Endogenous Growth Theory and Economic Development: Can Innovation Drive Long-Term Goals for Emerging Markets? The Case of India

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ABSTRACT

This research paper explores the interplay between economic diversification, innovation, and growth in small open economies, with a focus on addressing market failures under uncertainty. The study integrates insights from endogenous growth theory and general-equilibrium frameworks to analyse two key distortions: insufficient ex-ante investment in modern sectors and excessive ex-postproduction diversification. The paper argues that optimal policy should balance incentives for entrepreneurship and innovation while rationalizing production to align with comparative advantage. The model builds on the concept of "creative destruction," where vertical innovations drive growth but are hindered by intertemporal spillovers and
businesssstealing effects. Key determinants of growth—such as innovation size, skilled labour force, and research productivity—are examined alongside their welfare implications. The
paper also evaluates neoclassical theories of growth, comparing models cantered on physical capital, human capital, and learning-by-doing to empirical evidence. By synthesizing these
perspectives, the study aims to provide actionable policy recommendations for fostering
sustainable growth in developing economies, emphasizing the need to internalize knowledge spillovers and mitigate inefficiencies in resource allocation. The findings will contribute to
debates on industrial policy, R&D incentives, and the role of government in correcting market failures.

Keywords: Innovation, Human Capital, Endogenous Growth Theory, Technology Transfer

INTRODUCTION

Emerging market economies often aspire to sustained, long-term growth that will allow them to catch up with developed nations in income and development indicators. A central question in development economics is whether innovation – broadly defined to include technological progress, new ideas, and improvements in human capital – can serve as the primary engine for long-run economic growth in these countries. Traditional models of economic growth, such as the Solow–Swan neoclassical model, treated technological progress as an exogenous factor, essentially a "manna *from heaven*" that fuels growth from outside the economic system. However, the rise of endogenous growth theory in the late 20th century (pioneered by economists including Paul Romer and Robert Lucas Jr.) shifted the perspective by asserting that the sources of technological progress are internal to the economy . According to this theory, policy choices, investments in education and R&D, and the creation of knowledge have a direct and lasting impact on a nation's growth trajectory.

India provides a compelling context to examine these ideas. Over the past few decades, India has experienced periods of rapid growth – often dubbed the "Indian growth miracle" – especially in the post liberalization era since the 1990s. This growth has coincided with India's emergence as a global player in information technology services, the development of cutting-edge digital public infrastructure, and a vibrant startup ecosystem. Yet, India also faces **developmental challenges**: a large informal sector, still modest research spending relative to GDP, and socioeconomic constraints such as inequality and skills gaps. This paper asks: **Can innovation drive India's long-term growth, and by extension, serve as a sustainable development engine for emerging markets?** We approach this question by blending theory and evidence.

The structure of the paper is as follows. We begin with a review of the literature on economic growth models, from

classical and neoclassical theories to the rise of endogenous growth theory and discuss how these frameworks incorporate (or fail to incorporate) innovation. We pay special attention to insights from key economists – including Debraj Ray's development economics perspective, David Romer's macroeconomic analyses, and Robert Lucas Jr.'s work on human capital externalities – to understand the theoretical underpinnings of innovation-led growth. Next, we outline the theoretical framework that will guide our analysis, focusing on the role of knowledge, human capital, and spillovers, as well as the institutional and policy environment needed to foster innovation in a country like India.

We then delve into the heart of the paper: empirical case studies from India that illustrate the relationship between innovation and economic development. These include India's **Digital Public Infrastructure** (for example, how UPI and Aadhaar have transformed financial inclusion

and service delivery), the **startup and AI ecosystem** (demonstrating entrepreneurial innovation and technology diffusion), and **innovation in critical sectors** like renewable energy and agriculture. Through these cases, we examine the channels through which innovation contributes to growth and the extent to which it can help achieve long-term developmental goals. In the discussion section, we synthesize the findings, discussing mechanisms (how innovation translates to growth), constraints (what might hinder this process), and alignment with global objectives like the Sustainable Development Goals (SDGs). Finally, we conclude with reflections on policy implications – what strategies can emerge markets adopt to harness innovation for sustained growth – and note the limitations of our analysis and avenues for future research.

LITERATURE REVIEW

CLASSICAL AND NEOCLASSICAL GROWTH MODELS

Early theories of economic growth laid the groundwork for understanding how economies expand over time, but they differed in their treatment of technology and innovation. **Classical models**, such as Adam Smith's and David Ricardo's, emphasized factors like labour, capital, and land, with technological change often viewed as exogenous or not explicitly modelled. The Harrod–Domar model (an early development theory model) focused on savings and investment as drivers of growth and can be seen as a precursor to later models. Interestingly, Harrod–Domar assumed constant returns and could generate an equilibrium growth rate from within the model (making it in a sense an "endogenous" growth model, as we will revisit). However, Harrod– Domar lacked a mechanism for why an economy would naturally settle at a stable growth path, often leading to knife-edge conditions.

