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# Systemic Reconfiguration: A Framework for Sustained R&D Investment and Knowledge Commercialisation in Zambia's National Innovation System

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**Abstract: Zambia's pursuit of innovation-led economic development is fundamentally hindered by a severely underdeveloped National Innovation System (NIS). This study highlights a significant systemic gap characterised by chronic underinvestment in Research and Development (R&D), weak human capital development, and minimal knowledge commercialisation capacity. Comparative analysis shows that Zambia's R&D expenditure ranges from 0.03% to 0.28% of GDP, well below the African average of 0.42% and far beneath benchmarks set by advanced economies (2–3.5%). This results in a funding shortfall that is 10–12 times smaller than in advanced economies, and researcher density is 20 times lower than in the European Union (EU) and United States (USA). To address this structural inertia, we recommend a systemic reconfiguration based on global best practices. The key proposal is the creation of a National Research & Innovation Fund managed by the National Science and Technology Council (NSTC) and the National Technology Business Centre (NTBC), with a sustained annual allocation of at least 1% of GDP over the next decade from government ministries and agencies. This would also include incentivising the private sector and leveraging occasional external foreign research funding as the country tackles various developmental challenges. Crucially, institutional reforms should include adopting South Africa's NRF and NIPMO model and legislating Bayh-Dole–style rights (1980) to enable universities to own and license publicly funded research outputs, thereby fostering a resilient, research-industry integrated ecosystem**

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## I. INTRODUCTION

Innovation is globally recognised as the primary engine for sustained economic growth and structural transformation. For developing economies like Zambia, the transition to an innovation-led development model is crucial for achieving global and regional competitiveness in scientific publications, innovation outputs, and increasing the manufacturing share of GDP. Countries that are higher on the global innovation index are also higher in patenting and manufacturing output (Phiri et al., 2023). While a technical report highlights the need for constructing and refurbishing research infrastructure, including laboratories, workshops, and ICT facilities for public universities, this paper argues that the core constraint is structural and financial.

Zambia's research funding is characterised by unsustainable reliance on occasional foreign and donor-funded projects, which is insufficient for the country to catch up with African and global averages. A defining structural constraint to innovation-led development is the persistent underinvestment in Research and Development (R&D), coupled with weak human capital intensity and limited knowledge commercialisation capacity (Phiri et al., 2023). Comparative global evidence consistently shows that Zambia lags significantly behind both advanced and emerging economies across all key research and innovation indicators (Phiri et al., 2023).

This study aims to provide an integrative analysis of Zambia's systemic innovation deficits by benchmarking key indicators against African and global peers and to propose a coherent, policy-driven framework for systemic reconfiguration. The study contributes to the literature by linking funding architecture, institutional coordination, and commercialisation outcomes within a developing economy context, proposing a coordinated funding and commercialisation framework anchored in global best practices but adapted to Zambia's institutional context.

## II. LITERATURE REVIEW

Prior studies have established the empirical necessity of R&D investment and robust institutional frameworks for national innovation systems. The empirical literature consistently shows that sustained R&D investment above 1% of GDP is a critical threshold for transitioning toward innovation-driven growth (Mazzucato, 2018; OECD, 2021). Globally, innovation leaders such as the United States, Europe, and Asia spend between 2% and 3.5% of GDP on R&D and generate thousands of patents and startups each year.

Furthermore, high researcher density is strongly associated with knowledge spillovers, absorptive capacity, and technological upgrading (Romer, 1990; Aghion & Howitt, 2009). Conversely, a low researcher base, such as Zambia's 42–220 researchers per million, limits the potential for innovation production and diffusion. The institutionalisation of research commercialisation is also a significant topic, with the US Bayh–Dole Act (1980) and South Africa's Intellectual Property Rights (IPR) Act (2008) and National Research Foundation (NRF) serving as key legislative models that enable universities to retain ownership and license publicly funded research outputs (AUTM, 2022).

The "institutionalisation" of research commercialisation refers to the historical shift in academia where transferring technology from the laboratory to the market transitioned from being an ad-hoc, individual endeavour to a formal, legally mandated core function of modern universities.

Rather than allowing valuable research to languish in academic journals, governments worldwide recognised the need for structured systems that incentivise universities to protect, market, and license their discoveries. This institutionalisation is driven primarily by national legislation that shifts intellectual property (IP) ownership from the funding government to the executing research institution.

