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Innovation and economic growth in middle-income countries: The moderating role of remittances

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ABSTRACT

The prime objective of this paper is to examine the direct and moderating role of remittances in the innovation-growth nexus in MICs. Middle-income countries (MICs) can drive global economic growth by utilizing 75% of the population through technological development and boosting GDP by over one-third of the total. However, using human resources effectively and maintaining technical advancement standards in response to rapid economic changes remain a significant challenge. The study utilizes the "2nd generation unit root test and the panel corrected standard errors (PCSE) and the feasible generalized least squares (FGLS)" approaches. The FGLS and "Dumitrescu-Hurlin (D-H)" causality tests are applied to confirm the robustness of the PCSE approach. The study highlights the distinct and interconnected effects of remittances and innovation on economic growth in MICs, emphasizing their mutually reinforcing role in sustained growth. The interactive span demonstrates that remittances functioned as a substitute in the innovation-growth association. Finally, the study reveals a bidirectional causal affiliation between remittances and economic growth and a unidirectional causal connection between economic growth and innovation. MICs should enhance remittance transfer systems, invest in innovation, enhance skills, utilize public-private partnerships for efficient allocation, and balance entrepreneurship with macroeconomic stability.

Contribution/ Originality: This study pioneers remittances' direct and moderating role in the innovation-growth nexus in Middle-Income Countries (MICs). A special innovation index is used in the study. It is based on PCA (R&D, patents, trademarks) and the PCSE, FGLS, and D-H causality to deal with cross-sectional dependency, endogeneity, and heteroskedasticity.

1. INTRODUCTION

Economic growth is considered the most significant global challenge. Academics have published numerous studies to promote economic growth, yet many remain unexplored for cutting-edge strategies for sustainable development. The present paper illustrates a step towards that effort. The four fundamental drivers influencing GDP

growth are human capital, natural resources, capital formation, and technological progress (Khan, Ponce, Yu, & Ponce, 2022). The concentration of researchers is different over time due to the importance of each factor. However, many governments are still searching for innovative ways to ensure economic growth and safeguard living standards. Middle-income countries, with diverse economic structures and demographic profiles, are vital in the global economic hierarchy. Understanding the dynamics of remittances and innovation in these contexts helps comprehend economic trends and provides valuable insights for policymakers, researchers, and practitioners promoting sustainable growth. The influence of remittances and innovation on the economic route of middle-income countries has become a crucial topic in the rapidly changing global economic landscape. Therefore, the effect of these factors on economic growth in MICs is significant and must be acknowledged due to little evidence in the literature and in these nations.

The rationale behind selecting this topic in MICs includes the following: First, MICs comprise 75% of the world's population, yet they only contain about 33% of the GDP (World Bank, 2024). Hence, the large population can boost the economy by making skilled labor available to other nations and employing them in innovation-related activities. Second, despite using different approaches and variables in several studies, the link between remittances, innovation, and economic growth has received little scholarly attention. Third, due to data availability, most of the studies on these variables have been done in industrialized or Organization for Economic Co-operation and Development (OECD) countries, making it rare in middle-income nations. Fourth, only 25 of the 110 MICs have balanced data on R&D, patents, and trademarks, while the other 75 have imbalanced or no data (World Bank, 2024). It is explored that innovation activities are not enough for these reasons. Our findings might thus be a source of inspiration for those nations looking for ways to boost their innovation capacity. Thus, this research is likely to significantly improve the world economy by filling the identified research gap and using the enormous populations of MICs.

Remittances are the funds migrants transfer to their home countries, a significant source of outside finance for middle-income nations. Remittances are crucial for providing a lifeline for households, aiding in poverty alleviation, balancing trade deficits, reducing economic shocks, and promoting inclusive development in middle-income countries. However, their impact on growth requires careful analysis of utilization patterns, investment mechanisms, and the potential for fostering entrepreneurship. Previous research revealed a favorable and varied relationship between remittances and economic growth, offering a comprehensive grasp of the relationship. A positive nexus between remittances and economic growth has been identified in some studies, aligning with the endogenous growth paradigm (Meyer & Shera, 2017; Salahuddin & Gow, 2015). This theory states that remittances can function as endogenous sources of revenue, promoting economic growth in recipient nations through increased investment, consumption, and general economic activity. In contrast, the research shows substantial and negligible relationships between remittances and economic expansion (Cazachevici, Havranek, & Horvath, 2020; Siddique, Selvanathan, & Selvanathan, 2012; Zardoub & Sboui, 2021). Several elements, including the regulatory and economic frameworks and the effective allocation of remittance money, shape the intricate correlation between economic growth and remittances. By applying endogenous growth theory, we may better understand the function of remittances as inherent drivers of sustained GDP growth. Drawing on the extensive study shown above, our hypothesis (H_1) is that there is a positive correlation between remittances and GDP growth in MICs. This idea is derived from the complex relationship between these dynamic factors and suggests a mutually beneficial relationship that supports the economic development of MICs.

