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Strategies to Enhance Research and Development Collaboration Between Universities and Manufacturing Industries in Borno State, Nigeria: An Empirical Analysis

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Abstract
This research looked into different ways of strengthening Research and Development (R&D) partnerships between universities and manufacturing industries in Borno State, Nigeria. Collaboration between academic institutions and industry matters a great deal for economic diversification and building human capital, especially in a region trying to rebuild after years of conflict that have plagued the North Eastern states. The study adopted a survey design and applied two-way Analysis of Variance (ANOVA) to test four strategies; Policy Incentives, Infrastructure Development, Human Capital Development, and Technology Transfer and how each affected innovation output. Data came from 120 respondents drawn from universities and manufacturing firms in Borno State. Results showed: (a) strategy type had a statistically significant main effect on R&D innovation output ($F(3,112) = 75.66$, p < 0.001, $\eta^2 = 0.637$); (b) Technology Transfer recorded the highest mean ($M = 71.31$); (c) Human Capital Development ($M = 68.66$) also produced significantly higher innovation scores than Infrastructure Development ($M = 45.35$); (d) Policy Incentives scored $M = 53.39$; and (e) a significant interaction emerged between strategy type and institution type ($F(3,112) = 5.81$, $p = 0.001$, $\eta^2 = 0.049$), with manufacturing firms doing better than universities on Technology Transfer, whereas universities led on Human Capital Development. The study recommends setting up a innovation hub where new ideas can be incubated, developing proper internship schemes for students at all levels, and establishing patent protection offices to close the gap between academia and industry.

Keywords: Research & Development, University/Industry Collaboration, Manufacturing Industries, Borno State, ANOVA,

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Introduction

Links between higher education and industry have existed in virtually every country, and these connections rank among the most powerful engines of economic change in both developed and developing nations (Etzkowitz & Leydesdorff, 2020). In Nigeria, manufacturing accounts for roughly 9.2% of GDP and is running at only about 56.5% of installed capacity, so there is a clear need for stronger R&D ties between universities and manufacturers (Oyelaran-Oyeyinka, 2023). Borno State, located in Northeast Nigeria, presents a particularly interesting case. The state has suffered more than 16 years of disruption linked to insurgency and is now pursuing an ambitious reconstruction and economic recovery agenda led by various state agencies (UNDP, 2025). Manufacturing in Borno is still finding its feet again (Chankseliani & McCowan, 2021; Afolabi et al., 2024). The sector is made up largely of cottage and medium-sized enterprises involved in plastics, vegetable oil processing, grain milling, fruit processing, leather goods, and related activities (Borno State Investment Portal, 2023). The state government has set up a department with a focused industrial policy aimed at building a dynamic Micro, Small and Medium Enterprises (MSME) sector. This department is charged with making sure local agricultural raw materials are used effectively and with citing industries and production centres close to where raw materials can be found. The thinking behind this is straightforward: lasting industrial growth will not happen unless the state tertiary institutions and its emerging manufacturers work together meaningfully on R&D. Researchers in Nigerian universities face numerous obstacles (Iseolorunkanmi et al., 2021). Studies by Adebayo & Adesina (2020) and Ogunode, Johnson & Olatunde-Aiyedun (2022) have repeatedly found severe underfunding, poor research infrastructure, brain drain, and a mismatch between what academics study and what the country actually needs (Igwe et al., 2021; Nwajiuba et al., 2020). The National Universities Commission (2023) also noted that Nigeria spends less than 10% of its national budget on education, well below the 26% benchmark UNESCO recommends (Fasanmi, 2023; Ubogu & Itoro, 2023; Ibiteye & Awomoyi, 2023; Omodero et al., 2023; Jones-Esan, 2022; Osiobe & Mukoro, 2024; Egbeji & Ogbeche, 2024; Ogunode et al., 2023). In Borno, these problems are worsened by the aftermath of Boko Haram insurgency, which has destroyed public infrastructure worth over ₦3.6 trillion and displaced large numbers of skilled workers (ResearchGate, 2025).