The neoclassical growth model, developed by Robert Solow and Trevor Swan in the 1950s, introduced a paradigm shift by incorporating diminishing returns to capital and emphasizing technological progress. In the Solow–Swan model, an economy converges to a steady-state level of per capita income determined by exogenous factors (savings rate, depreciation, and population growth), and long-run per capita growth is driven entirely by an exogenous rate of technological progress. Innovation, in this model, remains unexplained – it is simply assumed to occur at a constant rate from outside the model. Solow's model famously predicted conditional convergence, meaning poorer countries would catch up to richer ones in per capita income only if they shared similar savings rates, population growth, and access to the same technology. In practice, pure convergence failed to materialize globally; many poor countries did not catch up as quickly as the model suggested, implying that other factors were at play.

Empirical work in the late 20th century sought to test and refine the neoclassical model. A notable contribution was by **Mankiw, Romer, and Weil (1992)**, who augmented the Solow model by adding **human capital** (for example, average years of schooling) as an additional factor of production. This extension improved the model's fit with cross-country data and showed that countries converge in income levels only after accounting for differences in human capital accumulation. In other words, a country's long-run output is higher if it not only invests in physical capital but also in education and skills – a hint towards the importance of innovation and knowledge 2 1 . The augmented Solow model still treats technological change as exogenous but acknowledges that **education (a form of innovation in human resources)** contributes to growth in a way like capital.

Despite these refinements, classical and neoclassical models left a big question unanswered: *what determines the rate of technological progress?* If long-term growth hinges on innovation, leaving it unexplained is unsatisfying, especially for policymakers wanting to accelerate development. This limitation set the stage for **endogenous growth theories**.

ENDOGENOUS GROWTH THEORY

Endogenous growth theory emerged in the 1980s as a response to the shortcomings of the Solow–Swan framework. Pioneers of this theory, notably **Paul Romer (1986, 1990)** and **Robert Lucas Jr. (1988)**, argued that economic growth is primarily driven by **forces within the economy** – particularly the accumulation of knowledge, human capital, and innovative ideas. The core insight is that unlike physical capital, knowledge and technology can have **increasing returns to scale** and are **non-rivalrous** (one person's use of an idea doesn't prevent another from using it). This breaks the neoclassical assumption of diminishing returns that would otherwise cause growth to taper off.

Romer's models introduced R&D and knowledge accumulation into formal growth theory. In Romer (1990), firms invest in **research and development (R&D)** to create new products or processes, and these innovations spill over to benefit others in the economy. The result is that the economy can sustain a positive long-run growth rate driven by innovation incentives. **Policy measures** play a crucial role in Romer's framework – for instance, patent laws or R&D subsidies can affect the rate of innovation. In fact, a hallmark implication of endogenous growth models is that **policy can permanently raise growth rates** (not just levels of output), a stark contrast to the Solow model where policy could only affect the steady-state level of income, not the growth rate. As an example, subsidizing education or R&D can increase the long-run growth rate by encouraging more knowledge production. David Romer (not to be confused with Paul

Romer) has been instrumental in disseminating these ideas in macroeconomic literature, emphasizing how **idea-driven growth** can be sustained and how government intervention might be justified to support research and human capital development in the presence of positive externalities.

Lucas (1988), in his seminal paper "On the Mechanics of Economic Development," focused on **human capital accumulation** as the engine of growth. In the Lucas model, individuals allocate time between working and accumulating skills. Because an individual's human capital not only raises their own productivity but also has an external effect on others (for example, more educated workers can raise the productivity of their coworkers or generate knowledge that benefits society), there are spillover benefits to education. Lucas famously remarked on the almost limitless potential of human capital externalities for improving welfare, stating: *"The consequences for human welfare involved in questions about human capital spillovers are simply staggering. Once one starts to think about them, it's hard to think of anything else."*. This underscores the idea that educating people and fostering skills can create a virtuous cycle of innovation and growth, especially pertinent for developing countries with large young populations like India.

In summary, endogenous growth models collectively highlight that **innovation is not an unexplained residual**; it is the result of intentional actions by individuals, firms, and governments. As Debraj Ray succinctly puts it in his development economics treatise: *"Technical progress, which determines long-run growth rates, is actually made by conscious actions of people, and therefore should not be regarded as exogenous."* Moreover, technology may **not flow freely** across countries 1 , implying that developing countries cannot always rely on simply importing innovations; they need to build the capacity to innovate or effectively adopt and adapt technologies. This point is particularly salient for India – while the country has benefited from imported technologies in many sectors, it has also had to develop home-grown innovations suited to its unique challenges (such as low-cost frugal innovations and scalable digital platforms for a vast population).

INNOVATION AND GROWTH IN THE INDIAN CONTEXT

How do these theories map onto the real-world experience of an emerging economy like India? India's growth story provides evidence for both the traditional growth drivers and the newer, innovation-led mechanisms. Until the 1980s, India's growth was relatively sluggish ("Hindu rate of growth" as it was pejoratively called) and largely driven by capital

accumulation in a closed economy framework. Reforms in 1991 opened up the economy, improved competitive pressures, and facilitated technology transfer from abroad. Since then, the Indian economy accelerated, averaging around 6-7% annual GDP growth for several decades, and even exceeding that in some years of the 2000s. This raised the question among economists: is India's growth simply a one-time catch-up due to liberalization and mobilization of labour and capital, or is it **sustainable in the long run through innovation**?

