilities, and radical innovation plays a pivotal role in this pursuit. For countries lacking access to advanced military technologies due to geopolitical tensions or embargoes, the capacity to innovate radically is not merely a developmental goal but a matter of national security. By moving beyond incremental upgrades and investing in high-risk, long-horizon technological development, such states seek to reduce dependency, close capability gaps, and signal deterrent strength (Bitzinger, 2014; Irfan et al., 2023). Asymmetric innovation trajectories further enable weaker actors to challenge dominant power structures through disruptive means (Mehta, 2021), while spillovers from defense R&D can stimulate wider industrial upgrading (Safdari Ranjbar, Fatemi, 2022).

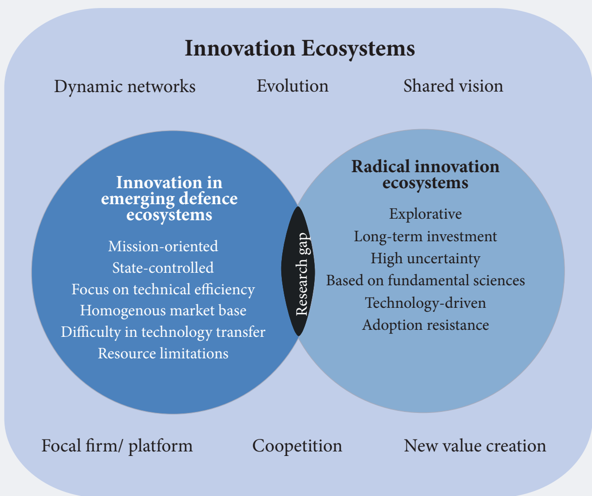
However, while the motivation is clear, the conceptual understanding of how radical innovation might unfold in these settings remains underdeveloped. Much of the literature focuses on advanced defense ecosystems in the United States (Gholz, Sapolsky, 2021), Russia (Kashin, 2018), or NATO countries (Efthymiopoulos, 2019; Fiott, 2017), where innovation is supported by mature industrial bases, stable alliances, and large-scale procurement mechanisms. A few studies examine non-Western cases — such as China (Yuan et al., 2016) and South Korea (Moon, Paek, 2010) — but these are typically framed as exceptional trajectories and do not yield a transferable framework for less resourced contexts. Moreover, existing research tends to emphasize descriptive system mapping or normative policy guidance, while neglecting the analytical tensions that arise when attempting to integrate radical innovation dynamics into politically centralized, resource-constrained defense environments.

The present research responds to this gap by conceptualizing the intersection of three theoretical domains: innovation ecosystems, radical innovation, and emerging defense systems (Figure 1). These domains rest on fundamentally different assumptions. Innovation ecosystems emphasize distributed interaction, evolving networks, and value co-creation among heterogeneous actors. Radical innovation entails long-term exploration, institutional flexibility, and openness to failure, making it highly dependent on absorptive capacity, interdisciplinary integration, and learning loops. Emerging defense ecosystems, in contrast, tend to be mission-oriented, state-controlled, inward-looking, and governed by formal hierarchies, secrecy norms, and budgetary inflexibility. This misalignment is not incidental but structural as the conceptual space in which these three domains intersect is marked not by synergy but by tension. The juxtaposition reveals that many of the conditions considered essential for radical innovation are not only absent in emerging defense ecosystems but are directly obstructed by their institutional logic.

Three interlocking tensions are central to this problem. First, there is a fundamental contradiction between the openness required for exploratory innovation and the closed nature of defense environments. Knowledge flows that fuel innovation ecosystems—through user feedback, cross-sector collaboration, and academic–industry exchange—are frequently constrained by classification, compartmentalization, and national security restrictions. Second, radical innovation depends on the capacity to absorb uncertainty and pursue untested technological paths, yet defense institutions often operate under risk-averse procurement regimes designed to ensure operational continuity. The result is a structural preference for incremental improvement over technological discontinuity. Third, whereas innovation ecosystems rely on decentralized initiative and horizontal coordination, emerging defense ecosystems are typically organized through vertical chains of command that limit agency at the organizational periphery. In such systems, entrepreneurial actors lack both institutional legitimacy and resource autonomy, reducing the potential for bottom-up innovation.

These tensions challenge the applicability of conventional innovation models in such settings. The

Figure 1. **Theoretical Framework**



Source: authors.

constraints involved are not merely technical bottlenecks or capability deficits that can be addressed through targeted policy, but deeper contradictions between innovation logic and governance logic. Attempts to apply mainstream innovation frameworks to these ecosystems without accounting for these contradictions risk overlooking the mechanisms through which innovation is filtered, slowed, or redirected. As such, the question is not how to replicate radical innovation systems under ideal conditions, but how to understand the partial, constrained, and adaptive forms innovation may take in structurally misaligned environments. This requires a conceptual approach that begins not from the assumption of functionality but from an inquiry into the points of friction where competing institutional logic collides. This research adopts such stance as it treats emerging defense ecosystems not as incomplete versions of advanced systems, but as analytically distinct fields in which innovation emerges under tension. By placing the structural contradictions at the center of analysis, this article aims to clarify the conditions under which radical innovation becomes possible, unlikely, or redirected—and to offer a basis for theorizing innovation under constraint.

Research methodology

In the qualitative research phase, data are collected through interviews to design a model for radical innovation in emerging defense ecosystems. The statistical population included three groups of experts: 1) senior managers active in defense innovation policymaking, 2) managers and researchers from organizations focused on defense radical innovation (e.g., Organization for Defensive Innovation and Research), and 3) Defense R&D project specialists with previous participation in advanced technology development projects (e.g., satellites, guided missiles, advanced materials, radar systems, and drones). As the knowledge and experience of the research subject were more crucial than the number of participants, judgmental and snowball sampling methods were combined to identify suitable interviewees. As a result, the interviews started with the participation of a group of identified experts, who then suggested other experts while paying attention to the selection criteria. Sampling considered five critical criteria: 1) critical role in radical innovation development, 2) reputation among other experts, 3) theoretical understanding of the topic, 4) diversity of interviewees, and 5) their willingness to participate. The sampling process was extended to 27 interviews to ensure theoretical saturation. The final pool of interviewees consisted of 9 policymakers, 11 institutional managers and researchers, and 7 R&D project specialists.

The interviews started with presenting radical innovation and innovation ecosystems to the interviewees, as some had engineering backgrounds and were unfamiliar with the terminology. Then, the actors, roles, strategies, and culture of defense innovation ecosystems were discussed throughout their lifecycle. Finally, the interview focused on the unique characteristics of radical innovation and its prerequisites to fully address the research question. In addition to structured probes, participants were encouraged to elaborate on their experiences and perspectives. Key lines of inquiry included: the distinction between systems and ecosystems; institutional and cultural features enabling radical innovation; stakeholder incentives and necessary reforms in defense innovation governance; and the differences between radical and incremental innovation strategies. Interviewees also provided concrete examples of radical innovation, described perceived barriers and catalysts to such innovation, and reflected on the types of collaborative arrangements required. Finally, they shared perspectives on how national innovation systems can evolve to better support breakthrough defense technologies. These interviews were meticulously recorded and subsequently transcribed for import into MAXQDA. The analysis phase included three steps: initial coding, where the data was broken down into discrete parts; axial coding, which focused on establishing connections between these codes; and selective coding, where a central category capturing the essence of the research was selected from the analyzed codes. Finally, the validity of this phase was confirmed by holding a follow-up focus group, external reviewing, and recoding of data samples through MAXQDA's intercoder agreement.

After extracting the drivers and sub-dimensions of radical innovation in the defense industry from the interviews, they were prioritized with fuzzy AHP. Although AHP is widely practiced in mathematical optimization and operational research (Liu et al., 2020), its weakness in fully reflecting the human thinking style through crisp numbers resulted in the development of fuzzy AHP (Coffey, Claudio, 2021). Comparing Fuzzy AHP with Fuzzy ANP, Fuzzy AHP emphasizes pairwise comparisons and crisp linguistic terms, simplifying the decision-making process under fuzzy conditions and enhancing clarity and interpretability. When contrasting Fuzzy AHP with Fuzzy TOPSIS, Fuzzy AHP allows the inclusion of sub-dimensions into a hierarchy and is also more agile in prioritizing a few drivers and sub-dimensions (Junior et al., 2014). Compared to Fuzzy VIKOR, Fuzzy AHP's structure enables decision-makers to systematically evaluate criteria and alternatives under fuzzy conditions, leading to more coherent and reliable decision outcomes. Lastly, in contrast with Fuzzy PROMETHEE, Fuzzy AHP's logical integration provides a more robust and transparent methodology for deriving priority weights and rankings in fuzzy decision contexts (Macharis et al., 2004). Overall, Fuzzy AHP is preferred over other MCDM techniques for this particular research as it can reflect experts' qualitative responses through fuzziness, organize a three-level hierarchical framework, and analyze and interpret a small hierarchy (with only four drivers and twelve sub-dimensions) with more agility and transparency. To implement Fuzzy AHP, a researcher-made questionnaire was designed to compare the drivers and sub-dimensions extracted in the qualitative phase. The questionnaire was distributed among 67 experts purposefully selected from participants in innovative projects within the defense industry. These individuals were national elites actively collaborating with the defense innovation ecosystem and had expressed willingness to contribute to the study. The authors had access to a curated pool of these experts and distributed the survey online to facilitate access and participation. The disciplinary backgrounds of the respondents included engineering and technical sciences (44), humanities and social sciences (18), basic sciences (1), medical sciences (3), and other fields (1). In terms of academic qualification, the sample comprised 2 B.Sc., 37 M.Sc., 8 Ph.D. candidates, and 20 Ph.D. holders, ensuring the analytical sophistication required for pairwise comparisons under fuzzy conditions. Consistent with the fuzzy AHP methodology, the respondents were asked to perform pairwise comparisons of the four main drivers and their twelve associated sub-dimensions. After validating the consistency of responses—achieving an inconsistency rate below 0.1—the data were analyzed. Based on the Chang methodology (1996), the initial matrix was constructed using fuzzy triangular scales (Samouei et al., 2016) and the geometric mean of each pairwise judgment. Subsequently, the fuzzy values of matrix elements were calculated to derive the final prioritization.

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \odot [\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}]^{-1} \quad (1)$$

Then, the relative magnitude of drivers and sub-dimensions is calculated according to Equation 2, where l, m, and u are the lower, middle, and upper values of fuzzy triangles, respectively.

$$V(M_2 \geq M_1) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{if } m_2 < m_1 \end{cases} \quad (2)$$

Finally, each driver and sub-dimension's weight and relative importance are calculated according to Equation 3.

$$V(M \geq M1, M2,\ldots, Mk) = \min V(M \geq Mi),\ i = 1,\ldots,k. \quad (3)$$

Radical innovation model for defense ecosystem

After extracting and classifying primary codes from 27 interviews, twelve sub-dimensions and four main drivers were identified. These include: (1) developing radical innovation culture, (2) developing radical innovation governance, (3) developing radical innovation resources, and (4) developing radical innovation processes.

Developing radical innovation culture

Cultural transformation is widely perceived as the most foundational shift needed to support radical innovation. It involves not only modifying behaviors but challenging legacy assumptions about how innovation is conceived, implemented, and legitimized. Developing radical innovation culture includes "promoting radical innovation", "developing organizational culture", and "developing collaboration culture."

Promoting radical innovation. Organizations lock in their paradigms, capabilities, and previous investments, which act as critical obstacles to radical innovation development. Therefore, encouraging a risk-taking culture, supporting innovative activities with high uncertainty, and nurturing an alternative defense innovation discourse promote radical defense innovation. A recurring challenge is the institutional ambiguity surrounding what qualifies as radical innovation. This ambiguity often leads to conflation with incremental efforts and dilutes organizational focus. Developing formal classification systems and assessment criteria to distinguish between types of innovation would sharpen strategic alignment and reduce resource dispersion. Additionally, building legitimacy for radical innovation requires reframing it not as an occasional disruption but as an ongoing strategic necessity — one that safeguards national security through anticipatory capability development.

Developing organizational culture. Radical innovation in defense ecosystems requires more than technical breakthroughs; it depends on a flexible organizational culture that encourages learning, leadership-driven exploration, and a tolerance for failure. A rigid culture can stifle this progress, limiting the discovery of new values that often extend beyond economic benefits. Innovation environments benefit from cultivating individualism, leadership support, and shared language among stakeholders to reduce misalignment and build innovation momentum. Organizational learning mechanisms — such as after-action reviews and structured reflection — help transform both setbacks and breakthroughs into durable institutional capacity. Moreover, the cultural norms of many defense organizations remain dominated by procedural correctness rather than adaptive experimentation. Overcoming this requires not only managerial support but symbolic acts — such as awarding internal prizes for discontinued but instructive projects — to change perceptions about productive failure. Building internal narrative tools that reframe failure as "mission knowledge" rather than "error" can gradually displace the existing aversion to risk.

Developing collaboration culture. Cross-functional knowledge sharing is essential, especially in defense ecosystems where fields such as AI, robotics, and materials science intersect. Interdisciplinary teams that break down silos and foster real-time collaboration accelerate innovation. Collaborative platforms and flexible scheduling practices enhance integration, especially when innovators are granted sufficient autonomy. Moreover, recognizing innovators' contributions and securing long-term economic rights through tailored incentive systems—especially non-financial rewards — was seen as essential for sustaining high-level talent. Persistent inter-agency mistrust and rigid clearance boundaries often inhibit the formation of such collaborations. Delineating fast-track protocols for trusted partnerships and modular information-sharing agreements can reduce these friction points while maintaining operational security. In addition, the absence of shared digital environments for synchronous collaboration makes real-time problem-solving nearly impossible across organizations. Deploying secure multi-organizational platforms could streamline collaboration without compromising confidentiality. Building alliances through temporary task forces that include both internal and external innovators can also accelerate high-risk experimentation under time constraints.

Developing radical innovation governance

Governance was described as both the engine and the bottleneck of radical innovation. Current decision-making models were often mismatched with the dynamism required for high-risk innovation. Radical innovation governance includes developing "policy framework," "institutional framework," and "organizational structure".

Developing policy framework. Radical innovation typically originates from foresight-oriented visions and roadmaps that guide development. Leaders should define specific but evolving goals aligned with strategic advantage. Although goals cannot be crystal clear due to inherent uncertainty, excessive ambiguity can also hinder progress. A more structured approach to long-term policy integration would involve embedding radical innovation goals into national security doctrines and creating annual cross-sector foresight summits. These summits can serve as formal spaces to recalibrate vision documents based on emerging technological and geopolitical developments. Moreover, policies should institutionalize periodic reallocation of funds from low-impact projects to emerging high-potential areas, guided by predefined indicators of novelty, risk appetite, and ecosystem impact. Regular policy audits can ensure alignment between operational practices and the evolving innovation mandate.

Developing institutional framework. Institutional contexts must match environmental requirements for radical innovation. Collaboration among stakeholders must be redefined to facilitate open innovation in the defense ecosystem. Top-level agreements between defense organizations support decision-making and provide full backing for radical innovation. The lack of coordination among research units, procurement bodies, and regulatory authorities often leads to sequential instead of concurrent innovation cycles. This temporal misalignment slows the entire ecosystem. Establishing a tri-sector coordination council with legislative status can synchronize regulatory adaptation, procurement responsiveness, and research trajectories. Additionally, cultivating cross-institutional leadership exchange programs can foster shared mental models and strengthen informal communication lines. Furthermore, political interference was seen as a recurring disruptor that undermines consistency in innovation strategies. The institutional framework must thus shield key innovation functions from external volatility while enabling coordinated action across actors.

Developing organizational structure. Rigid defense protocols hamper creativity. Flat structures enhance participation and facilitate decision-making. To develop radical innovations, revising manager appointment criteria, removing unnecessary restrictions, and encouraging centralized, mission-oriented institutions are necessary. It is also essential to build differentiated career tracks for innovation-oriented professionals. These tracks should reward technical creativity, project ambidexterity, and cross-domain leadership, allowing personnel to alternate between R&D, policy, and field roles. This flexibility would better match the emergent needs of radical innovation initiatives and build cumulative innovation expertise within institutions. Encouraging "dual ladder" promotion models—where managerial and technical tracks are equally rewarded—can also reduce the attrition of high-potential innovators.

Developing radical innovation resources

Resource limitations were frequently cited as both structural and self-inflicted. Underuse of existing capacities and fragmentation of strategic investments often outweigh absolute scarcity. Expanding radical innovation resources includes developing "infrastructure," "human capital," and "financial resources".

Developing infrastructure. Radical innovation infrastructure, including user-participatory prototyping labs and test environments, is vital for adapting technologies to battlefield requirements. A network of integrated labs, national research centers, and Fab Labs enables faster testing and adaptation. Several facilities operate in silos with overlapping missions and capabilities. Developing a centralized infrastructure roadmap with cross-institutional access rights and real-time equipment availability databases would significantly optimize capacity usage. Furthermore, innovation infrastructure must be paired with simulation environments for scenario-based testing, especially for dual-use technologies. The lack of such simulation infrastructure often results in premature scaling or misalignment with operational realities. Embedding evaluation metrics into infrastructure usage — not just project outcomes — can improve accountability and enable strategic renewal of assets.

