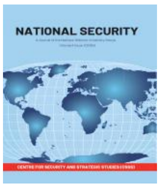

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Strategic Modelling for High-Technology Sectors: Addressing Economic Security in Emerging Economies amidst US-China Geopolitical Competition

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Abstract

This paper presents a quantified strategic model to support emerging economies in enhancing economic security and technological self-reliance in high-technology sectors, using the semiconductor industry as a primary case study. Situated in the context of intensifying US- China geopolitical competition, the study analyses the readiness of India and Kenya to develop resilient semiconductor ecosystems. A mixed-methods approach, combining literature review, stakeholder surveys, and expert validation, informs the development of a weighted scoring model that captures the influence of geopolitical dynamics, domestic capabilities, and regional collaboration on economic outcomes. Findings reveal that, while India demonstrates moderate readiness through policy initiatives such as the Production Linked Incentive (PLI) scheme, significant gaps remain in R&D investment and advanced manufacturing. Kenya, though at an earlier stage, demonstrates potential through digital infrastructure projects like Konza Technopolis but faces foundational challenges in capacity building and policy alignment. The study further generalises the model to other high-tech sectors such as renewable energy, telecommunications, and artificial intelligence, offering a scalable framework for policymakers. By identifying priority areas and proposing a structured implementation roadmap, this study contributes actionable insights for emerging economies seeking to navigate technological transitions and build resilient, globally competitive high-tech industries.

Keywords: *High-Technology Policy, Economic Security, Semiconductor Industry, Geopolitical Competition, Emerging Economic*

Introduction

The escalating geopolitical rivalry between the United States and China has reshaped the global technological and economic order, especially in the semiconductor sector. This competition has disrupted supply chains, introduced trade restrictions, and triggered a shift in international partnerships. For emerging economies in the Global South, this presents both risks and opportunities that demand strategic, data-driven responses. India and Kenya serve as illustrative examples. India has made progress in semiconductor design and introduced policy tools, such as the Production Linked Incentive (PLI) scheme, but still faces challenges in infrastructure and research and development (R&D). Kenya, though earlier in its development journey, shows promise through projects like Konza Technopolis, though it requires stronger investments and policy alignment. Both nations emphasise the need for a structured framework that bridges infrastructure gaps, fosters regional cooperation, and aligns with global technological trends. Current strategies often lack mechanisms to quantify the influence of geopolitical shifts, domestic capacity, and collaboration on economic security. This research addresses that gap by proposing a quantified strategic model for high-technology sectors, using semiconductors as a case study. Through an analysis of India and Kenya's ecosystems, the study offers policy- relevant insights and demonstrates the model's broader applicability across other high-tech domains.

Theoretical Framework

This study is grounded in International Political Economy (IPE), specifically the Economic Nationalism school, which posits that states must proactively secure strategic industries to safeguard their national interests. In high-technology sectors, such as semiconductors, this involves industrial policy, state intervention, and efforts to achieve technological sovereignty. The analysis is further informed by Neo-Schumpeterian theory, which emphasises innovation systems, institutional capacity, and knowledge diffusion as essential to long-term economic competitiveness. This dual-theoretical framework is well-suited to understanding how emerging economies can develop high-tech capabilities amid geopolitical and economic asymmetries.

The escalating US-China tech rivalry has significantly altered global semiconductor supply chains. Since 2014, China has invested over $150 billion to reduce foreign dependency in chip manufacturing (Chung, 2022), while the US responded with the CHIPS and Science Act, committing $52 billion to domestic semiconductor capacity (SIA, 2023). These moves have disrupted global supply chains, exposing vulnerabilities in nations that rely heavily on imports. India, for example, imports 88% of its semiconductor components (IESA, 2024), prompting it to launch a $10 billion Production Linked Incentive (PLI) Scheme to attract global firms (Ministry of Electronics and IT, 2021). Kenya, although earlier in its journey, has initiated the Konza Technopolis project to build foundational digital and innovation infrastructure (Gibson, 2024).

Despite policy efforts, both countries face persistent structural challenges. India lacks cutting- edge fabrication units and invests just 0.7% of its gross domestic product (GDP) in R&D (Mehrotra, 2023), while Kenya's ecosystem suffers from limited infrastructure, minimal venture capital, and weak policy coordination (Gibson, 2024). These constraints typify broader issues in the Global South, such as skill shortages, fragmented policy, and underfunded innovation systems. Targeted reforms are necessary. India's PLI model can serve as a template, while Kenya must institutionalise a coherent high-tech policy aligned with Vision 2030. Regional mechanisms, such as the African Continental Free Trade Area (AfCFTA) and India's participation in the Quad Semiconductor Partnership, illustrate the strategic value of alliances in advancing joint R&D, infrastructure, and supply chain diversification (Brown, 2023). Human capital development is equally crucial. Programs such as Skill India and proposed exchanges with Taiwan and Japan can address workforce gaps. These strategies align with both IPE's emphases on state-driven industrial transformation and Neo-Schumpeterian insights into innovation-led development. A quantified strategic model is thus essential to guide emerging economies in navigating high-tech transitions and securing economic resilience.

