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Innovation Inputs, Outputs and the Ambiguity of Conversion Efficiency: Four Developing Economies, 2020–2025

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Abstract

Governments across the developing world have expanded policy support for innovation, yet the relationship between innovation-system inputs and outputs remains insufficiently understood outside OECD contexts. This study aims to compare the innovation-system performance of South Africa, Kenya, and Morocco, which represent markedly different policy models, with that of Viet Nam, a lower-middle-income economy widely regarded as an innovation overperformer, while examining the diagnostic meaning of innovation conversion efficiency. Adopting a deliberately model-free comparative descriptive approach, the study employs no econometric estimation and makes no causal claims. Publicly verifiable secondary indicators were obtained from Global Innovation Index economy profiles for 2020–2025 and supplemented with UNESCO and World Bank research expenditure data and venture capital tracker data. Ordinal rankings were transformed into bounded percentile scores to construct an Input Capability Score and an Output Performance Score, whose ratio generates a Conversion Efficiency Ratio representing output performance relative to measured input capability. The findings reveal four distinct trajectories. Viet Nam was the only economy to increase both input capability and output performance while its conversion ratio moved toward parity, indicating input-led maturation. Morocco recorded the largest output gain among the four economies, whereas South Africa exhibited declining input capability alongside output recovery. Kenya registered the highest conversion ratio in the sample; however, this reflected a shrinking input base rather than strengthening innovation capability. These findings demonstrate that a high

conversion ratio cannot, in isolation, be interpreted as evidence of a stronger innovation system because similar ratios may arise from markedly different underlying input–output trajectories. The study contributes a transparent descriptive framework for comparing innovation-system performance in developing economies and highlights the importance of interpreting conversion efficiency jointly with changes in input capability when assessing innovation policy and system development.

Keywords: Conversion Efficiency; Global Innovation Index; Innovation Policy; National Innovation Systems; Developing Economies

INTRODUCTION

Innovation support policy has moved from the periphery to the centre of development strategy. Over the past two decades, governments in low- and middle-income economies have created innovation agencies, research funds, technology parks, startup acts, tax credits for research and development, and sovereign venture vehicles at a pace that would have been difficult to imagine in the 1990s. The intellectual justification is well established: sustained increases in per capita income depend less on factor accumulation than on the capacity of an economy to generate, absorb and commercialise new knowledge. What is far less settled is whether the specific instruments that developing-country governments have adopted actually deliver, and under what conditions the resources committed to an innovation system are converted into measurable innovative and economic performance.

This question is not merely academic. Fiscal space in most developing economies is narrow, and every unit of public money directed toward a research fund or an incubator is a unit not directed toward primary health care, basic education or transport infrastructure. The opportunity cost of innovation policy is real, and the burden of demonstrating value falls on the policy community. Yet the evidence base that policymakers in Africa and Southeast Asia draw upon remains dominated by two genres. The first is the single-country qualitative case study, rich in institutional detail but difficult to generalise. The second is the cross-national econometric study, methodologically ambitious but often built on data series so sparse and so inconsistently measured in developing contexts that the resulting coefficients rest on heroic assumptions about data quality. Between these two genres lies an underexploited middle ground: rigorous, transparent, model-free comparison of what the available public data actually show.

This article occupies that middle ground. It compares three African economies whose innovation policy models differ substantially — South Africa, Kenya and Morocco — and benchmarks them against Viet Nam, a lower-middle-income Asian economy that has been identified repeatedly as performing above expectation for its level of development. The comparison is deliberately restricted to descriptive statistical procedures applied to publicly available, internationally harmonised indicators. No regression is estimated, no structural model is specified, and no causal claim is advanced. The analytical contribution lies instead in the construction and interpretation of a small set of transparent, reproducible measures that make cross-country and cross-time comparison meaningful, and in the diagnostic reading of those measures.

The three African cases were not chosen arbitrarily. They represent three recognisable configurations of innovation policy in the developing world. South Africa possesses the most institutionally elaborate science, technology and innovation architecture on the African continent, with a dedicated national department, a research foundation, a technology innovation agency and a longstanding research and development tax incentive. Kenya represents a market-led configuration in which private entrepreneurial dynamism, particularly in mobile financial services and off-grid energy, has run ahead of state investment in research capability. Morocco represents a state-led, infrastructure- and industry-anchored configuration in which innovation policy is embedded in broader industrial acceleration and digital transformation strategies, and in which foreign direct investment and export platforms play a structuring role. Viet Nam, the benchmark case, combines a party-state-directed strategic agenda with deep integration into global electronics value chains and an unusually rapid recent legislative push on science, technology and digital transformation.

Placing an Asian benchmark alongside three African cases is itself a methodological choice with a rationale. Comparisons confined to a single region risk mistaking regional norms for global standards; an economy may appear to be performing well simply because its neighbours are performing poorly. Introducing Viet Nam provides an external reference point drawn from a similar income category, allowing the African trajectories to be read against a case where the input-to-output relationship has been widely described as unusually productive. The comparison also has practical value for Vietnamese policy debate, which has increasingly looked to diverse international experience as the country pursues its stated ambition of raising research intensity substantially by the end of the decade.

The study is guided by four research questions. First, how did measured innovation input capability evolve in the four economies between 2020 and 2025? Second, how did measured innovation output performance evolve over the same period? Third, how efficiently did each economy convert measured input capability into measured output performance, and how stable was that conversion over time? Fourth, what diagnostic and policy inferences can legitimately be drawn from these patterns, given the acknowledged limits of the underlying data and of a model-free design?

