Research Article

Innovation as a Propellant of Per Capita Income in Two Rapidly Transitioning Asian Economies: A Comparative Analysis of China and India

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Abstract
China and India have been experiencing dramatic economic growth and catching up fast with the advanced countries. Technological innovation (domestic & foreign) is one of the critical factors, which is thought to have played a significant role in their output growth. Both domestic and foreign innovations have substantial footprints and are strengthening over time. However, little is known in the literature about their impact on output growth. Thus, we investigate the role of domestic and foreign innovations in explaining per capita output in two rapidly transitioning Asian economies (China and India) during 1990-2021. Employing time series estimation techniques viz. Fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS), and canonical cointegration regression (CCR), our study demonstrates that both domestic and foreign innovations significantly drive their per capita output. However, the impact of domestic innovation is observed to be predominant compared to foreign innovation. Similarly, total investment significantly explains per capita output. The decomposition of total investment shows that it is the private investment which stimulates per capita income of China and India. Public investment has a significant adverse impact on China's per capita income. Surprisingly, trade openness adversely impacts per capita output, which is not to suggest to adopt a reversal in their trade openness (trade protective policy) with the rest of the world but could significantly imply greater caution on their trade policy. Moreover, moderate inflation and financial development positively and significantly affect their per capita incomes. Finally, our analysis throws some important policy implications.

Keywords: domestic & foreign innovations, private & public sector investments, per capita income, China, India

1 INTRODUCTION
The main aim of this current study is to examine whether domestic and foreign innovations in China and India influence their output growth over the period, 1990-2021. This is imperative in the context when China and India have experienced dramatic sustained economic growth over the past three decades. The real GDP per capita grew by 1,140.09% and 267.07% (Table 1) in China and India, respectively, between 1990 and 2021, which led to a significant transformation in the landscape of the global economy. China and India are catching up faster with the advanced countries[1]. Technological development might have played a significant role for these major changes. It is extensively recognized in the literature that technology is a key driver of economic growth. Solow[2], in his seminal paper, highlighted that technological progress is external to the operation of firms and is vital to long-run economic progress. Technology augments output generation by efficiently utilizing available resources. It builds up developing economies’ heterogeneous capability, along with efficient utilization of resources contributing to their...
Table 1. Output and Innovation Growth in China and India between 1990 and 2021

<table>
<thead>
<tr>
<th>Variable</th>
<th>China</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita</td>
<td>1,140.09%</td>
<td>267.07%</td>
</tr>
<tr>
<td>Total innovation</td>
<td>15,542.33%</td>
<td>1,511.85%</td>
</tr>
<tr>
<td>Foreign innovation</td>
<td>3,593.82%</td>
<td>1,220.83%</td>
</tr>
<tr>
<td>Domestic innovation</td>
<td>24,362.34%</td>
<td>2,190.06%</td>
</tr>
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</table>

Notes: GDP per capita is the GDP per capita (constant 2015 USD). Source: Author’s calculation drawing data from WDI, World Bank.

innovations in China and India drive their output growth. Both have experienced outstanding long-term output growth by affecting labour and capital productivity[8].

However, gradually the debate on the contribution to output growth has shifted from technological progress to intensely gravitate towards the contribution of innovation to output growth over the last two decades. The basic difference is that technological progress represents technological improvements, while innovation represents the creation and implementation of new ideas, methods, products, or processes and is not limited to technology; instead, it involves various fields. Notably, innovation helps to produce new goods and services and significantly affects domestic production capacity. It augments capital and labour productivity and makes a significant quantity of output available, besides ensuring greater transparency, efficiency and overall productivity. Several scholars strongly argue innovation majorly drives output growth[10-14]. Fu and Shi[14] firmly argued innovation is a crucial factor that drives long-term output growth and sustainable development. Therefore, concluding that technological innovation is a crucial component and helping these developing economies to catch up with developed economies[1].

Within this broad ongoing debate and frame of discussion, here we bring on to the spot a neglected aspect in the concomitant empirical literature i.e. investigating the role and contributions of domestic innovation and foreign innovation in developing economies’ output growth, which has not received much attention. This deserves empirical attention from a comparative perspective for the two largest Asian fastest-growing economies. In other words, both domestic and foreign innovations have substantial footprints and this footprint is strengthening over time in developing economies like China and India. However little is known about their impacts on output growth. Assessing the contribution of domestic and foreign innovations in developing economies is highly imperative from a comparative policy perspective. However, surrounding the above-mentioned issue, many relevant questions have remained unanswered. This study, therefore, addresses two critical questions: (i) Do foreign and domestic innovations in China and India drive their output growth? and (ii) Are both types of innovations (foreign and domestic) equally important for growth or do they have a differential impact on China’s and India’s output growth? These questions need significant attention to understand the contribution of domestic and foreign innovations especially in developing economies like China and India.

Large developing economies have significant potential to augment their physical and human capital compared to any other poor and advanced economies. Hence, large economies like China and India with significant presence of physical and human capital are more likely to generate and attract foreign innovations, affecting their economy-wide activities. Both domestic and foreign players are likely to play a significant role in China’s and India’s innovation activities, which is demonstrated statistically as well. The total innovation in China and India grew up by 15,542.33% and 1,511.85%, respectively, between 1990 and 2021. Segregating total innovation into foreign (developed by foreign innovators) and domestic (developed by domestic innovators) during the same period, foreign innovation rose by 3,593.82% and 1,220.83%, and domestic innovation rose by 24,362.34% and 2,190.06% in China and India, respectively (Table 1).

However, gradually the debate on the contribution to output growth has shifted from technological progress to intensely gravitate towards the contribution of innovation to output growth over the last two decades. The basic difference is that technological progress represents technological improvements, while innovation represents the creation and implementation of new ideas, methods, products, or processes and is not limited to technology; instead, it involves various fields. Notably, innovation helps to produce new goods and services and significantly affects domestic production capacity. It augments capital and labour productivity and makes a significant quantity of output available, besides ensuring greater transparency, efficiency and overall productivity. Several scholars strongly argue innovation majorly drives output growth[10-14]. Fu and Shi[14] firmly argued innovation is a crucial factor that drives long-term output growth and sustainable development. Therefore, concluding that technological innovation is a crucial component and helping these developing economies to catch up with developed economies[1].

China and India are two large and rapidly transitioning Asian economies. Both happen to be middle-income countries and have been experiencing an accumulation of considerable physical and human capital over the years. They have further potential to increase physical and human capital comparing other economies. They are also likely to stimulate and generate domestic innovation and attract foreign innovation. China and India’s innovation, no matter whether it is foreign or domestic, grew significantly between 1990 and 2021. Corresponding to innovation growth, their output expanded enormously during this period. However, comparing the two, India’s GDP per capita and innovation grew much lesser than China’s (Table 1). Both have experienced outstanding output growth. Various socioeconomic, including major macroeconomic dimensions, have appreciably changed. Their level of innovation has reached a new milestone. Such dramatic development motivates us to examine whether domestic or foreign innovation drives China and India’s output growth.

Innovation embodies improvement in scientific and technical knowledge; although this has received significant attention in theory, but it is largely neglected in most empirical literature. Given public goods characteristics of accumulation of intangible knowledge capital (non-rivals and non-exclusion), even if private firms produce it by engaging in research and development (R&D) activities, it can give rise to increasing returns on account of its faster spillover through the spread of modern information technologies (rapid and cheap communication technologies). Grossman and Helpman[15] argued that the international environment and comparative
advantage impinge on firms located in specific countries to invest in the creation of knowledge and technology and achieve specialization in the production of goods, affecting their economic performance. Therefore, competition is the primary motivator of innovation and knowledge accumulation. The countries that cannot accumulate knowledge by increasing their investment and appropriation of knowledge and technology spillover benefits from trade partner countries stand to lose instead of making significant economic gains.