India has notable strengths that bolster innovation-led growth. It has a large pool of human capital in absolute terms – every year, millions of graduates (many in STEM fields) enter the workforce. The country's success in the IT services sector since the 1990s is one illustration of how investing in technical education (e.g., the IIT system) and leveraging knowledge spillovers (like learning from global firms via outsourcing contracts) created a new engine of growth. The informational and communications technology (ICT) revolution helped raise productivity and spawned entirely new industries in India, from software services to business process outsourcing, which expanded rapidly and integrated India into the global economy. This highlights innovation in process and organization – not just new products, but new ways of doing business (e.g., offshoring) – as a source of growth.

At the same time, India's experience also shows the importance of **institutions and policy** in unlocking innovation. For many years, India's R&D spending hovered around only ~0.6–0.7% of GDP, which is low compared to advanced economies (which often spend 2–3% of GDP on R&D) 4 . Moreover, much of India's R&D has historically been conducted by the government or public sector (e.g., in agriculture, defence, space, and atomic energy), with comparatively lower private sector research intensity. Recognizing the need to boost innovation, the Indian government in recent times launched initiatives like **"Start-up India"**, increased investment in higher education and innovation labs, and improved the ease of doing business to encourage entrepreneurship. Debraj Ray has noted that complementary reforms (like addressing credit market frictions and infrastructure bottlenecks) are also essential, as they enable innovative firms to start and grow.Overall, India's case suggests that innovation can indeed be a driver of growth, but it requires a conducive ecosystem. The literature indicates that when India's policies have encouraged openness, skill development, and technology diffusion, growth accelerated (as seen post-1991). Conversely, when innovation is stifled by heavy regulation or underinvestment (as arguably in the pre-1991 era of the "license raj"), growth faltered. Therefore, understanding how *endogenous factors* are at play in India's development is crucial for formulating strategies for long-term growth, which we turn to in the theoretical framework.

THEORETICAL FRAMEWORK

ROLE OF KNOWLEDGE, HUMAN CAPITAL, AND SPILLOVERS

The theoretical framework guiding this paper centres on the idea that **knowledge is the key asset** for long-term growth in an economy. We draw on endogenous growth theory, which formalizes the role of knowledge and human capital in growth models. In this view, **knowledge** (which can include scientific know-how, technical expertise, managerial skills, etc.) differs from traditional factors of production because it can generate **increasing returns**. If a firm discovers a more efficient production process, that idea can often be replicated at almost zero additional cost across the firm or even by other firms (unless tightly protected by patents). This non-rival nature means that the aggregate production function of the economy does not necessarily suffer from diminishing returns – doubling the knowledge base could potentially double output, even if physical capital faces diminishing returns individually.

HUMAN CAPITAL – the education, skills, and health of workers – is both a product of knowledge (since education accumulates knowledge) and a contributor to knowledge creation (skilled workers innovate and adapt technologies better). Lucas (1988) modelled human capital H as a separate factor in the production function and allowed for an external effect of average human capital on productivity. Essentially, each worker's productivity increases not only with their own skills but also with the average skill level of the workforce (a **spillover effect**). These **spillovers** are critical: they imply that private decisions (like an individual's choice to go to college) have social benefits beyond the private

benefits, leading to underinvestment in human capital from society's perspective if left to the market. This is why governments often subsidize education or directly provide it – to internalize the externality.

In the context of India, the role of human capital has been evident in sectors like ICT and pharmaceuticals, where a critical mass of skilled engineers and scientists created a virtuous cycle of learning and innovation. Moreover, **knowledge spillovers** in geographic clusters (such as the IT hub in Bangalore or the automotive cluster in Chennai) showcase how proximity and networks facilitate the spread of ideas. A programmer switching jobs from one startup to another carries tacit knowledge that can boost the new firm's productivity. Theoretical models such as **Romer (1990)** include a term for the "stock of knowledge" available to researchers, which increases with cumulative R&D. As more research is done, it becomes easier to do further research because scientists stand on the shoulders of predecessors. This can lead to *endogenous* growth because each innovation makes the next one a bit easier or opens new possibilities.

In our theoretical lens, **innovation** is more than just high-tech R&D; it includes any improvement or new idea that boosts productivity. This could be a new product, a new method of production, a new market opening, or a new way to organize a business. For emerging markets, **"frugal innovation"** or adaptations of existing technology to local contexts are very important forms of innovation. For example, developing a low-cost portable ECG machine in India is an innovation that doesn't rely on frontier science, but cleverly adapts engineering to make health technology affordable – it increases social welfare and can contribute to growth by improving health outcomes (healthier workers are more productive) and potentially creating an export product for other developing countries.

Summing up, our framework assumes that *if* an emerging economy invests in knowledge (education, research) and creates conditions for spillovers (networks, openness, mobility of talent, digital connectivity), it can sustain growth from within, rather than hitting a wall as capital accumulation slows. We will use this framework to interpret India's case studies: e.g., seeing digital infrastructure as a way to spread knowledge and services, or seeing the startup ecosystem as a manifestation of educated youth applying knowledge to create value.