The contribution of the article is threefold. Methodologically, it offers a small, fully documented toolkit for converting the ordinal information published in international innovation rankings into bounded, comparable cardinal measures suitable for descriptive comparison — a toolkit that other researchers can apply to any set of economies and any period for which profiles are published. Empirically, it documents four sharply distinct trajectories that a simple reading of headline rankings conceals. Conceptually, it advances an argument about interpretation: that a high ratio of output performance to input capability, often celebrated as evidence of efficiency or frugal innovation, is diagnostically ambiguous, because the ratio rises both when outputs strengthen and when inputs deteriorate. Distinguishing these two cases requires reading the ratio jointly with the trajectory of the input base, and the four cases examined here illustrate precisely why that joint reading matters.

The remainder of the article proceeds as follows. Section 2 reviews the conceptual literature on innovation support policy, national innovation systems and the input–output translation problem, and identifies the gap the study addresses. Section 3 sets out the research design, data sources, transformation procedures and analytical steps in sufficient detail for full replication. Section 4 presents the results. Section 5 discusses their interpretation in relation to prior scholarship and draws out implications, including for Viet Nam. Section 6 concludes and identifies directions for further research.

Literature Review

1. Innovation support policy: from market failure to system building

The earliest economic rationale for public support of innovation rested on market failure. Because knowledge is partially non-rival and imperfectly excludable, private actors capture only a fraction of the social returns to their research investment and therefore invest less than is socially optimal. This underinvestment argument justified a familiar suite of

instruments: public research funding, patent protection, research and development subsidies and fiscal incentives. It remains the intellectual foundation of most tax-based innovation support in operation today.

The market-failure frame, however, proved insufficient for explaining why economies with comparable levels of research spending achieved radically different innovation outcomes. The systems-of-innovation literature that emerged from the late 1980s reframed the problem. Innovation was recast not as the output of a production function taking research expenditure as input, but as the emergent property of a network of interacting organisations and institutions — firms, universities, public research institutes, financiers, standard-setters, regulators and users — embedded in a specific national or sectoral context. On this reading, the central task of innovation policy is not simply to increase the quantity of research effort but to address system failures: missing organisations, weak linkages, institutional rigidities, capability deficits and coordination problems.

The systemic perspective has substantial implications for developing economies. If innovation performance depends on the density and quality of interactions rather than on expenditure alone, then economies with thin research bases may still register meaningful innovation outcomes where linkages, absorptive capacity and diffusion channels are strong. Conversely, economies that have accumulated formal research capacity may fail to translate it into commercial or economic outcomes if the connective tissue of the system is weak. This asymmetry — capability without translation, or translation without capability — is central to the analysis presented below.

A third strand, more recent and more contested, emphasises the state as an active shaper of markets rather than a corrector of their failures. In this mission-oriented framing, public actors take on directional risk, create and shape markets, and pursue explicit societal objectives. The framing has been influential in policy discourse across both African and Asian developing economies, visible in national artificial intelligence strategies, digital transformation programmes and green industrial plans. Its critics note that mission-oriented policy places heavy demands on state capacity — precisely the resource that is scarcest in many of the settings where the framing has been most enthusiastically adopted.

2. A working taxonomy of support instruments

For comparative purposes it is useful to distinguish instruments along two dimensions: the mode of delivery and the object of support. On the delivery dimension, the

standard distinction is between direct support, in which the state transfers resources to identified beneficiaries through grants, concessional loans, public venture capital, research contracts or scholarships; and indirect support, in which the state alters the incentive environment through tax credits, accelerated depreciation, public procurement preferences, regulatory sandboxes or administrative simplification. A third category, which fits awkwardly into the direct–indirect binary, comprises infrastructural and network support: science parks, technology hubs, open laboratories, national research infrastructure, digital backbone investment, and brokered linkages between universities, research institutes and firms.

On the object dimension, support may target the generation of new knowledge, the diffusion and absorption of existing knowledge, the formation and scaling of innovative enterprises, the supply of skilled human capital, the protection and commercialisation of intellectual property, or the creation of demand for innovative goods and services. The distinction between generation and diffusion is particularly consequential for developing economies. A substantial body of work argues that for economies operating well inside the global technological frontier, the returns to policies that promote technology adoption, managerial capability and incremental firm-level upgrading typically exceed the returns to policies that subsidise frontier research. Innovation policy in such settings is, on this view, largely a matter of building firm capabilities rather than of funding laboratories.

3. The translation problem and its measurement

If innovation policy is understood systemically, then the appropriate evaluative question is not only how much a country invests but how effectively investment is translated into outcomes. International innovation measurement frameworks have institutionalised this distinction by separating input pillars — institutions, human capital and research, infrastructure, market sophistication, business sophistication — from output pillars covering knowledge and technology outputs and creative outputs. The separation permits an explicitly relational reading: an economy can be located not only by its absolute standing but by the relation between what it puts in and what it gets out.

Interpreting that relation, however, is less straightforward than it appears. A favourable output-to-input relation is frequently celebrated as evidence of efficiency, of frugal or resource-constrained innovation, or of entrepreneurial dynamism compensating for state weakness. Each of these readings may be correct in a particular case. But the same statistical pattern arises when the input base contracts while outputs merely fail to fall as

quickly — a situation that signals fragility rather than efficiency. The literature on frugal and grassroots innovation in low-income contexts has documented genuine instances of the former. The measurement literature has been comparatively quiet on how to distinguish the two, and this article treats that distinction as a substantive analytical problem rather than a technical footnote.