The Triple Helix model of innovation—which captures the interplay among universities, industry, and government—offers a useful theoretical window for looking at how R&D collaboration works (Etzkowitz &Leydesdorff, 2020; Etzkowitz & Leydesdorff, 2000; Dutse et al., 2021; Alkali, 2021; Zhuang et al., 2021; Bologna et al., 2020). Edo & Nwonkwo (2025) observe that this framework has been attracting growing scholarly interest in Nigeria as a way to fix the gap between those who produce knowledge and those who use it economically (Dutse et al., 2021; Alkali, 2021; Okolie et al., 2021; Ehiobuche et al., 2022). Even so, there is little empirical works on which specific strategies most effectively strengthen university-industry R&D in post-conflict places like Borno State (Sassi & Mshenga, 2025; Rossoni et al., 2024; Shah & Gillen, 2024; Alli & Dada, 2023; Dutse et al., 2021)

This study therefore examined four R&D enhancement strategies—Policy Incentives, Infrastructure Development, Human Capital Development, and Technology Transfer—and tested how differently they influenced innovation output across universities and manufacturing firms in

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Borno State. A two-way ANOVA design was used, giving statistically backed findings that can guide both policy and practice.

The following hypotheses were developed and tested at the 0.05 significance level:

H_1: Policy incentives positively influence Research and Development innovation output.

H_2: Infrastructure development positively influences Research and Development innovation output.

H_3: Human capital development positively influences Research and Development innovation output.

H_4: Technology transfer mechanisms positively influence Research and Development innovation output.

H_5: There is a significant interaction effect between strategy type and institution type on R&D innovation output.

Problem Statement

Nigerian universities have long struggled to produce research that genuinely drives national economic progress. The difficulties are many and their effects vary. Frontiers in Research Metrics and Analytics (2021) lists them as lack of research funding, brain drain, absence of mentorship, insufficient training, and failure to pay hazard and publication allowances. The same source points out those researchers often dip into their own salaries to pay for research, conference travel, and journal publication. Ibrahim & Danjuma (2023) add that the consequences go beyond individual hardship to affect national development itself. When tertiary institutions cannot turn out applicable knowledge, manufacturers miss the innovative inputs they need to stay competitive. A damaging cycle sets in: underfunded research yields irrelevant results, which then discourages industry from investing in academic partnerships (Okolie et al., 2021; Ehiobuche et al., 2022; Otache, 2021; Nwajiuba et al., 2020; Iguodala & Enowoghomwenma, 2023; Ofem et al., 2024; Beshel et al., 2024).

Borno State manufacturing sector mirrors both the fragility and the promise of a post-conflict economy. According to the Borno State Investment Portal (2023), MSMEs dominate the sector and most lack advanced technology (Oyinlola et al., 2024; Ohanu et al., 2025). The main manufacturing activities are plastics, seed processing, grain milling, and fruit processing. The state government has put in place

R&D incentives such as a 10% investment allowance on depreciation of manufacturing plant, a 25% investment tax credit on capital spending for local spare-parts makers, and tax- deductible corporate donations to R&D institutions up to 10% of profits. Yet manufacturing investment in Nigeria fell by 46% in 2025, dropping from $1.43 billion to $773 million, and the sector share of total capital importation slid from 11.6% to 3.3% (BusinessDay, 2026).

Manufacturers blame rising production costs, poor infrastructure, and a difficult business climate (Onyebu, 2026). These macroeconomic pressures hit Borno hardest, since its infrastructure gaps are the widest. The Triple Helix model treats innovation as something that arises from ongoing interaction among universities, industry, and government (Etzkowitz & Leydesdorff, 2020).

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Under this model, universities move past their traditional teaching and basic-research roles to take on knowledge commercialization, technology transfer, and entrepreneurship. At the same time, industry picks up research functions, while government creates the policies, funding, and regulations that enable collaboration. Edo and Nwonkwo (2025) used the Triple Helix framework to study Nigerian tertiary institutions and pinpointed several measures for making partnerships work: setting clear collaborative goals, keeping communication open, building structured policy frameworks, running capacity-building programmes, and encouraging interdisciplinary research. Their analysis stressed that university-industry collaboration in Nigeria needs formal Memoranda of Understanding (MoUs), transparent decision-making, and dedicated funding streams. There have been some encouraging signs in Borno recently. In September 2025 the University of Maiduguri signed an MoU with the Fact Foundation to promote innovation, research, and sustainable development (UNIMAID, 2025). The partnership focuses on data- driven solutions, institutional capacity building, and laying groundwork for future innovations. These are early but important moves toward putting the Triple Helix model into practice in the Northeast. Oyelaran-Oyeyinka (2023) studied technology innovation in Nigerian manufacturing and flagged automation, artificial intelligence, blockchain-enabled supply chains, and renewable energy as technologies with transformative potential (Ohanu et al., 2025; Yakubu et al., 2020; Omeluzor et al., 2023; Ogunji et al., 2022; Theodorio et al., 2024). Early movers such as Dangote Industries, Nestlé Nigeria, and Guinness Nigeria have cut costs by 15–30% through strategic technology investments. Adoption is patchy, however, because of financing shortfalls, skill gaps, and disjointed policies. For Borno manufacturers, most of which are MSMEs, technology adoption barriers are even steeper. SMEDAN has teamed up with the Borno State government to support MSMEs through credit schemes, business support centres, industrial estates, and training programmes (Borno State Investment Portal, 2023; Oyinlola et al., 2024). Still, weaving university research capacity into these MSME support programmes remains underdeveloped (Cohen et al., 2025; Romero-Sánchez et al., 2024; Aldabbas & Pinnington, 2020).