Methodology

This study employs a mixed-methods approach that integrates a literature review on global semiconductor dynamics with primary data from 81 expert stakeholders in India's semiconductor sector. Respondents were selected using purposive sampling to ensure expertise across the domains of policymaking, engineering, and industry. A weighted scoring model was employed to quantify the effects of independent variables (IVs), such as trade restrictions and foreign direct investment (FDI) inflows, and intervening variables (INVs), like research and development (R&D) intensity, infrastructure readiness, and regional collaboration, on economic security outcomes. This approach enables policymakers to prioritise actions based on the influence of each factor. Stakeholder feedback shaped variable weights; for instance, geopolitical risk was ranked highest in the Indian context due to its supply chain dependency. The model is designed to be scalable for other high-tech sectors.

The strategic framework developed for this study is structured as follows:

a. Independent Variables (IVs): Geopolitical and economic drivers (e.g., sanctions, trade barriers, FDI).

b. Intervening Variables (INVs): National capabilities in R&D, skilled labour, and regional alliances.

c. Dependent Variables (DVs): Economic security and technological self-reliance, measured by indicators like GDP contribution and innovation outputs.

This study employs a weighted scoring model to assess the influence of external (IV) and internal (INV) factors on economic security (DV) in the semiconductor sector. Drawing from stakeholder surveys and the literature (Chung, 2022; IESA, 2024), the model assigns relative importance to each variable group. The core relationship is represented as

Economic Security (ES) = α(IV) + β(INV)

Where:

- **α** represents the weight assigned to geopolitical and economic factors (SIA, 2023).
- **β** reflects the influence of domestic capabilities and regional collaboration (Sharma, 2024).

Weights were normalised ($\alpha + \beta = 1$) to ensure a balanced representation of global and local dynamics (Gibson, 2024). The model's robustness was supported by preliminary tests in other high-tech sectors, such as renewable energy, confirming its scalability.

Independent Variables (IV)

a. Geopolitical Factors ($\alpha_1 = 0.40$): Export controls, sanctions, and trade restrictions were prioritised due to their disruption of supply chains (Chung, 2022).

b. Economic Factors ($\alpha_2 = 0.20$): FDI flows, global market shifts, and technology transfer agreements are key enablers of technological growth (IESA, 2024).

c. Total Contribution ($\alpha = 0.60$): Combined, these external variables accounted for 60% of the economic security score (SIA, 2023).

Intervening Variables (INV)

a. Domestic Capabilities (β_1 = 0.25): R&D intensity, infrastructure readiness, and workforce skills were highlighted as essential for building resilience (Ministry of Electronics and IT, 2021).

b. Regional Collaboration (β_2 = 0.15): Trade alliances and shared platforms like AfCFTA support diversification and reduce foreign dependence (Gibson, 2024).

c. Total Contribution (β = 0.40): Internal capacities contributed 40% to the overall score (Sharma, 2024).

Scoring Methodology**:** Each sub-factor was scored between 0 and 1, and final ES scores were computed using:

$$ES = (0.6 \times IV) + (0.4 \times INV)$$

Illustrative Calculation:

- IV Score: Export controls (0.25), FDI (0.15), market shifts (0.20) = 0.60
- INV Score: Infrastructure (0.20), R&D (0.10), regional trade (0.10) = 0.40
- Economic Security Score: ES = (0.6 × 0.60) + (0.4 × 0.40) = 0.52

A score of 0.52 reflects moderate readiness and highlights critical areas, particularly domestic innovation and infrastructure, that require strategic intervention to strengthen economic security (SIA, 2023).

The model contrasts India's structured ecosystem, supported by its PLI policy and talent base (Ministry of Electronics and IT, 2021), with Kenya's early-stage development and regional positioning (Gibson, 2024). Readiness scores, derived from a weighted analysis, enable each country to identify targeted areas for improvement. This methodology provides a replicable model to guide high-technology strategies across the Global South.

Results and Discussion

The findings of this study provide a nuanced understanding of how external and internal variables interact to shape the technological trajectories of emerging economies, with a particular focus on the semiconductor sector. Through a quantified strategic model, the study establishes a causal relationship among independent variables (IVs), intervening variables (INVs), and dependent variables (DVs), offering a robust framework for evaluating strategic readiness and informing policy choices. By integrating stakeholder surveys with regional data, the model enables context-specific analysis that can support the development of resilient high- tech ecosystems tailored to the unique capabilities and constraints of individual countries.

At the core of this analysis are two principal external drivers—geopolitical dynamics and economic factors. The intensifying technological rivalry between the United States and China has catalysed global realignments in supply chains and investment flows. China's investment of over $150 billion in its domestic semiconductor sector and the United States' allocation of

$52 billion through the CHIPS Act illustrate contrasting strategies aimed at securing technological self-sufficiency (Chung, 2022; SIA, 2023). These shifts not only influence global production patterns but also create new opportunities and pressures for emerging economies seeking to integrate into the semiconductor value chain.

Economic incentives such as foreign direct investment (FDI) and technology transfers further amplify the importance of responsive domestic policies. India's Production Linked Incentive (PLI) scheme has successfully attracted major technology firms like Micron, thereby enhancing the country's design and manufacturing base (Ministry of Electronics and IT, 2021). These external variables form the foundation upon which domestic and regional capacities—classified as intervening variables—mediate and translate potential into performance.

Domestic capabilities remain unevenly distributed across the countries studied. India, despite its advanced IT sector and supportive policies, still lacks cutting-edge fabrication facilities and allocates only 0.7% of its GDP to research and development. Kenya faces even more fundamental challenges: its flagship initiative, Konza Technopolis, remains in the nascent stages of development, and the country suffers from a fragile innovation infrastructure and a shortage of highly skilled personnel (Mehrotra, 2023; Gibson, 2024). These internal constraints significantly shape how countries can respond to global trends.