A related caution concerns the ordinal nature of published rankings. Ranks are not interval-scaled: the substantive distance between the fortieth and fiftieth positions is not equivalent to that between the hundredth and hundred-and-tenth. Rankings also shift when the number of covered economies changes, when indicators are added or retired, or when data availability alters. Comparisons of raw ranks across years are therefore hazardous, and any serious longitudinal use of ranking data must address the problem explicitly. Section 3 sets out the transformation adopted here.

4. Prior evidence on the four cases

Scholarship on South Africa's innovation system has consistently emphasised an institutional paradox: comparatively strong formal research and policy infrastructure combined with weak translation into broad-based economic upgrading, persistent inequality of access to that infrastructure, and a research effort that has struggled to grow relative to the size of the economy. Studies of Kenya have emphasised the reverse configuration, documenting an entrepreneurial and digital-services ecosystem of continental significance, particularly in mobile money and off-grid energy, that has developed with relatively limited public research investment and against a backdrop of persistent gaps between legislated intent and implementation capacity. Research on Morocco has highlighted the embedding of innovation policy within an industrial acceleration and export-platform strategy, the role of foreign investment in automotive and aeronautics value chains, and substantial recent public commitment to digital infrastructure and education, alongside continuing weaknesses in business-sector research and in university–industry linkage.

Work on Viet Nam has documented rapid improvement in innovation outputs relative to a modest research base, an innovation profile heavily shaped by foreign-invested electronics manufacturing and high-technology export flows, and an intensifying policy agenda in science, technology and digital transformation, coupled with recognition that domestic research intensity remains low by regional standards and that university–industry linkages remain underdeveloped.

What is missing from this literature is a systematic comparison. The four economies have been studied largely in isolation or within regional groupings; they have not been placed on a common, transparently constructed metric and compared over a consistent period. Nor has the interpretive ambiguity of the output-to-input ratio been examined across cases that differ precisely in whether their inputs are expanding or contracting. This study addresses both gaps.

METHODS

1. Research design

This study employs a comparative, longitudinal, indicator-based descriptive design. It is explicitly model-free. No regression is estimated, no latent structure is assumed, no counterfactual is constructed and no causal effect is claimed. The design choice is deliberate and reflects three considerations.

First, the number of units is small. Four economies observed over six years yields twenty-four panel observations, a sample in which any multivariate estimation would exhaust its degrees of freedom before controlling for the confounders that a causal claim would require. Second, the underlying data for developing economies contain substantial gaps, imputations and vintage inconsistencies; estimating a structural model on such data produces coefficients whose apparent precision would misrepresent the actual state of knowledge. Third, and most importantly, the analytical question motivating this article is descriptive rather than causal. The question is what the available public evidence shows about how four innovation systems have moved, not what would have happened had policy differed.

A model-free design carries an obligation of transparency. Every transformation applied to the raw data is stated as a formula, every source is identified, and every computed value is reported, so that a reader with access to the same public sources can reproduce every number in Section 4 without recourse to proprietary software or undocumented judgement.

2. Case selection

Cases were selected purposively on three criteria. First, policy-model contrast: the three African cases were chosen to represent institutionally elaborate (South Africa), market-led (Kenya) and state-led industrial (Morocco) configurations. Second, data continuity: each case has an uninterrupted profile in the international innovation measurement framework

across the full study period, avoiding the gaps that afflict many African economies. Third, benchmark comparability: Viet Nam was selected as an external reference because it occupies a comparable income category to two of the African cases, has been repeatedly identified as an overperformer relative to its development level, and is the setting for which the study's policy implications are drawn.

3. Study period

The period 2020 to 2025 was selected for three reasons: it provides six consecutive observations for each economy; it spans a common macroeconomic shock and recovery, which partially standardises the external environment across cases; and it corresponds to the period in which each of the four governments adopted or substantially revised a flagship innovation, digital or science and technology strategy, making the window policy-relevant as well as statistically convenient.

4. Data sources

The primary data are the annual economy profiles published within the Global Innovation Index framework, from which three ordinal series are extracted for each economy and year: overall position, innovation input position and innovation output position. These profiles are published openly and are archived by year, allowing verification.

Three categories of contextual data supplement the primary series and are used for interpretation rather than for index construction. Gross domestic expenditure on research and development as a share of gross domestic product is drawn from the UNESCO Institute for Statistics series as distributed through the World Bank development indicators. Venture and technology funding volumes are drawn from published annual ecosystem trackers. Qualitative policy information — the identity of lead agencies, flagship programmes and legislative instruments — is drawn from official government and agency documents and is used solely to characterise policy configurations, not to generate any quantitative value.

5. Transformation of ordinal data

Published ranks cannot be compared directly across years because the number of covered economies varies: 131 in 2020, 132 in 2021, 2022 and 2023, 133 in 2024 and 139 in 2025. Raw rank comparison would therefore confound genuine movement with changes in coverage. To address this, each rank is converted into a bounded percentile score using a linear order-statistic transformation:

$$S = [(N - R) / (N - 1)] \times 100$$

where R is the published rank of the economy in a given year, N is the number of economies covered in that year, and S is the resulting score on a zero-to-one-hundred scale. The transformation assigns 100 to the top-ranked economy and 0 to the bottom-ranked economy in every year, and is monotone in rank. It removes coverage-driven distortion and yields a value that is directly comparable across years and economies.

Applying the transformation to the input rank produces the Input Capability Score (ICS); applying it to the output rank produces the Output Performance Score (OPS). Both are interpreted as relative standing within the covered population of economies, not as absolute measures of innovation activity.

6. Derived measures

Three derived measures are computed.