Developing human capital. Human capital transformation is central to radical innovation. Technology champions, guardians, and inspirational leaders drive ideas into action. Succession planning and internal knowledge transfer mechanisms help prevent critical capability loss. Leader-centered team design, backed by tailored incentives, supports motivation and performance. The current overreliance on formal degrees and traditional career progression models hinders the infusion of diverse innovation capacities. Recognizing informal learning trajectories—such as hands-on technical portfolios and hackathon performance — can diversify the talent pipeline. Additionally, the ecosystem would benefit from establishing multi-generational mentorship programs, where seasoned experts engage with emerging professionals in experimental projects. This would create continuous loops of tacit knowledge transfer and role modeling. Formalizing lateral mobility within innovation units can also help prevent the compartmentalization of expertise and distribute high performers across priority areas. It is also essential to build differentiated career tracks for innovation-oriented professionals. These tracks should reward technical creativity, project ambidexterity, and cross-domain leadership, allowing personnel to alternate between R&D, policy, and field roles. This flexibility would better match the emergent needs of radical innovation initiatives and build cumulative innovation expertise within institutions. Encouraging “dual ladder” promotion models — where managerial and technical tracks are equally rewarded — can also reduce the attrition of high-potential innovators.

Developing financial resources. Financial constraints remain a central barrier to radical innovation. A stable and independent financial base, supported by diversified research sources, ensures resilience. It is also important to distinguish between core funding for infrastructure and contestable project-specific funding. The latter must include failure-tolerant provisions and flexible reallocation mechanisms. Funding instruments such as rolling horizon grants and milestone-triggered bonuses can improve responsiveness and encourage continuous learning across projects. Moreover, innovation accounting systems must shift from fixed-output tracking to learning-based metrics—capturing adaptability, portfolio synergy, and exploratory traction. This would recalibrate incentives toward long-term ecosystem development. Developing an ecosystem-wide fund that allows resource pooling across defense and dual-use actors may also resolve duplication and allow for riskier bets.

Developing radical innovation processes

Processes are not just operational tools but the connective tissue through which ideas gain traction. Process deficiencies act as both symptoms and sources of institutional rigidity. Radical innovation processes include “knowledge management”, “project management,” and “open innovation”.

Developing knowledge management. Radical innovation depends on dynamic knowledge ecosystems. Beyond formal documentation, the integration of tacit and explicit knowledge supports sustained exploration. To address this, defense organizations need structured knowledge repositories, idea generation systems, and thematic learning hubs. The inconsistent categorization of knowledge across units creates retrieval barriers. Developing a shared ontology — classifying innovation knowledge under unified taxonomies — would streamline access and accelerate reuse. In parallel, incentives for real-time documentation and codification must be institutionalized so that knowledge does not remain locked within individual projects. Integrating codification into performance metrics could align documentation with professional recognition. Establishing communities of practice within and across organizations would support live problem-solving and break isolation around emerging knowledge areas.

Developing project management. Projects aimed at radical innovation must account for both market and technological uncertainties. Milestone-based evaluation frameworks, rather than traditional fixed-output models, allow for more realistic performance tracking. Managers with both academic and industrial credentials are essential for navigating frontier projects. The ecosystem lacks standardized templates for adaptive project scoping. Developing a repository of project charters, risk registers, and pivot logic models from past radical projects would inform better upfront design. Moreover, embedding project historians — professionals responsible for narrating and preserving the evolution of projects — could enhance institutional learning and provide context for retrospective evaluation. Advanced scenario-planning tools and postmortem protocols can also help refine future strategies and avoid repeating avoidable failures.

Developing open innovation. Despite high security requirements, selective openness can amplify defense innovation. Collaboration with academia, startups, and specialized communities broadens the solution space. Developing strategic openness guidelines — specifying domains, timeframes, and collaboration modes that can safely engage external actors — would remove ambiguity and encourage more frequent partnerships. Public innovation campaigns on non-sensitive problem statements can help identify unconventional solutions and signal the defense ecosystem's openness to external ideas. Finally, creating a classified version of a technology readiness level (TRL) framework would allow defense organizations to communicate innovation maturity across different actors while respecting security constraints. Bridging institutions — such as defense-linked accelerators—can act as buffers between external partners and core security assets.

Accordingly, several persistent obstacles continue to constrain the effectiveness and coherence of radical innovation efforts within the defense ecosystem. These challenges reveal deep-seated structural rigidities that undermine the strategic intent of innovation policies (Table 1). In the cultural domain, organizational behavior remains shaped by bureaucratic inertia and a strong preference for continuity over disruption. This deeply embedded conservatism often favors legacy platforms and established technological pathways, leading to a pervasive emphasis on incremental refinement rather than high-risk exploration. Risk aversion, both at the institutional and individual levels, further weakens the pursuit of radical trajectories. Failures are treated as reputational liabilities rather than as essential feedback mechanisms, stifling the experimental learning loops necessary for innovation maturity. A particularly limiting condition is the lack of a shared discourse between innovators and operational units; engineers, scientists, and commanders frequently operate within separate conceptual frameworks, resulting in breakdowns in communication, misaligned priorities, and limited absorptive capacity for novel technologies.

Table 1. **Failure Factors for Radical Innovation in Emerging Defense Ecosystems**

Dimension	Factors
Culture	• Organizations› bureaucratic culture • Defense industry›s tendency toward old technologies • Desire for incremental innovations • Risk aversion and resistance toward accepting failures • Lack of common language between innovators and operational teams
Governance	• Lack of bold vision and roadmap • Lack of prioritization based on defense needs • Lack of agreement at the macro level • Lack of independence and autonomy in R&D teams • Too much focus on security aspects
Resources	• Lack of laboratory infrastructure • Conflict between long-term employment patterns and intellectual flow dynamics • Employees› inherent weakness in radical innovation • Lack of motivation for radical innovation • Dependence on limited public resources
Processes	• Closed approach toward innovation • Lack of distinction between academic and technical knowledge • Inadequacy of documented scientific resources for reaching knowledge edges • Lacking the critical mass of knowledge • Ignoring interdisciplinary knowledge

Source: authors.

At the level of governance, the absence of a bold, future-oriented vision has led to fragmented policy agendas and inconsistent leadership support. Innovation strategies are rarely tied to battlefield needs or broader defense transformation goals, leading to a proliferation of isolated initiatives with low cumulative impact. Strategic ambiguity is compounded by an absence of consensus at the macro level, with key stakeholders often pursuing conflicting priorities. Institutional arrangements tend to reinforce siloed behavior, while excessive centralization and procedural rigidity reduce the operational autonomy of R&D teams. The dominance of security-centric considerations — while understandable in a defense context — often creates additional delays in coordination, limits inter-agency collaboration, and discourages openness to external knowledge sources.

Deficiencies in resource capabilities further constrain innovation potential. Infrastructure for advanced experimentation, especially prototyping laboratories and simulation facilities, remains fragmented and outdated. Long-term employment structures prioritize loyalty and continuity over flexibility and expertise renewal, making it difficult to attract or retain personnel capable of operating across emerging technical domains. Many organizational actors lack the interdisciplinary mindset and agility needed to manage radical innovation processes. Motivation is undermined by the absence of competitive incentives, dynamic career pathways, or opportunities for visible impact. On the financial side, the ecosystem remains overly reliant on short-term, state-sponsored funding cycles, with minimal engagement from commercial or hybrid capital sources. This dependency restricts risk appetite and discourages sustained investment in radical, long-horizon initiatives.

Finally, procedural failures reflect weaknesses in how innovation processes are designed, executed, and evaluated. Closed innovation norms continue to dominate, limiting the inflow of ideas and reducing engagement with academia, startups, or dual-use technology developers. The boundary between theoretical research and field-adaptable technology remains blurry, resulting in misaligned outputs and underutilized capabilities. Codification and documentation practices are generally underdeveloped, leading to poor institutional learning and limited knowledge transfer across projects. The system also lacks mechanisms to accumulate critical mass in strategic knowledge areas, particularly in interdis-

Table 2. **Hierarchical Structure of the Framework**

Dimensions	Components
Culture	• Collaboration culture • Radical innovation importance • Organizational culture
Governance	• Policy framework • Institutional structure • Organizational structure
Resources	• Human capital • Financial resources • Infrastructure
Processes	• Knowledge management • Open innovation • Project management

Source: authors.

ciplinary and fast-moving fields where defense relevance is emerging but not yet fully institutionalized. Collectively, these structural and procedural failures underscore the fragility of the current ecosystem and the need for deliberate interventions to remove institutional bottlenecks, recalibrate priorities, and unlock latent innovation capacity.

Prioritizing drivers and sub-dimensions

The hierarchical structure is developed on two levels according to the theoretical framework extracted in the qualitative section (Table 2) to prioritize drivers and sub-dimensions with fuzzy AHP.

In the following, radical innovation resources are prioritized as an example. Considering the fuzzy values and calculating the geometric mean of experts' opinions, Table 3 presents the matrix of pairwise comparisons of resources.

Then, the fuzzy value of the matrix cells is calculated as follows.

$$S_I = (2.48, 2.67, 2.88) \odot \left(\frac{1}{9.91}, \frac{1}{9.11}, \frac{1}{8.40}\right) = (0.25, 0.29, 0.34)$$

$$S_{HC} = (3.00, 3.27, 3.58) \odot \left(\frac{1}{9.91}, \frac{1}{9.11}, \frac{1}{8.40}\right) = (0.30, 0.36, 0.43)$$

$$S_{FR} = (2.92, 3.17, 3.45) \odot \left(\frac{1}{9.91}, \frac{1}{9.11}, \frac{1}{8.40}\right) = (0.29, 0.35, 0.41)$$

Next, the relative magnitude degree of sub-dimensions is calculated.

$$V(M_I \geq M_{HC}) = \frac{0.30 - 0.34}{(0.29 - 0.34) - (0.36 - 0.30)} = 0.38$$

$$V(M_I \geq M_{FR}) = \frac{0.29 - 0.34}{(0.29 - 0.34) - (0.35 - 0.29)} = 0.46$$

$$V(M_{HC} \geq M_I) = 1;\ V(M_{HC} \geq M_{FR}) = 1;\ V(M_{FR} \geq M_I) = 1$$

$$V(M_{FR} \geq M_{HC}) = \frac{0.30 - 0.41}{(0.35 - 0.41) - (0.36 - 0.30)} = 0.91$$

Finally, the minimum magnitude degree of each sub-dimension is considered as its weight, which is later normalized (Table 4).

Table 3. **Fuzzy Matrix of Pairwise Comparisons of Radical Innovation Resources**

	Infrastructure (I)	Human Capital (HC)	Financial resources (FR)
Infrastructure (I)	(1, 1, 1)	(0.8, 0.9, 1.02)	(0.68, 0.76, 0.86)
Human Capital (HC)	(0.98, 1.11, 1.25)	(1, 1, 1)	(1.02, 1.17, 1.33)
Financial Resources (FR)	(1.17, 1.31, 1.47)	(0.68, 0.76, 0.86)	(1, 1, 1)

Source: authors.

Table 4. **Weight of Resources' Sub-dimensions**

	I	HC	FR	Weight	Normalized weight
Infrastructure (I)	–	0.38	0.46	0.38	0.16
Human Capital (HC)	1	–	1	1	0.44
Financial Resources (FR)	1	0.91	–	0.91	0.40

Source: authors.

Therefore, human capital and financial resources are the most critical radical innovation resources, respectively. Other sub-dimensions are also prioritized with similar calculations, resulting in Table 5.

Discussion

The innovation systems approach has helped fulfill strategic objectives in defense industries. However, the complexity, uncertainty, and systemic interdependencies inherent in radical innovation demand a more ecosystem-oriented perspective — especially in contexts constrained by geopolitical pressures and resource limitations (Khotbesara et al., 2023). This article contributes by proposing and prioritizing a model tailored for radical innovation in Iran's defense sector, highlighting four key drivers and twelve sub-dimensions (Figure 2, table 6).

The combined attention to radical innovation sources, culture, process, and governance indicates a comprehensive ecosystem lens. Promoting fundamental research, adopting a long-term orientation, and fostering a tolerance for failure exemplify core characteristics of radical innovation within the model. Defense-specific conditions are reflected in efforts to relax excessive ideological restrictions and enhance commercial translation of defense technologies. Similarly, reversing skilled labor outflows exemplifies how emerging country contexts shape innovation capabilities. Accordingly, the findings both resonate with and depart from existing research on innovation ecosystems. While many conceptual foundations—such as the role of leadership, openness, and network-based governance—are shared, the defense setting imposes structural constraints

Table 5. **Priorities of Drivers and Sub-Dimensions of Radical Innovation in Defense Industries**

Drivers (weight)	Dimensions	Drivers' weights	Dimensions' relative weights	Dimensions' weights
Culture (0.05)	Radical innovation importance	0.3	0.001	11
	Organizational culture	0.2	0.001	12
	Collaboration culture	0.49	0.002	10
Governance (0.23)	Policy framework	0.48	0.110	3
	Institutional structure	0.41	0.094	4
	Organizational structure	0.11	0.025	9
Resources (0.49)	Infrastructure	0.16	0.078	6
	Human capital	0.44	0.216	1
	Financial resources	0.4	0.196	2
Processes (0.23)	Knowledge management	0.38	0.087	5
	Project management	0.29	0.067	8
	Open innovation	0.34	0.078	7

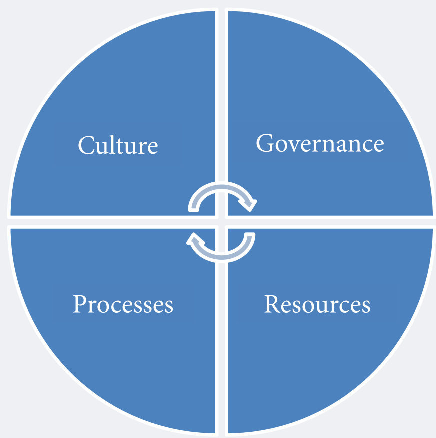
Source: authors.

and distinctive priorities. For instance, although ecosystem theory emphasizes agility and horizontal coordination, defense innovation often unfolds within rigid hierarchies. Rather than replicating commercial templates, the model favors sector-specific adaptations like semi-autonomous R&D units or dual-ladder institutional configurations.

Organizational dynamics offer a useful entry point for comparison. In both defense and non-defense settings, small and flexible structures promote creativity by reducing bureaucratic inertia (Diederiks, Hoonhout, 2007). However, changes to structure or workflows in defense contexts face heightened resistance due to security protocols, mission criticality, and entrenched administrative norms. Therefore, change management should be pursued with special precautions, focusing on a fundamental change in thinking patterns (Bao et al., 2019). Ambidextrous leadership also plays a nuanced role in radical innovation. In defense, this ambidexterity must also reconcile compliance with risk tolerance, blending procedural discipline with adaptive responsiveness. Accordingly, leaders solve the agility-discipline conflict as accumulating decision-making power in the leader leads to agile and accountable decisions. They must balance the various demands of stakeholders and team members while supporting the creation of new ideas and focusing on selected ideas with an ambidextrous approach (Alexander, Van Knippenberg, 2014). An innovative leader should have the soft skills to interact with human resources and the hard skills to manage complex technological projects (Robbins, O'Gorman, 2015). Also, leaders' forgiveness encourages radical innovation by promoting self-sacrifice among the team (Mallén-Broch, Domínguez-Escrig, 2021).

This ambivalence stems from the fact that open innovation in radical ecosystems can increase imitation risks. As a result, knowledge governance exhibits structural similarities with broader innovation ecosystems, but its operationalization diverges significantly. In general contexts, open innovation enhances absorptive capacity and accelerates knowledge flow. However, in defense, the stakes of knowl-

Figure 2. **Cyclic Scheme of Radical Innovation Model for Emerging Defense Ecosystems**



Source: authors.

Table 6. **Components of the Radical Innovation Model for Emerging Defence Ecosystems and Their Weights**

Dimensions	Components (weight values)
Culture	• Collaboration culture (0.02) • Radical innovation importance (0.01) • Organizational culture (0.01)
Governance	• Policy framework (0.110) • Institutional structure (0.094) • Organizational structure (0.025)
Resources	• Human capital (0.216) • Financial resources (0.196) • Infrastructure (0.078)
Processes	• Knowledge management (0.087) • Open innovation (0.078) • Project management (0.067)

Source: authors.

edge leakage are higher. While firms benefit from open source strategies in the short term — given the wide use of technology, rapid adaptations, and the variety of contributors — they risk long-term erosion of competitiveness. Patenting becomes vital for technology and knowledge protection (Holgersson, Granstrand, 2017). Moreover, whereas general ecosystems promote openness across all stages, defense settings require calibrated openness. Given the ambiguity in goals, difficulty in valuation, and other collaboration conflicts, idea generation and technical and commercial evaluation fit better with a closed innovation framework. In defense ecosystems, selective openness tends to occur only at the integration or application stage, when the risk of leakage has diminished and regulatory clarity improves. Selective integration of external knowledge under regulated conditions becomes feasible only at later stages (Domínguez-Escrig, 2018).