Regional integration mechanisms offer an important buffer and accelerator. Kenya benefits from its participation in AfCFTA, which enhances access to regional markets and fosters supply chain integration. India, in contrast, is actively involved in the Quad Semiconductor Partnership, which promotes shared technological development and strategic alignment with regional partners (Brown, 2023). These regional collaborations serve as amplifiers for domestic strategies, helping countries overcome limitations through shared knowledge, infrastructure, and investment.

The ultimate outcomes of interest—economic security and technological self-reliance—are heavily influenced by these interactions. Economic security is assessed in terms of GDP contributions, export diversification, and the resilience of investment flows (IESA, 2024), while technological self-reliance is defined by the ability to manufacture domestically and innovate sustainably. Kenya's continued reliance on imported technologies highlights the urgency of building local capacity, while India's policy-driven advances demonstrate the potential of aligning national strategy with global shifts.

To quantify these dynamics, the study employs a weighted scoring model to assess strategic readiness. India scores 0.65, reflecting moderate success in leveraging its skilled workforce and policy environment, despite ongoing infrastructure and R&D gaps. Kenya scores 0.37, pointing to more systemic barriers such as weak innovation ecosystems and a limited industrial base (Gibson, 2024; African Development Bank, 2023). This scoring framework confirms that external drivers (such as FDI and geopolitical realignments) influence internal enablers (such as domestic talent and regional cooperation), which in turn shape national outcomes in economic and technological terms.

The study affirms the importance of a systems-based approach to semiconductor development in emerging economies. It underscores the need for targeted interventions that enhance domestic capabilities, deepen regional collaboration, and align policy frameworks with evolving global dynamics. Such alignment not only improves strategic readiness but also accelerates the path toward economic resilience and technological autonomy in an increasingly competitive and fragmented global landscape.

The Stakeholder feedback

The stakeholder feedback gathered in this study provides a critical empirical dimension to the theoretical and policy-oriented insights identified through the literature review. These responses help to contextualise and validate the model's assumptions by highlighting real-world perceptions of the semiconductor sector's strategic vulnerabilities and opportunities. The findings reinforce the relevance of the study's conceptual framework while offering practical observations that inform policy design.

One of the most salient themes emerging from stakeholder input is the disruptive influence of geopolitical dynamics on semiconductor supply chains. A majority of respondents pointed to export controls and trade restrictions—particularly those stemming from US-China tensions— as primary disruptors to global supply chain stability. This empirical insight aligns closely with recent studies highlighting how the intensification of technological rivalry between major powers has led to production bottlenecks and uncertainty in component availability (Chung, 2022; SIA, 2023). These geopolitical frictions were widely viewed by stakeholders as beyond the control of individual emerging economies, yet they significantly constrain their capacity to plan and scale domestic semiconductor production.

In addition to external pressures, domestic capacity deficits were consistently identified as a critical internal barrier. Respondents emphasised that inadequate infrastructure and limited investment in research and development (R&D) remain core challenges to achieving technological self-reliance. This corroborates existing data on India's underdeveloped fabrication ecosystem and its relatively modest investment in semiconductor innovation (Sharma, 2024). Similarly, Kenya's infrastructural limitations and nascent R&D base were echoed in stakeholder assessments, underlining the systemic nature of these constraints. The consistency between literature and stakeholder insights reinforces the importance of prioritising domestic capability development in national strategies.

A more nuanced finding relates to the perceived role of regional collaboration. Although regional integration and partnerships were assigned a lower overall weight (15%) in the quantitative scoring model, qualitative feedback suggests that their strategic importance is growing. Stakeholders noted that platforms such as the Quad Semiconductor Partnership and bilateral trade agreements—including the India-Australia Economic Cooperation and Trade Agreement—offer valuable avenues for mitigating supply chain vulnerabilities and fostering shared innovation platforms (Gibson, 2024; Brown, 2023). While not yet a dominant factor in shaping national outcomes, regional alliances were increasingly viewed as essential for long- term sectoral resilience.

To assess the robustness and adaptability of the strategic model, a sensitivity analysis was conducted by varying the weights assigned to both independent and intervening variables. The analysis revealed that increasing the weight of domestic R&D intensity from 0.25 to 0.35 resulted in a measurable improvement in India's economic security score—from 0.65 to 0.70. This shift highlights the outsized role that innovation capacity plays in enhancing economic resilience. Conversely, reducing the weight of geopolitical risk from 0.40 to 0.30 led to a slight decrease in India's overall score, underscoring the model's responsiveness to external dependencies.

These findings demonstrate that the model is not only analytically sound but also dynamic and adaptable. By allowing for recalibration based on country-specific priorities and shifting geopolitical conditions, the model serves as a flexible decision-support tool for policymakers. It facilitates scenario planning, priority-setting, and targeted intervention design, ensuring that semiconductor sector strategies remain responsive to evolving global and domestic realities.

Application to India's Semiconductor Sector

India's semiconductor industry, while showing promising momentum, remains in the early stages of development relative to global leaders such as Taiwan and South Korea. Applying the quantified strategic model developed in this study provides a structured lens through which to assess India's readiness in this critical sector. Drawing on stakeholder feedback, sectoral data, and a weighted indicator framework, the analysis identifies both India's strategic strengths and enduring structural weaknesses. This dual perspective helps clarify where policy and investment efforts can be most effectively targeted.