The Conversion Efficiency Ratio (CER) is defined as:

$$CER = OPS / ICS$$

A value above unity indicates that the economy stands higher in the international distribution on outputs than on inputs; a value below unity indicates the reverse; a value at unity indicates parity of relative standing. The ratio is a positional statement, not a productivity estimate: it does not measure output per unit of expenditure and must not be read as such.

The rank gap is defined as the arithmetic difference between input rank and output rank in the same year. A positive gap means the economy ranks better on outputs than on inputs. The gap is reported alongside the ratio because it is expressed in the raw units that readers of published rankings will recognise, providing an intuitive cross-check on the transformed measures.

Period change is reported as the simple arithmetic difference between the 2025 and 2020 values of each score, denoted ΔICS and ΔOPS. Compound growth rates were considered and rejected, because percentile scores are bounded and relative, and a compound rate computed on such a series has no meaningful economic interpretation.

7. Analytical procedures

The analysis proceeds in five steps. Step one tabulates the raw ordinal data for all economies and years, establishing the evidentiary base. Step two reports the transformed panel of ICS, OPS, CER and rank gap for all twenty-four observations. Step three examines each economy's trajectory individually, identifying direction, magnitude and turning points. Step four computes cross-sectional and pooled association measures. Both the Pearson product-moment coefficient and the Spearman rank-order coefficient are reported for the pooled association between ICS and OPS; reporting both guards against the possibility that a single influential observation drives an apparently strong linear association. Step five assembles a comparative typology combining the level and direction of each measure.

Association coefficients are reported as descriptive summaries of co-movement within this specific set of twenty-four observations. Because the observations are not independent — six repeated measures on each of four economies — the reported significance values are indicative only and are not treated as inferential tests about a wider population of economies.

8. Robustness checks

Two checks were performed. First, the percentile transformation was recomputed using the alternative convention $S' = [(N - R + 0.5) / N] \times 100$, which handles boundary cases differently; all substantive orderings and trajectory directions were unchanged, with differences confined to the second decimal place. Second, the derived measures were recomputed excluding 2020, the year most affected by pandemic-related data disruption; the ordering of economies on every measure was preserved and the direction of every trajectory was unchanged.

9. Methodological limitations

Four limitations are inherent to the design and are stated here so that the results in Section 4 are read appropriately. First, the input and output constructs are those of the source framework; the study inherits its indicator selection and its equal-weighting conventions and does not independently validate them. Second, the percentile transformation preserves order but not the true underlying distances between economies, so score differences should be read as ordinal-plus rather than as fully cardinal. Third, methodological revisions to the source framework across editions mean that year-on-year movement partly reflects measurement change as well as real change; this is why the analysis emphasises multi-year

direction rather than single-year movement. Fourth, and most fundamentally, no design of this kind can establish that policy caused the observed patterns. Statements in Sections 4 and 5 are consistently framed as description and interpretation, never as effect estimation.

RESULTS

1. The evidentiary base

Table 1 reports the raw ordinal data extracted from the annual economy profiles for all four economies across the six-year study period, together with the number of economies covered in each edition. These figures are the sole primary input to every subsequent computation.

Table 1. Published innovation rankings, 2020–2025 (overall / input / output position)

Year	Economies covered	South Africa	Kenya	Morocco	Viet Nam
2020	131	60 / 49 / 68	86 / 92 / 78	75 / 85 / 69	42 / 62 / 38
2021	132	61 / 55 / 68	85 / 89 / 76	77 / 84 / 67	44 / 60 / 38
2022	132	61 / 69 / 61	88 / 103 / 79	67 / 87 / 56	48 / 59 / 41
2023	132	59 / 71 / 57	100 / 104 / 91	70 / 90 / 55	46 / 57 / 40
2024	133	69 / 75 / 61	96 / 105 / 87	66 / 89 / 47	44 / 53 / 36
2025	139	61 / 68 / 60	102 / 116 / 85	57 / 77 / 51	44 / 50 / 37

Source: Compiled by the authors from annual Global Innovation Index economy profiles.

Read as raw ranks, the six-year pattern already suggests divergence. Morocco improved its overall position by eighteen places, from seventy-fifth to fifty-seventh. Kenya deteriorated by sixteen places, from eighty-sixth to hundred-and-second. South Africa returned to its starting position after a marked dip in 2024. Viet Nam ended two places below its 2020 position. But raw ranks cannot be compared meaningfully across editions covering different numbers of economies, and Viet Nam's apparent two-place decline illustrates the problem precisely: it occurred while the covered population expanded by eight economies. The transformation set out in Section 3.5 is required before any of these movements can be interpreted.

2. The transformed panel

Table 2 reports the full transformed panel: Input Capability Score, Output Performance Score, Conversion Efficiency Ratio and rank gap for each economy in each year.

Table 2. Transformed panel of derived measures, 2020–2025

Economy	Year	ICS	OPS	CER	Rank gap
South Africa	2020	63.1	48.5	0.768	−19
South Africa	2021	58.8	48.9	0.831	−13
South Africa	2022	48.1	54.2	1.127	+8
South Africa	2023	46.6	57.3	1.230	+14
South Africa	2024	43.9	54.5	1.241	+14
South Africa	2025	51.4	57.2	1.113	+8
Kenya	2020	30.0	40.8	1.359	+14
Kenya	2021	32.8	42.7	1.302	+13
Kenya	2022	22.1	40.5	1.828	+24
Kenya	2023	21.4	31.3	1.464	+13
Kenya	2024	21.2	34.8	1.643	+18
Kenya	2025	16.7	39.1	2.348	+31
Morocco	2020	35.4	47.7	1.348	+16
Morocco	2021	36.6	49.6	1.354	+17
Morocco	2022	34.4	58.0	1.689	+31
Morocco	2023	32.1	58.8	1.833	+35
Morocco	2024	33.3	65.2	1.955	+42
Morocco	2025	44.9	63.8	1.419	+26
Viet Nam	2020	53.1	71.5	1.348	+24
Viet Nam	2021	55.0	71.8	1.306	+22
Viet Nam	2022	55.7	69.5	1.247	+18
Viet Nam	2023	57.3	70.2	1.227	+17
Viet Nam	2024	60.6	73.5	1.212	+17
Viet Nam	2025	64.5	73.9	1.146	+13

Source: Authors' computation from Table 1 using the transformation in Section 3.5.