It is theoretically demonstrated that innovation determines long-term economic development by channelling improved knowledge to economic processes. The innovating firms are significant propellers of economic growth. Although some studies have endogenised innovations in their empirical models, however, they suffer from measurement problems. Following Griliches[16] interpretation of Solow’s growth model, studies based on Solow’s methodology related the residuals to an accumulation of a “knowledge stock”. Since it refers to increases in output for a given combination of factor inputs, it is referred to as “total factor productivity”. Since, in reality, modern economies do not operate under conditions of perfect competition, these residuals capture not only technical progress and product market innovation but also changes in returns to scale and mark-ups. It also captures measurement errors and effects of unmeasured inputs, such as human capital, R&D, and other intangible investments. By including only fixed capital and labour in the production function, it is difficult to interpret the remaining residual as the contribution of knowledge and attribute those remaining contributions to underlying technological factors unless it is properly captured in the model.

Adopting a Schumpeterian framework, Aghion and Howitt[17] considered the familiar Cobb-Douglas aggregate production function, expressed as a function of capital and “efficiency units” of labour, and where the efficiency parameter represented the state of technological knowledge to which all innovations contribute. They theoretically showed capital accumulation and innovation are both essential inputs to long-run growth. More innovation stimulates capital accumulation by raising the marginal productivity of a successful innovator. However, this result contradicted the conventional belief that innovation alone determines the long-run growth rate while capital accumulation determines only the level of the long-run growth path.

Achieving sustainable development goals without efficient technological innovations and their applications in large developing economies like China and India would be a distant dream for the global economy. However, expanding China’s and India’s economic pie without sufficient domestic and foreign innovations may buttress their environmental degradation concerns arising from CO₂ emission. The global CO₂ discharge was 36.8 billion tons in 2019 which reflects a major concern. Serious environmental concerns are also at the forefront of both China’s and India’s ecology. The CO₂ emissions of China and India are 7.38 and 1.91 tonnes per capita, respectively[18]. Hence, assessing whether domestic and foreign innovations matter for output growth in China and India is important. Significant domestic and foreign innovations not only stimulate output[17,19] but also help to maintain social, economic, and environmental sustainability. Innovation is a major factor for sustainability and is commonly accepted among scholars and practitioners[20-22]. Moreover, Rout et al.[18] observed that innovation improves environmental sustainability significantly. Shrivastava et al.[23] established that innovation is instrumental in achieving sustainable development.

With this backdrop, our contribution to the literature is fourfold. First, the magnitude of domestic and foreign innovations is substantial in China and India, which may play a critical role in their macroeconomic performance. However, literature has failed to investigate whether China and India should focus on domestic or foreign innovations for the sustainability of their high-income growth. In this context, this is the first study that deals with domestic and foreign innovations and their impact on income growth. Second, China and India are the two rapidly transitioning Asian economies that have experienced sustained outstanding income growth over a few decades except few deviations in certain years. The level of innovation dimensions has appreciably changed. Analyzing the contribution of domestic and foreign innovations to China’s and India’s growth is critical to formulating appropriate macro policy. Third, apart from innovation dimensions, we consider public and private investment, inflation, openness, and financial development variables to assess their impact on per capita income from a comparative perspective. Finally, we have applied multiple cointegrating models, such as fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and canonical cointegration regression (CCR) to provide unbiased and consistent/robust results. These cointegrating models are proposed to be appropriate to the context given the time series characteristic of our data sets. The estimation procedures are adapted to overcome nonstationary problems associated with the level series and adjusted for serial correlation, autocorrelation, and endogeneity problems, providing precise and consistent estimates and overcoming misleading estimates.

Our datasets mostly follow the integration of order I(1). It implies that all the series are found stationary at the first differences even though they are nonstationary at their levels. Accordingly, we employ FMOLS, DOLS,
and CCR techniques. Our empirical analysis finds that innovation (total) significantly accelerates China’s and India’s per capita income. The decomposition of innovation into domestic and foreign innovations with an appropriate specification demonstrates that both domestic and foreign innovations play crucial roles in driving the per capita income of both economies. However, the magnitudinal impact of domestic innovation is relatively higher than the magnitudinal impact of foreign innovation. Similarly, investment (total) significantly induces per capita output. Mainly, it is private investment that plays a crucial role in increasing China and India’s per capita GDP. Public investment has a significant adverse impact on China’s per capita income, while it does not significantly impact India’s per capita income. Surprisingly, trade openness adversely impacts per capita income of both economies, which is not to suggest for a reversal in their trade openness (trade protective policy) with the rest of the world but could significantly imply greater caution to their trade policy.

2 LITERATURE SURVEY

2.1 Innovation and Economic Growth

The association between innovation and output growth has become a focal point of scholarly exploration. This growing field of study seeks to unravel the relationship between innovation dynamics and their consequent impact on economic development. As technological advancements continue to reshape industries and societies, understanding the nuanced ways in which innovation impacts growth and development is imperative for policymaking, businesses, and researchers alike. The literature survey delves into key findings and perspectives within the domain, shedding light on multifaceted dimensions of innovation and its profound implications on economic prosperity. Zeira[24] analysed a model of economic growth, with technological innovations that reduce labour requirements but raise capital requirements. He observed that technological innovations are not everywhere adopted, but only in countries with high productivity. Technology adoption significantly amplifies differences in productivity between countries which explains the differences in per capita income and growth of countries and the divergence and convergence phenomenon.

Chandrashekar and Basvarajappa[25] examined the share of private and government in total R&D expenditures and the broad areas in which they spend on R&D. They observed a major percentage of R&D expenditure in India is being incurred by the government which has witnessed an increase from 76.8% to 79.6% during 1994-1995 to 1999-2000. While the industry registered an increase in R&D expenditure but its share in R&D expenditure decreased 23.1% in 1994-1995 to 20.4% in 1999-2000. The government’s R&D spending majorly went to Defence, Space and Atomic Energy and the share of both increased from 48 per cent of government R and D expenditure in 1994-1995 to 52 per cent in 1999-2000. Then they linked these R&D expenditure components with value added in industries/sectors in India. Observing agriculture and mainstream industries are the main drivers of India’s growth, they suggested more technology inputs in these areas which can make India globally more competitive. To investigate the growth impact of innovation in an endogenous growth framework, Ulku[26] used patent and R&D data for 20 OECD and 10 Non-OECD countries during 1981-1997. Employing various panel models, he discovered a positive relationship between per capita GDP and innovation for both OECD and non-OECD countries, while the effect of R&D stock on innovation was significant only for OECD countries with large market sizes. Although the results supported endogenous growth models, however, they did not observe constant returns to innovation, implying that innovation does not lead to permanent increases in economic growth. From this, they implied that their results did not necessarily suggest a rejection of R&D-based growth, as neither patent nor R&D data capture the full range of innovation and R&D activities.

Cainelli et al.[27] showed past economic performance affects innovation and that innovation activities (especially investments in ICTs) have a positive impact on growth and productivity. Productivity and innovation are self-reinforcing each other, and it boosts economic performance. These findings provided empirical support for the endogenous nature of innovation in services. Arguing that public capital can affect growth not only through productivity, but also through innovation capacity and human capital accumulation, Agénor and Neanidis[28] examined the interactions between innovation, public capital, and human capital in an OLG model of endogenous growth for a panel of economies. They showed that higher innovation performance promotes growth directly, whereas public capital has both direct and indirect growth effects by promoting human capital accumulation and innovation capacity. Contesting that innovation, R&D expenditures and investments in technology are prerequisites for ensuring competitiveness and progress, and through them achieving sustainable economic growth, Pece et al.[29] investigated the role of innovation on sustainable growth for CEE countries. To quantify innovation, they used several variables, such as the number of patents, the number of trademarks, and R&D expenditures. They provided evidence of a positive relationship between economic growth and innovation for CEE countries (Poland, Czech Republic and Hungary).