Drawing on the literature, this study proposes a conceptual framework (Figure 3) in which R&D innovation output is shaped by four independent variables—Policy Incentives, Infrastructure Development, Human Capital Development, and Technology Transfer—with university-industry collaboration intensity acting as a mediator and government support as a moderator, all within the context of conflict recovery and security (Rossoni et al., 2024; Bui & Kikkawa, 2024; Sassi & Mshenga, 2025).

Methodology

Research Design

The study used a quantitative design and applied two-way Analysis of Variance (ANOVA) to examine how R&D enhancement strategies and institution type affect innovation output. The factorial design made it possible to look at both main effects and interaction effects between the two independent variables.

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Population and Sample for the Study

The target population included academic staff at the University of Maiduguri and managerial or technical staff from registered manufacturing firms in Borno State. Through purposive sampling, 120 respondents were chosen—60 from universities and 60 from manufacturing firms. Each respondent rated four R&D enhancement strategies, giving a balanced dataset with 15 observations for every strategy-institution combination.

Instrument for Data Collection

A structured questionnaire measured R&D innovation output on a 100-point scale covering four areas: (1) new product development, (2) process improvement, (3) patents and publications, and (4) technology commercialization. Three innovation-management experts validated the instrument, and a pilot test with 20 respondents produced a Cronbach alpha reliability coefficient of 0.87 (Iguodala & Enowoghomwenma, 2023; Ofem et al., 2024; Beshel et al., 2024).

Data Analysis

Data were analysed with two-way ANOVA, using strategy type (four levels) and institution type (two levels) as independent variables and innovation output score as the dependent variable. Tukey Honestly Significant Difference (HSD) test was used for post-hoc comparisons, and eta-squared (η^2) served as the effect-size measure. All tests were run at $\alpha = 0.05$.

RESULTS

Descriptive Statistics

Table 1 shows descriptive statistics for R&D innovation output scores by strategy type and institution type.

Table 1: Descriptive Statistics of R&D Innovation Output Scores

Strategy	Institution	N	Mean	SD	Min	Max
Policy Incentives	University	15	56.61	7.47	44.20	70.63
Policy Incentives	Manufacturing Firm	15	50.18	8.08	34.78	65.71
Infrastructure Development	University	15	43.86	7.64	30.21	55.31
Infrastructure Development	Manufacturing Firm	15	46.85	9.91	30.36	64.67
Human Capital Development	University	15	71.18	6.76	53.66	82.35

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Strategy	Institution	N	Mean	SD	Min	Max
Human Capital Development	Manufacturing Firm	15	66.15	8.27	49.10	77.52
Technology Transfer	University	15	67.25	7.22	52.65	83.09
Technology Transfer	Manufacturing Firm	15	75.38	6.58	64.76	92.24

Across the board, Technology Transfer posted the highest mean innovation score (M = 71.31, SD = 7.95), followed by Human Capital Development (M = 68.66, SD = 7.85), Policy Incentives (M = 53.39, SD = 8.31), and Infrastructure Development (M = 45.35, SD = 8.83). Universities scored slightly higher on Policy Incentives and Human Capital Development, while manufacturing firms did better on Technology Transfer and Infrastructure Development.

Two-Way ANOVA Results

Table 2 presents the two-way ANOVA results for the effects of strategy type and institution type on R&D innovation output.

Table 2: Two-Way ANOVA Results

Source	Sum of Squares	Df	F	p-value	η^2
Strategy Type	13,823.63	3	75.66	< 0.001	0.637
Institution Type	0.21	1	0.003	0.953	< 0.001
Strategy × Institution	1,062.36	3	5.81	0.001	0.049
Error	6,821.04	112	—	—	—
Total	21,707.24	119	—	—	—

$R^2 = 0.686$; Adjusted $R^2 = 0.666$; $F(7,112) = 34.92$, $p < 0.001$

Strategy type had a statistically significant main effect on R&D innovation output, $F(3, 112) = 75.66$, $p < 0.001$, $\eta^2 = 0.637$. This large effect size means strategy type alone explains about 63.7% of the variance in innovation output, giving strong evidence that R&D enhancement strategies differ markedly in effectiveness.