Innovation's role in driving economic growth has become increasingly significant as technological advancements significantly alter global economic landscapes. Innovation can substantially improve productivity, efficiency, and competitiveness by encompassing technical, organizational, and social dimensions. The strategic integration of innovative practices can lead to economic diversification, fostering the growth of new industries and market niches. Middle-income countries face challenges transitioning from resource-dependent to knowledge-based economies, making understanding innovation dynamics essential. However, Solow (1957) acknowledged the impact of technological advancements on GDP expansion, establishing the "new economic growth model." Romer (1990) used

a model to guide empirical research, confirming the findings. New growth theories proposed that innovation derived contemporary economic growth, making it a significant research area (Pece, Simona, & Salisteanu, 2015). Innovation can increase production possibilities, which is one of the essential driving forces of GDP expansion. Innovative products and services largely depend on investment in R&D (Zachariadis, 2003). Innovation drives economic growth, competitiveness, and progress in emerging and developed countries (Hasan & Tucci, 2010). Therefore, firms or governments should give priority to innovation due to the achievement of long-run GDP improvement. Scientific innovations and empirical studies in developed countries significantly contribute to the motivational factors for increasing GDP. Sufficient funds in various innovation proxies, such as trademarks, research and development (R&D), patents, scientific research, and so on, have upgraded the innovation capability of these countries.

Several empirical studies Gyedu, Heng, Ntarmah, He, and Frimppong (2021); Pradhan, Arvin, Nair, and Bennett (2020) and Sesay, Yulin, and Wang (2018) indicated a positive link between innovation and advancements in GDP. However, some researchers found the opposite effect (Feki & Mnif, 2016). In middle-income countries, there is little evidence of this problem. This investigation will fill this gap. Innovation is characterized by adopting novel technologies, practices, and methodologies. Thus, the empirical research of this concept aims to shed light on the complex mechanisms by which innovation serves as a catalyst, accelerating and sustaining economic progress in MICs. Based on the things we've talked about so far, we'd like to put forward the hypothesis (H2) that there is a strong, positive, and mutually beneficial link between innovation and economic growth in middle-income countries (MICs).

Remittances and innovation are decisive for assessing economic progress. Remittances stimulate economic development, supporting consumption, healthcare, welfare, education, household income, etc. Innovation and technical advancements simultaneously boost GDP by generating new goods and services and cross-industry information sharing. Combining remittances and innovation allows for an inclusive understanding of innovation, socio-economic dynamics, human capital development, and a higher standard of living. This study aims to understand the interrelated processes that facilitate the synergistic contribution of remittances and innovation to economic growth.

The work significantly enhances previous studies by addressing four significant research gaps. First, the study aims to empirically analyze the distinct and integrated affiliation of remittances and innovation on GDP growth. However, few studies have demonstrated the different impacts of economic growth. Consequently, no proof can be found in the literature about the interactive effects of remittances and innovation on GDP growth. Second, this study addresses a complex issue in MICs with various proxies due to multicollinearity problems. Hence, the study utilizes PCA to develop an innovative index comprising R&D, patents, and trademarks, a unique feature in the current economic literature. Third, most earlier studies were conducted in developed, OECD, or Central and Eastern Europe (CEE) nations. The evidence for this issue is scant in MICs. Therefore, this study aims to fill this gap, too. Consequently, we hypothesize (H3) that remittances positively moderate and strengthen the long-term innovation-growth nexus in MICs. Fourth, the study investigates the causal relationship between economic growth, innovation, and remittances, a relationship often overlooked in previous research. Therefore, we also postulate (H4) a reciprocal causal relationship between the chosen determinants in MICs.

1.1. Remittances, Innovation, and Economic Growth in MICs

Every country should prioritize its economic growth. Middle-income nations may find it challenging to accomplish this aim despite the possible obstacles. These countries often find themselves caught in the "middle-income trap," where they cannot continue rapid economic development and stay up with countries with higher incomes. However, receipt of remittances and innovation are potential factors that can improve the economy of MICs.