Network structures and actor roles within the ecosystem also evolve differently. General ecosystem literature favors decentralized orchestration and peer-based learning, whereas defense systems rely more on centralized leadership. In radical innovation collaborations, paradoxes — such as formality versus flexibility, long-term commitment versus costly termination, and co-creation versus knowledge conservation — must be managed (Sadovnikova et al., 2016). Structured networks governed by formal rules and aligned objectives are more effective for radical innovation than loosely governed bilateral relationships. This insight is particularly applicable to defense systems where trust must be formalized, and intellectual breadth is often lacking (Czakon et al., 2020).

Beyond organizational and governance structures, user engagement also diverges across ecosystems. Although resistance from end-users is common due to complexity and switching costs, in defense contexts, this reluctance is amplified by risk aversion, operational doctrine, and psychological burden (Lettl, 2007). Consequently, team-driven innovation often outpaces user-generated input (Robbins, O'Gorman, 2015), though involving select lead users with cross-disciplinary backgrounds can still support institutional learning (Scaringella et al., 2017). These comparisons reveal that many ecosystem principles remain relevant but require recalibration to defense-specific institutional logics. Accordingly, radical defense innovation ecosystems should be understood as adaptive, semi-open systems governed by strategic constraint. While general ecosystem theories offer valuable starting points, their application in defense settings must contend with sectoral legacies, institutional rigidity, and national security imperatives. The concept of innovation champions, for instance, is less about entrepreneurial freedom and more about navigating political and bureaucratic constraints with mission-driven resolve. Likewise, adaptability in defense ecosystems is not merely institutional agility but also strategic ambiguity management — ensuring long-term continuity while absorbing shocks and constraints.

These theoretical insights link directly to practical implications. Fundamental research undergirds technological breakthroughs but suffers from valuation challenges, time delays, and political interference. Policy frameworks must avoid blue-sky inefficiencies while sustaining long-horizon initiatives. Defense innovations with commercial spillover potential should be supported through dual-use pathways that secure IP while encouraging diffusion. Open innovation protocols, if carefully designed, can promote collaboration without compromising confidentiality. Likewise, rigid HR models in the public defense sector limit the inflow of creative talent. Reforms must prioritize cross-functional mobility, innovation-aligned recruitment, and cultural renewal. Furthermore, among the four main drivers, resource development — especially in human capital and finance — emerged as the most influential. Meanwhile, macro-level governance and political structure had stronger shaping effects than internal organizational features. These patterns underscore the importance of structural enablers over tactical adjustments. A recurrent gap in defense innovation culture is the absence of systemic thinking — reflected in fragmented governance, siloed expertise, and underdeveloped feedback loops.

Addressing various aspects of the research can direct future studies. Scholars could compare radical and incremental innovation dynamics in defense to refine context-specific strategies. Multi-case studies comparing defense and civilian ecosystems could clarify the generalizability of key findings. Further exploration of defense-sector catch-up strategies and science diplomacy would enrich policy relevance. From a methodological standpoint, alternatives to Fuzzy AHP—such as Fuzzy ANP or combined VIKOR models — could improve scenario robustness and account for interdependencies. Comparative testing using Fuzzy TOPSIS might also offer empirical validation across contexts.

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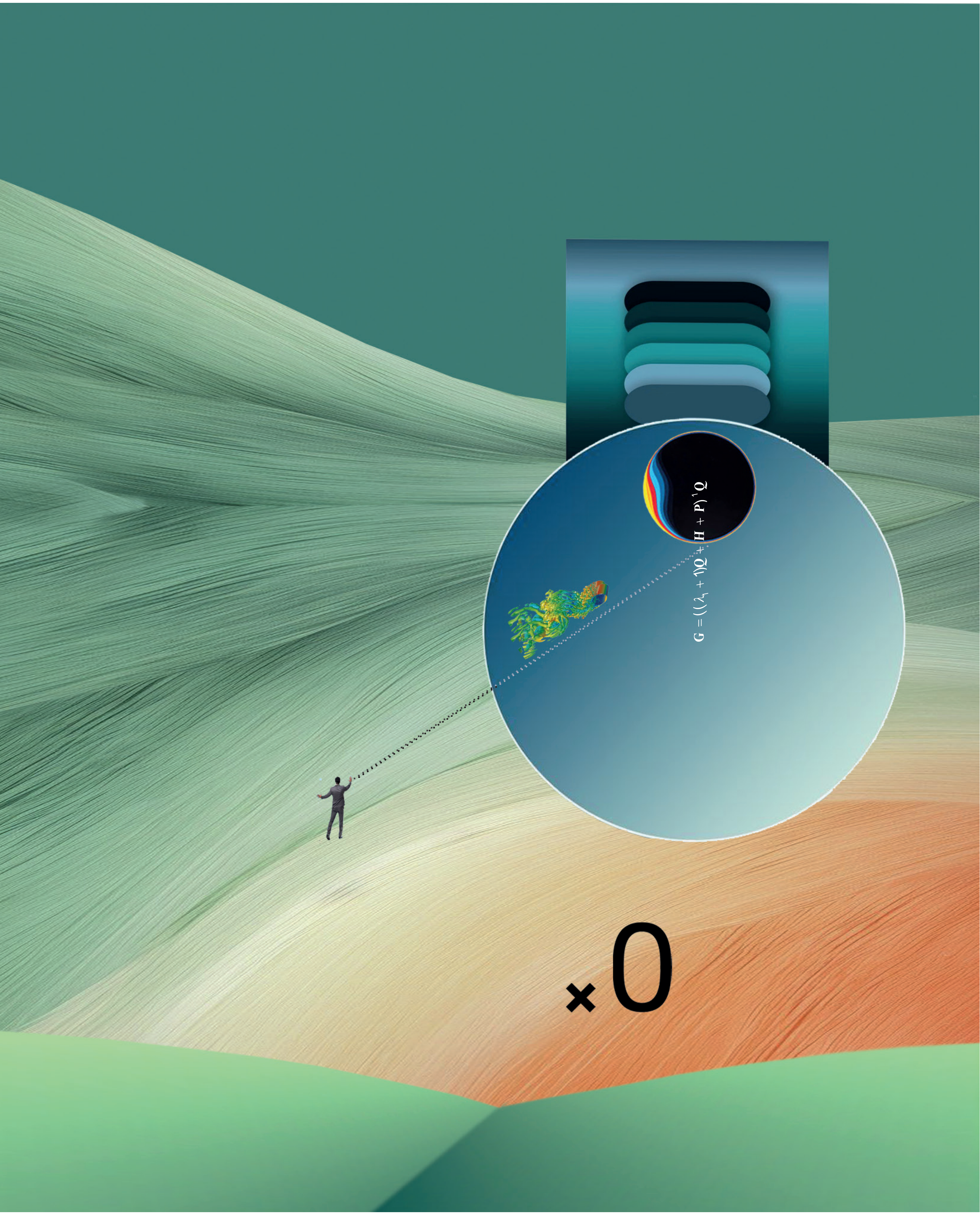
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Formation Modelling for Inter-Agent Negotiation and Collaboration with the Same Value System

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Abstract

To maintain the efficiency and competitiveness of the organization, it is necessary to integrate resources and data, which requires cooperation between all agents. Negotiations are inter-agent interactions between members of different teams necessary to achieve corporate goals. Success is determined by the context-specific mental attitudes of the participants. The article analyzes the cooperation of agents based on common values and the influence of various characteristics on this process: communication about the strategy, horizontal or hierarchical structure of teams, ambidexterity of managers, personnel training and knowledge acquisition. The complexity of the subject - the dynamics of agent behavior in various processes and their interaction with the corporate environment - required the use of agent-based modeling and simulation (ABMS). This method allows you to effectively analyze complex relationships and behavior of agents in dynamic systems, exploring the mechanisms of intra-corporate interaction through the transformation of real conditions into mathematical models of various scenarios. To develop the methodology, the DARMA structure (Development of Artificial Representative Designs in Agent-based Modeling and Simulation) is proposed. The results show the influence of managerial ambidexterity and structure type on the level of agent cooperation: horizontal approaches provide greater depth of interaction compared to hierarchical ones, which facilitate only basic interaction.

Keywords: agent-based modelling; inter-agent collaboration; negotiation; same value system; team structure; ambidextrous leadership; knowledge absorption

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Introduction

Organizations enhance their competitive advantage by fostering collaboration and integrating diverse resources to drive innovation (Lusch et al., 2010). Traditionally, hierarchical structures were the dominant mechanisms for managing collaboration, as they provided control and efficiency (Dickson, 2000). However, modern organizations increasingly adopt team-based structures that emphasize cross-functional interactions and flexibility (Warner, Wäger, 2019). While this shift enhances adaptability, it also introduces challenges in alignment, coordination, and maintaining a shared purpose across diverse teams (Schneider, 2020). Previous research has explored how structural changes impact organizational responsiveness and resource sharing (Gittel, 2016), yet understanding the mechanisms that facilitate inter-agent collaboration—particularly within teams that share value systems but exhibit cognitive diversity—remains an open question.

Cognitive diversity, defined as variations in thinking styles, expertise, and problem-solving approaches, plays a critical role in organizational decision-making and innovation (Wang et al., 2016). While a shared value system fosters trust and alignment among team members, cognitive diversity introduces new perspectives that can enhance problem-solving but also create coordination difficulties (Stein et al., 2024). Prior studies have examined demographic diversity, but research on how cognitive diversity influences collaboration within structured organizational settings remains limited (Qu et al., 2024). Furthermore, the role of ambidextrous leadership in integrating cognitive diversity while preserving shared value systems is underexplored (Fernández-Pérez de la Lastra et al., 2022). Addressing how organizations can optimize collaboration by leveraging cognitive diversity within shared value systems represents a critical research gap, as visualized in Figure A1 (see Appendix)[1].

This study examines the interplay between organizational communication, ambidextrous leadership, cognitive diversity, and shared value systems in shaping inter-agent collaboration. While previous research has explored hypergame theory in competitive decision-making (Sasaki, Kijima, 2016), its application in collaborative environments involving cognitive diversity has not been thoroughly examined. Using Agent-Based Modeling and Simulation (ABMS), this study models how cognitively diverse agents navigate shared value systems and collaboration dynamics. Unlike prior research that focuses solely on structural or behavioral influences, this study integrates cognitive diversity as a crucial parameter in inter-agent collaboration modeling, providing a novel perspective on balancing innovation-driven diversity with structured coordination mechanisms. Figure A1 represents the conceptual framework that maps the role of leadership, team structure, communication, and knowledge-sharing in shaping inter-agent collaboration within shared value systems.

This research contributes to organizational behavior, strategic management, and computational modeling literature by offering a structured framework for optimizing collaboration in knowledge-intensive environments. It expands the application of hypergame theory to collaborative contexts, introduces cognitive diversity as a key driver in inter-agent collaboration, and provides practical insights on managing cognitive differences through strategic leadership and communication. The findings are expected to inform both theoretical advancements and managerial practices in designing adaptive team structures.

Literature Study

Organizations have the complex reality of various elements and phenomena. Researchers focus on several organizational elements that interact directly with the collaboration process between teams and agents within them.

Communication of Organization Strategy and Awareness of purposes

Wang et al. (2021) stated that shared vision, usually seen as a top-level concept, facilitates information and resources flow and exchange within the organization as a relational process to strengthen the coordination efficiency, understanding facilitation, constructing robust cooperation, and communication basis. Whether top management's strategic awareness message is more effective in influencing boundary personnel. Previous research studies also concluded that leadership capabilities, specifically in hybrid workplace conditions, significantly affect the awareness of members' goals in their organizations (Nugroho, Hermawan, 2022).

Awareness describes an individual's comprehension reflection about why the change is being made, the nature of the change, and the risk of not changing (Hiatt, 2006). There are several factors that influence the change awareness of the people (Angtyan, 2019): (a) individual view an existing state, (b) how a person views a situation, (c) the reliability of the sender's, (d) false informa1tion or rumours spreading, and (e) the rationale for the change is debatable. There are three stages of situational awareness relating to various mental models from Endsley (2018) study, namely: (a) perception of the elements in the environment, (b) current situation comprehension meaning in relation to the operator's responsibilities and objectives, (c) mental image ability to guide future projection.

Communication of organizational strategy intensity related to the agent's awareness of purpose affects inter-agent collaboration. The occurrence of awareness

[1] The materials in the Appendix are available on the article's online page: https://doi.org/10.17323/fstig.2025.24279

of purposes from members is set based on probabilities that can be assigned a value and at this study's intended value based on the previous research (Nugroho, Hermawan, 2022) as real-world environment data.

Ambidextrous Leadership

Leaders must be flexible, synthesized in dialectical thinking that negates the dichotomy and yields knowledge, and connect various shared knowledge contexts inside and outside the organization (Nonaka, Takeuchi, 2019). Organizational and leader ambidexterity mixed to solve the dilemma between exploration and exploitation in highly competitive environments (Fernández-Pérez de la Lastra et al., 2022). There are two modes of organizational learning, exploration and exploitation, as the prominence of organization ambidexterity to utilize their resources (Raisch et al., 2009). Exploration focuses on new possibilities with several generic terms, i.e., innovation, discovery, experimentation, and flexibility; on the other side, exploitation focuses on old certainties with several generic terms, i.e. efficiency, refinement, selection, and execution. Exploration and exploitation are essential but often compete for scarce organizational resources and attention.

Guo et al. (2020) studied ambidextrous leadership using 'loose–tight leadership' as leader–member exchange to study management dynamics from the perspective of power in the organization. Leader–member exchange is the relationship between leaders and other individuals, emphasizing an effective, mature, and reciprocal exchange which benefits all parties. The influence of ambidextrous leadership of team leaders in sharing value systems focuses on exploiting their work and exploring various opportunities for developing future work for their team members to their team structure. This research investigates the effect of ambidextrous leadership of team leaders to the agent's same value system and enhancement of inter-agent collaboration.

Team Organization Structure

Demands forms of organization quite differ from bureaucracies because of rapid technological changes, devolution, scarce resources, and rising interdependence that make an increasingly 'networked' world (Barley et al., 2017). Lee and Edmondson (2017) emphasized this phenomenon's several terms, including less-hierarchical organizing, flat organizations, and team-based work. Less-hierarchical organizing defines as efforts to adapt the managerial hierarchy to make more decentralized authority relative to classic unity of command hierarchical principles, supervision of lower offices by higher offices, and obedience to superiors. Decentralized authority is implemented by decreasing the number of levels of formal authority (i.e., "flattening" the formal hierarchy) or by creating a more equitable distribution of authority across existing hierarchical levels. Zhang et al. (2014) stated that flatness is an organizational state with few levels in the hierarchy or chart and a few management levels in the chain of command. Few chains of command tiers reduce hierarchical costs or barriers associated with cross-functional communication and shortens the length of decision-making to make joint decision-making and cooperation (Zhang et al., 2014). At lower levels of centralization, authority is assigned to lower echelons, increasing their feelings of psychological ownership of the products at their responsibilities and their feelings of responsibility and reducing internal resistance (Walheiser et al., 2021).

Organization members in self-managed teams that make more decision-making on behalf of the organization delegate managerial authority to groups of individuals who are close to and experts (Lee, Edmondson, 2017). In a collaborative community, members can self-organize and self-manage (actor-oriented), which is increasingly used as an emerging organizational form in knowledge-intensive environments (Haakonsson et al., 2017). A low degree of centralization of the decision-making process can complement and enhance the knowledge performance that may result from formalization and complexity (Zhou, Li, 2012). Tall and hierarchical teams produce less novelty often develop existing ideas relative to flat, egalitarian teams, and increase short-term citations but decrease long-term influence (Xu et al., 2022).

Considering various discussions and research results in the literature above, in this study, the organizational structure is focused on agent autonomy and decision-making difference between hierarchical and flat organization structures. This study explores the differences in hierarchical and flat team structures between interacting agents in producing higher inter-agent collaboration.

Cognitive Diversity and Team Collaboration

Cognitive diversity refers to the differences in thinking styles, knowledge, skills, and values among individuals within a team or organization (Wang et al., 2016). Unlike demographic diversity, which is based on observable characteristics, cognitive diversity influences how individuals process information, approach problem-solving, and generate innovative solutions (Qu et al., 2024). Research suggests that teams with high cognitive diversity tend to enhance creativity, adaptability, and decision-making quality, as they integrate multiple perspectives to address complex challenges (Kanchanabha, Badir, 2021). However, cognitive diversity does not automatically result in better collaboration; instead, it can create coordination challenges, communication barriers, and potential conflicts when team members struggle to align their differing mental models (Rocca, Tylén, 2022). Managing cognitive diversity effectively requires strong leadership and structured communication to ensure that diverse perspectives are synthesized into collective decision-making (Meussen et al., 2018).