India possesses several competitive advantages that position it as a potential semiconductor hub within the Global South. Chief among these is strong policy support from the central government. The introduction of ambitious schemes such as the Production Linked Incentive (PLI) and Design Linked

Incentive (DLI) programs demonstrates a concerted effort to build domestic semiconductor capabilities. The PLI scheme alone earmarks $10 billion for semiconductor fabrication, assembly units, and R&D promotion, reflecting a clear prioritisation of this sector at the national level (Ministry of Electronics and IT, 2021).

Another strength lies in India's expanding domestic demand, driven largely by the Digital India initiative and a rapidly growing consumer electronics market. The electronics sector is projected to grow at a compound annual growth rate (CAGR) of 16% between 2022 and 2028, with an estimated market value reaching $300 billion by the end of the period (IESA, 2024). This robust internal demand creates a stable foundation for long-term industry viability.

Additionally, India benefits from a significant human capital advantage. With a large pool of engineering and software professionals, India has established itself as a key talent reservoir for the global semiconductor industry. Notably, nearly 20% of global chip designers are of Indian origin, and multinational firms such as Intel, Qualcomm, and Texas Instruments have set up major design and R&D centres in India (Kumar, 2024). This workforce advantage enhances the country's attractiveness as a destination for semiconductor-related investment and design innovation.

Despite these strengths, several structural weaknesses continue to constrain India's progress toward technological self-reliance. The most pressing of these is the absence of advanced fabrication infrastructure. India currently lacks operational semiconductor fabrication facilities capable of producing cutting-edge sub-7 nm chips. Most existing capacity is concentrated in assembly, testing, and packaging (ATP), which occupies the lower end of the value chain and limits India's full integration into the global semiconductor ecosystem (Sharma, 2024).

Another major limitation is India's underinvestment in research and development. With R&D expenditure standing at just 0.7% of GDP, India lags behind key competitors such as South Korea (4.8%) and China (2.4%). This investment gap hinders the country's ability to advance in strategic frontier technologies, including artificial intelligence (AI), 5G, and quantum computing (Mehrotra, 2023). Without targeted efforts to boost R&D spending, India risks falling further behind in critical areas of technological innovation.

India's semiconductor supply chains also remain highly vulnerable. The country continues to depend heavily on imports for essential materials, specialised equipment, and critical components. This over-reliance exposes the sector to disruptions stemming from geopolitical tensions, export controls, and trade restrictions—factors that are increasingly shaping the dynamics of the global semiconductor market (SIA, 2023).

The quantified strategic model used in this study provides a detailed evaluation of these dynamics. Based on empirical data and stakeholder inputs, the model assesses the relative weight and impact of both external and internal variables on India's economic security and technological self-reliance. Geopolitical and economic factors—including export controls, FDI flows, and global market shifts—were assigned a combined weight of 0.6. While India has benefited from increased FDI, particularly as firms seek alternatives to China amid escalating tensions, it remains indirectly vulnerable to global supply chain shocks and policy volatility (Chung, 2022).

Intervening variables, comprising domestic infrastructure readiness, R&D intensity, and regional partnerships, were weighted at 0.4. Stakeholders rated India's infrastructure readiness at 0.65 and its R&D intensity at 0.50 on a normalised scale of 1.0. These scores suggest moderate progress but underscore the need for sustained strategic investment to build a more robust and self-sufficient technological ecosystem (IESA, 2024).

The model highlights a complex but actionable path forward for India's semiconductor sector. Strategic policy frameworks and a growing talent base provide a strong foundation, but meaningful advances will require targeted interventions in fabrication capabilities, innovation investment, and supply chain security. The quantified model enables policymakers to identify leverage points and track progress toward greater economic resilience and technological autonomy in an increasingly competitive global landscape. The final readiness score for India's semiconductor ecosystem is derived using the formula:

$$ES = (0.6 \times IV) + (0.4 \times INV)$$

Substituting the values:

$$ES = (0.6 \times 0.60) + (0.4 \times 0.55) = 0.65$$

This score reflects India's moderate resilience in the semiconductor sector. It indicates positive momentum resulting from robust policy interventions and a growing market, but also underscores persistent infrastructural and innovation-related limitations (Chung, 2022; IESA, 2024).

Application to Kenya's Semiconductor Sector

Kenya's semiconductor sector, while still in its infancy, presents emerging opportunities for integration into regional and global value chains. Positioned strategically within the African continent and supported by initiatives such as Konza Technopolis, Kenya aspires to become a regional innovation hub. The country has demonstrated a growing policy commitment to digital infrastructure and benefits from regional trade agreements such as the African Continental Free Trade Area (AfCFTA), which offers a platform for enhanced economic integration and technology-driven development (Gibson, 2024). Despite these enablers, Kenya's ability to build a resilient semiconductor ecosystem remains constrained by foundational challenges. These include the absence of key semiconductor-specific infrastructure, such as fabrication facilities or assembly, testing, and packaging (ATP) units, and persistent underinvestment in research and development (R&D), which has remained below 0.8% of GDP (African Development Bank, 2023). Fragmented coordination between public institutions and the private sector further complicates the formation of a cohesive innovation ecosystem, limiting the translation of policy ambition into technological outcomes.