INSTITUTIONAL AND POLICY FRAMEWORK IN INDIA

Endogenous growth doesn't happen in a vacuum – institutions and policies form the **ecosystem** that enables or hinders innovation. In India's case, several institutional factors are noteworthy:

- **EDUCATION AND SKILL DEVELOPMENT SYSTEMS:** India has some world- class institutions (IITs, IIMs, AIIMS for medical, etc.), but also wide variance in quality. Universal primary education has improved (near-universal enrolment now), but quality issues persist. Higher education has expanded with many private colleges, though quality varies. Government policies like the New Education Policy (NEP 2020) aim to foster critical thinking and research from early on, which is relevant for long-run innovation capacity.

- **DIGITAL INFRASTRUCTURE AND REGULATORY ENVIRONMENT:** One of India's institutional innovations has been the development of a Digital Public Infrastructure (DPI) known as the India Stack, which includes Aadhaar (national digital ID), UPI (unified payments interface), and other open APIs for services. This has created a common platform enabling private innovation on top of public digital rails. It's a novel public-private approach: the government provides foundational tech infrastructure and businesses build innovative solutions (fintech apps, e-government services, etc.) atop it. The regulatory environment has generally supported these innovations, e.g., the Reserve Bank of India (RBI) encouraging payment innovation, or TRAI in telecom maintaining competition which drove down data costs (important for digital innovation reach).

- **EASE OF DOING BUSINESS AND STARTUP ECOSYSTEM SUPPORT:**

Historically, India was notorious for red tape. Reforms have improved this; the World Bank's Ease of Doing Business index (before it was discontinued) showed India jumping many ranks in the 2010s. This came from measures like

simplifying company registration, digitizing tax filings, faster insolvency resolution (Insolvency and Bankruptcy Code 2016), etc. A better business climate encourages entrepreneurship, which is essentially decentralized innovation. The **Start-up India** initiative (launched in 2016) provides startups with easier compliance norms, tax exemptions for a few years, and dedicated support (like incubators, mentorship programs). Furthermore, **access to finance** for innovative ventures has improved, with a growing venture capital industry and government-backed funds (such as the Fund of Funds for Startups).

In sum, India's institutional and policy environment is a **mixed bag** – with some exemplary successes (digital ID and payments infrastructure, a thriving startup scene in certain industries) and some persistent weaknesses (low overall R&D spending, uneven education outcomes, bureaucratic hurdles). The theoretical expectation is that a supportive institutional framework – one that protects property rights, invests in human capital, encourages competition, and addresses market failures – is necessary to unleash the full potential of innovation-led growth. We will see in the case studies how specific policies have enabled innovation (e.g., UPI's design and promotion) or how the lack of support (e.g., in agricultural research) might constrain growth.

RESEARCH QUESTIONS AND METHODOLOGY

This study is primarily a synthesis of theory and empirical observations, aimed at exploring the central research question: **Can innovation drive long-term economic growth in emerging markets, specifically in India?** Within this broad question, we address several sub-questions: -

RQ1: What does endogenous growth theory predict about the role of innovation in sustaining long-run growth, and how is this relevant to an emerging economy like India? - **RQ2:** Through what mechanisms has innovation contributed to India's economic development in recent decades?

To address these questions, the methodology of this paper is **qualitative and analytical**. We conduct a literature review (as presented above) to ground our understanding in established economic theory and prior empirical studies. We then adopt a **case study approach** for the Indian context, selecting key domains where innovation's impact on development is evident. The case studies – digital public infrastructure, the startup/AI ecosystem, and innovation in renewable energy and agriculture – serve to illustrate and provide concrete evidence for the more abstract concepts of endogenous growth.

While we do not perform new econometric analysis in this paper (due to scope and length constraints), we rely on the findings of existing empirical research (such as Madsen et al. 2010 for R&D's effect on growth, or various surveys on startups and AI) to answer our research questions. This method allows us to integrate insights from multiple studies and draw a holistic picture. We also incorporate qualitative insights from economists like Debraj Ray on development processes, to ensure that our analysis remains attuned to the broader development context (e.g., the need for jobs, equity considerations, etc., in an innovation-led growth paradigm).

The approach is thus interdisciplinary, lying at the intersection of economic theory, policy analysis, and development studies. By triangulating theoretical expectations with real-world evidence from India, we aim to derive nuanced conclusions about the promise and pitfalls of relying on innovation for long-term growth in emerging markets.

EMPIRICAL CASE STUDIES FROM INDIA

INDIA'S DIGITAL PUBLIC INFRASTRUCTURE (DPI): UPI REVOLUTION

One of the most striking examples of innovation driving development in India is the creation of **Digital Public Infrastructure** – notably the Unified Payments Interface (UPI). These are technological innovations at a systems level,

orchestrated largely by the government (in collaboration with the private sector), that have transformed the economic landscape by enabling millions of people to participate more fully in the economy.

UNIFIED PAYMENTS INTERFACE (UPI), launched in 2016 by the National Payments Corporation of India (NPCI), is another transformative innovation. UPI is a real-time payment system that allows instant transfer of funds between bank accounts via mobile devices, using a simple identifier (like a virtual payment address). It basically created an **open, interoperable platform** on which banks and fintech companies could offer seamless payment services. The growth of UPI has been explosive. From a few hundred thousand transactions in its first year, UPI now processes billions of transactions every month. In the financial year 2023–24, UPI handled about **13,000 crore transactions (130 billion)**, up from just 92 crore (920 million) in FY 2017–18. In 2023, the total annual value of UPI transactions reached **₹182 lakh crore** (approximately
$2.2 trillion), marking a 59% increase in transaction volume over the previous year [6] [7] . This implies that UPI has largely digitized a substantial share of cash transactions in India, bringing more of the economy into the formal digital realm. Indeed, UPI has made India the **global leader in real-time digital payments**, accounting for 46% of all such transactions worldwide in 2022
[8] .