Two features of Table 2 warrant immediate comment. First, the ordering of economies on the Output Performance Score in 2025 — Viet Nam 73.9, Morocco 63.8, South Africa 57.2, Kenya 39.1 — differs from the ordering on the Input Capability Score — Viet Nam 64.5, South Africa 51.4, Morocco 44.9, Kenya 16.7. Morocco and South Africa exchange positions depending on which side of the system is examined. Second, the Conversion Efficiency Ratio exceeds unity in twenty-two of twenty-four observations, the

two exceptions being South Africa in 2020 and 2021. This near-universal pattern reflects a structural feature of the source framework as applied to developing economies rather than exceptional efficiency: the input side is measured largely through institutional quality, tertiary enrolment, research spending and infrastructure indicators on which developing economies score poorly, while the output side includes indicators such as trademark activity, creative goods trade, mobile application development and industrial design filings on which they perform comparatively better. The absolute level of the ratio therefore carries limited information; its trajectory and its relationship to the input trend carry considerably more.

3. Period change

Table 3 reports the change in each measure between the first and last years of the study period.

Table 3. Period change, 2020–2025

Economy	ΔICS	ΔOPS	CER 2020	CER 2025	Mean CER	SD of CER
South Africa	−11.6	+8.8	0.768	1.113	1.052	0.185
Kenya	−13.3	−1.6	1.359	2.348	1.657	0.356
Morocco	+9.5	+16.1	1.348	1.419	1.600	0.240
Viet Nam	+11.4	+2.4	1.348	1.146	1.248	0.065

Source: Authors' computation. SD denotes population standard deviation across the six annual observations.

Figure 1 displays the two score series graphically, and Table 3 yields the study's central empirical result: the four economies occupy four different quadrants of the change space. Morocco and Viet Nam improved their relative input standing; South Africa and Kenya lost input standing. Morocco, Viet Nam and South Africa improved their relative output standing; Kenya did not. The combination of these two directions defines four distinct trajectories, examined in turn below.

The standard deviation column adds a further dimension. Viet Nam's conversion ratio varied within a very narrow band, with a standard deviation of 0.065 — roughly one-fifth of Kenya's 0.356. Stability of the input–output relationship is itself an indicator of systemic coherence: it suggests that changes on one side of the system are matched by changes on the other rather than occurring independently.

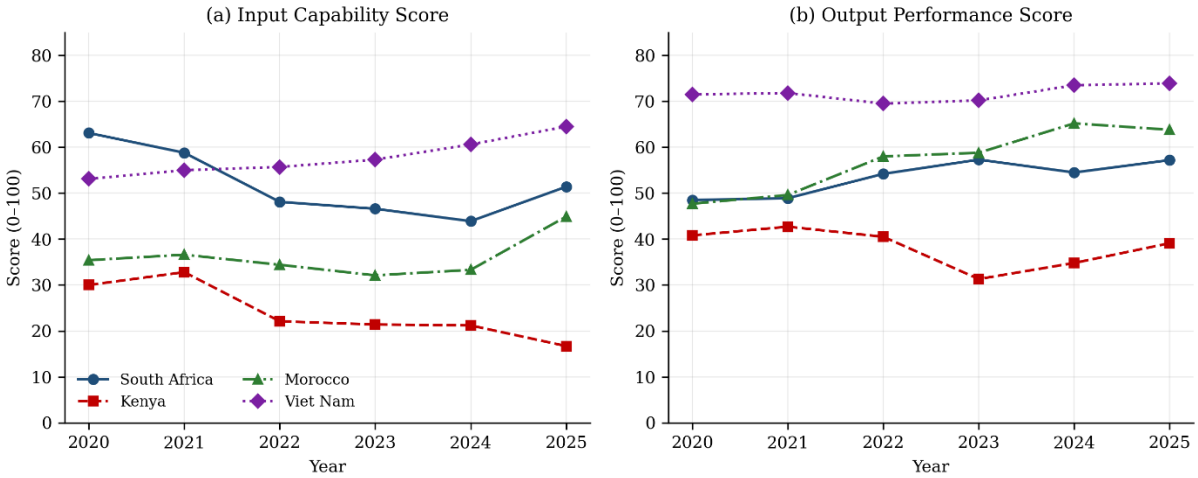

Figure 1. Trajectories of Input Capability Score and Output Performance Score, 2020–2025. Source: Authors' computation from Table 1.

4. Trajectory analysis

Viet Nam: input-led convergence. Viet Nam is the only economy in the sample whose Input Capability Score rose in every single year of the study period, from 53.1 in 2020 to 64.5 in 2025, a gain of 11.4 points. Its Output Performance Score also rose, from 71.5 to 73.9, but by considerably less. The mathematical consequence is that the conversion ratio declined steadily, from 1.348 to 1.146, and the rank gap narrowed from twenty-four places to thirteen. It would be a serious misreading to treat this declining ratio as deteriorating efficiency. The ratio fell because the denominator strengthened, and it converged toward unity from above — the signature of an innovation system whose capability base is catching up with an output profile that was previously running ahead of it. Viet Nam retains the highest absolute scores on both sides of the system throughout the period, and by 2025 it stands in the sixty-ninth percentile of covered economies on overall innovation position.