Nevertheless, stakeholder feedback gathered during this study points to considerable untapped potential. Respondents emphasised that with focused investments in human capital development, infrastructure, and R&D, Kenya could position itself as a viable participant in regional supply chains, particularly within the African context. The quantified strategic model was therefore applied to assess Kenya's semiconductor readiness, combining qualitative insights with empirical data to provide a composite resilience score.

In the model, independent variables (IV) comprising geopolitical and economic factors such as regional trade arrangements and foreign direct investment were assigned a weight of 0.4. Kenya's engagement in AfCFTA and its collaborations with international partners were viewed positively, reflecting the country's favourable positioning within regional economic frameworks (African Development Bank, 2023).

Intervening variables (INV), which include domestic capabilities such as infrastructure readiness, R&D intensity, and regional collaboration, were assigned a higher weight of 0.6, given their centrality in enabling or constraining technological self-reliance. Stakeholders identified critical deficiencies in these areas, with infrastructure readiness rated at 0.40 and R&D intensity at 0.35 on a normalised scale of 1. These scores are consistent with findings from the World Bank (2024), which cites Kenya's limited industrial and research capacity in high-tech sectors, and from the African Development Bank (2023), which emphasises sub- Saharan Africa's low R&D spending compared to global standards.

Applying the weighted scoring formula (Economic Security = 0.4 × IV + 0.6 × INV), Kenya's semiconductor resilience score is calculated as follows:

$$ES = (0.4 \times 0.40) + (0.6 \times 0.35) = 0.37$$

This score indicates low readiness, suggesting that Kenya must address critical infrastructure and capability gaps to establish a viable semiconductor ecosystem (African Development Bank, 2023; Gibson, 2024).

Implications for Kenya

Kenya's semiconductor readiness score of 0.37 underscores the significant structural and strategic gaps that must be addressed if the country is to emerge as a meaningful player in the global semiconductor value chain. While this score reflects current limitations, it also points to areas where targeted investments and policy reforms could unlock substantial opportunities.

One of Kenya's most valuable assets is its strategic position in East Africa. As a key member of the African Continental Free Trade Area (AfCFTA), Kenya stands to benefit from greater regional economic integration and expanded market access. By leveraging these regional frameworks, Kenya can attract foreign direct investment and foster the development of a collaborative semiconductor ecosystem that spans national borders. Such integration could also facilitate technology transfers and shared infrastructure investments, amplifying the country's role in regional supply chains.

Additionally, the Konza Technopolis initiative presents a promising platform for anchoring Kenya's semiconductor ambitions. Designed as a smart city and innovation hub, Konza offers the foundational infrastructure that can be expanded to include semiconductor-related activities such as assembly, testing, and packaging facilities. The project's emphasis on ICT development and knowledge-based industries aligns well with the requirements of a semiconductor ecosystem and provides a focal point for future investments (World Bank, 2024).

However, realising this potential will require overcoming a series of formidable challenges. Chief among these is the need for substantial financial investment in semiconductor-specific infrastructure and human capital development. Building fabrication or ATP facilities demand not only capital but also access to highly specialised technical expertise—resources that are currently limited in Kenya. Furthermore, addressing the skills gap will necessitate reforms in higher education and vocational training systems to produce the talent needed to support this complex industry.

In parallel, there is an urgent need to strengthen policy frameworks that support semiconductor development. This includes creating clear regulatory pathways, offering fiscal incentives, and raising awareness among public and private stakeholders about the sector's strategic economic importance. As global competition for semiconductor leadership intensifies, countries with well-articulated national strategies and cross-sectoral coordination will be best positioned to secure investment and partnerships (Chung, 2022).

Ultimately, Kenya's semiconductor aspirations must be anchored in a deliberate, long-term strategy that addresses foundational deficits while capitalising on emerging strengths. By aligning its regional influence, innovation infrastructure, and policy ambitions, Kenya can carve out a niche in the global high-technology ecosystem. In doing so, it would not only enhance its technological sovereignty but also contribute to regional economic security and resilience in an increasingly digitized global economy.

Generalisation to High-Technology Sectors

Building on the quantified strategic model developed for the semiconductor sector, this section evaluates its applicability across broader high-technology industries—specifically renewable energy, telecommunications, and artificial intelligence (AI)—in emerging economies. These sectors share structural parallels, allowing the model to guide strategic planning in similarly constrained contexts.

Similarities across High-Tech Sectors

Across high-tech sectors in emerging economies, several systemic challenges converge, revealing structural patterns that transcend individual industries. Whether in semiconductors, renewable energy, or advanced telecommunications, these sectors share a standard set of constraints that are primarily rooted in limited domestic capabilities and heavy reliance on global supply chains. One of the most pervasive issues is supply chain vulnerability. Emerging economies are often heavily reliant on a small number of global hubs for critical inputs, making them vulnerable to external disruptions. For instance, over 80% of the world's rare earth elements—essential for clean energy technologies and telecommunications—are processed in China, while the global supply of high-performance chips for artificial intelligence systems is concentrated in Taiwan (Mehrotra, 2023; SIA, 2023). This concentration creates strategic chokepoints that undermine the ability of developing countries to secure and scale their high- tech production.