Measuring the technological progress of SSA countries from Intellectual Property Rights (IPR), Adam[30] investigated its impact on the per capita income growth of SSA countries. Finding the negative effect of IPR on economic growth from ordinary regression and SUR methods, he concluded that most innovation in SSA
may be imitative or adaptive in nature. A stronger IPR might protect foreign firms at the expense of domestic firms. Therefore, the challenge for SSA countries is to reform their IPR regime, while limiting the potential adverse effects of improved protection, and to facilitate access and benefits of strong IPR protection to local entrepreneurs. The SSA countries need to focus on implementing IPR policy such that it plays a positive role in inducing technology acquisition and creation, and local business development. The negative effect of IPR on growth does not necessarily mean that strengthening IPR is not good for the region, but it might need a more effective institutional environment to operate efficiently. IPR by itself is not sufficient to ensure technological progress. It must form part of a coherent set of complementary policies that maximize the potential of IPR to raise competition. Maradana et al. [33] using six different measures of innovation viz. patents-residents, patents-non-residents, research and development expenditure, researchers in research and development activities, high-technology exports, and scientific and technical journal articles, they investigated the long-run relationship between innovation and per capita economic growth in 19 European countries during 1989-2014. Finding a long-run relationship and presence of both unidirectional and bidirectional causality between innovation and per capita economic growth for most of the countries, they concluded that innovation indicators are strongly linked with per capita income growth.

Zhou et al. [32] recognised the role of scientific and technological innovation (measured in patents) at the core of Chinese development and examined its role as a new driver of qualitative growth in Chinese provinces along with the role of financial development (measured in credit supply). He considered the integration of regional credit and technological innovation as a double-edged sword of economic growth as credit can play an important role in the attainment of technological development. They observed that regional credit and technological innovation importantly contribute to the provincial economic growth of China, while the interaction of regional credit and technological innovation worsens the same. Therefore, they argued that China should rationally allocate regional credit resources, strengthen technological innovation capabilities, and boost up integrated development of regional credit and technological innovation to facilitate regional economic integration and sustainable development.

Observing the number of patent applications for China has increased during 2021 by 16.1% and its growth exceeding GDP growth, Wang and Xu [35] investigated the impact of technological innovation on economic growth for China during 1990-2019. Estimating through OLS and WLS models, they observed that when the government’s expenditure on science and technology innovation increases (1%), it greatly improves economic growth (127%). They concluded that a country’s economic growth needs technology promotion and strong support from the government, as financial support has the most significant effect on economic growth. Sarangi [34] considering G20 countries verified whether innovation lead to economic growth during 1961-2019. They found evidence of causality running from innovation to growth. Wen et al. [35] examined whether economic openness (EO) is conducive to promoting regional growth in a sample panel of 30 provinces in China from 2004 to 2018. The results of the mediation effect model show that technological innovation is an important channel for EO to accelerate economic growth. Although with improvement in regional economic development, the benefits of EO increase, however, its positive effect has slowed down in regions with very high levels of economic development.

Aminullah [36] analysed the technology innovation forecast and economic growth in Indonesia and established that developing general-purpose technology innovation stimulates sustainable economic growth. Guo et al. [37] investigated the dual role of exploitative and exploratory green innovations in fostering sustainable economic growth in China. They showed that the impact of green innovations on economic growth varies across various regions. Tao et al. [38] employed annual observations of several variables of Asian and European countries from 1996 to 2021 and demonstrated significant regional heterogeneity and time-varying effects of technological innovation on economic growth. Drawing data from Word Bank from 1990-2022 in 60 countries, Hoa et al. [39] found a bidirectional relationship between innovation and economic growth. He et al. [40] examined a panel data set for 38 Asian countries from 1990 to 2021 utilizing several statistical models and found a positive and significant relationship between technological innovation, and economic growth. However, reviewing the large body of literature we identify that there exists a significant research gap in distinguishing the role of domestic innovation from foreign innovation and their impact on economic growth. There are no comparative analyses investigating the role of both while incorporating other important growth-determining factors for India and China.

2.2 Investment and Economic Growth

Theoretically, the investment multiplier propagated by Keynes in 1936 induced intense debates over the association between investment and national output/income. The investment multiplier demonstrates the association between the increment in investment and the resultant increment in national income. However, following the investment multiplier, Harrod-Domar and Solow in their growth models conceptualized how investment produces a dramatic impact on the expansion of production and economic growth over time. Investment can build new establishments and strengthen productive capacity which accelerates...
national income. Investment is critical to faster growth of developing economies. It can lead to improved new infrastructure, strengthen industrialization, stimulate employment and thereby, income and output. However, a large body of literature while analyzing the association between investment and economic growth across countries has also provided a conflicting opinion. For example, Renshaw and Richards and Jorgenson and Fraumeni showed a positive impact of investment on output growth. Conversely, Blomström et al. found no evidence of investment affecting economic growth.

Until the 1980s, most of the analysis focused on how increased aggregate investment leads to economic growth, however, over time, researchers decomposed the effect of aggregate investment into public and private investments, which provided better insights about types of investment that matter for economic growth. First, the theoretical view of public investment is that it stimulates macroeconomic performance by increasing the productivity of available physical and human capital. It also allures new private investment to reap the benefits of higher productivity, by accelerating output growth. In this context, several empirical works provided evidence that there is a positive association between public investment and output growth. However, several other works contested that a positive association between public investment and economic growth may turn into a negative if public investment exceeds a certain limit where public investment may crowd out private investment. Studies by Phetsavong and Ichihashi, Makuyana and Odhiambo, and Nguyen confirmed a negative relationship between public investment and output growth. Some studies observed no significant association between public investment and economic growth.

Aschauer argued that the effect of public investment on macroeconomic performance lies not only in the productivity of public capital but also in the overall macroeconomic condition. Miyamoto et al. established that a country with good quality governance may have higher positive output effects of public investment than a country with weaker governance. Gwartney et al. illuminated that a country with higher-quality institutions achieves more growth per unit of public investment and attracts a higher magnitude of private investment. These literatures have considered different countries covering various periods of analysis. However, reviewing a large chunk of literature, we conclude that the literature provides ambiguous results without a consensus on the impact of public investment on output growth.

On the other hand, the literature demonstrates that private investment has a larger impact on economic growth. Gwartney et al. illuminated that the impact of private investment on growth is much larger than that of public investment. Several other works also demonstrate that output growth is largely driven by private investment. Nguyen pointed out private investment has a positive impact on the growth of Vietnam. Haque found private investment positively affects Bangladesh’s growth both in the short and long run. Makuyana and Odhiambo observed similar result. Phetsavong and Ichihashi showed private domestic investment plays a critical role in contributing to economic growth. Ghani and Din demonstrated that growth is largely driven by private investment. Ramirez and Nazmi postulated that private investment significantly contributes to the economic growth of Pakistan. No study provides a comparative analysis of how investment is affecting growth in India and China.

### 2.3 Other Variables and Economic Growth

Apart from innovations and investment dimensions, we considered other important variables such as inflation, openness, and financial development that may influence the output growth of developing economies. The addition of these variables also avoids the model misspecification. However, a brief review of these dimensions may add value to this paper. First, we focus briefly on inflation’s impact on output growth literature. Aydin et al. studied the impact of inflation on economic growth for five Turkish Republics and found that there is a nonlinear relationship between inflation and growth rate. Moreover, they established that an inflation rate above 7.97% negatively affects economic growth while an inflation rate below this (7.97%) positively affects economic growth. Ekinci et al. pointed out that below the threshold, the inflation-growth relationship is insignificant, and above the threshold, inflation affects growth negatively. According to Ghossoub inflation and economic growth are positively associated with a low level of inflation rate, while this correlation becomes negative when inflation rises above a certain threshold level.