Morocco: the strongest output advance. Morocco recorded the largest output gain in the sample, 16.1 points, lifting its Output Performance Score from 47.7 to 63.8 and moving it past South Africa on the output side by 2022, a position it retained thereafter. Its trajectory has a distinct shape. Between 2020 and 2024 the output score rose steeply while the input score drifted slightly downward, driving the conversion ratio to a sample-period peak of 1.955 in 2024 — the second-highest single value in the entire panel. Then, in 2025, the input score jumped by 11.6 points in a single year, from 33.3 to 44.9, the largest single-year input movement observed anywhere in the panel. The conversion ratio consequently fell to 1.419

even as the output score remained near its peak. Morocco thus traversed, within a single six-year window, from an output-led pattern toward a more balanced one.

South Africa: input erosion, output recovery. South Africa presents the most complex trajectory. It is the only economy that began the period with a conversion ratio below unity: in 2020 it ranked forty-ninth on inputs but only sixty-eighth on outputs, a negative rank gap of nineteen places. This is the classic signature of an economy with substantial formal innovation capability that is not being translated into output. Over the following three years the ratio crossed unity and rose to 1.241, but the crossing was driven predominantly by input deterioration: the Input Capability Score fell 19.2 points between 2020 and 2024, from 63.1 to 43.9, while the output score rose more modestly. In 2025 the input score partially recovered to 51.4 and the output score reached its period high of 57.2. The net six-year picture is an input loss of 11.6 points offset by an output gain of 8.8 points. South Africa is the only case in which the translation problem identified in the prior literature is visible in the data as a starting condition and appears at least partially resolved by the end of the period — but resolved as much by a falling denominator as by a rising numerator.

Kenya: divergence without compensation. Kenya's trajectory is the most concerning in the sample. Its Input Capability Score fell from 30.0 to 16.7, a loss of 13.3 points and the steepest proportional decline in the panel: by 2025 Kenya stood in the seventeenth percentile of covered economies on innovation inputs. Its Output Performance Score did not compensate, falling marginally from 40.8 to 39.1. The conversion ratio nonetheless rose to 2.348, the highest single value in the entire twenty-four-observation panel, and the rank gap widened to thirty-one places. This is the clearest possible illustration of the interpretive ambiguity identified in Section 2.3. Read in isolation, Kenya's 2025 ratio is the most impressive number in Table 2. Read alongside its input trajectory, the same number documents an economy whose measured capability base has contracted faster than its outputs have fallen — an arithmetic artefact of denominator collapse rather than a marker of efficiency.

5. Association between inputs and outputs

Figure 2 plots all twenty-four observations in input–output space against the parity line. Across the pooled twenty-four observations, the Pearson product-moment coefficient between ICS and OPS is 0.743 and the Spearman rank-order coefficient is 0.697. Both are positive and of similar magnitude, indicating that the association is not an artefact of a small

number of influential observations. The pooled association means that economies and years with stronger relative input standing tend also to display stronger relative output standing.

Two cautions apply. First, the association is computed on repeated measures of four economies and is therefore driven substantially by between-country rather than within-country variation; it summarises co-movement in this specific panel and supports no inference about a wider population. Second, the coefficient describes contemporaneous association only. Because innovation processes involve lags of uncertain and probably heterogeneous length, no timing structure is imposed and none should be inferred.

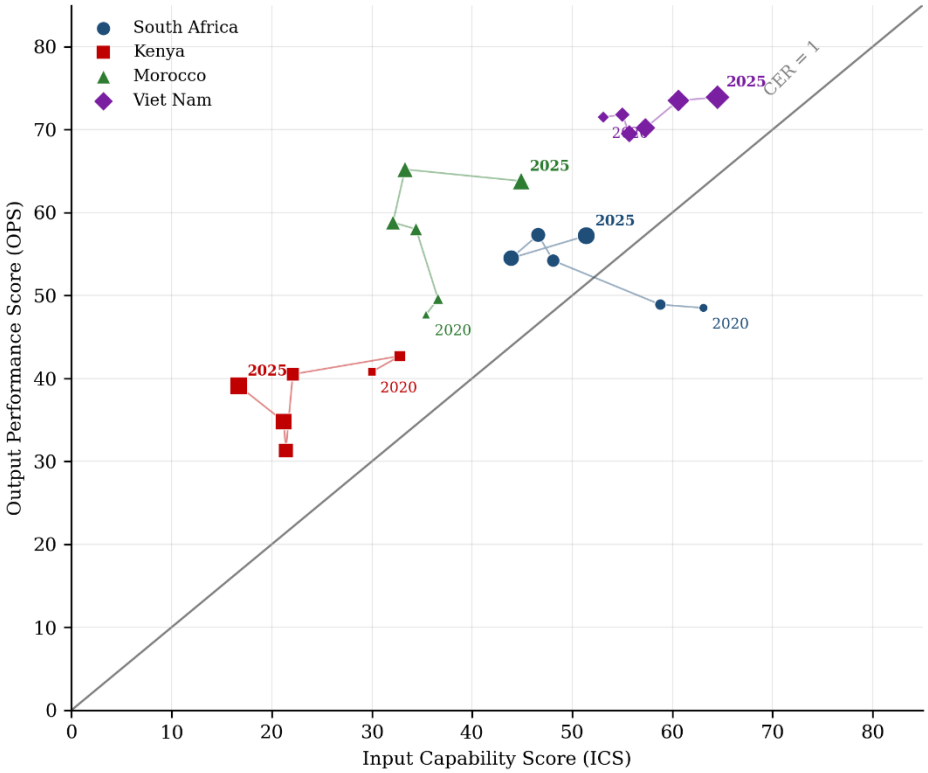

Figure 2. Input–output positions of the four economies, all twenty-four observations, with the parity line (CER = 1). Marker size increases with year; the first and last observation of each economy are labelled.