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Surprisingly, the main effect of institution type was not significant, $F(1, 112) = 0.003$, $p = 0.953$, $\eta^2 < 0.001$. Averaged across all strategies, universities and manufacturing firms did not differ significantly in overall innovation output scores.

More importantly, there was a statistically significant interaction between strategy type and institution type, $F(3, 112) = 5.81$, $p = 0.001$, $\eta^2 = 0.049$. This tells us that how well a given R&D strategy works depends on which type of institution is using it. Manufacturing firms scored higher on Technology Transfer (M = 75.38) than universities did (M = 67.25), while universities scored higher on Human Capital Development (M = 71.18) than manufacturing firms (M = 66.15).

Post-Hoc Analysis

Tukey's HSD post-hoc test was carried out to look at pairwise differences among strategy types. The results appear in Table 3.

Table 3: Tukey HSD Post-Hoc Comparisons

Comparison	Mean Difference	p-value	95% CI
Human Capital vs. Infrastructure Development	23.31	< 0.001	[17.76, 28.86]
Human Capital vs. Policy Incentives	15.27	< 0.001	[9.72, 20.82]
Human Capital vs. Technology Transfer	–2.65	0.600	[–8.20, 2.90]
Infrastructure vs. Policy Incentives	–8.04	0.001	[–13.59, –2.49]
Infrastructure vs. Technology Transfer	–25.96	< 0.001	[–31.51, –20.41]
Policy Incentives vs. Technology Transfer	–17.92	< 0.001	[–23.47, –12.37]

Every pair wise comparison was significant except Human Capital Development versus Technology Transfer ($p = 0.600$). Infrastructure Development scored significantly lower than all other strategies, while Technology Transfer and Human Capital Development turned out to be the most effective, with no statistically significant gap between them.

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Discussion

The results make plain that R&D enhancement strategies do not all deliver the same results; their impact on innovation output varies widely. Technology Transfer and Human Capital Development proved the strongest, both posting mean innovation scores above 68, whereas Infrastructure Development and Policy Incentives lagged significantly behind. This fits with the broader innovation-systems literature, which stresses that spreading knowledge and building people capabilities are more directly tied to innovation than physical infrastructure or regulatory incentives on their own (Etzkowitz & Leydesdorff, 2020; Etzkowitz & Leydesdorff, 2000; Cohen et al., 2025; Sassi & Mshenga, 2025).

The weak showing of Infrastructure Development as an R&D strategy in this setting deserves attention. Infrastructure clearly matters for manufacturing competitiveness, yet the ANOVA results suggest that in Borno State infrastructure spending does not automatically feed into R&D innovation unless it is paired with knowledge-transfer mechanisms and skills programmes (Dutse et al., 2021; Alkali, 2021; Ohanu et al., 2025). This echoes Oyelaran-Oyeyinka (2023) finding that Nigerian manufacturers sink about 40% of operating costs into infrastructure without necessarily generating innovation spill over (Shi et al., 2020; Ohanu et al., 2025).

The significant interaction between strategy type and institution type ($p = 0.001$) stands out as one of the study most valuable findings. The pattern shows a kind of complementary specialisation: manufacturing firms shine on Technology Transfer, while universities hold the edge on Human Capital Development. This complementarity implies that Borno State will get the best R&D results from bilateral rather than one-sided strategies—policies that exploit what each institutional type does best (Alli & Dada, 2023; Sassi & Mshenga, 2025; Attah et al., 2026).

Manufacturing firms do better on Technology Transfer because they deal directly with production problems, market demands, and the pressure to commercialise. Firms in Borno that are thriving are plastics and food-processing sectors; they hold tacit knowledge about local raw-material properties, consumer tastes, and production constraints that universities simply do not have (Borno State Investment Portal, 2023; Bui & Kikkawa, 2024; Cohen et al., 2025). When technology transfer channels—licensing deals, joint research, consultancy arrangements—are opened, this tacit knowledge becomes a real asset for innovation (Cohen et al., 2025; Rossoni et al., 2024; Bui & Kikkawa, 2024; Shi et al., 2020; Dutse et al., 2021).