Employing quarterly data covering the period 1961-Q1 to 2019-Q4, Mandeya and Ho investigated the impact of inflation and inflation uncertainty on South Africa’s economic growth. They observed that inflation negatively affects growth in both the short and long run, while inflation uncertainty is a short-run phenomenon in South Africa with no bearing in the long run. Similarly, Asafo-Adjei et al. developed an analysis drawing data for G8 countries and articulated that uncertainties pose a more persistent and dynamic challenge to the G8 countries’ efforts to achieve sustained economic growth. Observing the previous literature, we conclude that a higher rate of inflation harms economic growth, irrespective of the size of the economies. This is because inflation reduces the quantity of resources available for domestic investment. Saving declines and a significant proportion of this saving is channelized to foreign rather than domestic investment.
investment. At the same time, the flow of capital from abroad is discouraged\(^\text{[63]}\).

In contrast, Mallik and Chowdhury\(^\text{[64]}\) examined the relationship between inflation and GDP growth for four South Asian countries such as Bangladesh, India, Pakistan and Sri Lanka. They found evidence of a long-run positive association between GDP growth rate and inflation for all four countries. Drawing data for the Palestinian economy, Razia et al.\(^\text{[65]}\) also established a positive association between inflation and economic growth. However, Akinsola and Odhiambo\(^\text{[66]}\) pronounced that the impact of inflation on economic growth varies from country to country and over time. Niken et al.\(^\text{[67]}\) found a trivial effect of inflation on the economic growth of Ethiopia.

Second, we focus on the literature that examines the association between openness and economic growth. Gundlach\(^\text{[68]}\) pointed out that openness matters for economic growth. Employing two-panel data sets such as one of 56 countries covering the period 1951-1998, and another of 105 countries over 1960-1997, Karras\(^\text{[69]}\) found that trade openness’s impact on economic growth is positive, permanent, statistically significant, and economically sizable. He statistically showed that if trade (exports plus imports) openness increases by 10 percentage points, then the GDP per capita growth rate increases by 0.25 to 0.3 per cent. Similarly, Andersen and Babula\(^\text{[70]}\) and Baldwin\(^\text{[71]}\) pronounced a positive association between trade openness and economic growth. Keho\(^\text{[72]}\) examined the impact of trade openness on economic growth for Cote d’Ivoire over the period 1965-2014 and found a similar result that trade openness has positive effects on economic growth both in the short and long run. Employing an endogenous economic growth model, Hye et al.\(^\text{[73]}\) attempted to determine the long-run association between trade openness and economic growth in China. Their analysis highlighted that individual trade indicators and composite trade openness index are positively related to economic growth in the long run and short run. However, their rolling window analysis showed that openness is negatively associated with economic growth only for some years.

Conversely, Stensnes\(^\text{[74]}\) pointed out that for countries with the least developed institutions of conflict management, greater openness reduces growth rates. Fetahi-Vehapi et al.\(^\text{[75]}\) studied 16-year panel data of 10 SEE countries over the period 1996 to 2012 and found that the positive effects of trade openness on economic growth are conditioned by the initial income per capita and other explanatory variables, otherwise, there is not robust evidence between these two variables.

Lastly, we attempt to provide a brief discussion of the literature that examines the association between financial development and economic growth. Levine\(^\text{[76]}\) demonstrated a strong positive connection between the functioning of the financial system and long-run economic growth. Liang and Jian-Zhou\(^\text{[77]}\) employed data from 286 Chinese cities over the period 2001-2006 and examined the relationship between financial development and economic growth at the city level in China. They found that most traditional indicators of financial development are positively associated with economic growth. However, the utilization of a state-ruled banking sector as an indicator of financial development showed a negative association between financial development and economic growth. It is because of the distorting nature of the government. Hassan et al.\(^\text{[78]}\) found a positive connection between financial development and economic growth in developing countries. Interestingly, Valickova et al.\(^\text{[79]}\) suggested that stock markets support faster economic growth than other financial intermediaries. Using data for a panel of 40 countries over the period 1989-2011, Durusu-Ciftci et al.\(^\text{[80]}\) found a positive long-run effect on the steady-state level of GDP per capita. They confirmed that the contribution of the credit markets is substantially greater.

Recently, Asteriou and Spanos\(^\text{[81]}\) examined the association between financial development and economic growth in the face of the recent financial crisis, using a panel dataset of 26 European Union countries over the period 1990-2016. They pointed out that before the crisis, financial development stimulated economic growth, while after the crisis it hindered economic activity. Nguyen et al.\(^\text{[82]}\) confirmed that financial development has a positive effect on economic growth, and their relationship is linear in 22 emerging markets over the period 1980-2020. Bayraktar et al.\(^\text{[83]}\) have studied the link between economic growth and financial development for emerging markets and middle-income economies. They showed financial development indicators have a positive effect on growth in the presence of institutional quality. However, if institutionalization is not included in the model, the effect of financial development indicators on economic growth is statistically insignificant. Similarly, Oroud et al.\(^\text{[84]}\) established that financial development is the driving force behind economic growth in Jordan. Segovia and Cepeda\(^\text{[85]}\) stated that increases in the level of bank credit extended to private non-financial firms increased the state’s GDP per capita growth in Mexico. In contrast, Singh et al.\(^\text{[86]}\) analysed the impact of financial development on economic growth in India and found a consistently negative impact of financial development on economic growth in the long and short run.

3 METHODOLOGY
3.1 Model Specification

Our analysis involves accounting for innovation (including domestic and foreign innovations) in output growth i.e. investigating to what extent innovation matters for output growth of two major developing economies (China and India). However, Innovation
and human capital are highly correlated because the former can be an outcome of the later. Our correlation analysis shows a highly positive correlation between human capital (measured by mean years of schooling) and innovations (measured by the number of patent applications). Results are shown in Table 2. As a consequence of the high correlation between human capital and innovation, we have dropped human capital and considered innovation parameters in the model specification. Then, the study examines whether innovation (and its components comprising foreign and domestic innovation) affects the economic growth of both China and India.

First, we consider the Cobb-Douglas (CD) type of function and the mathematical expression of our analysis is as follows.

\[ EG_t = T^{\delta_1} I^{\delta_2} \]  

(1)

Decomposition of total innovation (TI) into domestic innovation (DI) and foreign innovation (FI), we have the following expression.

\[ EG_t = DI^{\delta_1} FI^{\delta_2} \]  

(2)

Taking the logarithm on both sides of Equations (1) and (2), one can write the expression as follows.

\[ \ln EG_t = \delta_0 + \delta_1 \ln TI_t + \delta_2 \ln I_t + \delta_3 \ln CPI_t + \delta_4 \ln O_t + \delta_5 \ln FD_t + \mu_t \]  

(3)

\[ \ln EG_t = \delta_0 + \delta_1 \ln DI_t + \delta_2 \ln FI_t + \delta_3 \ln CPI_t + \delta_5 \ln O_t + \delta_6 \ln FD_t + \mu_t \]  

(4)

By adding a constant \( \delta_0 \) and error term \( \mu_t \) in Equations (3) and (4), the complete equations can have the following expressions as,

\[ \ln EG_t = \delta_0 + \delta_1 \ln TI_t + \mu_t \]  

(5)

\[ \ln EG_t = \delta_0 + \delta_1 \ln DI_t + \delta_2 \ln FI_t + \mu_t \]  

(6)

However, the story does not end here because apart from innovation variables, several other variables serve as indispensable goals in explaining economic growth. Many conventional theories (for instance, Harrod-Domar, Ranis-Fi, Big-Push etc.) including Solow model have established that investment is a critical factor that helps maintain sound long-term economic growth. Investment contribution to economic development is immense. So, we have augmented both Equations (5) and (6) with total investment \( I \) comprising of public \( (Pu. I) \) and private \( (PI) \) investment in both the models. Besides the dimensions of innovations and investment, other variables such as inflation, openness, and financial development can have a significant influence on economic development. We further augment both Equations (5) and (6) by considering inflation measured by the consumer price index \( (CPI) \), openness \( (O) \) measured by export plus imports \( (% \text{ of GDP}) \), and financial development \( (FD) \) indicators in the model. Incorporation of these important variables in the model can help us to avoid model misspecification problems. The augmented Equations (5) and (6) can take the following expressions as:

\[ \ln EG_t = \delta_0 + \delta_1 \ln TI_t + \delta_2 \ln I_t + \delta_3 \ln CPI_t + \delta_4 \ln O_t + \delta_5 \ln FD_t + \mu_t \]  