Source: Authors' computation from Table 1.

6. Contextual indicators

Table 4 assembles contextual indicators used in Section 5 to interpret the patterns above. These figures come from different sources with different reference years and different measurement conventions, and are presented for orientation rather than as a comparable series.

Table 4. Contextual innovation-system indicators

Economy	R&D expenditure (% of GDP, most recent available)	Technology funding raised, 2025	Dominant sectoral profile of funded ventures
South Africa	approx. 0.62 (2022)	approx. US$715 million	Fintech and enterprise services
Kenya	approx. 0.8 (older vintage)	approx. US$1.04 billion	Off-grid energy and climate solutions
Morocco	approx. 0.7 (older vintage)	Below the continental top four	Industrial, digital and export-linked activity
Viet Nam	approx. 0.42–0.43 (2021)	Not directly comparable to African trackers	Electronics manufacturing and digital services

Sources: UNESCO Institute for Statistics via World Bank development indicators; published annual technology funding trackers. Figures are approximate and vintage-inconsistent; see Section 5.4.

Table 4 introduces a striking discordance. Kenya reports the highest research intensity among the three African cases on the most recent available vintage, and attracted the largest technology funding volume on the continent in 2025 — yet it registers the lowest Input Capability Score in the panel by a wide margin. Two explanations are consistent with the data. The research intensity figure for Kenya rests on an older survey vintage than South Africa's, so the comparison may not reflect current conditions. And funding concentration matters: a very large share of Kenya's 2025 total was accounted for by a small number of late-stage energy companies raising substantially through debt instruments, which is a different economic phenomenon from broad-based early-stage innovation financing. Capital inflow into a handful of scaled ventures does not necessarily register as system-wide input capability, and the divergence between these indicators is itself an analytically informative finding.

7. Comparative typology

Table 5 summarises the four trajectories.

Table 5. Comparative typology of trajectories, 2020–2025

Economy	Input direction	Output direction	CER direction	Typology	Principal risk signalled
Viet Nam	Rising	Rising	Converging toward unity	Input-led maturation	Input base still low in absolute terms
Morocco	Rising (late, sharp)	Rising strongly	Peaked then fell	Output-led with late input catch-up	Sustainability of the 2025 input jump

Economy	Input direction	Output direction	CER direction	Typology	Principal risk signalled
South Africa	Falling then partial recovery	Rising	Crossed unity, then stabilised	Translation improvement on an eroding base	Continued erosion of the capability base
Kenya	Falling steeply	Flat to slightly falling	Rising sharply	Ratio inflation through denominator decline	Fragility of outputs without capability renewal

Source: Authors' synthesis of Tables 2 and 3.

DISCUSSION

1. The ambiguity of conversion efficiency

The central interpretive contribution of this study concerns the reading of output-to-input ratios. Such ratios are widely invoked in policy commentary as evidence that an economy is innovating efficiently, or punching above its weight, or demonstrating frugal ingenuity in the face of resource constraint. The four trajectories documented in Section 4 show that the same statistic can mean two entirely opposite things.

Consider Kenya and Viet Nam in 2025. Kenya's conversion ratio is 2.348; Viet Nam's is 1.146. On a naive reading, Kenya converts capability into performance roughly twice as effectively as Viet Nam. The trajectories in Table 3 dissolve this reading. Kenya's ratio is high because its Input Capability Score fell to 16.7 while its Output Performance Score merely stagnated; Viet Nam's ratio is low because its input score rose faster than its already-strong output score. Kenya's high ratio is a symptom of contraction; Viet Nam's declining ratio is a symptom of maturation. The direction of the input series, not the level of the ratio, carries the diagnostic information.

This yields a simple interpretive rule with practical value for analysts and policy audiences. A conversion ratio above unity should be read as evidence of genuine translation capability only when the input series is stable or rising. When the input series is falling, a rising ratio should be read as a warning: the system is producing outputs on a base that is contracting, and the sustainability of those outputs is in question. Applied to the present sample, this rule classifies Morocco and Viet Nam as robustly favourable, South Africa as favourable but conditional on arresting input erosion, and Kenya as unfavourable despite possessing the most impressive ratio in the dataset.

The rule also has implications for how developing-country governments use international rankings. Where a rising headline position coincides with a falling input score, the improvement may be positional rather than substantive, driven by the relative deterioration of comparator economies or by output indicators — trademark filings, creative goods, mobile applications — that respond to short-run commercial activity rather than to accumulated technological capability. Ranking movements are a starting point for diagnosis, not a substitute for it.

2. Interpreting the four configurations

Viet Nam. The finding that Viet Nam is the only economy to strengthen its input standing every year is consistent with the qualitative record of intensified policy activity in science, technology, innovation and digital transformation over the period, and with continued expansion of high-technology manufacturing and export activity. It sits alongside a well-documented tension: measured research intensity remains low, at roughly 0.42 per cent of gross domestic product on the most recent available vintage, well below the level of regional comparators and far below the two per cent target that Vietnamese policy discourse has articulated for the end of the decade. The input gain documented here therefore appears to be driven less by domestic research expenditure than by improvements in infrastructure, market and business sophistication, human capital and institutional conditions. This composition matters for policy: it suggests the input gain rests on foundations that are broad but shallow in research terms, and that the next phase of improvement will require the more difficult work of building domestic research and development capacity in the enterprise sector.