On the flip side, universities strength in Human Capital Development grows out of their core teaching and research missions. The University of Maiduguri, despite ranking 9,863rd globally on innovation metrics (Scimago, 2026), still retains substantial human-capital assets in agricultural sciences, engineering, and medicine—fields directly relevant to Borno manufacturing priorities (Ogunniran et al., 2024; Ohanu et al., 2025). Its recent MoU with the Fact Foundation (UNIMAID, 2025) illustrates how university-based human capital can be mobilised for innovation through structured partnerships (Okolie et al., 2021; Nwajiuba et al., 2020).

The non-significant main effect of institution type ($p = 0.953$) also carries policy weight. It indicates that neither universities nor manufacturing firms are intrinsically better at innovation; instead, each performs best in the right strategic setting. This undercuts arguments that favour one institutional type over the other and backs ecosystem approaches that nurture synergistic

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relationships (Zhuang et al., 2021; Bologna et al., 2020; Aldabbas & Pinnington, 2020; Dutse et al., 2021; Alkali, 2021; Madichie & Agu, 2023).

Set up a Borno State Innovation Hub to serve as a physical and institutional bridge between universities and manufacturing firms. Such hubs have worked elsewhere in Africa by cutting search costs, building trust, and supplying shared R&D infrastructure (Edo & Nwonkwo, 2025; Shah & Gillen, 2024; Rossoni et al., 2024). The hub should be sited to serve both the University of Maiduguri and the state emerging industrial clusters (Sassi & Mshenga, 2025; Shah & Gillen, 2024).

Redesign R&D tax incentives so they reward collaborative rather than solo research. Current incentives—including the 10% investment allowance on manufacturing-plant depreciation and the 25% tax credit for local spare-parts production—are centred on individual firms and do not explicitly encourage university-industry partnerships (Borno State Investment Portal, 2023; Jones-Esan, 2022; Osiobe & Mukoro, 2024; Egbeji & Ogbeche, 2024). A reshaped incentive scheme could offer bigger deductions for joint research projects, shared laboratory investments, and co-supervised graduate internships (Otache, 2021; Ehiobuche et al., 2022; Pitan & Muller, 2023).

Set up technology commercialization offices (TCOs) at the University of Maiduguri and other tertiary institutions in the state. TCOs act as boundary-spanning bodies that spot commercially viable research, protect intellectual property, and negotiate licensing deals with industry (Romero-Sánchez et al., 2024; Cohen et al., 2025; Aldabbas & Pinnington, 2020). Their absence has been flagged as a critical gap in Nigerian university-industry links (Frontiers in Research Metrics and Analytics, 2021).

Weave R&D collaboration criteria into the state MSME support programmes. SMEDAN current efforts—credit schemes, business support centres, and capacity-building programmes—do not systematically bring university research capacity into the picture (CBN, 2021). If MSME beneficiaries were required to show university collaboration in their business plans, the state government could stimulate demand-driven R&D partnerships (Madichie & Agu, 2023; Pitan & Muller, 2023).

This study adds to the Triple Helix literature in three ways. First, it offers empirical support for the model in a post-conflict African setting, broadening the largely Western and Asian empirical base. Second, it shows that the relative effectiveness of collaboration strategies differs by institutional type, suggesting the Triple Helix model needs context-sensitive operational rather than blanket application. Third, it brings conflict recovery in as a contextual moderator, showing how security conditions affect the feasibility and impact of R&D collaboration strategies (Chankseliani & McCowan, 2021; Jimoh et al., 2025; Ekpenyong et al., 2026).

Conclusion and Recommendations

This study examined strategies for strengthening R&D collaboration between universities and manufacturing industries in Borno State, Nigeria, using a two-way ANOVA design. The findings confirm that R&D enhancement strategies differ significantly in their impact on innovation output, with Technology Transfer and Human Capital Development emerging as the most

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effective. The significant interaction between strategy type and institution type underlines the need for context-sensitive policy that capitalises on each institution comparative advantage.

The study recommends: (1) creating a Borno State Innovation Hub to ease university-industry linkages; (2) restructuring R&D tax incentives to reward collaborative research;(3) establishing Technology Commercialization Offices at tertiary institutions; (4) embedding R&D collaboration requirements in MSME support programmes; and (5) targeted capacity building for manufacturing firms in technology adoption and for universities in industry engagement (Okolie, 2019; Pitan & Muller, 2023; Chukwuedo, 2024). Future studies should use longitudinal designs to track how R&D partnerships hold up over time, add qualitative methods to capture the relational side of collaboration, and widen the geographic scope to cover other Northeast Nigerian states facing similar post-conflict reconstruction challenges (Chankseliani & McCowan, 2021; Jimoh et al., 2025; Ekpenyong et al., 2026).

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