(7)

\[ \ln EG_t = \delta_0 + \delta_1 \ln DI_t + \delta_2 \ln FI_t + \delta_3 \ln CPI_t + \delta_5 \ln O_t + \delta_6 \ln FD_t + \mu_t \]  

(8)

\[ \ln EG_t = \delta_0 + \delta_1 \ln DI_t + \delta_2 \ln FI_t + \delta_3 \ln CPI_t + \delta_5 \ln O_t + \delta_7 \ln FD_t + \mu_t \]  

(9)

Where \( EG \) is the economic growth. \( \delta_0 \) is the intercept or constant. \( \delta_1 \text{ to } \delta_7 \) in Equations (5-9) are coefficients of respective regressors. \( \mu \) is the error term capturing unobserved factors that influence the dependent variable with \( t \) subscript indicating the time dimension of variables. We have estimated Equations (5-9) by exploiting FMOLS, DOLS, and CCR models, which have their relevance to estimate our models. The details about FMOLS, DOLS, and CCR models are presented in the subsequent section.

### 3.2 Data

The primary aim of our paper is to examine whether innovations (including total innovation, and domestic and foreign innovations) explain output growth in China and India during 1990-2021. If innovations explain growth, then it boils down to asking whether it is domestic innovation or foreign innovation that explains the output growth of both economies. Here, the dependent variable

<table>
<thead>
<tr>
<th>Table 2. Correlation between Human Capital and Innovation in India and China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>India</strong></td>
</tr>
<tr>
<td>InHuman Capital</td>
</tr>
<tr>
<td>lnTotal Innovation</td>
</tr>
<tr>
<td>lnDomestic Innovation</td>
</tr>
<tr>
<td>lnForeign Innovation</td>
</tr>
<tr>
<td><strong>China</strong></td>
</tr>
<tr>
<td>InHuman Capital</td>
</tr>
<tr>
<td>lnTotal Innovation</td>
</tr>
<tr>
<td>lnDomestic Innovation</td>
</tr>
<tr>
<td>lnForeign Innovation</td>
</tr>
</tbody>
</table>

Notes: Human capital is measured by mean year of schooling and ln stands for log value.
is being captured by real GDP per capita, a commonly used measure of a country's economic performance. Although GDP per capita has been criticised from various perspectives, it still throws valuable information about a country's per capita output. Next, our serious concern is to measure innovation. Dosi and Nelson[89] provided an explicit definition that innovation is the actual introduction and tentative application of new ideas or tools, which several studies captured through R&D investment expenditures. For instance, Rossi et al.[88] and Rodil et al.[93] used R&D as a proxy for innovation. R&D, however, generates measurement problems because only some R&D activities lead to innovation. Further, all innovations do not come from R&D actions[90].

However, the number of patents can to a large extent be the main parameter of technological innovations[92], and a vital indicator to measure innovation activities[92], which have a more comprehensive coverage than R&D actions[93]. Comparing patent applications and grants, however, certain problems are being faced with patent grants as a measure of innovation. For instance, a patent is granted after the patent office completes the examination process and determines whether the invention meets the criteria for patentability. It takes a long time to grant the patent, which does not precisely reflect the year of innovation. The patent granting period differs considerably over time and across regions[16,94]. Therefore, our study exploits the number of patent applications rather than the number of patents granted to measure innovation accurately. We exploit patent applications filed by residents and non-residents, which are referred to as domestic innovation, and foreign innovation, respectively.

Besides investigating the role of our main interest variable (innovation), we have controlled other key variables based on their importance in empirical model specification. These variables have been chosen based on the extant literature. Apart from the innovation dimension, we consider total investment (comprising private and public investments), consumer price index measure of inflation, exports plus imports of goods and services (% of GDP), consumer price index and GDP per capita, a commonly used measure of a country’s economic performance. Although GDP per capita has been criticised from various perspectives, it still throws valuable information about a country’s per capita output. Next, our serious concern is to measure innovation. Dosi and Nelson[89] provided an explicit definition that innovation is the actual introduction and tentative application of new ideas or tools, which several studies captured through R&D investment expenditures. For instance, Rossi et al.[88] and Rodil et al.[93] used R&D as a proxy for innovation. R&D, however, generates measurement problems because only some R&D activities lead to innovation. Further, all innovations do not come from R&D actions[90].

However, the number of patents can to a large extent be the main parameter of technological innovations[92], and a vital indicator to measure innovation activities[92], which have a more comprehensive coverage than R&D actions[93]. Comparing patent applications and grants, however, certain problems are being faced with patent grants as a measure of innovation. For instance, a patent is granted after the patent office completes the examination process and determines whether the invention meets the criteria for patentability. It takes a long time to grant the patent, which does not precisely reflect the year of innovation. The patent granting period differs considerably over time and across regions[16,94]. Therefore, our study exploits the number of patent applications rather than the number of patents granted to measure innovation accurately. We exploit patent applications filed by residents and non-residents, which are referred to as domestic innovation, and foreign innovation, respectively.

Besides investigating the role of our main interest variable (innovation), we have controlled other key variables based on their importance in empirical model specification. These variables have been chosen based on the extant literature. Apart from the innovation dimension, we consider total investment (comprising private and public investments), consumer price index measure of inflation, exports plus imports of goods and services (% of GDP), measures of openness, and credit to private sector measures of financial development. These are commonly treated as crucial factors explaining economic growth. Data for all these variables are drawn from standard international databases and the sources are detailed in Table 3.

### 3.3 Application of Econometric Tools

We check for unit root tests (ADF and PP tests) to verify the order of integration of the time series of variables incorporated in our growth model. Both ADF and PP test results are reported in Table 4 which shows that our data series follow I (1). It implies that all the series are stationary at the first differences, although, nonstationary at their levels. This suggests the application of advanced time series econometric techniques rather than the traditional OLS model. The nonstationary of datasets at the level suggests the application of cointegrating models. We employ FMOLS, DOLS, and CCR techniques. These cointegrating models are appropriate for estimation as they take care of nonstationary problems at the levels and adjust for serial correlation, autocorrelation and endogeneity problems. FMOLS, DOLS, and CCR estimation methods determine the long-run association between independent and dependent variables in a single cointegrating vector. These are fully efficient methods.

Phillips and Hansen[95] postulated a semi-parametric adjustment to avoid the problem generated by the long-run association of cointegrating equations and independent variables’ shocks. This framework of Phillips and Hansen is considered as FMOLS. FMOLS model highlights an asymptotically unbiased and efficient estimator allowing for the standard Wald test involving asymptotic Chi-square statistical inference[96]. Park[97] highlighted a framework known as CCR. It considers the stationary conversion of the data to attain the least square estimate to eliminate
Table 4. Unit Root Test Results