Another shared constraint lies in infrastructure deficits. Advanced manufacturing infrastructure, such as semiconductor fabs or ATP (assembly, testing, and packaging) units, is often lacking. India, despite its growing tech ecosystem, still lacks operational sub-7nm fabrication facilities, while Kenya has yet to establish any semiconductor-specific production units (IESA, 2024; Gibson, 2024). Similar limitations are evident in the renewable energy sector, where inadequate power storage systems and weak grid capacity hamper large-scale deployment. Broadly, infrastructure readiness scores in the Global South range from 0.30 to 0.50, underscoring persistent gaps in the foundational systems necessary to support high-tech industries (Mehrotra, 2023).

Closely tied to these issues are deficiencies in talent and research and development (R&D). Innovation ecosystems in emerging economies frequently struggle with chronic underinvestment in R&D and a shortage of skilled professionals. India allocates only 0.7% of its GDP to R&D, which is significantly below the 4.8% invested by South Korea, a global leader in innovation (Mehrotra, 2023). Kenya, for its part, faces the dual challenge of underfunded research institutions and the migration of skilled talent abroad in search of better opportunities (African Development Bank, 2023). These limitations curtail the ability of high- tech sectors to generate indigenous innovation and reduce dependence on external technologies.

Shared Opportunities

An illustrative cross-sector example is India's success in scaling up domestic solar panel manufacturing under the National Solar Mission, which provides a replicable model for other sectors. Through targeted incentives, infrastructure investments, and international partnerships, India has emerged as one of the world's largest producers of solar panels, second only to China. Similarly, Kenya's M-Pesa platform demonstrates how public-private collaboration in telecommunications can create globally recognised innovation ecosystems. These examples reinforce the applicability of the proposed model beyond semiconductors, extending to renewable energy, digital services, and artificial intelligence sectors.

Implications for Emerging Economies

These shared patterns suggest the need for an integrated, multi-sectoral strategy that focuses on supply chain diversification, human capital development, and infrastructure development. Cross-country learning and regional alliances can mitigate resource asymmetries, strengthen technological ecosystems, and enhance global competitiveness.

Proposed Strategic Model for High-Technology Sectors

Building on insights from the semiconductor case study, this proposed strategic model offers a scalable and quantified framework to enhance economic security and technological self- reliance across high-technology sectors in emerging economies. The model integrates five interdependent core components adaptable to diverse national contexts and sectoral priorities. First, infrastructure development is foundational; initiatives such as India's $10 billion Semiconductor Mission and Kenya's Konza Technopolis illustrate efforts to establish sector- specific manufacturing and R&D hubs (Ministry of Electronics and IT, 2021; Gibson, 2024). Second, effective policy frameworks and targeted incentives are critical.

India's Production Linked Incentive (PLI) and Design Linked Incentive (DLI) schemes have attracted global players like Micron and Vedanta (IESA, 2024), while Kenya's tax concessions at Konza aim to boost investment (African Development Bank, 2023). Third, regional collaboration through mechanisms such as the AfCFTA and the Quad Semiconductor Partnership promotes shared infrastructure, joint research, and diversified supply chains (Brown, 2023; African Development Bank, 2023). Fourth, investment in R&D remains essential, with India's R&D-to-GDP ratio at just 0.7%, significantly lower than South Korea's 4.8% and China's 2.4%. Meanwhile, Kenya's nascent ecosystem requires significant capacity building (Mehrotra, 2023; World Bank, 2024). Finally, talent development is vital for sustainability. India's Skill India initiative and Kenya's academic partnerships with countries like Taiwan and Japan help bridge workforce gaps and foster innovation (Kumar, 2024; Gibson, 2024). This integrated model equips emerging economies with the tools to formulate context- sensitive strategies that enhance competitiveness and long-term resilience in the high- technology domain.

Generalised Quantified Model for High-Tech Economic Security

To evaluate the economic security of high-technology sectors in emerging economies, this study proposes a generalised and scalable strategic model built on a quantified framework. The model captures the interplay between external and internal enablers of technological development by integrating *Independent Variables (IVs), such as geopolitical dynamics and foreign direct investment (FDI), with Intervening Variables (IVs), including* domestic infrastructure readiness, R&D intensity, and regional collaboration. This relationship is mathematically represented as:

$$\text{HTES} = \gamma(\text{IV}) + \delta(\text{INV})$$

Here, **γ** denotes the weight assigned to geopolitical and global economic factors (e.g., trade restrictions, export controls), while **δ** captures the weight of domestic capabilities and regional cooperation (Chung, 2022; African Development Bank, 2023). In practice, an equal weight distribution ($\gamma = 0.5$, $\delta = 0.5$) provides a balanced assessment of both external and internal drivers. For example, applying this model to an emerging economy with IV = 0.65 (indicating relatively favourable geopolitical positioning and FDI access) and INV = 0.45 (indicating moderate domestic readiness and regional integration), yields:

$$\text{HTES} = (0.5 \times 0.65) + (0.5 \times 0.45) = 0.55$$

This moderate score suggests progress in some areas, such as international engagement and investment attraction, while underscoring the need to enhance domestic R&D investment, build robust infrastructure, and strengthen regional alliances. The model thus provides policymakers with a diagnostic tool to prioritise interventions that improve resilience and competitiveness in high-technology sectors across the Global South.