In inter-agent collaboration, cognitive diversity can either enhance or hinder team effectiveness depending on how well it is integrated into the shared value system. On one hand, a diverse cognitive landscape broadens the team's problem-solving capacity, leading to more innovative solutions and improved adaptability (Stein et al., 2024). On the other hand, excessive divergence in cognitive approaches can cause fragmentation and misalignment, reducing the team's ability to operate cohesively (Basharat, Spinelli, 2008). Studies highlight that a balance between cognitive diversity and a strong shared value system is critical for optimizing collaboration, as it allows for both creative exploration and coordinated execution (Lix et al., 2022). This study examines how inter-agent collaboration can integrate cognitive diversity while maintaining a cohesive strategic vision to foster organizational resilience and long-term innovation.

Sharing the Same Value System

Real-world interactions and disputes can be described, analyzed, modeled, predicted and determined for the possible resolutions or equilibria by hypergame (Kovach, Lamont, 2019). Sasaki and Kijima (2016) have introduced the hypergame concept, described as a linked set of perceptual games, rather than as single moves, that deals with players who may misperceive some components of a game and interpret as expressing a particular player's perception of the situation.

Sasaki and Kijima (2016) explained a poly-agent system of models of decision situations by four different types: simple hypergame, symbiotic hypergame, hypergame sharing the same value system, and ordinal non-cooperative game. The hypergame sharing the same value system level happens after each agent shares the understanding of the situation and produces a sort of consistency between the interpretations, then become perceives other's preference with global consistency where both agents believe face the same game. The concept of hypergame in this study used in four different types of decision situation models as a conception of an agent's mental model in interacting with other agents to develop collaboration. The agents are in a condition of shared understanding of the situation, then work with other teams to produce a sort of consistency between the agents. In this study, the hypergame concept does not use in a mathematical equation approach but applies in the mental model conception of agents and includes it in the modelling process.

The focus of this study is on information by iterating interactions, they can improve the perceptions close to the true nature's game. The hypergame shares the same value system level as intra-organization agent interaction that facilitates collaboration happens. The same value system is formed in a condition when an agent already has an awareness of purpose sourced from the communication of organizational strategy and an understanding of the important value of ambidexterity in exploiting current jobs and exploring future job opportunities that are influenced by ambidextrous leadership. The occurrence of the same value system sharing in the agent's interaction is set based on probabilities that can be assigned a value, and in this study, the intended value is based on the researcher's previous research as real-world environment data.

Knowledge-Intensive Environments and Absorption Levels

The organization's success depends on its members' ability to collaborate in knowledge-intensive environments (Haakonsson et al., 2017). Knowledge is the main component of any different intellectual capital configuration (through human capital, social capital, or organizational capital) to gain an organization's strategic goals pursued. (Fernández-Pérez de la Lastra et al., 2022) Knowledge-creating process inspires the organization to do more than strive to be profitable or focus on the competition but also survive and envision the future (Von Krogh et al., 2012).

The exchange of knowledge and skills as a central part of operant resources from one party/individual to another party/individual is part of the premise that forms the basis for the formation of services and products (Vargo, Lusch, 2016). People create knowledge by combining tacit and explicit knowledge in their social interaction with each other and the environment (Von Krogh et al., 2012). Inkpen and Tsang (2005) stated that managing collaborations skill and the development of knowledge absorptive capacity are serendipitous benefits of collaboration. Access to knowledge is reflected as a fundamental and pervasive concern in inter-organizational collaborations.

Organization concert and effort to create a knowledge-intensive environment is essential for business success by strengthening knowledge re-growth. Employee development and knowledge programs range from classic ones such as employee competency training, self-learning, monitoring periodic work evaluations, coaching programs, specific project/ad-hoc assignments, community sharing, rolling of work and assignments, certification targets, and improvement of business group cycle. Furthermore, each agent has a knowledge level as mastery level of knowledge, considering the assumption that when the inter-agent collaboration process involves agents with sufficient levels of knowledge, it will be a differentiator from the quality of the collaboration carried out.

Inter-agent Collaboration

Collaboration is a reciprocal process in which two or more individuals or organizations that have common objectives work together by sharing resources and knowledge to seek more benefits (Son, Rojas, 2011). There are several kinds of collaboration terms used by several researchers: inter-organizational collaborations (Kaya, 2019), supply chain collaboration (Cao, Zhang, 2011), collaborative community (Haakonsson et al., 2017), and intra-organizational collaboration (Kaya, 2019). Inter-agent collaboration in this study researcher defines as activities of working and sharing between each agent as a representation of different teams or work units in the internal organization.

There are five key dimensions of collaboration that construct the process of collaboration (Thomson et al., 2007): (a) governance as working rules on behavior and relationship, (b) administration as action implementation and management, (c) mutuality as beneficial interdependencies experience on a shared or differing interests for an issue, (d) norms as longer-term "psychological contract" based on trust, relationships, and reputation, (e) autonomy that's sourced from agency involvement between self-interest and collective interest.

In this study, inter-agent collaboration becomes the dependent variable which is influenced by various other variables that have been described previously. The occurrence of inter-agent collaboration in the agent's interaction is set based on probabilities that can be assigned a value. This study's intended value is based on previous research (Nugroho, Hermawan, 2022) as real-world environment data.

Agent-Based Modeling

Filatova et al. (2013) explains that ABMS as a modelling and simulation technique has the primary added value ability to represent human actors/agent behavior becomes more interactions, realistically, heterogeneity, evolutionary learning, accounting for bounded rationality, and out of equilibrium dynamics, combined with the dynamic heterogeneous representation of the spatial environment representation. However, no model will completely represent reality, but it helps to understand phenomena better. Building realistic but simple societal models is the main barrier to this approach because most social and psychological theories are not expressed simply in a way implemented in computer models. Although models that do not reflect actual socio-cognitive processes, even if "artificial", this does not mean they are not realistic because they can clarify the system's dynamics under diverse conditions to support policy assessment useful or produce interesting result situations to explore more in-depth investigation. Therefore, it is essential for decision-makers and modelers to always pay attention to the assumptions and imitations of a model from the studies being conducted.

The ABMS model study needs to fill in parameter values to determine the strength of the relationship when an increase in an element is associated with an increase in a related element. Previous research that used to fill these values was titled "Strengthening Collaboration through Perception Alignment: Hybrid Workplace Leadership Impact on Member Awareness, Understanding, and Learning Agility" (Nugroho, Hermawan, 2022).

This research was conducted from April to May 2022, using a survey questionnaire as a measurement tool with variables: Hybrid Workplace Leadership Capabilities, Awareness of Purpose, Understanding of Self & Others, Learning Agility, Perception Alignment, and Inter-Team/Organization Collaboration. Previous research used a quantitative approach with PLS-SEM by utilizing bootstrapping process application; there are path coefficient results between constructs in total effect to see the significance and strength of the relationship between constructs as shown at figure A2. These results used as probability values or several parameter assumptions setting in this ABMS study.

Research Method

ABMS is a method to model complex systems based on agents with their autonomous behavior and interaction (Macal, North, 2010). Agent-based simulation models are powerful tools and are increasingly popular among researchers in the modelling and simulation of complex systems (Nguyen et al., 2008). This study uses NetLogo as a computer application program based on Wilensky and Rand (2015). A set of interaction rules arrange agents' actions and consider relevant information of the environment to evoke agents' behavior that evolves in ABMS (Kroshl et al., 2015).

There are three sequential steps that consist of several research sub-processes to build agent-based modelling and simulation, namely: input, process, and output, as seen in Table 1.

Conceptual Design

The conceptual design contains various variables that are the target of research to determine the content and conceptions explored during modeling. Three stages conceptualize in this agent-based modelling study starting from the initial condition of interaction, sharing the same value system, and the last inter-agent collaboration, as seen in Figure A3.

The initial condition of interaction have four elements of organization: (a) communication of organization strategy related to the intensity of its presence in the organization environment, (b) team leader with ambidextrous leadership related to the ownership of this ability by the team leader, (c) knowledge-intensive

Table 1. **Research Model Development Process**

Input	Process	Output
• Research Questions • Research Purposes • Literature Review • Conceptual Design	• Behavior Target Content • Conception • Modeling Representation • Coding Implementation	• Alternative Scenario Development • Simulation of Alternative Scenario • Analysis • Conclusion

Source: authors.

environment related to the knowledge-intensive level conditions in the organization, (d) team organizational structure is separated into two differentiating conditions between hierarchical or flat team structure.

Then in the second stage, there are attributes and behavior of team members as agents in the environment and the team, namely their ownership of awareness of purposes due to the communication of organizational strategy and the influence of leaders regarding working in an ambidextrous manner. Sharing the same value system happens when two agents already have the same value system, which becomes his capital when interacting with agents from other teams. For agents in a hierarchical team, work interactions with agents from other teams depend on approval and direction from the team leader, in contrast to agents from flat teams who are more autonomous. When an agent interacts with an agent from another team, if both have the same value system that is equally formed, there will be a process of sharing the same value system relationship. It will become the foundation for further interaction in the collaboration process.

Finally, the third stage is about realizing inter-agent collaboration. Conceptually it needs to be a reminder that the interaction process builds collaboration between agents who are representatives of the team and needs to get approval to make the process or product resulting from their interaction recognized as a team collaboration. In this case, the team structure will differentiate the stages in decision-making, where flat teams have a leaner decision-making process compared to hierarchical teams, especially in terms of collaboration involving agents with high knowledge absorption thinking (higher collaboration).

Agent-based Process Development

Conceptual framework design translates to research model process by Designing Artificial Representative Models on Agent-based (abbreviated to DARMA framework), as seen in Figure A4.

The DARMA framework identifies research variables from the conceptual design that is prepared, considering the behavior target content that arises from variables and relationships between variables. Then defining the conception of the flow and interaction between related variables possibly happening and the alternative impact or result on the real world conceptually wanted to be captured in the model. This concept must translate into a modelling representation programmed in the application. Researchers must consider the programming process, logic, algorithm, and coding limitations that can translate into the representation model.

Based on this framework, the cascade down the detail of each research variable for inter-agent collaboration visualization is in Table 2.

Then process developed of each variable and agent simplify on one page overview of ABMS design, as seen in Figure A5.

Researchers were detailing model representation drawn in the logic design flow of the model that's break down the process to implement the design. Logic design flow describes the sequential and stages details of the variables in the running model between agents in this study's agent-based model and simulation. The logical design flow of this research for the hierarchical team model version is in Figure A6 and for the flat team model version in Figure A7.

Agent's Behaviors and Attributes

Based on logic design, step-by-step interaction details are built to set-up each agent's behavior and attribute with several parameter settings. The behavior settings as the basic parameters of each agent consist of movement spot, behavior setting, attribute change impact and real-world representation. Step-by-step interaction details with impact on changes in color and status attributes of team members are shown in Figure A8 for the hierarchical team model and Figure A9 for the flat model version.

Agents & Environment Customization Setting

The agent-based model is structured to simulate several scenarios of different agent and environment conditions and analyze the results. Several settings related with situations, attributes, and parameters of agents and environments can be customized on various simulation scenarios as shown in Table 3 below.

Agent-based Modeling and Simulation Scenario Implementation

The visualization of the ABMS model in Netlogo 6.2.2 application is shown on Figure A10 based on the design, parameters, flow, and characteristics. The analysis was carried out using the ABMS modeling developed to run simulations. The agent and environment are set according to the scenario sequence studied. Determination of the scenario chosen by cascading down each condition of variables and interactions between agents that may arise within the organization. Each major scenario has several sub-scenarios in it that describe alternative conditions of each research variable variation selected, for comparison analysis between conditions.

Results of each alternative condition in the sub-scenario assembled to get the pattern for the research analysis process. There are four major scenarios simulated as summarized in Table 4 below.

The scenarios in the model represent processes of four years (4 X 365 days) or 1460 ticks' days simulation in the NetLogo 6.2.2 program, considering that most scenarios within that time have produced saturated patterns. Furthermore, each alternative scenario runs in the 25 times iteration process, and the average result of the iteration becomes data for analysis of each proposition.

Table 2. **Designing Artificial Representative Models on Agent-based for Inter-agent Collaboration**

1) Awareness Team Member

Variables	Internationalization of Organization Strategy Communication
Conception	Organization strategies communication campaign / activities to gaining organization members awareness in thinking and doing job
Modeling Representation	Team members interaction with organization strategy communication campaign, with probability to capture / internalize it
Coding Implementation	- Meet with stars as representative of organization strategy, communication campaign - There is a multiplication with the probability value of possible awareness - Stars can be custom, represent of degree of campaign in organization

2) Autonomous Team Member

Variables	Organization Structure Types (Hierarchical / Flat)
Conception	Types of organization structure reflect on hierarchical / flat process to do work activities (i.e. autonomy, flexibility, decision making tiering)
Modeling Representation	Team members moving out procedure from their team to interaction area with other team members
Coding Implementation	- Meet with team leader to get approval and order to moving out from team area, as representation rigid boundaries for hierarchical organization type - There is a multiplication with the probability of approve going out - As a contrast, team members have flexible autonomy to move in flat organization type

3) Team Member Acceptance of Ambidexterity

Variables	Leadership Type
Conception	Leadership type and capabilities of team leader / coordinator / seniors to manage and influence team members in exploiting current job and exploring future development
Modeling Representation	Leaders / seniors interaction, also as value transfer / influence, with team members from their or other teams
Coding Implementation	- Interaction with leaders / seniors that have ambidexterity value for influencing members to adopt and have mindset to develop collaboration - Team members may be influenced by the ambidexterity of their leaders / seniors but do not yet have awareness of organizational strategy

4) Same Value System Team Member

Variables	Same Value Perception
Conception	Team members have same fundamental organization value perception about their organization strategy awareness and ambidexterity in exploiting current and exploring future
Modeling Representation	Team member completely get awareness of organizational strategy and influencing by ambidextrous leader
Coding Implementation	- Have met and passed the process with the star and ambidextrous leader - There is a multiplication with the probability of same value

5) Finalize Collaboration

Variables	Inter-agent Collaboration
Conception	Matching with other agent that have organizational same value perception as foundation to doing job, after series of agent interaction with various value
Modeling Representation	Interaction and matching process between members from different teams based on organization strategy and ambidexterity perspective as fundamental organizational same value
Coding Implementation	- Meet with team member from other team that have same value - There is a multiplication with the probability value of collaborated members

6) Decision Making Collaboration

Variables	Organization Structure Types (Hierarchical / Flat)
Conception	The length of the decision-making process is influenced by the type of organizational structure, including decisions related to collaboration processes or outputs. The hierarchical type is characterized by layers of process stages in decision making compared to the flat type
Modeling Representation	Team members meet with decision makers to get approval on collaboration process / output
Coding Implementation	- Meet with team leader to review the collaboration and if pass go to top management (chief or deputy) to get approval of collaboration process / output in hierarchical type. But in flat type, collaboration approval directly to final decision makers (chiefs or deputies) - There is a multiplication with the probability value of collaborated persons

Table 2 continued	
7) Simple Collaboration vs Higher Collaboration	
Variables	Knowledge Level Distinction
Conception	Knowledge level of each collaborated members become a baseline represent the mastery of competences and experiences of the job to distinct the type of inter-agent collaboration (simple and higher collaboration)
Modeling Representation	Knowledge level of two collaborated members distinction the collaboration result
Coding Implementation	- Low knowledge level (until certain distinction point) grouping as simple collaboration - Higher knowledge level (from central distinction point) grouping as higher collaboration

Source: authors.

Findings And Discussion

Communication of Organizational Strategy and Inter-Agent Collaboration

The simulation of the model shows in Figure A10 as a graph of the dynamics of inter-agent collaboration affected by various communication of organization strategy intensities (a scenario in this study from 3, 10, and 20). Based on a comparison of the results between the three graphs in Figure A11, the pattern of line shifts of the four types of inter-agent collaboration shows an increase between the graph with increasing communication intensity.

Simulation of the team leaders with (or without) ambidextrous leadership impacts the appearance of the same value system and inter-agent collaboration in the flat and hierarchical team shown in Figure A12. The ambidextrous leadership in the hierarchical team leader affects the number of appearances of the same value system followed by the emergence of inter-agent collaboration. Meanwhile, when the flat team and the hierarchical team are both led by a team leader with ambidextrous leadership, all the teams together produce the same number of same value systems and inter-agent collaboration, which is relatively high compared to the two previous conditions.