<table>
<thead>
<tr>
<th>Country</th>
<th>Variable</th>
<th>ADF</th>
<th>PP</th>
<th>ADF</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Level</td>
<td>1st diff.</td>
<td>Level</td>
<td>1st diff.</td>
</tr>
<tr>
<td>India</td>
<td>lnGDP per capita</td>
<td>0.361</td>
<td>-5.489***</td>
<td>0.379</td>
<td>-5.569***</td>
</tr>
<tr>
<td></td>
<td>lnTotal innovation</td>
<td>-1.003</td>
<td>-5.011***</td>
<td>-0.999</td>
<td>-5.004***</td>
</tr>
<tr>
<td></td>
<td>lnDomestic innovation</td>
<td>0.831</td>
<td>-5.213***</td>
<td>0.952</td>
<td>-5.213***</td>
</tr>
<tr>
<td></td>
<td>lnForeign innovation</td>
<td>-1.289</td>
<td>-5.459***</td>
<td>-1.304</td>
<td>-5.778***</td>
</tr>
<tr>
<td></td>
<td>lnTotal investment</td>
<td>-2.097</td>
<td>-8.868***</td>
<td>-1.657</td>
<td>-8.720***</td>
</tr>
<tr>
<td></td>
<td>lnPrivate investment</td>
<td>-1.573</td>
<td>-5.080***</td>
<td>-1.589</td>
<td>-5.071***</td>
</tr>
<tr>
<td></td>
<td>lnPublic investment</td>
<td>-2.574</td>
<td>-4.939***</td>
<td>-2.617</td>
<td>-4.928***</td>
</tr>
<tr>
<td></td>
<td>lnFinancial development</td>
<td>-1.318</td>
<td>-3.429**</td>
<td>-0.764</td>
<td>-5.101***</td>
</tr>
<tr>
<td></td>
<td>lnCPI</td>
<td>-0.669</td>
<td>-6.514***</td>
<td>-1.685</td>
<td>-3.052**</td>
</tr>
<tr>
<td></td>
<td>lnOpenness</td>
<td>-2.022</td>
<td>-4.690***</td>
<td>-1.982</td>
<td>-4.749***</td>
</tr>
<tr>
<td>China</td>
<td>lnGDP per capita</td>
<td>-2.070</td>
<td>-2.404</td>
<td>-2.426</td>
<td>-2.524***</td>
</tr>
<tr>
<td></td>
<td>lnTotal innovation</td>
<td>-1.248</td>
<td>-5.136***</td>
<td>-1.248</td>
<td>-5.136***</td>
</tr>
<tr>
<td></td>
<td>lnDomestic innovation</td>
<td>-0.565</td>
<td>-2.432</td>
<td>-0.628</td>
<td>-3.588***</td>
</tr>
<tr>
<td></td>
<td>lnForeign innovation</td>
<td>-1.989</td>
<td>-5.526***</td>
<td>-2.444</td>
<td>-5.540***</td>
</tr>
<tr>
<td></td>
<td>lnTotal investment</td>
<td>-2.098</td>
<td>-3.569***</td>
<td>-1.895</td>
<td>-3.512***</td>
</tr>
<tr>
<td></td>
<td>lnPrivate investment</td>
<td>-1.510</td>
<td>-6.902***</td>
<td>-1.347</td>
<td>-6.902***</td>
</tr>
<tr>
<td></td>
<td>lnPublic investment</td>
<td>-1.252</td>
<td>-7.581***</td>
<td>-1.358</td>
<td>-7.581***</td>
</tr>
<tr>
<td></td>
<td>lnFinancial development</td>
<td>-0.313</td>
<td>-5.469***</td>
<td>-0.137</td>
<td>-5.509***</td>
</tr>
<tr>
<td></td>
<td>lnCPI</td>
<td>-0.358</td>
<td>-5.331***</td>
<td>-2.235</td>
<td>-2.813***</td>
</tr>
<tr>
<td></td>
<td>lnOpenness</td>
<td>-2.105</td>
<td>-6.677***</td>
<td>-2.238</td>
<td>-6.677***</td>
</tr>
</tbody>
</table>

Notes: ADF and PP stand for Augmented Dickey-Fuller and Phillips-Perron tests. *, **, and *** refer to level of significance at 10%, 5%, and 1%, respectively. Source: Author’s estimation drawing data from WDI, World Bank (Table 3).

the long-run association between cointegrating equations and stochastic regressor shocks\[99\]. The model also asymptotically removes the endogeneity problem via the long-run cointegrating equation’s correlation and regressor innovations\[99\]. If estimators are systematically corrected, the asymptotic property is not disturbed by endogeneity or serial correlation\[99\].

Stock and Watson\[100\] also proposed a model for building asymptotically efficient estimators that can eliminate the reverse causality in a cointegrating model. This Stock and Watson\[100\] model is known as the DOLS model. Stock and Watson introduce leads and lags in the model which can asymptotically eliminate possible bias emanating from endogeneity or serial correlation issues\[100\]. In sum, FMOLS, CCR, and DOLS models are sophisticated econometrics tools which provide efficient estimators adjusting for small sample, simultaneity, endogeneity, and serial correlation problems in the model. We have estimated equations 5 to equation 9 using FMOLS, CCR and DOLS approach.

4 EMPIRICAL RESULTS AND DISCUSSION

Scatter plots or correlation analyses between dependent (GDP per capita) and independent variables for China and India are represented in Figures 1 and 2, respectively. The scatter plot analysis for China and India shows that GDP per capita is positively associated with innovations, no matter whether it is total or domestic or foreign innovations. Perhaps, new and better product is the consequence of innovations. Innovation also provides better methods of production leading to increased efficiency and productivity, which increases per capita output in both China and India causing a positive association between GDP per capita and innovations.

Investment also plays a significant role in stimulating economic growth. Our scatter plot visualization shows that GDP per capita is positively associated with the total investment in China and India. Particularly, China’s GDP per capita is significantly and positively correlated with total investment and its components viz. private and public investment. India’s GDP per capita is negatively associated with total investment, and private investment and negatively correlated with public investment. A significant amount of total investment or private or public investment can positively contribute to economic growth, by stimulating countries’ GDP per capita. If investment is made in productive sectors, it can accelerate productivity, entice further investment and stimulate economic development.

Surprisingly, India’s public investment is negatively associated with its GDP per capita (Figure 2). This may be because of the crowding out effect or mismanagement or inefficient utilization of public investment, as a result, leading to public sector losses and the resultant piling of...
government deficits in the 1980s and 1990s. Significant public sector investment without proper return may also tend to increase government borrowings leading to high interest rates for private sector borrowings. As a consequence, the cost of investment increases leading to crowding out private investment which can harm GDP per capita. Otherwise, inefficient utilization of public investment may negatively affect per capita output. However, it is difficult to draw any concrete inference just by visualizing the scatter plot analysis, hence, rigorous empirical analysis is imperative for making constructive conclusions on the relationship between GDP per capita and investments including public and private investment.

GDP per capita is positively correlated with inflation measured by the CPI in China and India. Policymakers and central banks often prescribe a moderate inflation rate to sustain their growth. China and India’s average inflation rate remains moderate which may be stimulating their growth and thus, per capita output. Maintaining a moderate and low stable price level is conducive to sustaining economic growth. Moreover, openness measured by exports plus imports of goods and services (% of GDP) and financial development are positively associated with GDP per capita. The acceleration of openness and financial development strengthened both the economies’ growth and thus, their per capita output. However, as emphasised earlier, a scatter plot only reflects a visual relationship between two variables, not that a change in one variable leads to a change in another. Some third variables might drive the observed association. Thus, it requires rigorous statistical analysis to establish whether innovations and other control variables matter for China’s and India’s output growth.

To verify a robust statistical relationship, we apply sophisticated econometrics tools viz. FMOLS, DOLS, and
CCR for empirical analysis. First, we focus on whether total innovation affects GDP per capita. Results shown in Table 5 demonstrate that total innovation in China and India significantly increases their GDP per capita. It shows that a 1% increase in total innovation leads GDP per capita to increase in a range of 0.423% to 0.489% in India and 0.443% to 0.454% in China. The study augmented the model with additional control variables such as investment, CPI, openness, and financial development. The estimated results are presented in Table 6. It shows that total innovation has a positive and significant impact on the GDP per capita of both countries. The result is also consistent with alternative specifications. Moreover, this is in line with the findings of Ahlstrom\textsuperscript{[11]}, Moser\textsuperscript{[12]}, Manning\textsuperscript{[13]} and Fu, Shi\textsuperscript{[14]} stipulating that innovation has a positive impact on growth. Several players such as government, businesses, institutions (educational), etc. significantly contribute to fostering the development of innovation. Encouraging and facilitating innovation can accelerate economic growth and eventually contribute to an upsurge in GDP per capita.