Implications for High-Technology Sectors

The proposed strategic model offers a scalable and adaptable framework for enhancing economic security in high-tech sectors across emerging economies. Quantifying the influence of geopolitical pressures, domestic infrastructure, and regional collaboration enables the development of targeted policy interventions. For example, India can deepen its investments in advanced fabs and R&D while leveraging Quad partnerships to enhance supply chain resilience. At an earlier stage, Kenya can prioritise foundational infrastructure and utilise platforms like the AfCFTA to enter global value chains. The model's flexibility makes it applicable beyond semiconductors, across sectors such as AI, renewable energy, and telecommunications, offering a structured path for sustainable, innovation-driven growth in the Global South.

Positioning the Model Among Existing Strategic Frameworks

While the proposed High-Tech Economic Security (HTES) model offers a novel, quantified approach, it aligns conceptually with established frameworks, such as Porter's Diamond Model, the Technology Readiness Index, and the OECD Innovation Policy Framework. However, unlike these models, which often emphasise market competitiveness or national innovation capacity in isolation, the HTES model integrates both geopolitical externalities and domestic capabilities into a single, quantified framework. This makes it particularly suited to emerging economies facing systemic vulnerabilities from global supply chain disruptions. By explicitly weighting external and internal factors, the model offers a more holistic and actionable tool for policymakers navigating complex high-technology transitions.

Application to the Semiconductor Sector: India and Kenya

India and Kenya represent distinct yet instructive cases in semiconductor sector development. India's Production Linked Incentive (PLI) scheme has attracted global firms like Micron and Vedanta (Ministry of Electronics and IT, 2021). However, the country still imports 88% of its semiconductor components (IESA, 2024), and its R&D spending remains at 0.7% of GDP (Mehrotra, 2023). With a readiness score of 0.65, India shows moderate progress, driven by policy support and talent but limited by gaps in advanced fabrication and innovation infrastructure. Kenya, in contrast, is still in its nascent stage.

Initiatives like Konza Technopolis signal intent but are hindered by the absence of fabrication or ATP facilities and R&D spending below 0.8% of GDP (African Development Bank, 2023). Its readiness score of 0.37 highlights foundational gaps in infrastructure, talent, and policy coordination (Gibson, 2024). Common challenges include infrastructure deficits; India must develop sub-7nm fabs, while Kenya needs advanced technology processing (ATP) capabilities (Sharma, 2024). India should scale its R&D investment to 2% of GDP, while Kenya can utilise AfCFTA frameworks to foster regional R&D hubs (World Bank, 2024). India must also streamline the implementation of PLI, and Kenya should adopt a coherent high-tech policy to attract foreign direct investment (FDI). These findings underscore the value of the strategic model in guiding targeted interventions for semiconductor resilience in emerging economies.

Generalising the Model to Other High-Technology Sectors

The quantified strategic model developed in this study, based on the interplay between external geopolitical factors and internal domestic capabilities, can be effectively applied to other high-technology sectors beyond the semiconductor industry. These include renewable energy, telecommunications, and artificial intelligence (AI), where emerging economies face similar structural challenges and growth opportunities.

Similar to the semiconductor sector, renewable energy in emerging economies is heavily reliant on concentrated global supply chains, with over 80% of rare earth element processing controlled by China (Chung, 2022). This dependency poses strategic vulnerabilities for countries like India and Kenya. India can mitigate these risks by investing in domestic solar and battery manufacturing, as well as enhancing R&D in storage technologies. Kenya, with more limited capacity, could leverage regional frameworks such as AfCFTA to establish collaborative solar assembly hubs and reduce external dependencies.

Robust telecom infrastructure is critical for digital transformation, particularly with the expansion of 5G and broadband access. India has made significant advancements through public-private partnerships, with major players such as Reliance Jio and Bharti Airtel spearheading the rollout of 5G. Kenya, on the other hand, can harness the potential of Konza Technopolis as a digital infrastructure hub and strengthen regional partnerships to lower costs and improve connectivity across East Africa (Gibson, 2024).

AI advancement relies heavily on access to high-end semiconductors and a skilled workforce. Export restrictions on AI chips from leading tech nations heighten risks for import-dependent countries. India benefits from a strong IT ecosystem and over 1.5 million annual engineering graduates, positioning it well for AI innovation. Kenya, though at an earlier stage, can strengthen its AI sector by investing in technical training and forging academic exchange programs with advanced economies like South Korea and Japan (Gibson, 2024).

Model Validation, Strategic Cooperation, and Policy Implications

Applying the High-Tech Economic Security (HTES) model across various sectors enables a systematic assessment of national readiness. Using weighted scores for external (IV) and internal (INV) factors, India scores 0.60, indicating moderate preparedness driven by strong policy frameworks and a skilled workforce. In contrast, Kenya scores 0.375, reflecting early- stage development with significant infrastructure and talent gaps. These results confirm the model's applicability across high-tech sectors and national contexts.

To improve these scores, strategic cooperation is essential. Regional alliances such as the African Continental Free Trade Area (AfCFTA) provide mechanisms for resource pooling and joint infrastructure projects in Africa. Similarly, India's bilateral partnerships with Japan and Taiwan, as well as Kenya's engagements with international development agencies, offer avenues for technology transfer and innovation scaling (Brown, 2023). For policymakers, this model offers a clear, evidence-based roadmap for prioritising interventions. By identifying gaps in infrastructure, R&D, and workforce development and aligning them with international trends, emerging economies can build resilient, future-ready high-tech ecosystems that are both globally competitive and economically secure.