In summary, Aadhaar and UPI demonstrate how **technological innovation in public infrastructure** can directly and indirectly fuel economic development. They directly increase productivity (e.g., delivering subsidies more efficiently, reducing transaction frictions) and indirectly enable further innovation (fintech, ecommerce growth, digital lending based on payment data, etc.). These innovations also highlight the importance of **policy support**: the Indian government and regulators actively promoted UPI (even mandating zero fees to ensure rapid adoption) and made sure these platforms remain inclusive and open. This case exemplifies endogenous growth theory's point that policy (here, building infrastructure for innovation and ensuring positive network externalities) can raise the long-term growth path of the economy by unleashing creative potential.

STARTUP AND AI ECOSYSTEM: ENTREPRENEURSHIP AND THE TECHNOLOGY BOOM

India's economic development has increasingly been intertwined with the rise of a dynamic **startup ecosystem**, particularly in technology sectors. This represents a shift from the traditional big-company or government-led innovation model to a more decentralized, marketdriven model of innovation. Over the last decade, India has become home to one of the largest startup communities in the world, often ranked third globally in terms of number of startups, after the US and China. As of 2023-24, India had an estimated **300,000 startups** (3 lakh startups) with **over 100 unicorns** (startups valued above $1 billion) across sectors. This boom is a testament to the entrepreneurial energy in the country and the enabling environment that has started to take shape.

Several factors contributed to this rise: - **Demographic Advantage:** A large youth population that is increasingly college-educated and digitally savvy has meant a surge in potential entrepreneurs and a workforce ready to staff new ventures. - **Globalization and Diaspora:** Many Indian entrepreneurs are inspired by or have experience in Silicon Valley and other global tech hubs. There's been a reverse brain drain to some extent, with successful Indians abroad returning to start ventures or fund startups in India. **Policy and Infrastructure:** As discussed, improvements in ease of business, availability of digital infrastructure like UPI, and government programs encouraging startups have lowered entry barriers. **Funding:** The availability of venture capital, both domestic and foreign, has skyrocketed. Global investors see India as the next big market, and local investor networks have matured. The result is that startups in India raised tens of billions of dollars in funding cumulatively over the past few years, fuelling rapid growth.

An interesting aspect of India's startup ecosystem is its **geographical spread**. While big metropolitan cities like Bangalore, Delhi, and Mumbai are the primary hubs, about **40% of tech startups are now emerging from smaller "Tier II and III" cities**. Cities such as Jaipur, Indore, Kochi, and many others are producing startups, leveraging local talent and lower costs. This diffusion of innovation activity beyond the metros is encouraging from a development standpoint, as it could lead to more balanced regional growth and job creation. It suggests the innovation culture is taking root more

widely, not just in traditional elite enclaves.

In conclusion, India's startup and AI ecosystem exemplifies endogenous growth in action: entrepreneurs (often highly educated individuals) are using knowledge to create new products and services, attracting investment, and in the process, contributing to economic growth. The government's role has been to nurture this ecosystem with supportive policies and infrastructure, while largely leaving innovation to the market's dynamism. This case study shows the potential of *home-grown innovation* in an emerging market, moving away from a model of only adopting foreign technology to developing solutions for domestic and global markets. The output of this ecosystem – whether measured in new jobs, productivity gains, or contribution to GDP – is a key determinant of whether innovation can truly propel India to developed-country income levels in the long run.

R&D INVESTMENT IN RENEWABLE ENERGY AND AGRICULTURE

Innovation is also critical in sectors that are foundational for sustainable development: **energy and agriculture**. These sectors have direct implications for India's long-term growth and its ability to meet development goals (like SDG 7: Affordable and Clean Energy, and SDG 2: Zero Hunger, SDG 13: Climate Action). We examine how India is investing in and fostering innovation in these areas, and what challenges it faces.

RENEWABLE ENERGY: India's energy demand is massive and growing as the economy develops and urbanizes. Historically, this demand was met largely by coal and oil, making India one of the largest greenhouse gas emitters (though on a per capita basis, emissions are much lower than in developed countries). Recognizing the twin needs of energy security and climate change mitigation, India has made a strategic pivot to renewables. The country set an ambitious target of reaching **500 GW of non-fossil fuel electricity capacity by 2030** 10 . As of late 2024, non-fossil (renewable + nuclear + hydro) accounted for about 45% of installed power capacity 10 , with renewables (solar, wind, biomass) around 180 GW out of a total ~400 GW capacity 11
. This is a remarkable achievement – renewables were virtually negligible two decades ago in India's mix.