However, from the above results based on total innovation, it is not obvious whether both countries focus on their domestically developed innovation or foreign innovation. It is because total innovation is the combination of domestic and foreign innovations. The decomposition of total innovation into domestic and foreign innovations may deepen our understanding with many important policy insights. The decomposition of innovation results is presented in Table 7 which shows that both domestic and
foreign innovation significantly stimulate GDP per capita in China, whereas only domestic innovation significantly increases GDP per capita in India (Table 7). India’s foreign innovation reduces its GDP per capita, although insignificantly. Noting that several factors may explain per capita income, hence it may lead to under-specification of the model as we have only used foreign and domestic innovations as the independent variables in the model. To avoid model misspecification, we have augmented this basic model with the addition of several control variables such as investment, CPI (inflation), openness, and financial development. The estimated augmented models are reported in Tables 8 and 9. It shows that both foreign and domestic innovations significantly accelerate China and India’s per capita GDP.

Surprisingly, it shows that domestic innovations have a greater magnitudinal impact on per capita income than foreign innovation. China and India's domestic innovation play a critical role in explaining their per capita GDP. Domestic innovation is perhaps more compatible with local market needs, consumer preferences, and certain challenges confronted by the population. Innovations that are well-suited to these domestic markets are more likely to have a significant effect on increasing productivity and thus, per capita output/income. Domestic innovation has a larger benefit of developing a comprehensive understanding involving its adaptations to

### Table 5. Results Involving Whether Total Innovation Affects Economic Development

<table>
<thead>
<tr>
<th>Variable</th>
<th>India</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FMOLS</td>
<td>DOLS</td>
</tr>
<tr>
<td>InTotal innovation</td>
<td>0.489*** (0.076)</td>
<td>0.423*** (0.104)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.924*** (0.330)</td>
<td>1.209*** (0.456)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.872</td>
<td>0.932</td>
</tr>
</tbody>
</table>

Notes: FMOLS, DOLS, and CCR stand for fully modified least squares, dynamic least squares, and canonical cointegrating regression, respectively. *** refers to the level of significance at 1%. Source: Author’s estimation drawing data from WDI, World Bank (Table 3).

### Table 6. Results Involving Whether Total Innovation with Other Control Variables Affect Economic Development

<table>
<thead>
<tr>
<th>Variable</th>
<th>India</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FMOLS</td>
<td>DOLS</td>
</tr>
<tr>
<td>InTotal innovation</td>
<td>0.117*** (0.027)</td>
<td>0.210*** (0.057)</td>
</tr>
<tr>
<td>InTotal investment</td>
<td>0.264*** (0.080)</td>
<td>0.292 (0.407)</td>
</tr>
<tr>
<td>InCPI</td>
<td>0.594*** (0.034)</td>
<td>0.480*** (0.124)</td>
</tr>
<tr>
<td>InOpenness</td>
<td>-0.468*** (0.068)</td>
<td>-0.665*** (0.204)</td>
</tr>
<tr>
<td>InFinancial development</td>
<td>0.283*** (0.069)</td>
<td>0.414*** (0.160)</td>
</tr>
<tr>
<td>Constant</td>
<td>1.264*** (1.264)</td>
<td>1.148*** (0.310)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.991</td>
<td>0.998</td>
</tr>
</tbody>
</table>

Notes: FMOLS, DOLS, and CCR stand for fully modified least squares, dynamic least squares, and canonical cointegrating regression, respectively. ***, and *** refer to level of significance at 5%, and 1%, respectively. Source: Author’s estimation using econometric tools.

### Table 7. Results Involving Whether Domestic and Foreign Innovations Affect Economic Development

<table>
<thead>
<tr>
<th>Variable</th>
<th>India</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FMOLS</td>
<td>DOLS</td>
</tr>
<tr>
<td>InDomestic innovation</td>
<td>0.458*** (0.027)</td>
<td>0.510*** (0.080)</td>
</tr>
<tr>
<td>InForeign innovation</td>
<td>-0.032 (0.026)</td>
<td>-0.060 (0.076)</td>
</tr>
<tr>
<td>Constant</td>
<td>1.440*** (0.042)</td>
<td>1.386*** (0.095)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.984</td>
<td>0.991</td>
</tr>
</tbody>
</table>

Notes: FMOLS, DOLS, and CCR stand for fully modified least squares, dynamic least squares, and canonical cointegrating regression, respectively. *** refers to the level of significance at 1%. Source: Author’s estimation using econometric tools and drawing data from WDI.
Table 9. Results Involving Whether Various Types of Innovations Along with Splitting Up Total Investment Affect Economic Development

<table>
<thead>
<tr>
<th>Variable</th>
<th>FMOLS India</th>
<th>CCR India</th>
<th>FMOLS China</th>
<th>CCR China</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnDomestic innovation</td>
<td>0.211** (0.019)</td>
<td>0.144*** (0.010)</td>
<td>0.262*** (0.010)</td>
<td>0.253** (0.016)</td>
</tr>
<tr>
<td>LnForeign innovation</td>
<td>0.027** (0.009)</td>
<td>0.027** (0.010)</td>
<td>0.100** (0.020)</td>
<td>0.109** (0.026)</td>
</tr>
<tr>
<td>LnTotal investment</td>
<td>0.356** (0.036)</td>
<td>1.022*** (0.066)</td>
<td>0.107 (0.081)</td>
<td>0.030 (0.103)</td>
</tr>
<tr>
<td>LnCPI</td>
<td>0.417*** (0.026)</td>
<td>0.643*** (0.024)</td>
<td>0.474*** (0.040)</td>
<td>0.452*** (0.053)</td>
</tr>
<tr>
<td>LnOpenness</td>
<td>-0.392*** (0.035)</td>
<td>-0.778*** (0.045)</td>
<td>-0.108*** (0.037)</td>
<td>-0.080*** (0.043)</td>
</tr>
<tr>
<td>LnFinancial development</td>
<td>0.102*** (0.102)</td>
<td>0.051 (0.038)</td>
<td>0.174*** (0.067)</td>
<td>0.214*** (0.094)</td>
</tr>
<tr>
<td>Constant</td>
<td>1.229*** (0.031)</td>
<td>0.727*** (0.052)</td>
<td>0.485*** (0.193)</td>
<td>0.538** (0.246)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.991</td>
<td>0.972</td>
<td>0.997</td>
<td>0.995</td>
</tr>
</tbody>
</table>

Notes: FMOLS and CCR stand for fully modified least squares, and canonical cointegrating regression, respectively. *, **, and *** refer to level of significance at 10%, 5%, and 1%, respectively. Source: Author’s estimation using econometric tools.

local conditions leading to more effective implementation and exploitation. Whereas, foreign innovations may throw valuable insights into adjusting them to the local requirements by modification and customization. We conclude that while domestic innovation can play a critical role, foreign innovation can also contribute significantly to increasing per capita GDP. Hence, both China and India are benefited from both domestic and foreign innovations. However, the relative degree of impact depends on several factors such as the nature of innovations, local adaption, access to such innovations which hinges on their cost and financial markets, etcetera.

The views of orthodox and heterodox theoretical perspectives contribute immensely involving the impact of real investment on output growth. Our empirical analysis shows that total investment has a significant positive impact on China and India’s GDP per capita (Tables 6 and 8). The significant level of investment can contribute to economic growth by expanding the production structure, which stimulates countries’ GDP per capita. Particularly, if investment is made in productive sectors, that can accelerate productivity, entice further investment and stimulate economic development.