Conclusion

This study proposes a quantified strategic model to guide the development of the high- technology sector in emerging economies, particularly within the geopolitical context of intensifying US-China rivalry. By applying the model to India and Kenya's semiconductor trajectories, the research illustrates how geopolitical, economic, and domestic variables intersect to shape technological resilience and economic security. The model's extension to sectors such as renewable energy, telecommunications, and artificial intelligence further demonstrates its adaptability and relevance. While the model remains nascent, built on limited expert responses and preliminary data, it offers a structured foundation for strategic planning. Future iterations should incorporate a broader cross-country dataset, sector-specific variables, and longitudinal studies to validate and refine the framework. Policymakers in the Global South can view this model positively to identify sectoral priorities, target investments more effectively, and forge regional and international collaborations. In doing so, emerging economies can transform geopolitical disruptions into opportunities for innovation, self- reliance, and long-term economic resilience.

Recommendations: Operationalising the Strategic Model for High-Technology Sectors

This paper presents a quantified strategic model designed to guide emerging economies in strengthening economic security across high-technology sectors. While the model offers a structured framework that integrates geopolitical, economic, and domestic variables, it remains in a nascent stage, having been developed primarily from stakeholder inputs within India and supplemented by secondary data from Kenya. As such, its findings, while indicative, require further empirical validation and refinement through broader cross-country application and longitudinal analysis.

This study's strategic model provides a structured foundation for high-technology policy planning, but it also comes with certain limitations. First, the analysis is limited to India and Kenya, which may not reflect the full diversity of emerging economies. A broader application across regions, such as Southeast Asia or Latin America, would strengthen generalizability. Second, while the model is proposed as sector-agnostic, it has been validated only in the semiconductor sector. Future work should apply it to other industries, such as renewable energy or AI, to confirm its scalability. Third, the model currently relies on static expert-derived weights and cross-sectional data, limiting its responsiveness to evolving geopolitical and market dynamics. Integrating adaptive weighting methods or longitudinal analysis would improve its policy relevance over time. Finally, the model has not yet been operationalised within live policy monitoring platforms. Future research should explore integrating it with national digital dashboards for real-time strategy evaluation and adjustment. Addressing these areas would enhance the model's robustness, ensuring greater utility for policymakers navigating complex high-tech transitions.

Building on the model's diagnostic outputs, this paper proposes a five-step policy implementation roadmap to guide emerging economies in operationalising high-tech sector strategies:

a. Apply the model to assess national readiness across geopolitical, economic, and domestic factors.

b. Use model scores to identify sectoral and infrastructural gaps requiring immediate intervention.

c. Develop targeted schemes (e.g., PLI/DLI) and align them with model-identified priority areas.

d. Institutionalise multi-stakeholder mechanisms to validate model assumptions and weights continuously.

e. Integrate the model with national policy dashboards to enable real-time monitoring and policy recalibration.

This roadmap provides a structured pathway for policymakers to move from diagnostic analysis to actionable, sector-specific strategies. Based on the model's insights, the following targeted recommendations are proposed for India, Kenya, and similar economies in the Global South:

Emerging economies should adopt national high-technology policies that incorporate the strategic model's metrics to identify policy bottlenecks and priority sectors. India's PLI/DLI schemes offer replicable templates (Ministry of Electronics and IT, 2021), while Kenya should design a unified high-tech policy aligned with AfCFTA objectives (Gibson, 2024).

The model underscores infrastructure readiness as a key determinant of economic security. India must expedite the development of advanced fabrication facilities, while Kenya can focus on establishing ATP and innovation hubs, such as Konza. Public-private partnerships (PPPs), informed by model-based gap analysis, can direct capital toward high-impact projects (Sharma, 2024; African Development Bank, 2023). The model outputs assign significant weight to R&D intensity. India should increase its R&D-to-GDP ratio from 0.7% to 2% (Mehrotra, 2023), while Kenya can establish collaborative research clusters through the AfCFTA. Cross-country R&D consortia could focus on shared challenges, such as energy storage, chip design, and health technology.

Using the model's sectoral analysis, training programs should be tailored to fill critical gaps— e.g., chip fabrication, AI, and quantum computing. India can scale initiatives like Skill India, while Kenya can expand international exchange programs with South Korea, Japan, and Taiwan to upskill its youth (Kumar, 2024; Gibson, 2024).

The model validates the strategic value of regional collaboration. India should expand its cooperation through the Quad, while Kenya can utilise the AfCFTA as a platform for shared infrastructure and joint procurement of technological equipment. A regional high-tech development fund or semiconductor consortium could amplify this cooperation (Brown, 2023).

By identifying technology and capital deficits, the model helps countries strategically align with international partners. India's partnerships with Taiwan and Japan offer a precedent; Kenya can form bilateral frameworks with donor agencies and tech powers to facilitate technology transfer and industrial scale-up (World Bank, 2024). Given the model's emphasis on long-term resilience, countries must ensure environmental sustainability in their high-tech endeavours. Green energy uses in chip fabs, circular economy strategies for e-waste, and water-efficient production methods should be prioritised (Mehrotra, 2023; Gibson, 2024).

Future Research Direction

Future research should apply the model to a broader range of countries and sectors to validate its generalizability. Incorporating dynamic data analytics, such as machine learning-based weight adjustments, could further enhance model accuracy. Ultimately, piloting the model in collaboration with national policy agencies would provide valuable real-world feedback, enhancing its practical value for informed strategic decision-making in emerging economies.

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