Table 3. **Simulation Scenarios, by type of Agent Behavior**

1. Team structure (Burns, Stalker, 1961; Mintzberg, 1979; Tushman, O'Reilly, 1996)
- Flat structure allows multiple leaders - Hierarchical structure has one leader per team - Random structure chosen by the program
2. Team leader (O'Reilly, Tushman, 2013; Mom et al., 2009; Gibson, Birkinshaw, 2004)
- Ambidextrous leader manage both exploration and exploitation strategies effectively - Non ambidextrous leader manage either exploration or exploitation strategies - Random leader chosen by the program
3. Team member (Gupta et al., 2006; Lavie et al., 2010)
Customizable for the first and second teams
4. Communication (Gibson, Birkinshaw, 2004; Jansen et al., 2008)
Proportion of communication intensity compared to the number of team members in each team
5. Knowledge growth (March, 1991; Levinthal, March, 1993; Gupta et al., 2006)
Flexible schedule options; replicates real-life scenarios of skill and knowledge development through structured and unstructured learning activities
6. Knowledge level (Nonaka, Takeuchi, 1995; Grant, 1996; Nugroho, Hermawan, 2022)
- Simple collaboration - Higher collaboration
7. Inter-agent collaboration (Simsek, 2009; Nugroho, Hermawan, 2022; Raisch, Birkinshaw, 2008)
- Probabilities of: awareness; approved going out; ambidexterity; collaboration - Perfect probabilities - Random 50:50 probabilities
8. Cognitive Diversity (Wang et al., 2016; Qu et al., 2024; Rocca, Tylén, 2022)
- Low: Agents have similar thinking styles and predictable decision-making processes. - Medium: Agents exhibit moderate diversity in thinking, leading to balanced creativity and efficiency. - High: Agents demonstrate significant variation in cognitive styles, increasing innovation but requiring strong integration mechanisms
Source: authors.

Table 4. **Four Major Scenarios**

Description	Variables Tested
Scenario 1	
Tests the proposition: «The intensity of communication of organizational strategy related to agent awareness of purpose affects inter-agent collaboration»	- Communication of organizational strategy - Awareness of purpose - Inter-agent collaboration
Scenario 2	
Tests the proposition: «Ambidextrous leadership of team leader affects agent same value system and enhances inter-agent collaboration, especially in hierarchical teams»	- Ambidextrous leadership - Same value system - Inter-agent collaboration
Scenario 3	
Tests the proposition: «Differences in hierarchical and flat team structures between interacting agents result in more collaboration in flat structures»	- Team organizational structure - Knowledge absorption level - Inter-agent collaboration
Scenario 4	
Tests the proposition: «Strengthening knowledge re-growth impacts inter-agent collaboration, especially in both flat and hierarchical teams»	- Knowledge-intensive environment - Inter-agent collaboration - Team organizational structures
Source: authors.	

Hierarchical and Flat Team Structures and Inter-Agent Collaboration

The structure composition between teams greatly influences the dynamics of forming inter-agent collaboration. A simulation of the dynamics of inter-agent collaboration affected by different team structures between the hierarchical and flat teams is shown in Figure A13. The graph in this figure represents these situations sequentially: (a) the first team is flat, then the second team is hierarchical, (b) the first and second teams are flat, (c) the first and second teams are hierarchical.

Interaction between flat and hierarchical teams results in inter-agent collaboration with higher types of inter-agent collaboration patterns that appear more in flat teams, and conversely, simple types of inter-agent collaboration appear more in hierarchical teams. The results of simple types of inter-agent collaboration in the condition that the two teams met in a hierarchical manner showed the most significant number, forming the largest total collaboration. Conversely, when the two flat teams met, there were fewer simple types of inter-agent collaboration and a reduced total number of collaborations compared to the others.

The graphic result in Figure A14 visualizes the effect of knowledge source re-growth on inter-agent collaboration with simulations of knowledge source re-growth become shorter sequentially from 182, 120, 90, 60, to 30 days. Higher types of inter-agent collaboration will grow faster in both flat and hierarchical teams when the intensity of knowledge source re-growth is shorter, but simple types of inter-agent collaboration decrease significantly as seen at Table 5.

Agent-based Model Verification and Validation

There is testing for verification and validation processing to increase confidence in the modeling results that developed based on the ABMS approach (figure A15). Railsback and Grimm (2019) stressed the need for validation approaches, especially for an ABMS, that consider a model valid based on the qualitative and subjective evaluations of its contextual adequacy rather than on an objective representation of the system under study.

Following are some matters related to verification and validation. Model verification is a process to determine whether the abstract or conceptual model is correctly translated to the programming implementation (Railsback, Grimm, 2019). The verification process in NetLogo 6.2.2 programming found in the code writing at "Check" menu. This menu will light up and display a message if there is missing, incorrect or unable to run programming logic when the program implemented. Models of this study has been checked and tested working well to produced diagrams and results.

Model validation is a process to determine the extent to which the conceptual model developed is sufficiently reasonably accurate to reflect conditions in the real world and the output of the simulations is consistent with real-world output (Railsback, Grimm, 2019).

Table 5. **Recapitulation of Inter-Agent Collaboration – Knowledge Re-growth of Knowledge-Intensive Environment**

Pattern	Learning periods (*days*)				
	182	**120**	**90**	**60**	**30**
Participation in basic cooperation by representatives of the first team	92.392	65.653	48.735	35.624	21.944
Participation in high-level collaboration by representatives of the first team	66.666	90.125	108.656	122.438	137.540
Summary: participation in interaction by representatives of the first team	159.058	155.778	157.390	158.062	159.484
Participation in basic cooperation by representatives of the second team	135.983	109.971	90.523	65.436	36.881
Participation in high-level collaboration by representatives of the second team	26.628	51.167	70.477	100.211	129.224
Summary: participation in interaction by representatives of the second team	162.611	161.138	160.999	165.646	166.104
Overall cooperation indicator	321.669	316.916	318.389	321.708	325.588
Source: authors.					

There are several validation techniques to test the developed modeling. Internal validity was checked by running the model for several replication simulations using different random seeds to see the sample replications' inconsistency (large variability). In this study, 50 replications were carried out for a model scenario, and statistical analysis resulting as normal distribution with p-value more than 0.05. Sensitivity Analysis was performed to determine if changes in the model inputs affect the model output as expected (Hunter, Kelleher, 2022). Changes in components/settings have an impact on changes in results in various testing scenarios, thus indicating that this model has sensitivity.

Discussion

This study integrates fundamental organizational elements that influence agents' internal values and cognitive processes in forming inter-agent collaboration using the hypergame conception and agent-based modeling and simulation (ABMS). The Designing Artificial Representative Models on Agent-based (DARMA) framework developed in this study enables the translation of real-world organizational dynamics into an artificial environment for computational simulations. These results provide insights into how organizational design, leadership, and structural configurations influence collaborative behaviors, offering implications for business management and public policy in optimizing team performance. Cognitive diversity emerges as a crucial factor in shaping these collaborative dynamics, as it enhances innovation and problem-solving while simultaneously introducing coordination complexities that organizations must navigate effectively (Wang et al., 2016; Rocca, Tylén, 2022).

The findings suggest that enhancing communication about organizational strategy significantly improves inter-agent collaboration. The simulation results indicate that as communication intensity increases, inter-agent collaboration strengthens, supporting Wang et al. (2021), who found that a shared vision enhances team members' commitment and behavior alignment. However, the impact of communication is more pronounced when cognitive diversity is considered, as diverse cognitive styles allow teams to process and interpret strategic messages differently, leading to richer discussions and greater adaptability (Qu et al., 2024). Similarly, the flat team structure generally fosters higher inter-agent collaboration, as it enables greater autonomy and flexibility in decision-making (Takahashi et al., 2004). However, the effect of team structure on collaboration is amplified when cognitive diversity is present, as diverse agents seek robust and suitable counterparts to leverage unique talents and competencies, reinforcing cross-functional problem-solving (Kanchanabha, Badir, 2021).

Leadership plays a key role in bridging cognitive diversity and collaboration. The results demonstrate that ambidextrous leadership strengthens the formation of shared value systems, leading to more robust inter-agent collaboration, particularly in hierarchical teams. This aligns with the work (Danişman et al., 2015), who found that leadership fosters organizational learning and knowledge integration. However, when both hierarchical and flat teams are led by ambidextrous leaders, collaboration dynamics shift—hierarchical teams experience higher cognitive alignment, while flat teams sustain divergent yet synergistic problem-solving approaches (Stein et al., 2024). Cognitive diversity further amplifies the effect of leadership, as diverse cognitive inputs require strong guidance to synthesize perspectives, align team efforts, and drive knowledge integration (Meeussen et al., 2018).

The study also highlights the role of knowledge re-growth dynamics in inter-agent collaboration. Findings indicate that shorter knowledge re-growth cycles lead to increased higher-order collaboration, supporting Vargo and Lusch (2016), who emphasize that knowledge exchange strengthens organizational relationships and co-creation of value. However, cognitive diversity influences how knowledge is absorbed and applied teams with high cognitive diversity demonstrate greater learning agility and adaptability, making them more effective in leveraging new knowledge to drive collaboration and innovation (Lix et al., 2022). Organizations should therefore design customized learning programs that account for both team structure and cognitive diversity, ensuring that knowledge is effectively integrated and applied across diverse teams.

Overall, this study confirms that cognitive diversity acts as both an enabler and a challenge in inter-agent collaboration. While it enhances innovation, adaptability, and problem-solving, it can also lead to fragmentation and misalignment if not managed effectively. To optimize collaboration, organizations must balance cognitive diversity with structured leadership, communication, and shared value systems (Basharat, Spinelli, 2008). Future research should further explore contextual mechanisms that enable cognitive diversity to be fully leveraged without causing disruptions in team coordination and collaboration dynamics.

Conclusion

This research integrates real-world organizational behaviors with computational modeling through Agent-Based Modeling and Simulation (ABMS), demonstrating how key organizational elements such as leadership, communication strategies, team structure, and knowledge management influence inter-agent collaboration. The findings highlight that cognitive diversity plays a significant role in shaping collaboration dynamics, as diverse teams generate more innovative solutions but require effective coordination mechanisms to maintain alignment. The study confirms that ambidextrous leadership strengthens shared value systems, fostering collaboration, especially in hierarchical teams, whereas non-ambidextrous leadership limits collaborative efficiency in flat structures. Furthermore, knowledge re-growth accelerates higher-order collaborations, particularly in cognitively diverse teams, reinforcing the importance of continuous learning environments for sustaining long-term collaboration.

From a theoretical perspective, this study contributes to organizational behavior, strategic management, and ABMS literature by emphasizing the interaction between cognitive diversity, leadership, and team structures in collaboration dynamics. The results suggest that organizations should optimize cognitive diversity by balancing creativity with structured alignment mechanisms, ensuring that diverse perspectives enhance rather than hinder collaboration. Additionally, flat structures facilitate more dynamic collaboration, while hierarchical structures provide stability for structured decision-making, reinforcing the need for contextual leadership strategies to bridge these different collaboration models.

Practically, the study offers actionable insights for organizational leaders and managers. Organizations should strategically incorporate cognitive diversity into team composition, ensuring that diverse thinking styles are supported by strong communication channels and shared values. Investing in ambidextrous leadership development is crucial for fostering synergy between hierarchical and flat teams, while targeted knowledge-sharing initiatives can enhance team adaptability and long-term innovation. Strengthening strategic communication improves collaboration, but it must be carefully calibrated to avoid diminishing returns. Future research should explore empirical validation of these findings in different industries and cultures, incorporating external factors such as market conditions and cultural influences to provide a more comprehensive understanding of inter-agent collaboration dynamics.

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The Dark Side of ESG Ratings: Future Challenges for Corporate Strategies

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Abstract

This paper critically examines the methodological inconsistencies of Environmental, Social, and Governance (ESG) ratings and their impact on financial decision-making. While ESG scores are intended to guide investors and policymakers toward responsible business practices, discrepancies in rating methodologies raise concerns about their reliability and strategic value. Using a conceptual and theoretical framework, the paper integrates perceptions from institutional theory, signaling theory, and the sociology of valuation to explore how ESG ratings shape corporate sustainability narratives. It also draws on empirical studies to demonstrate inconsistencies in ESG scores and their consequences for financial markets. The study identifies three primary flaws in ESG ratings: (1) Divergent methodologies lead to inconsistent scores across rating agencies; (2) Firms prioritize ESG disclosure over actual sustainability improvements, fostering greenwashing; and (3) The lack of transparency in ESG rating methodologies distorts investment signals, leading to mispricing risks and misaligned sustainability incentives. Additionally, the absence of strong social indicators within ESG frameworks may contribute to the ineffectiveness of these ratings in truly capturing corporate sustainability.

The paper does not provide primary empirical analysis but synthesizes existing literature to propose a refined understanding of ESG ratings. It highlights the need for future research on regulatory standardization, AI-driven ESG assessments, and independent verification mechanisms. The findings suggest that investors should not rely solely on ESG ratings when making financial decisions. Instead, they should combine multiple sustainability metrics and qualitative assessments to avoid misleading investment choices. A lack of ESG rating standardization risks undermining public trust in sustainable finance and corporate responsibility efforts. Furthermore, the insufficient emphasis on social indicators within ESG ratings may hinder their ability to promote genuine corporate accountability and social progress.

This paper contributes to the growing critique of ESG rating methodologies by arguing that without regulatory intervention, ESG scores will continue to serve as unreliable indicators of corporate sustainability.

Keywords: ESG Ratings; sustainable finance; corporate governance; greenwashing; investment risk; standardization; financial markets; institutional theory; signaling theory; sustainability metrics

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Introduction

Over the past decade, ESG ratings have become central to sustainable-finance decision-making[1]. Yet despite their ubiquity, rating methodologies remain heterogeneous and opaque, producing inconsistent assessments that often fail to capture firms' true environmental and social impacts. Investors and regulators increasingly question whether these scores genuinely reflect stakeholder value or simply reward disclosure practices.

This paper interrogates three core flaws in prevailing ESG ratings:

- *Methodological divergence:* Agencies apply inconsistent weighting schemes and data-selection rules, leading to significant score disparities.
- *Disclosure-driven greenwashing:* Firms can attain high scores through robust reporting even when their environmental or labor practices remain deficient.
- *Misaligned investment signals:* Inter-agency correlations for ESG scores hover between 0.3 and 0.6, due to diverging methodologies and noisy data, confusing asset managers (Berger et al., 2022).

Drawing on institutional (DiMaggio, Powell, 1983), signaling (Spence, 1973), and valuation-sociology theories (Callon et al., 2002; Karpik, 2010; Muniesa et al., 2007), we first diagnose how regulatory gaps, signaling imperfections, and valuation devices co-produce unreliable ESG scores. We then propose three policy levers — standardization, independent verification, and outcome-based metrics — to realign ESG ratings with substantive sustainability goals.

The rise of ESG ratings functions as a dual signal to the market: they inform investors about a firm's risk profile and its commitment to sustainable practices. Firms with high ESG scores are often perceived as lower-risk investments, as they signal proactive management of environmental, social, and governance issues. Research indicates that improved ESG performance correlates positively with enhanced financial returns and market valuation (Kong et al., 2023; Narula et al., 2024). For instance, companies that adopt effective ESG policies not only mitigate compliance risks but also tend to outperform their peers in terms of profitability and stock market performance (Ting et al., 2019). Studies have established a positive correlation between ESG ratings and firm profitability across various markets, demonstrating that robust ESG practices are integral to sustainable business models (He, 2024). Moreover, the strategic implementation of ESG practices can influence external perceptions, thus affecting credit ratings and investment attractiveness (Bhattacharya, Sharma, 2019). For example, the mechanisms through which credit rating agencies evaluate firms increasingly incorporate ESG factors, reflecting a growing recognition that such practices enhance company credibility and trustworthiness (Li et al., 2024). Companies focusing on ESG metrics not only align with investor expectations but also benefit from improved access to capital, as sustainable investment strategies increasingly prioritize firms demonstrating strong ESG credentials (Juddoo et al., 2023).

Theoretical Background

Institutional Pressures on ESG Ratings

Institutional theory emphasizes how coercive, normative, and mimetic forces shape organizational behavior (DiMaggio, Powell, 1983). Regulatory interventions like the EU SFDR and IFRS standards aim to impose disclosure uniformity, yet enforcement remains inconsistent (Christensen et al., 2021). Normative pressures from investors and NGOs often yield symbolic compliance, while mimetic pressures foster methodological convergence without evaluative rigor. ESG ratings serve as an institutional tool that forces businesses to implement sustainability practices, not out of personal motivation, but to fulfill investor requirements and regulatory codes. The criteria set by rating agencies drive institutions to establish ESG strategies based on specific guidelines rather than genuine sustainability approaches. This situation results in symbolic compliance, where companies focus on improving their ESG scores instead of addressing fundamental sustainability issues (Burney, 2020; Pardy, 2020). A corporation may enhance disclosure transparency to achieve better ratings, even if it continues environmentally damaging operations (Flammer, 2021). This behavior raises concerns about genuine ESG integration within corporate strategies and the financial system.