However, the decomposition of investment into private and public investments shows that private investment mostly stimulates GDP per capita in both China and India (Table 9). China's GDP per capita has increased by 0.227% and India's GDP per capita has increased by 0.268% with a 1% increase in their respective private investments. This finding is in line with the findings of Gwartney et al. [57], Haque [49], Makuyana and Odhiambo [52], and Nguyen [53]. They strongly argue that private investment stimulates output. Surprisingly, China’s public investments have a significant negative impact on its GDP per capita (Table 9), while India’s public investment has an insignificant negative impact. Phetsavong and Ichihashi [32], Makuyana and Odhiambo [33] and Nguyen [41] confirmed a negative relationship between public investment and output growth. The negative impact of public investment may be because of the crowding-out effect led by mismanagement of resources.
or an inefficient utilization of public investment in both countries. For instance, significant public investment inflates government borrowing which increases interest rates and thereby raises the cost of investment. This may result in crowding out of private investment which can adversely impact GDP per capita. Moreover, inefficient utilization of public investment may negatively affect per capita output.

Apart from highlighting the role of innovation and investment in both economies, our results provide additional crucial insights about other important controlled variables. The inflation rate measured in the consumer price index has a positive and significant impact on China and India’s GDP per capita. A 1% increase in inflation, interestingly leads to an increase in their GDP per capita by 0.452% to 1.341% and 0.402% to 0.661% in China and India, respectively. Scatter plot analysis also confirmed a positive association between CPI and GDP per capita. Our finding is in line with extant literature. Mallik and Chowdhury\(^{[64]}\) and Ghossoub\(^{[60]}\) pronounced that a low or moderate inflation rate has a positive impact on output growth. The result is not so strange, as the policymakers and central banks often prescribe moderate inflation rates in both economies to sustain their continued economic growth performance more especially in recent years. In that respect, China and India’s average inflation rate over the last three decades has remained moderate which may be stimulating their growth and thus, per capita output.

While maintaining a moderate price level may be conducive to China’s and India's sustained economic growth, however, surprisingly greater openness measured by exports plus imports of goods and services (% of GDP) has a negative impact on the GDP per capita of both the countries (Tables 6, 8 and 9). The magnitude of negative impact is much lower for China compared to India. With the addition of more control variables in the model, the negative impact of openness for China becomes insignificant (Table 9), while for India it has a higher negative impact (-0.50). This could be because India has been facing a persistent trade imbalance which implies that India continuously imports more than its exports. This may have a higher negative impact on per capita GDP.

Openness is often associated with higher economic growth. However, in the context of China and India, on account of some conditioning factors, it works in the opposite direction; adversely affecting their GDP per capita. Although China and India (both) have experienced rapid economic growth but both face challenges like rising income inequality (low consumption, income, and wealth), unemployment, regional disparities and so on which might have served as hassles on their way to achieving rapid economic growth transitions than the current pace of transition. Perhaps the fruits of openness are not well distributed in China and India leading to a negative effect on their per capita income/output. Our scatter plots and regression analysis show that financial development has a positive and significant impact on China and India’s GDP per capita. In developing economies, financial development by strengthening the banking system and financial markets facilitates the accumulation of capital by channelling savings into productive investments. This interesting function of financial markets allows businesses and individuals to obtain funds for their economic activities leading to augmented capital stock and productivity and thus, leading to the realization of resultant per capita output/income. A well-designed approach to financial development including legal and regulatory frameworks in developing economies is critical for driving their economic growth success.

5 CONCLUSION AND POLICY SUGGESTIONS

In exploring whether innovation drives up economic growth of Asia’s two largest emerging economies, the study relates measures of innovation in terms of application patents with the per capita GDP of India and China for a comparative perspective. Our empirical results throw some interesting insights from the application of time series econometrics. It shows that total innovation leads to an increase in per capita incomes in both economies. Splitting total innovation into domestic and foreign innovations, it shows although both domestic and foreign innovation strongly and positively influence the per capita income of both economies, however, domestic innovation has relatively a pre-dominant impact comparing foreign innovation in both economies. Although gross investment has a mixed impact on the per capita income of China, but gross investment consistently and positively augments India’s per capita income.

On splitting gross investment into private and public investments, it further illuminates that while private investment augments per capita income in both economies, public investment has an adverse impact on per capita income of China, while the same has a weak negative impact on India’s per capita GDP. This could be because of crowding out hypothesis holds true for both economies; as a result, this offsets with income augmentation potentials of both economies. Surprisingly, trade openness shows an adverse impact in both economies, which is not to imply for adoption of a trade protection policy regime but to adopt cautious trade policies. Inflation and financial development greatly contribute to increasing the per capita income of both economies.

Moreover, it suggests that greater investment in
domestic innovation and R&D activities would support for faster growth experience of these economies than relying on foreign innovation activities. However, given that foreign innovation plays some crucial positive role, it should not be discouraged as this might have a significant complementary positive spillover effect on domestic innovation by promoting competition between domestic and foreign players in launching new products, or even by directly supporting domestic innovations. Public sector investment not resulting in significant per capita income improvement is quite a key concern for both economies. Necessary policy should be designed to induce the private sector to undertake innovation and investment activities for greater employment opportunities leading to higher economic growth and per capita incomes. The negative impact of public sector investment on growth could be because of the crowding out phenomenon, which should be checked towards ensuring greater private investment stimulating sustainable higher growth in both economies.

Innovation which refers to breakthroughs in scientific and technical knowledge, is a driver of international competitiveness and knowledge economy, enabling transforming the economies to witness rapid growth transitions. It can manifest in product, process, service and system performance improvement. It requires investment in tangible and intangible innovation assets – such as R&D, design, intellectual property, software development, skills, managerial capability, marketing and branding, design, training and skills, intellectual property, organizational and managerial abilities, etc. and resource commitments associated with it. It immensely contributes to productivity growth, which drives income and enhances the welfare of economies. In an integrated competitive and dynamic global market environment, engaging in innovation and new knowledge activities involves greater risk for private firms to appropriate returns from investment in innovations, therefore, a major responsibility of inducing investment in innovation in developing economies context like India and China still rests on their concerned central and regional governments to establish scientific and informational infrastructures, education and training, and public procurement. In case governments are facing a significant resource crunch to support this endeavour and do not have the direct ability to afford all the required innovation-related investment expenditures, they should at least create a proper enabling incentive system for private firms to undertake innovation and investment efforts to lay a proper foundation for the national system of innovation to support sustainable higher economic growth. The stimulatory monetary-fiscal policy framework can also be adopted at the national level towards encouraging significant private-sector innovation activities. The start-up programme meant for various innovations can also be covered under this programme to encourage entrepreneurs to undertake innovational activities and there should be a national strategy to mitigate various kinds of innovational risks faced by the entrepreneurs. This would take forward the developing economies to reach further heights in their path of development than relying on technological imports from other advanced countries on a sustained basis, implying significant leakages in their national income. Future studies can investigate how much each developing economies import technologies from the advanced world and to what extent those constitute the leakages from their national income. In case they have the necessary potential (comparative advantages given the huge population with a high youth base) in some specific areas, they can augment their national income by engaging in innovative activities at home, resulting in high per capita incomes and improved standard of living. The main limitation of the analysis is that we did not discuss how various policies are impacting (favouring and discouraging) the level of innovational activities at the home of developing economies. Once the policies interact with innovational activities and their roles are identified for innovational growth, more suitable policies can be appreciated by the policymakers for the greater benefit of these developing economies and the macro policy frameworks can be adopted accordingly. This can be an agenda of future research for developing economies. Besides, the macro policies should emphasise on quality education including well-designed curricula at different levels comparable with international standards and making the learning more practical based and solving real-life examples and problems of the society. The curricula should motivate undertaking innovational activities and improve the risk-taking capability of pupils rather than emphasising only on by heart learning everything from the textbooks.

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**Conflicts of Interest**

There is no conflict of interest/absence of any competing interest.

**Author Contribution**

Mallick H contributed conceptual and analytical development of the work along with making policy conclusion and overseeing the overall work. Rout SK contributed analytically as well as carried out estimation exercise and result analysis.

**Abbreviation List**

CCR, Canonical cointegration regression  
CPI, Consumer price index  
DOLS, Dynamic ordinary least square  
FD, Financial development
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