AGRICULTURE: Agriculture remains the backbone of livelihoods in India, though its share in GDP has shrunk to around 15%. Productivity growth in agriculture is crucial for India to ensure food security for its population and to release labour from farming to other sectors (a typical structural transformation pathway). Innovation in agriculture can come from many angles: improved **crop varieties** (higher yielding, drought resistant, etc.), better farming practices (precision agriculture, organic methods, etc.), enhanced farm machinery suited to Indian conditions (small tractors, efficient harvesters), and better **supply chain management** (cold storage, food processing innovation to reduce waste).

India had a major innovation-driven Agri boom in the 1960s-70s with the **Green Revolution**, which introduced high-yield variety seeds and chemical fertilizers in wheat and rice, catapulting India from chronic food shortages to self-sufficiency. That was a prime example of technology (albeit imported/adapted from global research) driving growth in a sector. Today, the challenges are different – yield growth has stagnated in many regions, climate variability is increasing, and the environmental costs of the Green Revolution (soil degradation, groundwater depletion) are becoming apparent. Thus, innovation is needed for a more **sustainable agriculture**.

DISCUSSION

MECHANISMS THROUGH WHICH INNOVATION CONTRIBUTES TO GROWTH

Bringing together insights from the case studies and theory, we identify several key **mechanisms** by which innovation drives long-term growth in an emerging economy like India: 1. **Productivity Increases:** Fundamentally, innovation raises the output that can be produced from a given amount of inputs – whether it's a new machine that allows a factory to produce goods faster, a better seed that yields more crop per hectare, or a digital platform that lets a worker accomplish more in a day. These productivity gains accumulate economy-wide, showing up as higher GDP per capita. For instance, digital payment systems like UPI reduce the time and effort for transactions (a productivity gain in the financial system), and widespread adoption means the whole economy can conduct commerce more efficiently.

Similarly, when farmers use an improved crop variety, the same land and labour yields more output, boosting agricultural productivity.

1. **INCREASING RETURNS AND CUMULATIVE GROWTH:** As per endogenous growth theory, innovation and knowledge can generate increasing returns. One practical interpretation of this is **learning-by doing**: the more you produce something, the better you get at it, reducing costs and improving quality, which in turn can make the product more competitive and increase demand, leading to more production. This virtuous cycle was seen in industries like automotive manufacturing in India – starting with high costs and lower quality decades ago, the industry learned and innovated to become globally competitive (for example, India is now a major exporter of small cars). With knowledge spillovers, one firm's learning can benefit others, making the *whole industry* more efficient over time. This sustains growth beyond what accumulation of capital alone would allow.

2. **SPILLOVER EFFECTS AND EXTERNALITIES:** Innovation in one area can have ripple effects across the economy. We saw how the digital infrastructure innovations (Aadhaar, UPI) not only directly improved their immediate use-cases, but also enabled innovations in other domains (e.g., ecommerce, digital lending, new fintech apps). These positive externalities amplify the impact of the initial innovation. Another example: investment in space technology by ISRO (India's space agency) has led to spin-off benefits in communications, weather forecasting for agriculture, and inspiration for a private space-tech startup scene. The broad lesson is that an innovation often creates knowledge that others can build on in unexpected ways, contributing to growth in areas far beyond the original investment.

3. **HUMAN CAPITAL DEVELOPMENT:** Innovation is both a product of human capital and a contributor to it. When a society prioritizes innovation, it usually means it is educating its population and encouraging creative problem-solving. This focus can raise the human capital of future generations (for example, seeing successful entrepreneurs or inventors may motivate more youth to pursue STEM education). In turn, a more educated workforce is more capable of producing further innovations. This feedback loop – education fuelling innovation and innovation raising returns to education – can underpin sustained growth. In India, the expansion of higher education in engineering, and the success stories of tech entrepreneurs, have had a cultural impact, creating aspirations and an environment where young people increasingly see opportunity in innovative careers rather than just traditional jobs.

Through all these mechanisms, innovation affects not just the quantity of growth (the GDP rate) but also the **quality of growth**. Ideally, innovation-led growth is more sustainable and inclusive, because it is based on skills and knowledge diffusion. But that ideal outcome is not automatic; it depends on how inclusive the innovation process is and how the benefits are distributed.

INSTITUTIONAL AND SOCIOECONOMIC CONSTRAINTS

While innovation has great promise, several **constraints and challenges** can limit its impact on long-term growth in India (and similarly placed economies): - **Education and Skill Gaps:** Even though India produces a large number of graduates, the average quality of education and skill training is uneven. There is a gap between the skills industry needs (for cutting-edge innovation) and what the typical graduate possesses. If a significant portion of the workforce remains lowskilled, they may not benefit from or contribute to the innovation economy, potentially widening inequality. Furthermore, basic education outcomes (literacy, numeracy) still lag in some regions, which is a constraint on building broad-based human capital.

- **DIGITAL DIVIDE:** The digital innovations like UPI and others assume access to technology. In India, while mobile penetration is very high, not everyone has a smartphone or reliable internet, especially among the poor or in remote areas. There's also a gender gap in digital access. If not addressed, this digital divide can mean that certain innovations primarily benefit urban or well-off populations, leaving behind others. The government is trying to mitigate this (e.g., cheap data plans made possible by telecom competition, public Wi-Fi programs, etc.), but it remains something to watch.