The Patent and Trademark Law Amendments Act, universally known as the Bayh-Dole Act (1980), is widely considered the foundational blueprint for global academic tech transfer.

- *The Pre-1980 Problem:*

Prior to this act, the U.S. federal government retained the title to any invention created with federal funding. Without exclusive rights, private industry was unwilling to invest the capital required to turn these raw patents into commercial products.

- *The Legislative Shift:*

Bayh-Dole decentralized IP ownership, allowing universities, non-profits, and small businesses to elect to retain title to their federally funded inventions.

- *The Institutional Impact:*

To manage these new assets, universities were forced to establish specialised Technology Transfer Offices (TTOs). The Act also mandated that universities must attempt to commercialise the technology (often prioritising small businesses) and must share a portion of the licensing royalties with the original academic inventors (Mwiya et al, 2024).

Inspired by the economic success of Bayh-Dole, South Africa sought to align its public research outputs with its national socio-economic development goals. This resulted in the Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act) of 2008.

- *Socio-Economic Mandate:*

While mirroring Bayh-Dole by granting universities ownership of publicly funded IP, the IPR Act places a stronger statutory emphasis on ensuring the IP is commercialised for the benefit of the people of South Africa.

- *Capacity Building:*

The Act mandated the creation of TTOs across South African universities and established the National Intellectual Property Management Office (NIPMO) to provide oversight, funding, and capacity-building support for these university offices.

- *The Role of the NRF:*

Within this ecosystem, the National Research Foundation (NRF) serves as the primary government funding engine for research, researchers and research infrastructure. The NRF works in tandem with the IPR Act by ensuring that the millions of Rand injected into public university research are strictly monitored for IP potential. Grant recipients are obligated to report promising discoveries to their respective TTOs before publishing, preventing the premature disclosure that would destroy patentability.

As highlighted by the Association of University Technology Managers (AUTM, 2022), legislative models like Bayh-Dole and the IPR Act share several critical outcomes that define the modern university:

Table 1 The Role of the NRF

| Core Pillar | Legislative Outcome |
|---|---|
| Asset Ownership | Shifts IP control from bureaucratic government agencies to the agile institutions that actually produced the research. |
| Inventor Incentives | Legally requires institutions to share financial windfalls (royalties/equity) with the scientists, driving a culture of entrepreneurial academia. |
| Ecosystem Creation | Justifies the operational budgets for professional TTOs, incubators, and university-affiliated venture funds. |
| Industry Collaboration | Provides private-sector companies with the legal clarity and exclusivity (via licensing agreements) required to confidently invest in early-stage, high-risk academic technologies. |

By establishing clear legal rules of engagement, these frameworks have successfully transformed universities from isolated "ivory towers" into primary engines for local economic development, startup creation, and global industrial innovation.

While prior studies have examined individual dimensions of Zambia's research system, there is limited integrative analysis linking funding architecture, institutional coordination, and commercialisation outcomes, leaving a research gap concerning a comprehensive systemic reconfiguration framework.

## III. THEORY

This study is grounded in three core economic theories of growth and innovation: Endogenous Growth Theory, New Structural Economics, and the Entrepreneurial State framework.

➢ *Endogenous Growth Theory*

Endogenous Growth Theory (Romer, 1990; Aghion & Howitt, 1992) asserts that sustained economic growth is driven by the accumulation of knowledge and innovation, which are non-rival and partially excludable goods. The resulting knowledge spillovers enhance economy-wide productivity (Akcigit, Hanley, & Serrano-Velarde, 2020). Chronic underinvestment in R&D and low researcher density, as seen in Zambia, structurally limit these spillovers, restricting the potential for endogenous growth (Aghion & Howitt, 2009).

➢ *New Structural Economics*

New Structural Economics (NSE), proposed by Lin (2012), emphasizes that successful structural transformation depends on industrial upgrading, which is tied to technological capability accumulation and cohesive innovation systems development. The observed weakness of Zambia's manufacturing base (8–10% of GDP) correlates with its limited R&D expenditure, confirming the theoretical link between weak innovation systems and poor industrial upgrading outcomes.

➢ *Intellectual Property Rights and the Entrepreneurial State*

The Entrepreneurial State framework (Mazzucato, 2013) highlights the pivotal role of public investment in driving high-risk, basic research. The effective translation of this public research into economic value requires specific institutional and legal frameworks (Audretsch, 2009; Acs, Estrin, Mickiewicz, & Szerb, 2018). Models such as the US Bayh–Dole Act (1980) provide the institutional mechanism—the right for universities to own and license IP from publicly funded research—essential for bridging the "commercialisation gap" and fostering university-driven spin-offs (Audretsch, 2013).