Signaling Dynamics in ESG Disclosure

Firms use ESG ratings to signal sustainable practices, but inconsistent methodologies blur signal interpretation (Spence, 1973). This introduces adverse selection, where firms with superior disclosures — not necessarily superior performance — benefit most (Krueger et al., 2024). Investors may misallocate capital due to opaque scoring. Companies use ESG ratings as communication tools to demonstrate responsible conduct to investors and stakeholders, regardless of actual sustainability achievements. High ESG ratings lead to lower risk perception and attract more investments from ESG-focused investors, encouraging superficial ESG perception management rather than authentic sustainability practice advancement (Feng et al., 2022). A primary issue arises

[1] Global sustainable assets under management have surpassed $35.3 trillion (McKinsey & Company, 2022).

from the information mismatch between companies and their rating institutions. Firms exploiting self-reporting processes for ESG evaluations can present their sustainability initiatives favorably while omitting unfavorable information. This ability to manipulate rating scores misrepresents true sustainability practices through fabricated results, thereby decreasing the validity of these assessments as accurate proxies.

Valuation Sociology of ESG Scores

Valuation studies conceptualize ESG ratings as "market devices" that do not just measure but construct value perceptions (Callon et al., 2002; Karpik, 2010; Muniesa et al., 2007). ESG scores shape investor imaginaries but are themselves shaped by provider assumptions, industry contexts, and geopolitical biases (Peirce, 2020) . Social constructs, rather than objective measurements, are used to quantify sustainability performance in ESG scores. Unlike financial indicators based on standardized accounting principles, ESG scores rely on diverse qualitative assessments and inconsistent weighting methods and approaches. The lack of shared theoretical principles among ESG scores results in subjective assessments that cause ratings to diverge, leading to unclear sustainability evaluations (Gyönyörová et al., 2021). Berger et al. (2022) identify three primary drivers of ESG rating divergence: Scope divergence (differences in the ESG factors considered by agencies), Measurement divergence (variations in how ESG factors are assessed), and Weight divergence (discrepancies in how ESG components are weighted in overall scores). General metrics that produce conflicting ESG ratings therefore diminish both their reliability and their usefulness in investment selection. The absence of a shared ESG framework creates difficulties that limit ESG ratings effectiveness in sustainable corporate assessment (Abhayawansa, Tyagi, 2021).

Methodological and Conceptual Critiques

Key problems include reliance on firm self-disclosures, subjective gap-filling, lack of cross-provider harmonization, and non-comparable metrics (Berger et al., 2022). Conceptually, ESG scoring frameworks often reflect shareholder-centric and PR-focused logic rather than actual sustainability (Hong, Kacperczyk, 2009).

The Divergence Problem: Lack of Standardization in ESG Ratings

Different Weightings and Methodologies

Different ESG rating providers generate scores that display minimal matching points as stated in introduction section. ESG dimensions receive weighted evaluations from rating agencies, producing divergent assessment results because different scoring systems exist among agencies, leading to distinct evaluation outcomes. Different rating organizations apply divergent evaluation methods when measuring corporate sustainability performance. Environmental performance takes precedence as a primary assessment area in certain agencies, while others value corporate governance and social responsibility evaluations the most (Wong et al., 2022). Companies are rated through subjective interpretations of sustainability data by various rating agencies since there is no universally accepted methodology. Regional differences primarily drive discrepancies in ESG ratings. Preferences in cultural norms and market-specific factors present in regional regulatory frameworks cause obstacles for assessing rating uniformity across various jurisdictions (Leng et al., 2023). European firms typically receive superior ESG ratings compared to North American companies because they must provide detailed sustainability disclosures, although their environmental consequences remain equivalent (OECD, 2020).

The Subjectivity of Measurement

The assessment methods used in ESG ratings differ from financial ratings (from Moody's and S&P) due to their qualitative nature, analyst-dependent voluntary reporting, and subjective evaluations (Mayer, Ducsai, 2023). Higher levels of ESG data release tend to produce more analytical discrepancies instead of clear insights because analysts process information in different ways (Berg et al., 2021). Subjectivity in this field stems mainly from the lack of standardization in data collection methods. Alongside being optional, firms submit their ESG information with ratings-beneficial content while leaving out unfavorable details. Analysts must use third-party sources, corporate sustainability statements, and media reports, which heightens the risk of biased interpretation. Furthermore, ESG rating agencies employ different weighting schemes for various ESG indicators. Each rating agency prioritizes different environmental parameters, such as carbon emissions, compared to focusing on supplier ethics or workforce diversity (Birindelli et al., 2018). The diverse ESG methodology used by rating agencies causes inconsistent ratings since different firms receive significantly different overall ESG scores based on the evaluating organization. The determination process of ESG scores remains completely non-transparent to outside observers. Different rating agencies maintain proprietary computational models to evaluate companies but do not publicly reveal their weighting criteria. This lack of transparency hinders investors from understanding the basis for diverse rating outcomes. The lack of transparent scoring practices influences investors' decision-making processes and diminishes officials' responsibility for ESG criterion application across various companies. The methodological divergences discussed earlier directly contribute to the misalignment between ESG scores and actual sustainability outcomes.

ESG Ratings and the Illusion of Sustainability

ESG Scores vs. Actual Carbon Emissions

The primary complaint against the ESG ratings system is its inability to measure the actual environmental impact of firms. According to studies, businesses with high ESG ratings pollute at similar levels to businesses rated lower[2]. The evaluation system gives preference to companies that promote thorough disclosure practices instead of assessing their real sustainability achievements. ESG ratings typically increase when companies present detailed sustainability reports combined with documented policies, regardless of their substantial carbon footprint. ESG rating systems disproportionately favor large, publicly listed companies with adequate resources for ESG reporting more positively than smaller firms, despite their actual sustainability results (Hassan, 2024). The nature of ESG ratings pretends to measure environmental impact but functions principally as an indicator of corporate disclosure transparency. The energy sector demonstrates the significant gap in ESG ratings when oil and gas companies achieve good governance scores while continuing their involvement in fossil fuel operations. Many investors mistakenly believe that high ESG ratings mean they support environmentally responsible corporations, but these ratings may reveal substantial environmental liabilities.

Portfolio Construction and ESG Misalignment

Behavioral research on ESG fund performance indicates variable outcomes among recent academic studies. ESG funds prefer businesses that disclose high scores instead of organizations with real sustainability influence (Kräussl et al., 2023). The 2022 Morningstar report stated that some ESG funds achieved higher performance during the COVID-19 crisis by avoiding volatile fossil fuel stocks, yet their long-term performance became uncertain after considering sector biases (Raghunandan, Rajgopal, 2022). Research indicates that ESG fund design methods may not match actual sustainability performance. The subjective nature of ESG ratings analyzed in previous sections makes their use in fund optimization necessary for rigorous evaluation. The implementation of these ratings for sustainable investing frequently results in situations where they deviate from actual sustainable goals. Investors have adopted the practice of averaging ESG scores for portfolio construction, but this method increases estimation errors instead of decreasing risk levels. The inconsistent approach to ratings across different agencies, combined with their subjective methodology, leads to false perceptions of sustainability when ESG scores are combined into investment portfolios. The addition of social and governance factors in ESG funds creates a key drawback because it weakens the environmental performance goals within these funds. The ESG rating system allows companies with high governance scores to mask their inadequate environmental performance and present themselves as more sustainable than they really are (Keeley et al., 2022). Aspects of ESG funds permit the inclusion of companies with challenged environmental practices because these companies demonstrate exceptional performance in other areas of ESG, like diversity policies or corporate ethics. The vague criteria create problems for investors seeking climate-positive funding because it leads them to fund companies with major carbon emissions. As reliance on ESG scores grows, regulators and investors must develop more precise and transparent ESG assessment methods to ensure that portfolios truly align with sustainability goals rather than simply adhering to rating agency methodologies.

The Unintended Consequences of ESG Ratings

Greenwashing and Corporate Manipulation

ESG ratings have a major problem because many businesses deploy illusionary environmental programs known as greenwashing to boost their ESG results yet fail to execute substantial changes (Flammer, 2021). Several firms choose to use their financial resources on ESG reporting and public relations activities instead of deploying them toward actual sustainable measures that may have meaningful effects on carbon reduction programs and ethical labor standards. The present ESG rating model encourages organizations to devote their resources toward easy accessibility practices such as diversity initiatives and sustainability protocols rather than spending them on solving fundamental and expensive structural challenges that include renewable energy adoption and supply chain emission reduction. The current ESG rating system leads companies to enhance their scores through regulatory compliance but not actual impact achievement (Sun et al., 2023). Through their ability to select favorable ESG criteria while keeping unfavorable ones out of view, companies generate an erroneous impression of responsible behavior. A company achieving top ESG scores from ratings can do so through effective gender equality policies even with active environmental violations and exploitative labor practices. The altering of information in ESG ratings diminishes investor trust in this evaluation system and hinders possible sustainable business transformations.

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[2] https://www.ft.com/content/b9582d62-cc6f-4b76-b0f9-5b37cf15dce4, accessed 06.07.2025.

Market Distortions and Mispricing Risks

Current stock market activity shows that ESG stock movements diverge from what investors predict regarding financial performance. The S&P 500 ESG Index shocked investors when Tesla was removed in 2022 while still delivering industry-leading electric vehicles, but ExxonMobil remained due to its large issue with carbon emissions. The Deutsche Bank subsidiary DWS Group experienced a 6% stock market decline because of regulatory investigations showing its excessive claims about ESG credentials[3]. This situation reveals how ESG scoring systems produce mispricing risks and unexpected market disturbances. Numerous studies have discovered that the relationship between ESG ratings and investment risk, along with performance returns, is not as straightforward as commonly thought (Qin, Wang, 2025). Investors who rely on ESG scores for their decisions may unintentionally receive false pricing information about their assets and market indications. Investors commonly misunderstand ESG scoring systems as risk measurement tools, which can result in mispriced stocks within highly rated ESG firms (Priyanto, Suhandi, 2023). Different ESG rating providers establish divergent perspectives on risk assessment because they assign distinct safety profiles to similar companies. Gibson et al. (2021) present research invalidating the common false notion that organizations with desirable ESG ratings will deliver superior market performance. ESG-aligned portfolios sometimes yield inferior results due to sector preferences, as investors tend to exclude oil and gas corporations from their portfolios during market periods. The reliance of investors on ESG scores can lead to purchasing assets at incorrect prices and suboptimal allocation of their investment funds. The absence of standardized approaches in ESG rating makes the connection between ESG achievements and financial outcomes problematic to prove. Some organizations achieve high ESG ratings even though they operate in risky conditions, leading investors to believe their investments are safe. ESG-based investment strategies lose credibility because various assessment standards create unreliable results that require more standardized evaluation procedures.

Policy Recommendations and Future Research Directions

Transparency and Standardization

A baseline ESG taxonomy must define key metrics, data quality standards, and scope boundaries. Agencies should publish methodologies and scoring rationales, enabling comparability and auditability. Policymakers, investors, and regulators should implement substantial actions to improve ESG rating credibility to achieve genuine sustainability results despite current limitations. The initial fundamental measure to advance ESG disclosure mandates must be standardized. The IFRS Sustainability Standards and other regulatory bodies need to develop a common ESG reporting framework to enhance sustainability assessment transparency and reduce rating variations (Zhang, Zhang, 2023). Standardization initiatives must be established to minimize rating inconsistencies between agencies because current performance rating differences weaken ESG score reliability for investment decision support.

Independent Verification

A ratings oversight body should certify ESG providers, audit compliance, and police conflicts of interest — similar to reforms in credit-rating markets. The verification process through independent entities must be implemented to ensure that sustainability information reported by companies corresponds to their actual sustainability achievements. Organizations need external audit procedures to prevent greenwashing, as such procedures would mitigate the practice of companies showing inflated ESG credentials through cherry-picked reports not backed by genuine environmental and social achievements. Sustainable reporting will gain investor trust and better corporate sustainability accountability through the implementation of independent evaluation systems for checking ESG statements.

Outcome-Based Metrics

Shift emphasis from disclosure breadth to outcome depth. Regulators should require firms to report on emission reductions, labor practices, and verified KPIs — penalizing non-performance. ESG scoring methodologies need to develop by placing measurable sustainability metrics at a higher level than subjective self-disclosures. The existing ESG ratings favor the assessment of corporate governance and social commitment more heavily than essential environmental indicators and metrics. The weight given to quantifiable indicators such as carbon intensity, energy usage, and waste reduction will make ESG ratings more interconnected with genuine sustainability outcomes beyond disclosing corporate information and practices. Rating agencies need to enhance their disclosure practices of their evaluation procedures. ESG assessments face an ongoing challenge because different rating agencies maintain unclear methods of scoring evaluation. The weighting techniques, assessment standards, and data retrieval mechanisms for ESG rating generation remain undisclosed to numerous organizations and investors.

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[3] https://www.reuters.com/business/finance/deutsche-banks-dws-allegations-greenwashing-2022-06-09/, accessed 05.07.2025.

A lack of proper methodological transparency about ESG ratings results in perceptions of arbitrariness that limit their ability to influence investment decisions and regulatory policies.

Future Research Directions

Future research should explore how advanced AI models (Zhang, 2023), blockchain technology, and data standardization can enhance the predictive power and reliability of ESG evaluations, making them truly effective tools for corporate governance and financial strategy. Researchers must also investigate the financial returns associated with high ESG evaluations. The long-term financial success of sustainable businesses remains debated among ESG integration supporters, who argue that these firms demonstrate stronger durability and profitability. Further studies are needed to determine if high ESG ratings correlate with better profitability, reduced operational risks, and improved business practices. Advanced understanding of this relationship will drive more effective ESG investment strategies and regulatory enhancements for ESG rating systems.

Conclusions

This paper analyzes ESG ratings to expose their major methodological problems, market disruptions, and the false sustainability effects they indicate. The problem with ESG scores being unreliable stems from rating agency differences and voluntary disclosure reliance, which reduces their trustworthiness. ESG scores face reliability issues due to different rating methods and selective disclosure practices, making them vulnerable to greenwashing. The undesirable results of ESG ratings demonstrate the necessity for significant improvement in existing ESG assessment systems because they cause market irregularities, financial insecurity, and superficial corporate sustainability statements. Empirical evidence and improved quantitative methods in scoring processes need to be implemented to preserve the value of ESG scores as authentic sustainability performance indicators. Achieving better ESG ratings depends on creating standardized disclosure protocols worldwide, along with independent assessment frameworks and measurable sustainability issues. Rating agencies and regulatory bodies need to provide detailed explanations of their methods while decreasing the reliance on data self-reporting to prevent corporate gaming of ratings. The evaluation process for sustainability requires investors to combine different impact-oriented evaluation standards alongside traditional ESG scoring systems. Dealing with the complexities of ESG ratings requires firms to adopt comprehensive strategies that encompass these criteria within their operational frameworks. By integrating ESG considerations into core business strategies, firms can enhance their value proposition, manage risks more effectively, and align with the evolving demands of socially responsible investors. This strategic focus on ESG not only aids in improving firm reputation and market valuation but also ensures resilient and competitive positioning in an increasingly conscientious market landscape.

Researchers maintain that ESG ratings contain beneficial concerns about risk mitigation even though their evaluation results are imperfect. According to Amel-Zadeh and Serafeim (2018), the data from ESG scoring can function as an assessment of company risk factors, especially when evaluating governance structure and social performance aspects. Organizations achieving high ESG scores tend to encounter reduced regulatory fines, fewer reputational damage incidents, and supply disruption occurrences. Firms integrating ESG measures demonstrate better market resilience because they possess robust governance and social systems. This can, in return, protect them during market upheavals. Standardization issues remain a limiting factor that reduces their capacity to provide forecast accuracy. ESG scores have limited capability to assess complete corporate risks because their effectiveness when used independently continues to be disputed. ESG ratings are useful for integrating sustainability factors into investments even with varying methodologies, according to Amel-Zadeh and Serafeim (2018). ESG rating systems induce firms to increase their transparency standards while implementing sustainability practices because investors actively monitor these criteria. The predictive reliability of such ratings faces substantial challenges due to their insufficient standardized evaluation system, according to critics (Yılmaz, Taşkın, 2025).

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Agency and Narrative Creativity as Tools in Transformative Transitions

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Abstract

In the context of a series of various global crises, the topic of transformational transitions of large-scale socio-economic systems to a new model of development is becoming a frontier for scientific discussions. There is a growing need for actors capable of effectively managing such comprehensive radical transformations with a focus on innovation. The issues of building up human agency of transformational type (TA) have always been the subject of increased relevance. Nevertheless, the degree of demand for this competence has increased dramatically in today's world of high turbulence, variability and instability, against the background of the complex nature of the development models – Industry 4.0. and 5.0 – that are becoming widespread, as well as the exhaustion of the potential of those management tools that were effective in previous, relatively stable contexts. This article explores the possibilities of TA formation and scaling, and proposes methods of working with this complex, elusive phenomenon to ensure successful development. Relying on a number of concepts (including his own development) and practical cases, the author reveals the "black box" of TA, bringing clarity to the processes of proper formation of rare, transformative abilities. The conclusions presented reveal the sources of renewing potential for management systems, the acquisition of which will allow different organizations to successfully adapt to the increasingly complex flow of change.