- **INFRASTRUCTURE BOTTLENECKS:** Physical infrastructure (electricity, roads, logistics) is also crucial for many innovations to translate into economic gains. For example, having the best digital marketplace means little if goods cannot be delivered efficiently due to poor transport infrastructure. India has been investing heavily in infrastructure, but gaps remain, and any lag can constrain the growth of innovation-driven enterprises (especially in manufacturing or in reaching rural markets).

POLICY IMPLICATIONS

The analysis above leads to several policy implications for India and other emerging markets aiming to harness innovation for long-term growth: 1. Invest in Human Capital at All Levels: A clear implication is the need for sustained investment in education and skill development. This spans primary education (to ensure basic literacy and numeracy, which lays the foundation for learning), secondary and tertiary education (with curricula updated to encourage creativity, problem-solving, and STEM skills), and vocational training. India should continue expanding and improving initiatives like Skill India. Higher education reform to encourage research (more funding for universities, incentives for research output, industry-academia linkages) is vital, as universities are often hotbeds of innovation. As Lucas (1988) highlighted, the externalities from human capital are huge, so this represents a high-return investment.

1. **INCREASE R&D EXPENDITURE:** Both public and private R&D spending need to rise. The government could target raising GERD from ~0.7% of GDP to at least 1.5% in the next decade, moving towards the levels of China or OECD countries. This could be done by higher budget allocations to scientific research agencies, providing matching grants or tax credits to private sector R&D, and establishing more centres of excellence in key fields (AI, biotech, clean energy, etc.). The decline in agricultural R&D intensity is particularly worrying 12 – reversing this trend by earmarking funds for Agri innovation (e.g., through a dedicated "Agricultural Innovation Mission") would pay off in terms of food security and rural incomes. Similarly, energy R&D for renewables and storage should be prioritized to meet net-zero commitments. Policymakers might also consider **mission-oriented innovation programs** (in the style of what some countries do, like a mission for sustainable cities or a mission for electric mobility) which set clear targets and bring stakeholders together.

2. **STRENGTHEN DIGITAL AND PHYSICAL INFRASTRUCTURE:** The success of

UPI and Aadhaar shows that when the government builds enabling digital infrastructure, the private sector innovation flourishes on top of it. This model can be extended: for example, continuing to build out broadband connectivity (especially to rural areas) as a public utility can enable a host of local innovations (like telehealth, ecommerce, elearning in villages). Physical infrastructure improvements (power, transport) remain fundamental – without reliable electricity, one cannot run high-tech labs or factories; without good logistics, startups in smaller towns can't get their products to market. The "Gati Shakti" national infrastructure plan and continued investment in 24x7 power are therefore complementary to the innovation agenda. Also, considering the importance of clusters for spillovers, infrastructure development should aim to create or strengthen innovation hubs (with good transport, housing, and connectivity to attract talent).

3. **FOSTER AN INCLUSIVE INNOVATION ECOSYSTEM:** Policymakers should

ensure that the fruits of innovation are widely shared and that more people can participate in innovative activities. This means promoting diversity in entrepreneurship – supporting women entrepreneurs, entrepreneurs from non-metro regions, and those working on solutions for rural or under-served communities. Government schemes can provide mentorship, seed funding, or incubation for startups in areas that might be overlooked by mainstream VC (for example, social enterprises, rural-focused startups). Additionally, labour market policies and social protection need to adapt as automation in certain industries rises, facilitating retraining and job transition programs becomes important. The idea of a **"universal basic income"** or basic social safety net has been floated by economists (including proposals by Debraj Ray and others) in case automation significantly displaces jobs; while not yet mainstream policy, it's an area for research and pilot programs to ensure no one is left behind.

In implementing these policies, the role of the state is not to replace the market in innovation, but to **catalyse and complement** it – fixing market failures, providing public goods (like basic research funding which the private sector may under-provide, or infrastructure), and ensuring equity. India's experience, with its mix of successes and gaps, provides valuable lessons: proactive public innovation (like UPI) can be gamechangers, but neglecting areas like education or agriculture research can become bottlenecks. Therefore, a holistic policy approach is needed, one that treats innovation as a central pillar of development policy, on par with (and indeed interacting with) macroeconomic stability, infrastructure, and human development policies.

CONCLUSION

In addressing whether innovation can drive long-term growth in emerging markets, with India as a focal example, this paper finds a strong affirmative, tempered by necessary conditions. **Innovation – in ideas, technology, and processes – has undeniably become a primary driver of India's economic progress in recent decades**, in line with the predictions of endogenous growth theory that emphasize internal engines of growth. By moving beyond the constraints of traditional capital accumulation, India's knowledge-driven sectors have helped sustain higher growth rates than would have been possible under an exogenous growth paradigm.

We saw through various lenses how innovation is contributing: a digital payments revolution enabling a more efficient and inclusive economy; a thriving startup ecosystem positioning India as a global innovation hub; and efforts in renewable energy and agriculture aiming to secure the future. These examples highlight that innovation is not a single monolithic phenomenon, but a multi-dimensional one – spanning high-tech R&D to grassroots ingenuity. They also underscore that **government action and policy frameworks play an indispensable role** in cultivating an environment where innovation can flourish and translate into broad-based development. Endogenous growth theory's insight that "policy measures can influence the long-run growth rate" is vividly reflected in India's case – had it not been for certain forward-looking policies (like investing in digital infrastructure or opening markets to competition), the innovation outcomes could have been much weaker.