## IV. METHODS

This study employed a Comparative National Innovation System (NIS) Benchmarking methodology to quantitatively diagnose Zambia's structural deficits. The analysis utilizes publicly available secondary data from international organizations and published research reports to establish quantitative gaps across core indicators: R&D intensity, human capital, knowledge output, and commercialisation.

➢ *Data Sources and Benchmarks:*

- R&D and Human Capital Indicators: Data from the UNESCO Institute for Statistics (2023) and World Bank (2024).
- Scientific Output: Scopus/SJR data (2024).
- Commercialisation Outputs: Association of University Technology Managers (AUTM, 2022) and country-specific reports (Phiri et al., 2023).

Zambia's performance was benchmarked against the African average, regional leaders (South Africa, Kenya, Egypt), and global innovation leaders (European Union, United States, and Asia) to provide the necessary empirical foundation for policy prescriptions.

## V. RESULTS

The comparative analysis reveals multiple, interconnected structural deficits across Zambia's NIS, as summarised in Table 1 (Comparative Research & Innovation Indicators: Zambia vs Global Benchmarks) and Table 2 (Africa Benchmark Comparator (for Policy Context).

Table 2 Comparative Research & Innovation Indicators: Zambia vs Global Benchmarks

| Indicator | Zambia | Africa (Avg.) | European Union | United States | Asia (Avg.) |
|---|---|---|---|---|---|
| R&D Expenditure (% of GDP) | ~0.03% to 0.28% | ~0.42% | ~2.2% | ~3.5% | ~2.6% |
| Researchers per Million Population | ~180–220 | ~200–300 | ~4,000–4,500 | ~4,300 | ~1,500–7,500 |
| Annual Scientific Publications | ~1,200–1,800 | ~120,000 (total continent) | ~900,000+ | ~700,000+ | ~800,000+ |
| Global Share of Publications | <0.05% | ~2–3% | ~25–30% | ~20–25% | ~35–40% |
| Patents (Annual, Resident + non-resident) | <20 | ~15,000 (continent total) | ~150,000+ | ~600,000+ | ~1,200,000+ |

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|---|---|---|---|---|---|
| University Startups/Spin-offs (Annual) | <5 | Limited/fragmented | ~3,000+ | ~1,000+ | Rapidly growing (esp. China, India, Korea) |
| Manufacturing Value Added (% of GDP) | ~8–10% | ~10–12% | ~15–18% | ~11% | ~20–30% |
| Innovation Ecosystem Maturity | Nascent | Emerging | Advanced | Highly Advanced | Advanced (fast-scaling) |

➤ *R&D Intensity and the Funding Gap*

Zambia's R&D expenditure is estimated to be between 0.03% and 0.28% of GDP. This figure is substantially below the African average of 0.42% and drastically below advanced economies like the United States (3.5%), the European Union (2.2%), and major Asian economies (2.6%) (UNESCO Institute for Statistics, 2023; World Bank, 2024). This disparity confirms a Funding Gap where Zambia invests 10–12 times less in R&D than advanced economies, failing to meet the critical 1% of GDP threshold (Mazzucato, 2018; OECD, 2021).

Table 3 Africa Benchmark Comparator (for Policy Context)

| Indicator | Zambia | South Africa | Kenya | Egypt |
|---|---|---|---|---|
| R&D (% GDP) | ~0.03% to 0.28% | ~0.8% | ~0.7% | ~1.0% |
| Researchers/million | ~42 to 220 | ~2,800 | ~300 | ~1,000 |
| Publications/year | ~1,500 | ~25,000+ | ~8,000+ | ~30,000+ |
| Patents/year | <20 | ~300+ | Low | Moderate |
| Manufacturing (% GDP) | ~10% | ~13% | ~9% | ~16% |

➤ *Human Capital Constraints*

Zambia has approximately 42–220 researchers per million population. This density is severely constrained compared to the European Union and the United States, which both exceed 4,000 researchers per million, representing a Human Capital Gap that is 20 times lower. Regionally, Zambia also lags significantly behind South Africa 2,800/million) and Egypt 1,000/million).