Keywords: transformative agency; innovation; transformational transitions; dynamic capabilities; unicorn companies; agency scaling; narrative theory

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Introduction

The current context is characterised by a continuous series of overlapping crises of different nature, which together create a prolonged permacrisis. The existing management models cannot produce adequate responses to this state of affairs (Behl et al., 2023). Education system reforms, among other things, are required to radically change the situation. The model underlying this system determines future professionals' understanding of the dynamics of ongoing processes, and their ability to comprehend (and deal with) complex problems. However, developing such competencies seems to be problematic for universities, largely due to the ingrained dominant belief ready-made solutions exist for any problem (Rappleye et al., 2024). According to the common wisdom, no matter how complex the challenges are, they can be met using existing tools, including improving the quality of education. Generally, the modern education system is designed to teach students to operate in stable contexts, not to adapt to rapidly changing, unprecedented conditions. It's extremely rigid, and ignores alternative tools and strategies. Meanwhile there's a growing body of research suggesting constructive ideas for changing the education paradigm to meet the challenges of developing relevant and in-demand competencies (Machado de Oliveira, 2021). Of particular interest is the line of research on fostering and scaling transformational agency (TA), which we will consider in detail below. However, this notion's place in the broader concept of "agency" as such should be determined first.

Agency is generally understood as the ability to perform actions or interventions which produce a certain effect.[1] Two levels of agency are distinguished. The first one is "basic" ("improving agency", IA), and involves actions to support and optimise existing institutional structures. The second level (TA) has a high transformational potential since it involves going beyond "improving the existing" and conducting radical structural transformations at the system and process level (Udehn, 2002). Key principles of TA include subjectivity, responsible choice (OECD, 2018), and non-standard novelty generation logic (Virkkunen, 2006). TA implies reconsidering basic understanding of human development potential and approaches to management on the basis of "ecosystem" and "relationship" metaphors. The emphasis is shifting to political will and proactivity. The contradictory nature and duality of TA effects must be noted. It undermines the previous modes of socio-economic and technological systems (SETS), challenges the status quo, but at the same time appears to be an effective (and sole) driver for such systems' renewal and adaptation in the situation of a permacrisis (Stetsenko, 2019).

This gives rise to new expectations of the education system: it should create a special type of human capital, TA competence carriers (Carayannis et al., 2024; Golovianko et al., 2023) capable of initiating and supporting multidimensional, complex transformations to facilitate the transition of SETS to more sustainable basis (Markard et al., 2012). Since such broad transformations cannot be achieved with a limited number of TA carriers, a need arises to find the most effective ways of scaling it up. The relevance of developing TA competencies is also due to the fact that transforming SETS through TA makes these systems highly (and adaptively) resilient to complex, turbulent conditions, and facilitates their access to a renewed resource base which ensures their competitiveness (McKelvey, 2010; Brown et al., 2025; Fletcher, Benveniste, 2025; Bromley, 2021).

Generally, the education system does not yet respond to this demand, which, however, is effectively met by the corporate sector and, recently, by specific universities and experimental laboratories (Grillitsch et al., 2023; Ozmen et al., 2023; Ma et al., 2022).[2] But these efforts are not sufficient to create the necessary mass of TA carriers capable of supporting major transformational transitions (at the level of industries, regions, and markets). And although the relevant debates have been going on for quite a while (Emirbayer, Mische, 1998), the existing literature does not provide a clear answer whether TA can be scaled up at the system level, and if so, exactly how it can be done (Fligstein, McAdam, 2012).

Thus the purpose of this paper is to present a possible theoretical foundation for the development and scaling of TA, and give examples of its practical application. The conceptual basis of our study was made by synthesising several theories, namely the theory of neostructuration (the author's own design) (Sorokin, Mironenko, 2025; Sorokin, 2023), theory of narrative (Fletcher, Benveniste, 2022), theory of complex adaptive systems (CAS) (McKelvey, 2010), and theory of transition management (Notermans et al., 2022), and theoretically interpreting unicorn companies as TA concentrators. Two corporate case studies will help us open the "black box" of the mechanisms large companies with long histories applied to scale up TA.

Literature review

Evolution of the education system

The present-day education system was created in the context of a "modernist" type of society characterised by strict adherence to established rules and an emphasis on specialised knowledge (Beetham, 1987). The design of such a system is based on the assumption of a

[1] Oxford Dictionary, 2012. https://www.oed.com/dictionary/business_n?tl=true, accessed on 05.07.2025.

[2] An example is the European "Science Education for Action and Engagement towards Sustainability" (SEAS) initiative implemented jointly by Austrian, Belgian, Estonian, Italian, Norwegian and Swedish educational systems in 2019–2022 (Erstad et al., 2025).

certain degree of stability and predictability of the environment. Since the mid-20th century, higher education has not simply reproduced, but shaped global social reality (Schofer et al., 2021; Meyer, 2010). The ideas of progress, rationality, and the fundamental cognoscibility of the world were broadcast. These framed the concept of a clearly mapped path to achieving a high quality of life. It was assumed that progress along this track was facilitated by ready-made solutions organising life at the national, corporate, or individual level. The broad proliferation of higher education allowed different social groups to become parts of a common culture based on universal "correct" standards.

According to the human capital theory, the key economic development factor is precisely the "right" education which matches the current and predictable demand in the labour market (Becker, 1962; Schultz, 1960; Meyer, 1977). The "new institutionalism" school questions the "objective rationalist" logic instilled by the education system, pointing to the resulting misconceptions about the actual operations of organisations. It is emphasised that cultural and structural aspects play a more important role. E.g. the survival and prosperity condition turns out to be not following the "maximise benefits" strategy, but becoming legitimate by relying on narratives about the superiority of certain technologies or organisational practices. Consequently, emerging organisations (companies, etc.) strive to imitate institutions that have successfully achieved such legitimacy in the past (DiMaggio, Powell, 1983).

During the 1950s-2000s, relatively steady progress was observed in both the economic, and socio-cultural dimensions, which has ingrained the belief in the positive impact of established educational approaches on social progress (Schofer et al., 2021; Psacharopoulos, Patrinos, 2018). Universities generated new knowledge and developed management tools. Priority was given to developing students' logical abilities, and the ability to analyse information while assuming a sole correct answer exists, and the system remains highly predictable (Meyer, 1977).

The growth of the service sector since the 1970s promoted researchers' and practitioners' growing interest in "soft skills" to improve interpersonal communication. However, the assumed objective was to broadcast existing meanings without creating any new ones. In other words, the development of such abilities was based on "reproductive" logic, rather than "transformational" one. International initiatives to assess the quality of education at all levels have been designed accordingly since the 1960s, including TIMMS, PIRLS, PISA, PIACC, etc.

However, in the 21st century the context has changed dramatically. The previous structural growth factors (market expansion, cheaper technologies, removal of barriers to international trade, educational mobility, etc.) have exhausted their potential. The literature discusses significant changes in the logic of SETS development caused by incessant impact of major external factors and internal processes, reducing their structural stability. This is indicated, e.g., by the theories of "strategic action fields" (Fligstein, McAdam, 2012), "morphogenetic society" (Archer, 2013), and proposed by the author of this paper "neostructuration" concept (Sorokin, 2023), which describes the conditions under which SETS not only change rapidly, but become fundamentally dependent on human agency (in the broad sense). Along with threats to SETS, also increases the potential for individual and collective TA which can radically transform them and bring to a new level. In various activity areas questions have increasingly arisen about the education system: to what extent it can create human capital capable of efficiently performing under growing complexity and uncertainty. The notion of a "TA shortage" has emerged (OECD, 2018; UNDP, 2024). The need to develop this competence is particularly obvious at the level of university educational programmes. However, there are problems even with operationalising the TA concept, not to mention developing the relevant skills. In the last decade, the discourse on different types of human agency (IA and TA) broke down into two unequal "camps". Each of them is described in more detail below.

Improving agency (IA)

The first, more popular line of research focuses on the occurrences and effects of agency caused by dominant factors independent of the will and efforts of the individual. These can be of both external (culture, technological and macropolitical systems) and internal origin (behavioural, mental-cognitive aspects). The relational approach[3] dominates here, which describes IA as agency "placed in context" and affected by socio-cultural interactions and dynamics (Stetsenko, 2019). This logic fits into the common understanding of the education system's most important achievement of recent decades, namely the focus on training and developing people in line with social contexts and practices. It is believed that setting the right "external" stimuli encourages overcoming crises and adopting more complex development models. As a consequence, more productive thinking and behaviour algorithms are expected to "trigger", e.g., divergent thinking (Fletcher, Benveniste, 2025). These theories are based on the complex human nature, different monodisciplinary perspectives (*homo economicus*, *homo politicus*, *homo soveticus*, etc.). It is assumed that individual reaction to external conditions can be predicted based on the context in which the individual find themselves, and on the understanding of their mental-cognitive patterns. Most such concepts follow "structural logic".

[3] Also defined as "situational", "contextual', "distributed" and 'ecological" approach (Stetsenko, 2019).

It would be wrong to claim that these approaches ignore human agency (in the broad sense) as a resource to conduct major structural transformations and assign it a secondary role in relation to the conditions (i.e. gives it the IA status). Promoting individual initiative, ingenuity, and creativity is also seen as important, but only in terms of reproducing and optimising existing contexts instead of radically transforming them. E.g. the need to develop the ability to map one's individual educational path is mentioned, but within the existing hierarchy. The possibilities of designing new, more complex action patterns or structures are not considered. Strategic management studies use concepts such as "innovation behaviour", "transformational leadership", etc., but focus solely on individuals' initiatives to support the existing frameworks. Creating genuine innovations which would change these frameworks is not mentioned (Brown et al., 2025; McKelvey, 2010).

In recent years the "entrepreneurial ecosystem" concept has been widely discussed, which denotes a set of many factors that "guarantee" creating the desired dynamics (Munoz et al., 2022). However, in the context of transformational transitions creating structural foundations is not a sufficient condition for the emergence of new enterprises and markets. IA skills work well only when complete information is available, and the environment is stable/predictable. In the new realities incremental improvements may prove futile, since they do not meet the relevant challenges. Individual TA begins to play an important role, as a tool for reconfiguring existing structures and building new, more flexible and adaptive ones. An example of practical TA is the "entrepreneurial leaps" concept (Sternad, Modritscher, 2022). It implies impacting organisational structure during the "transition phase" when difficult to predict "trigger moments" arise, leading to strong transformational effects (Coad et al., 2021). Behaviour-related aspects (which in most studies are seen as the main agency indicators) reflect intention rather than practical transformative action. In such situations there are no grounds to talk about transformation of the community, processes, etc. The only result is a change in the agent's position in the existing structure (Sorokin, Redko, 2024). There is a gap between mass educational programmes to develop IA skills, including creativity courses, and "niche" ones focused on TA (strategic management or MBA programmes) (Fletcher, Benveniste, 2025; Sorokin, Chernenko, 2022). At the same time, both these programme types lack tools for either measuring, or developing agency potential (Kim, 2016; Henriksen et al., 2019). The "epistemological gap" also remains insufficiently understood: despite the availability of current data on transformational potential of human agency in relation to SETS, the possibilities for developing it remain insufficiently studied. Moreover, regardless of the declared importance of TA, IA actually remains the main object of measurement (Reeve et al., 2020).

Transformational agency

The second "camp" in the agency debates, and in the development of relevant tool, is focused on TA$ it's smaller, but differentiated equally strongly. TA is seen as a complex phenomenon, essentially contrasting with the dominant understanding of agency as the ability to "act within existing frameworks observing established hierarchies, and support them" (IA). The focus is on individual potential to not only contribute to the qualitative transformation of an industry, company, project, etc., but drive the creation of new, or the adjustment of existing social structures relying on internal creative potential (Haan, Rotmans, 2018). There is no commonly accepted term to describe such abilities, partly because they are dynamic in nature and applied in unstable situations. This cluster also comprises modern interpretations of the cultural-historical theory (Stetsenko, 2020), the "agent involvement" concept (Klemenčič, 2023), and other notions (Sorokin, 2023). The most highly developed domain in TA-related research is focused on entrepreneurship and organisational change, e.g. in the context of the transition to a new technological order (Haan, Rotmans, 2018). New interpretations of entrepreneurial ecosystems (Muñoz et al., 2022) and of strategic management patterns (Brown et al., 2025) are proposed, along with those of major technological shifts (Haan, Rotmans, 2018), with an emphasis on TA's system-forming role.

Given the insufficient attention to the TA topic, this paper aims to fill this gap and outline ways to facilitate it. A possible theoretical basis for the development and (most importantly) scaling of TA will be considered below.

Methodologies for developing TA have already begun to emerge, but mainly outside the education sector, and they still remain of a "niche" nature. Overall, measuring TA remains one of the most important unsolved mass education problems the world over. University entrepreneurial training programmes could be considered a tool for developing the competence in question, but no relevant designs in this segment have actually proved their effectiveness (Sorokin, Redko 2024). Even among the world's leading universities there is no consensus on what skills students should have after entrepreneurial training, not to mention how to measure them (Sorokin, Chernenko, 2022). A knowledge base has been accumulated on individual characteristics and organisational climate that determine the effectiveness of training programmes. However, the success criteria typically do not go beyond developing entrepreneurial intentions and defending a training project, with no talk of students launching new enterprises (Nabi et al., 2017). There is no real understanding, in either scientific research or educational practice, of what tools help create successful entrepreneurs (Sorokin, Chernenko, 2022). The development of TA is often seen solely as a means to deal with "rigid", discriminatory structures (Klees, 2016). Its potential to support, and adapt to changes in such basic structures as school, family, corporations, development institutions, etc. is not taken into account.

In the transformational paradigm, reality is perceived as an object of constant transformations carried out by agents involved in social practices. The coevolution phenomenon emerges: agents change the world, and in the process change themselves. In other words, they do not simply react to what is happening, but proactively participate in the joint creation of both the world and themselves, beyond the "given" present. TA plays a central role in the overall socio-historical dynamics (Stetsenko, 2019).

At first glance, many of the teaching approaches, formats, and practices that have emerged in recent years may have high potential for developing TA. These include the agile teaching and learning methodology (ATLM), mentoring, developing entrepreneurial thinking, etc. However, their theoretical basis (and the actual effectiveness) remain insufficiently studied. In particular, teaching solutions for acquiring TA skills are discussed separately from the latest socio-economic trends, including transformational transitions.

Constructivism is considered to be a more advanced approach to education, based on the idea that students should create a new framework of concepts or improve the existing one, projecting it on real-life situations (Snowman, Biehler, 2005). It assumes that externally developed ideas and action practices are absorbed "inwards", since "real" situations imply a relatively stable context, through the prism of which the student perceives both the reality, and their own potential (Koreshnikova, Sorokin, 2024). It's not about developing TA as a new way of acting, or of interpreting reality. From this point of view, the term "constructivism" does not accurately describe the phenomenon under consideration, since the constructed image of reality is not objectively new: it's a product created in line with the model set by the educational environment. To overcome the limitations of this approach, an alternative "neo-constructivist" educational paradigm is proposed, which assumes that the context may have a high degree of uncertainty and no single "correct" answer or the sole "right" course of action to solve the problems at hand. Such an approach seems to be a key tool for supporting TA development, though specific relevant mechanisms remain unclear (Koreshnikova, Sorokin, 2024).

The question of how the objectives and potential of the education sector may change due to the development of AI technologies hasn't been sufficiently addressed either. The available data suggests that on the one hand, AI tools can be used to expand the scope for TA application, while on the other, their implementation may lead to replacement or even complete displacement of TA (Fletcher, Benveniste, 2025). E.g. according to an expert survey by Elon University, 44% of the respondents expected negative (rather than positive) effects of AI development on people's "ability to act independently"; 30% noted the same for "creativity and innovative thinking", and 50% for the "ability and willingness to deeply consider complex concepts" (Anderson, Rainie, 2025).

TA becomes a crucial factor determining the choice, and implementation of specific development paths in the situation of transformational transitions, characterised by both high structural volatility and diverse opportunities. The most complete understanding of the "transformational transition" concept is presented in the works by Erasmus University researchers (Rotmans et al., 2001; Haan, Rotmans, 2018). This concept describes a long-term, non-linear process of complex transformations of SETS in the technological, economic, environmental, and social dimensions during the transition from the old paradigm to a new, more sustainable and adaptive one (Rotmans et al., 2001). A successful "transition" requires three conditions: local-level innovation, changes in the interaction "mode"[4] within the system, and broader changes in the external landscape which promote evolution (Grin et al., 2010). This is a process of structural confrontation of "niches" (local, frequently peripheral networks of actors and patterns of their interaction), and "modes" (dominant player networks occupying "central" positions in the system, and their interaction patterns) (Avelino et al., 2019; Loorbach et al., 2017). However, TA is not determined by "niches" or "modes" (Avelino, Wittmayer, 2016; Haan, Rotmans, 2018; Fisher, Newig, 2016). The example of the energy industry shows the inconsistency of the approach which sees actors exclusively as "niche subjects". The space for possible strategies is much wider.