Crucially, the Indian experience illustrates that **innovation can be made to align with development goals**. When leveraged properly, it is a means to accelerate not just GDP growth but also improvements in welfare – reducing poverty, improving service delivery, and addressing sustainability. The alignment with SDGs indicates that innovation-led growth need not come at the cost of equity or environment, provided deliberate efforts are made to guide it. For example, digital innovations are bringing banking to the poor, and clean energy innovations are addressing climate concerns while powering growth. This integrative success is something other emerging markets can draw inspiration from.

However, the findings also caution that innovation is not an automatic panacea. Without the right enabling factors, the potential of innovation could fizzle out. India still has work to do in areas like raising R&D investment (to global benchmarks), improving the quality of mass education, and building stronger institutions that support innovation (from intellectual property regimes to financial systems that fund risky ventures). Moreover, social challenges such as inequality and employment displacement need proactive management. **Debraj Ray's concerns** about labour being potentially left behind in an era of automation remind us that human development must go hand-in-hand with technological advancement. If innovation benefits are concentrated in a few and bypass large sections of society, the growth it generates will not be socially or politically sustainable in the long run. Thus, inclusivity is not just a moral imperative but a practical one for sustained growth.

For India, the next few decades will be critical. The country stands at a juncture where, if it continues to foster innovation and addresses the bottlenecks identified, it could achieve a virtuous cycle of growth and development – potentially even the oft-cited goal of becoming an
$8 trillion economy by 2030 and beyond. Innovation will be at the heart of that journey, whether it's through **AI transforming industries, green technologies redefining energy and transport, biotech improving health and agriculture, or yet unimagined breakthroughs**. The trajectory of India suggests that emerging markets can indeed chart a different development path than earlier industrializers: one that is faster thanks to technology leapfrogging, and

possibly more sustainable by avoiding some of the pitfalls (like high carbon emissions or exclusionary growth) that characterized past development paths.

In conclusion, innovation can drive long-term goals in emerging markets like India, but its success is contingent on human capital, institutional quality, and deliberate policy support. **Endogenous growth theory provides a powerful framework to understand this process**, reminding us that the determinants of growth lie within – in the ingenuity of people and how societies cultivate that ingenuity. India's story so far offers evidence that nurturing innovation is a viable development strategy. The task ahead is to deepen this effort, ensure it remains inclusive and sustainable, and continuously adapt as new challenges and technologies emerge. If India and similar countries can do so, they will likely not only achieve their growth ambitions but also contribute significantly to global prosperity and innovation.

LIMITATIONS AND FUTURE RESEARCH

While this paper has provided a comprehensive overview, there are several limitations in our analysis that should be acknowledged, many of which point to directions for future research: - **Scope of Analysis:** We focused on select case studies (digital infrastructure, startups/AI, renewables, agriculture) which are by no means exhaustive. Other important areas of innovation in India, such as biotechnology (e.g., vaccine development where India has had success, as seen in COVID-19), manufacturing process innovations, or social innovations (like microfinance models pioneered in South Asia), were not covered in depth. Future research could broaden the scope to see how innovation in those domains affects growth and development.

- **CAUSALITY AND QUANTIFICATION:** Our approach was largely qualitative and based on secondary sources. While we cited empirical studies supporting certain claims (like R&D's contribution to growth), we did not ourselves conduct a quantitative causality analysis (e.g., running regressions on how innovation indicators affect GDP or productivity). As such, there is an implicit assumption that the relationship is causal, but proving causality is challenging due to endogeneity issues (for instance, richer countries can afford more R&D – so does R&D cause growth or vice versa?). Future research could employ econometric or macroeconomic modelling techniques to quantify more precisely how much of India's growth is explained by innovation-related factors, controlling for other variables.

- **HETEROGENEITY WITHIN INDIA:** India is a vast and diverse country; our analysis sometimes treated it as one unit. In reality, states differ greatly in their innovation capacity and development outcomes. For example, states like Karnataka and Maharashtra are innovation hubs, whereas some other states lag in both innovation and income. A more granular study could explore **subnational variations**, identifying why some regions succeed in fostering innovation (perhaps due to better local governance or specific policies) and others don't. This could inform targeted policy interventions at the state or local level.

- **COMPARATIVE ANALYSIS WITH OTHER EMERGING MARKETS:** Our focus was India-specific. It would enrich the discussion to compare India's experience with other emerging economies such as China, Brazil, or those in Southeast Asia, some of which have pursued innovation-led strategies (China's huge R&D push, for example). Comparative analysis could reveal what institutional or cultural differences influence how innovation translates to growth. It might also highlight best practices – for instance, Israel and South Korea transitioned to innovation-driven economies despite starting as developing countries; their experiences could offer lessons for India.

In conclusion, this paper should be seen as a stepping stone that brings together theoretical and empirical perspectives on innovation and development, specifically illuminating the Indian context. It opens many questions that merit further exploration. As the landscape changes – with new technologies emerging and global conditions evolving – continued research is essential to keep our understanding updated. The encouraging takeaway is that countries have agency in shaping their growth paths through innovation; the continuing task for researchers and policymakers is to figure out the most effective and equitable ways to exercise that agency.

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