➤ *Knowledge Production and the Output Gap*

Zambia produces approximately 1,200–1,800 peer-reviewed publications annually, contributing less than 0.05% to global scientific output. In contrast, the United States produces over 700,000 publications annually. Regionally, South Africa (25,000 publications annually) and Egypt (30,000) significantly outperform Zambia, demonstrating a negligible output gap.

➤ *Innovation Outputs and the Commercialisation Gap*

Annual patent filings in Zambia are fewer than 20, with university-based spin-offs estimated at fewer than five per year, indicating a Commercialisation Gap and a largely absent university-driven innovation ecosystem (Choongo et al., 2025). This contrasts sharply with the United States, which produces over 600,000 patent applications and more than 1,000 university spin-offs (Kadare et al., 2020) every year (AUTM, 2022).

➤ *Industrial Linkages*

The industrial sector reflects the NIS weakness, with Manufacturing Value Added contributing only 8–10% to GDP. This figure is below the African average (10–12%) and substantially below the 15–18% typical of the European Union, supporting the structural transformation theory (Lin, 2012).

## VI. DISCUSSION

The synthesised evidence confirms a deeply embedded systemic gap in Zambia's innovation ecosystem, characterised by persistently low R&D intensity, severe shortages in research human capital, limited scientific output, minimal commercialisation activity, and weak links between research institutions and productive industrial sectors. This outcome suggests that incremental reforms, such as isolated infrastructure refurbishment, are insufficient to bridge the funding, human capital, output, and commercialisation gaps. Instead, a systemic reconfiguration of the national innovation system is mandatory.

Empirical benchmarks show that Zambia's R&D expenditure—estimated between 0.03% and 0.28% of GDP—remains well below both the African average and global leaders, thereby limiting the build-up of knowledge capital necessary for sustained growth (UNESCO Institute for Statistics, 2023; World Bank, 2024). From an endogenous growth perspective, such underinvestment directly restricts the creation of technological spillovers and productivity gains, reinforcing long-term development constraints (Romer, 1990; Aghion & Howitt, 2009).

This structural deficit is further exacerbated by acute human capital limitations. With fewer than 200 researchers per million population, Zambia lacks the critical mass required to sustain a dynamic and self-reinforcing innovation system. The literature consistently demonstrates that researcher density is a key determinant of absorptive capacity, knowledge diffusion, and technological upgrading, implying that Zambia's current levels significantly undermine its innovation potential (Aghion & Howitt, 2009; Acs et al., 2018). Consequently, the country's scientific output remains marginal in global terms, contributing less than 0.05% of total publications, which in turn constrains its

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visibility, collaboration networks, and cumulative knowledge development.

More critically, the translation of research into economic value remains extremely limited. The near absence of patenting activity and university-based spin-offs reflects weak institutional mechanisms for intellectual property management and commercialisation. In contrast, countries that have implemented enabling legal frameworks—most notably the Bayh–Dole Act—have successfully transformed publicly funded research into commercially viable innovations, thereby strengthening the link between knowledge production and economic performance (AUTM, 2022; Mazzucato, 2013). Similarly, coordinated funding and institutional models, such as those observed in South Africa through the National Research Foundation, illustrate the importance of systemic alignment in driving research productivity and innovation outcomes.

The weak integration between research systems and industrial structures further compounds these challenges. Zambia's relatively low manufacturing contribution to GDP reflects limited technological capability and insufficient knowledge transfer from academia to industry. This aligns with structural transformation theory, which posits that industrial upgrading is contingent upon sustained investment in innovation systems and technological capabilities (Lin, 2012). In the absence of such investment, economies remain locked in low-value, resource-dependent production structures.

Taken together, these interrelated constraints indicate that Zambia's innovation deficit is not the result of isolated inefficiencies but rather a manifestation of systemic failure across funding, institutional, and policy dimensions. Incremental reforms—such as ad hoc infrastructure refurbishment or isolated capacity-building initiatives—are therefore insufficient to address the scale and complexity of the problem. Instead, what is required is a comprehensive reconfiguration of the national innovation system, encompassing sustained and predictable R&D financing, expansion of research human capital, institutionalisation of commercialisation mechanisms, and strengthened linkages between research and industry.

Such a systemic approach aligns with the broader innovation policy literature, which emphasises the need for coordinated, mission-oriented, and long-term investments in innovation ecosystems (Mazzucato, 2013; OECD, 2021). Without such a transformation, Zambia is unlikely to close the widening gap with regional leaders and global innovation economies.