Morocco. Morocco's trajectory is the clearest instance in the sample of sustained output improvement, and its 2025 input jump is the single largest annual movement in the panel. The prior literature associates Moroccan innovation performance with industrial acceleration, export-platform integration in automotive and aeronautics value chains, substantial public investment in education and digital infrastructure, and strength in intangible assets and industrial design rather than in frontier research. The pattern in Table 2 is consistent with that account: outputs advanced first and inputs followed. Whether the 2025 input improvement is durable cannot be established from a single observation, and this is the principal uncertainty attaching to the Moroccan case.

South Africa. The South African result — the only negative rank gap in the sample at the start of the period, converting to a positive gap by 2022 — provides quantitative expression to the institutional paradox that dominates the qualitative literature. An economy with the most elaborate formal innovation architecture on the continent began the period ranking substantially worse on outputs than on inputs. The subsequent improvement in the relationship is real but must be read carefully: two-thirds of the movement in the ratio between 2020 and 2024 is attributable to the falling input score rather than the rising output score. The 2025 partial input recovery is encouraging, but a research intensity of approximately 0.62 per cent of gross domestic product, below the one per cent continental aspiration, remains a binding constraint on the trajectory.

Kenya. Kenya's result requires the most careful framing, because it appears to sit in tension with the country's international reputation as an entrepreneurial and digital-services leader — a reputation that the 2025 funding data in Table 4 substantially support. The tension is instructive rather than contradictory. Kenya's technology funding leadership in 2025 was concentrated in a small number of scaled, capital-intensive energy ventures financed heavily through debt instruments. That is a genuine achievement, but it is a different phenomenon from the system-wide institutional, human capital and research capability that the input measure captures. An economy can host globally significant ventures while its underlying innovation capability base weakens, and Kenya's data suggest exactly this configuration. The policy implication is not that Kenya's entrepreneurial ecosystem is illusory, but that its foundations require deliberate replenishment through research funding, university–industry linkage and the implementation of legislated innovation frameworks.

3. Implications for Viet Nam

Four implications follow for Vietnamese innovation policy, framed as considerations rather than prescriptions given the design's descriptive nature.

First, the composition of input improvement deserves explicit policy attention. Viet Nam's input gain has been broad but is not evidently research-driven; a research intensity of roughly 0.42 per cent of gross domestic product sits well below what a stated two per cent ambition implies, and closing that gap will require mobilising enterprise-sector research spending rather than public expenditure alone, since the business sector is the dominant funder of research in every economy that has achieved high research intensity.

Second, the Kenyan case offers a cautionary lesson about concentration. Where a small number of large ventures dominate funding flows, headline figures can convey ecosystem health that broader capability indicators do not confirm. Vietnamese monitoring frameworks would benefit from tracking the dispersion of innovation activity across firms and regions, not only aggregate totals.

Third, the South African case indicates that formal institutional elaboration does not guarantee translation. Viet Nam's recent legislative and institutional intensification in science, technology and digital transformation is a necessary but not sufficient condition; the operative question is whether new instruments alter firm behaviour, and answering it requires evaluation infrastructure — administrative data linkage, beneficiary registries, counterfactual evaluation capacity — built alongside the instruments themselves.

Fourth, the Moroccan case suggests that output-led sequencing is viable. An economy can build innovation outputs through industrial integration, design and intangible assets before its formal research base matures, provided the input base is subsequently strengthened. This sequencing resembles Viet Nam's own historical path and reinforces the argument that the current policy priority is deepening the capability base rather than further expanding output-oriented promotion.

CONCLUSION

This study asked how innovation input capability and output performance evolved in South Africa, Kenya and Morocco between 2020 and 2025, how efficiently each economy converted the former into the latter, and what a comparison with Viet Nam implies for policy. It answered these questions using only transparent descriptive procedures applied to publicly verifiable indicators, without estimating any model or advancing any causal claim.

The answer to the first question is that the three African economies diverged sharply. Morocco improved its relative input standing by 9.5 points on the study's bounded scale; South Africa lost 11.6 points and Kenya lost 13.3. The answer to the second question is that output trajectories diverged similarly: Morocco gained 16.1 points, South Africa 8.8, and Kenya lost 1.6. Viet Nam, the benchmark case, was the only economy to record gains on both sides in every year of the period.

The answer to the third question is the study's principal contribution. Conversion efficiency, measured as the ratio of output standing to input standing, exceeded unity in twenty-two of twenty-four observations and cannot meaningfully be compared across economies at the level of the ratio alone. Its trajectory, read jointly with the direction of the input series, is what carries diagnostic content. On that joint reading, Kenya's sample-leading ratio of 2.348 in 2025 signals contraction rather than efficiency, because it arose from an input base that fell to the seventeenth percentile of covered economies. Viet Nam's much lower ratio of 1.146 signals maturation, because it arose from an input base that strengthened in every year observed.

The answer to the fourth question is that the four cases together suggest a sequencing logic. Output-led improvement is achievable through industrial integration, design activity and intangible assets before a research base matures — Morocco's path, and historically Viet Nam's. But that path is sustainable only if the capability base is subsequently replenished, and both South Africa and Kenya illustrate what happens when it is not. For Viet Nam specifically, the implication is that the binding constraint has shifted: with output performance already in the seventy-fourth percentile of covered economies, further progress depends on deepening domestic research capability, particularly within the enterprise sector, rather than on further output-oriented promotion.

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