To describe the structural conditions under which TA becomes a crucial transformation factor, the "transition space" concept is proposed: a spatio-temporal state in which the "mode"-related structural determinants are significantly weakened, while the variability of possible TA forms is extremely high (Bosman, 2022). In previous transitions (from agrarian to industrial economy, and then on to knowledge-based one), the system's target state can be identified, i.e. the state achieving which is seen as successfully completed "transition". An important feature of the current transformational transition phase is that such system state can be called "sustainable" only relatively. Unevenly, but ubiquitously growing demand for TA, not only by different-scale economic structures (such as corporations, industries, or the economy as a whole), but also in many other domains (Sorokin et al., 2025), forces us to reconsider the very idea of "sustainability".

[4] "Mode" means the dominant "rules of the game" in the scope of a "balanced", stable system which regulate the actors' interaction.

Summarising the literature review, it can be concluded that IA is limited to supporting and improving existing structures, while TA aims at radical transformation and creating new contexts. A combination of their best, most valuable characteristics seems to be an optimal choice. We are talking about combining established structural forms[5] with new action modes, communities, and institutions based on individual agency and the "fields" it creates (Sorokin, Froumin, 2022).

The role of narratives in scaling TA

A new publication (Fletcher, Benveniste, 2025) which presents the results of a unique study commissioned by the US military sector in 2021 to find the reasons for the low effectiveness of training strategists and agents of change appears to be a breakthrough in understanding the potential for TA scalability. The authors, Angus Fletcher and Mike Benveniste, developed a new method to teach creativity based on the narrative theory.[6]

Narrative creativity is understood as the cognitive ability to construct, and actually implement a vision of the world and one's place in it. This approach "side-lines" the principles of social science and educational practice based on the idea of the world being deterministic and stable, subjected to "random" fluctuations only occasionally.[7] Instead of abstract images and comparisons based on "randomness" and "logic" principles, actual stories and events in the course of which the best reality improvement practices were employed, and complex problems solved through TA are the key instruments here. In other words, the actor operates not with generalised "data", but with "events".

The authors emphasise that "compensating" human narrative abilities by technology is impossible. AI already surpasses humans in logical operations and in generating abstract or random content, but this does not yield practical effects in the form of "improvements" on a commensurate scale. Furthermore, exclusive reliance on logic and randomness principles significantly limits the potential for creating "strong" useful innovations, while for possessors of relevant skills who have received formal education (IA carriers), the risk of being "replaced" by AI increases. In reality, most educational initiatives, including creativity development practices in the formal and informal sectors, focus exclusively on teaching logic, without paying attention to the cognitive abilities associated with "narrative creativity". It is the formative impact of the education system built on the meritocracy principles, and the associated assessment through logical tests, which is seen as the reason for the sharp decline in creative abilities as early as in school (Fletcher, Benveniste, 2025).

As an alternative, it is proposed to focus on successful action patterns determined by the will and abilities of specific actors. The author of the narrative and their motives become the source of "truly creative" actions and strategies which transform the situation. The mechanism of interpreting and constructing reality is important here, which gives meaning to the practical improvement of the world and facilitates TA. It is exactly in developing this key natural ability to create innovations the modern education system faces significant difficulties (Fletcher, Benveniste, 2025). The model proposed by the authors can be seen as the missing element that allows to link high-level multidisciplinary social theory, economics, management, and psychology concepts with the reality of education practices.

The "narrative creativity" concept makes it possible to actually implement the neoconstructivist ideas proposed earlier. According to them, the educational situation should have the following characteristics: dynamism, high uncertainty, do not assume the existence of a single correct answer or course of action, encourage students to independently define problems and set goals, and use variable strategies.

Unicorn companies as TA hubs

An illustrative example of a very promising field for both practising and developing TA is provided by unicorn companies, with their extremely high capitalisation growth rate. To reach a value of 1 billion USD and above, other players need decades, while unicorns manage to reach this threshold in the first 10 years of their life. Unicorns show amazing flexibility during the periods of SETS failures (Kuckertz et al., 2020; Rodrigues, de Noronha, 2021). A key role in this phenomenon plays TA which is inherent in the overwhelming majority of such companies' founders. In recent years an exponential increase in the number of unicorns has been recorded. At the time the term "unicorn" was suggested (in 2013), there were just 38 players in the world meeting the criteria, and 10 years later this population has reached 2,600 (Dealroom, 2023). But despite the rapid increase such companies still remain a relatively unique phenomenon: e.g. in Europe only one in 100 start-ups achieves this status (Testa et al., 2022). The growth of the number of unicorns has significantly accelerated after COVID-19: in 2021 alone 472 new such firms were created. Unicorns play a crucial role in driving innovation and economic dynamism (Testa et al., 2022; Shahid, 2023). Their concentration has become a key indicator in global innovation rankings (WIPO, 2023). Unicorn start-ups share the characteristics of successfully transforming systems. Currently there are 2,615 such companies worldwide, 90% of which

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[5] Including the components vitally important for the society. E.g. the Russian expert discourse frequently employs concepts such as "civilizational foundations" or "traditional values".

[6] The narrative concept distinguishes constructive and destructive narratives. The success of dynamic actors (individuals and groups of any size) in creating breakthrough innovations and implementing significant changes depends on the ability to construct creative narratives (Varfolomeeva, 2021).

[7] Unlike, e.g., such concepts as "creativity", "meta-competences", "universal competencies", or "4k competencies"

are located in just 15 countries. The United States and China account for 54% and 12.42% of the total number of unicorns, respectively. Their highest concentration is noted in such industries as fintech (517 unicorns), healthcare (433), and transportation (234).

Ilya Strebulaev (2025)[8] analysed the competency background of the founders of more than 1,000 unicorns. They tend to have a top-level education, most often received at Stanford, Harvard, and MIT; the probability of meeting a PhD among them is six times higher than in the average US residents sample. Most founders graduate from American universities (80%), followed by Tel Aviv University (Israel), the University of Waterloo (Belgium), and the Technion (Israel).[9] The typical unicorn founder also has an additional portfolio of post-university knowledge. Having diverse previous experience is a more important prerequisite for a strong TA position than "structural advantages" in the usual sense. The rapid growth of unicorn companies has produced a stable, creative narrative which serves as a role model for potential followers. The global entrepreneurial techno-environment offers a new, meaningful "game" for all who dare to take an innovative action in the logic of the "hero entrepreneur" archetype, who uses advanced technologies to transform the way of life based on a non-standard logic. The established narrative is picked up by carriers of TA potential, which creates incentives for further growth of the number of such companies. Interestingly, these dynamics occur not so much "thanks to", as "in spite of" the overall, predominantly quite negative economic and market growth trends of the recent years. This can be seen as evidence of the neostructuring processes mentioned in the introductory section.

Case studies of TA in companies employing a narrative approach

A more complete understanding of the nature of transformational processes, and of the role of TA in them, provide case studies of companies with a rich background using different types of narratives. These cases highlight hidden tools for scaling up TA in corporate environment, along with exogenous and endogenous formats of conducting transformational transitions.

We'll examine two corporations that implemented transformational transitions under the supervision of outstanding top managers of the 20th century: General Electric (Jack Welch), and Intel (Andrew Grove), both of whom certainly were TA carriers. In the first case, the transition was initiated "from within" in a "closed" mode; in the second, it came "from outside" and required unprecedented response measures. Transformational transitions are accompanied by a unique phenomenon that changes the ingrained ideas about the nature of proactivity and reactivity. This paradox is also evident in the cases under consideration. For General Electric the external context remained relatively stable, so the transition to new development model was facilitated artificially and proactively within the company itself. On the other hand, Intel had to handle the transition reactively, since external threats forced the company to employ such a strategy.

Contrary to simplified ideas, "proactivity" is not a winning strategy in all cases: in certain contexts the only right path is "reactivity". According to the common wisdom, proactivity is by definition something "positive", while "reactivity" is interpreted rather in a negative way. However, in a situation of transformational transition such distinction loses relevance: rapid and unpredictable changes have to be responded to more and more often, which strengthens the relevant transformational measures. Thus in managing complex systems, "reactivity" can be a no less important quality than "proactivity".

In our study, the time factor plays a significant role in analysing TA scaling processes. Decades have passed since the aforementioned top managers have left the "scene" - a sufficient period of time to assess the growth of the TA seeds they have sown, and to what extent their successors have subsequently managed (or failed) to scale up this competence and augment the achievements.

There two cases significant differ in terms of management style, choice of narratives, and results of transformational transition. At the same time they have two factors in common: reliance on the SAS principles (the companies operated in high-stress situations but maintained functionality), and use of narratives. The key condition for maintaining self-organisation in ascending dynamics is combining narratives of different nature: "supporting" (which strengthen long-term commitment and promote adaptive tension necessary in the context of transition), and "existentially challenging" ones.

In the GE case, we rely on the paper (McKelvey, 2010) which reveals the mechanisms and results of the transformational management. During the 20 years of Welch's leadership, the company's capitalisation increased 40 times (Sirisha, Dutta, 2002; Hartman, 2003). Such impressive growth was largely made possible by the use of SAS principles, managing "adaptive tension"[10] on a distributed basis[11] (as opposed to the traditional top-down "objective-based management"), and certain narratives. Time shows. however, that over a long

[8] https://endeavor.org/stories/unicorn-founder-pathways/, accessed on 04.06.2025.

[9] https://news.crunchbase.com/edtech/unicorn-founder-myth-education-matters-strebulaev-stanford/, accessed on 04.06.2025.

[10] The concept of "adaptive tension" describes the gap between the current situation and the desired future for an individual or organisation, identifying which prompts strategy development, becomes an incentive for knowledge sharing and fundamental internal transformations in response to the changing context. (Moroz, Gamble, 2010).

[11] I.e. without having a single decision-making centre, distributing management responsibilities between various members of the organisation (McKelvey, 2010).

Table 1. **Key Narratives Used in the Presented Cases**

GE	Intel
• "Be first or second, or leave!" • "Face what you don't want to face" ("Facing reality") • "Strategy is not a long-term action plan" • "Forget existing competencies and master new ones" • "Successful innovations bring in big money" • "Don't wait for clear instructions" • "Learn from each other"	• "Find your way in an unfamiliar, difficult environment with no rules" • "We make the transition like crossing a "death shadow valley", knowing exactly what awaits us at the other end" • "We put all our eggs in one basket, but protect the basket" • "Moving in the same direction blocks new opportunities" • "Listen to Cassandras - people at the frontier of change" • "Break down the walls between Cassandras and the management"

Source: author.

distance this approach ceases to work after a change in leadership due to "attachment" to its initiator, who has failed to scale up TA even over their immediate circle. When Welch left his position in 2001, GE's dynamics gradually changed from upward to downward, and not long ago the company ceased to exist having disintegrated into several mediocre firms. Nobody was able to embrace the transformational agency inherent in the leader, despite all efforts. One of the key reasons for the failure to achieve the desired effect seems to be the unbalanced portfolio of narratives used, dominated by the ones which can be described as "harsh" and "existentially challenging". The single "supportive" one (tangible financial rewards for successful experimental innovation projects) could not save the situation. A successful transformational transition requires a subtle understanding of its different facets, literally at the 'halftone" level. In the context of an excessively turbulent and emergent process no clear strategy can be employed by definition; however, this does not cancel the need for a common vision, and at GE the latter was too abstract. In the process of creating innovations employees had to find ideas in an extremely uncertain environment, with no benchmarks, and under a challenging key narrative ("Be first or second, or leave!"). Initiators of unsuccessful projects were promptly let go, as were managers unable to fire "losers".

The transformational transition model employed by GE comprised the following components: artificially created adaptive tension, diverse personnel competencies, maximum freedom of action, challenging narratives prompting people to go beyond the possible, and generous financial rewards (for successful innovations). However, due to the lack of sufficiently "supportive" narratives this model undermined the potential for scaling up TA. It was believed that in a situation close to existential risk, employees should master paradoxical thinking on their own, by teaching each other (Slater, 2001), in the expectation that co-evolution will produce the necessary educational effect. However, as other projects indicate, this approach does not work. Thus in the GE case, the conditions for scaling TA turned out to be inadequate, and the company's upward dynamics remained dependent on the efforts by the single carrier of this agency type. This model worked as long as the top manager (the TA carrier) remained "on stage". With his departure, the factors supporting the process came to naught, the corporation gradually degraded, and eventually fell apart.

In the Intel case, Andrew Grove's book (Grove, 1999) served as the source of information; he managed to successfully conduct a transformational transition largely due to the unique climate created by using the right combination of different-type narratives. As a TA carrier, Grove turned the complex transition management process into an "uncomplicated technique" supported by a transformative narrative based on the following logic: in most cases, strategic turning points (permacrises) occur as a result of a tenfold change in external contextual forces. Facing such a challenge discourages one, and "paralyses" their intellectual ability. People lose their spirit and cannot cope with the tasks at hand. The only way to "survive" is move much faster than competitors, in a correctly chosen direction. At such time employees must provide maximum possible support to each other at all levels; a most favourable atmosphere for exchanging opinions must be created, and transition management experts should be involved. Creating and maintaining such a climate requires great enthusiasm, takes time, effort, and other factors. Top-down and bottom-up actions during a transition are equally necessary, which in a different context would be impossible. Despite the fact that Intel did have the initial potential (in the form of a strong corporate culture and an adequate resource base), it was able to complete the transformational transition only due to the factors mastered during this process. To overcome an extremely complex existential crisis, the company "reinvented" itself. Only in the framework of a "reinvention" logic (which implies extremely adaptive stretching of cognitive and mental powers) personnel can master TA, and then during the subsequent cycles skilfully scale up this rare agency type.

Table 1 presents some of the narratives that determined the course of evolution of the companies under consideration.

To conclude, we emphasise that successful implementation of complex, long-term projects requires a combination of narratives of different type. In addition to "supportive" and "challenging" narratives there is a third, no less important kind which encourage creating adaptive tension in favourable internal and external contexts with positive development dynamics and no danger of falling into inertia and changing pace. Such narratives can become the subject of further research to enrich the understanding of the roles of different narrative types in successfully completing transformational transitions and scaling up TA.

Conclusion

The ongoing chain of various-nature crises raises the question of transformational transition of systems, organisations, sectors, etc. to a new development model, giving this topic the status of a scientific discussions frontier and making it a key practical challenge. The literature on sociology, economics, management, psychology, education, and technology examines the driving forces of change from different perspectives. However, human agency at the transformational level (TA), which is the focus of this paper, remains insufficiently studied. TA implies a rare, and highly sought-after ability to radically transform socio-economic and other systems that have lost their upward dynamics, to create innovations. The education system is largely responsible for the development and scaling of TA skills. But it mostly reproduces "improving" agency (aimed at supporting and upgrading existing institutional structures), and this is observed in all countries. Such approaches worked well in times of relative stability and low pace of change. However, the current context of high turbulence, rapid change, and instability requires a new logic to deal with things "never encountered before". Against the background of the new, increasingly complex "global" agenda, including the transition to the latest economic models (Industry 4.0 and 5.0) and digitalisation of production processes, the exhausted potential of most of the existing "traditional" tools, and their inadequacy for responding to the new challenges is becoming obvious.

A certain contribution to understanding the nature of TA and methods of its development is made by the corporate sector and some universities, which in recent years have been actively experimenting in this area and achieved significant success. Their results indicate that a flexible combination of IA and TA characteristics allows to design new approaches to accomplishing major objectives, successfully conduct transformational transitions, and adopt more complex development models.

The paper analyses agency in the context of different stages of the education system, and explores possible approaches to developing and scaling up TA taking into account the potential of AI and the narrative theory. Case studies of companies transformed by TA carriers highlight the implicit characteristics of this agency type, and describe possible ways to develop relevant skills. They illustrate key theoretical postulates which structure and integrate the latest advances in open systems theories (Haan, Rotmans, 2018) with the social theory ideas (the neostructuration concept) and applied psychological and educational concepts, such as, e.g., the narrative creativity theory (Fletcher, Benveniste, 2025). Our analysis shows that skilful application of the narrative approach is becoming an effective tool for scaling up TA as a competence required for successful transformational transition of organisations, sectors, and other systems to new development models. It's based on the correct balance of different-nature narratives ("supportive" and "challenging" ones), finding which is a non-trivial task, despite the seeming simplicity of its formulation. One of the companies reviewed in the paper was unable to accomplish this objective, despite having a solid resource base. The problem of human agency, and its role in the transformational transitions of socio-economic, ecological and technological systems requires further research, which, given the current global and national challenges, would be crucially important both theoretically and practically.

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