## VII. CONCLUSION

The study concludes that Zambia's current reliance on occasional foreign and donor-funded research projects cannot sustain innovation-led growth or achieve global competitiveness. The pervasive structural constraints—particularly R&D expenditure below 0.3% of GDP and researcher density 20 times below that of advanced economies—necessitate a paradigm shift in both funding and institutional frameworks. The solution lies in establishing a sustained domestic funding architecture and institutionalising knowledge commercialisation based on successful global models.

## VIII. IMPLICATIONS AND RECOMMENDATIONS

The study yields specific policy implications and recommends a two-pronged, coordinated framework:

➢ *Establishing the National Research & Innovation Fund*

The overarching recommendation is to establish a National Research & Innovation Fund under the NSTC and NTBC, benchmarked against successful models like the US's Bayle- Dole Act (1980), as well as South Africa's Intellectual Property Rights Act (2008), NIPMO Model and the National Research Foundation (NRF) Act.

- Funding Target: Secure an annual allocation of at least 1% of GDP over the next decade.
- Funding Mechanisms: Mandate government ministries and agencies to allocate 1% per annum of their budgets for research and consultancy, incentivise private sector contributions, and harness donor/external funds into the NSTC/NTBC fund.
- Coordination: Mandate the NSTC as the single coordinating body for all research funding to prevent fragmentation.
- Disbursement and Alignment: Disburse funds annually to universities and research institutes based on competitive calls for infrastructure, researcher capacitation, research projects and commercialisation, aligning with a unified national research agenda (e.g., agriculture, mining, health, ICT, manufacturing, energy, etc).
- Infrastructure Sharing: Establish a national research infrastructure sharing mechanism and database through NSTC and the National Science Centre to reduce duplication in national research infrastructure investments.

➢ *Institutionalising IP and Commercialisation*

To institutionalise knowledge commercialisation, a robust legal and support framework must be adopted.

- IP and Research Legislation: Adopt South Africa's NRF and NIPMO model for IP management and legislate Bayh-Dole–style rights (1980) for universities to own and license IP from publicly funded research, similar to South Africa's Intellectual Property Rights Act (IPR Act) 2008.
- Ecosystem Support: Ensure Technology Management Offices (TMOs) in universities run innovation hubs. Leverage the Citizens Economic Empowerment Commission (CEEC) to fund university-linked startups, and the Zambia Development Agency (ZDA) and Multi-Facility Economic Zones (MFEZs) to facilitate investor partnerships, export markets, and industrial clustering.

## IX. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This section highlights research limitations, directions for future research and mitigating implementation risks.

➢ *Limitations*

The primary limitation is the reliance on stylised facts and aggregated comparative data for the quantitative diagnosis. Furthermore, the R&D expenditure data for Zambia 0.03% to 0.28% of GDP) exhibits significant variability, suggesting potential data reliability challenges or difficulties in capturing all R&D-related spending.

➢ *Directions for Future Research*

Future research should focus on Micro-Level Institutional Analysis by way of A qualitative study of the performance and operational challenges of existing TMOs and innovation hubs within Zambian research institutions. Additionally, private Sector Incentives could be included in an empirical investigation encompassing the optimal tax incentives, co-funding schemes, and innovation voucher mechanisms required to stimulate robust private sector R&D engagement in Zambia. Lastly, the Impact Modelling could be undertaken quantitatively on the expected long-term economic returns and structural transformation outcomes resulting from a sustained 1% GDP R&D investment in the Zambian economy.

➢ *Mitigating Implementation Risks*

To ensure the success of the systemic reconfiguration, three key risks and their mitigation strategies are proposed (Phiri et al., 2023): Firstly, there is the Risk of Fragmentation because of resources being scattered due to a lack of a central funding channel. This could be mitigated by mandating NSTC as the single coordinating body. Secondly, there is the Risk of Brain Drain in that Researchers may leave in frustration due to a lack of competitive funding. The recommendation for amelioration could be to provide competitive career pathways by way of sustained funding of four items: researcher capacity building, research facilities, research processes and strong commercialisation incentives. Thirdly, the Risk of Low Private Sector Engagement when the industry remains passive in R&D. To address this, it would be recommended that tax incentives be provided for R&D partnerships, co-funding schemes, and innovation vouchers with the private sector.

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