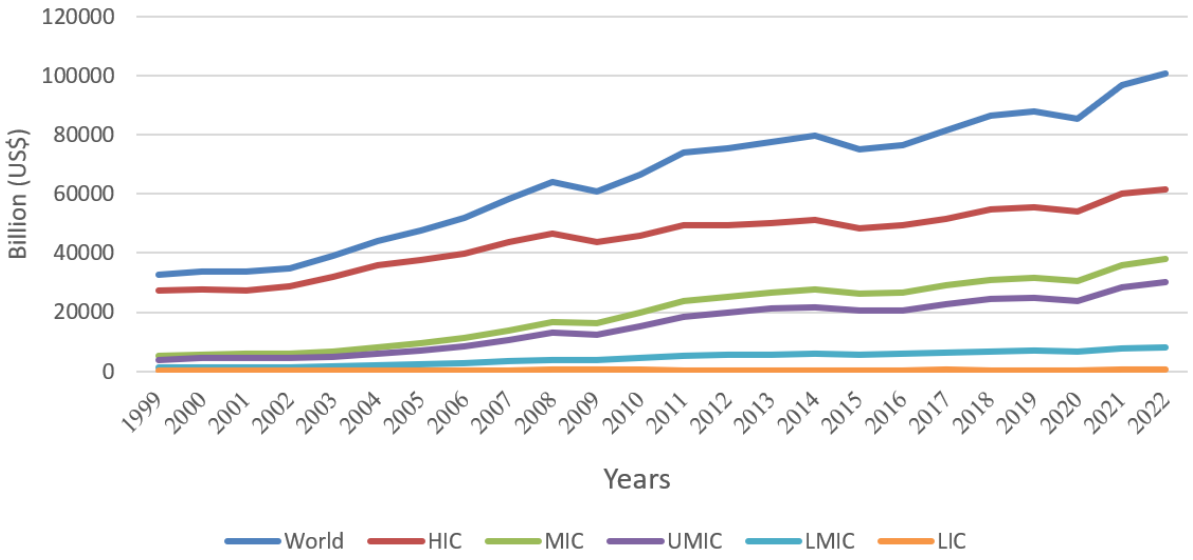

Figure 1. Trend of GDP growth.

Figure 1 visually represents the global gross domestic product (GDP) growth from 1999 to 2022 (World Bank, 2024). On the graph, nations are categorized as high-income countries (HIC), middle-income countries (MIC), lower-income countries (LIC), or upper-middle-income countries (UMI). Over the previous 23 years, the global GDP has grown consistently, with the HICs experiencing the most expansion. The projected GDP of the entire planet in 2023 is $120 trillion. The graph shows that the gap between HICs and the rest of the world is growing.

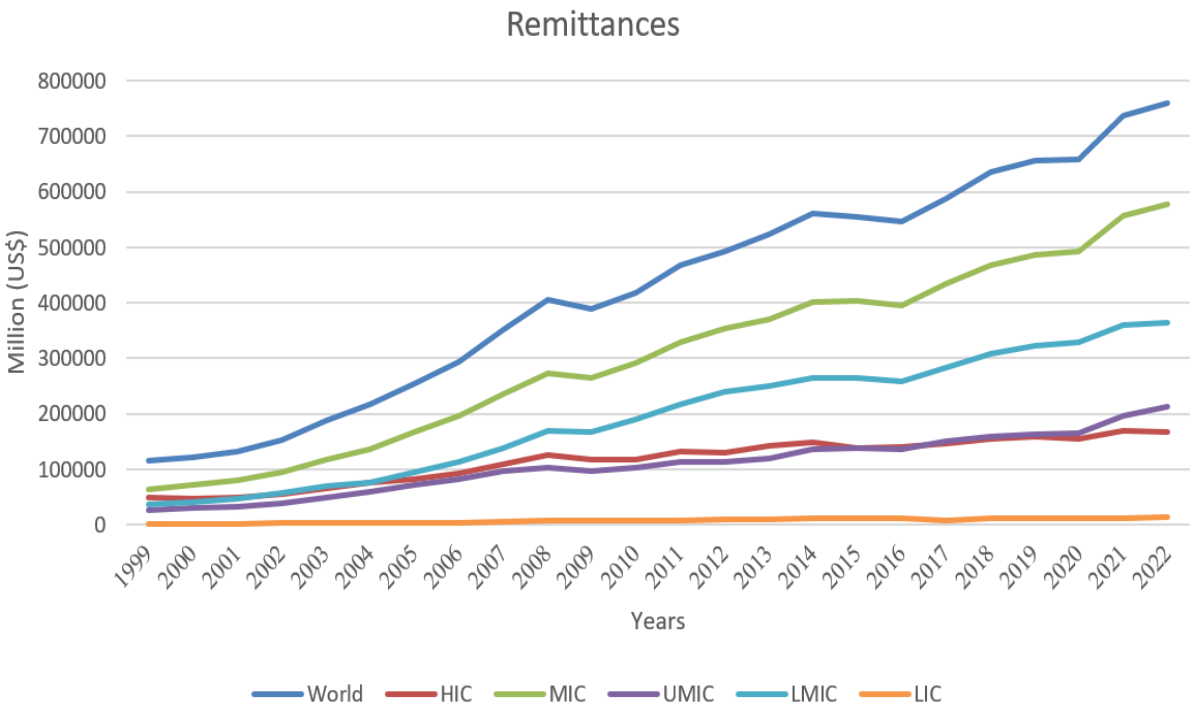

Figure 2. Trend of remittances.

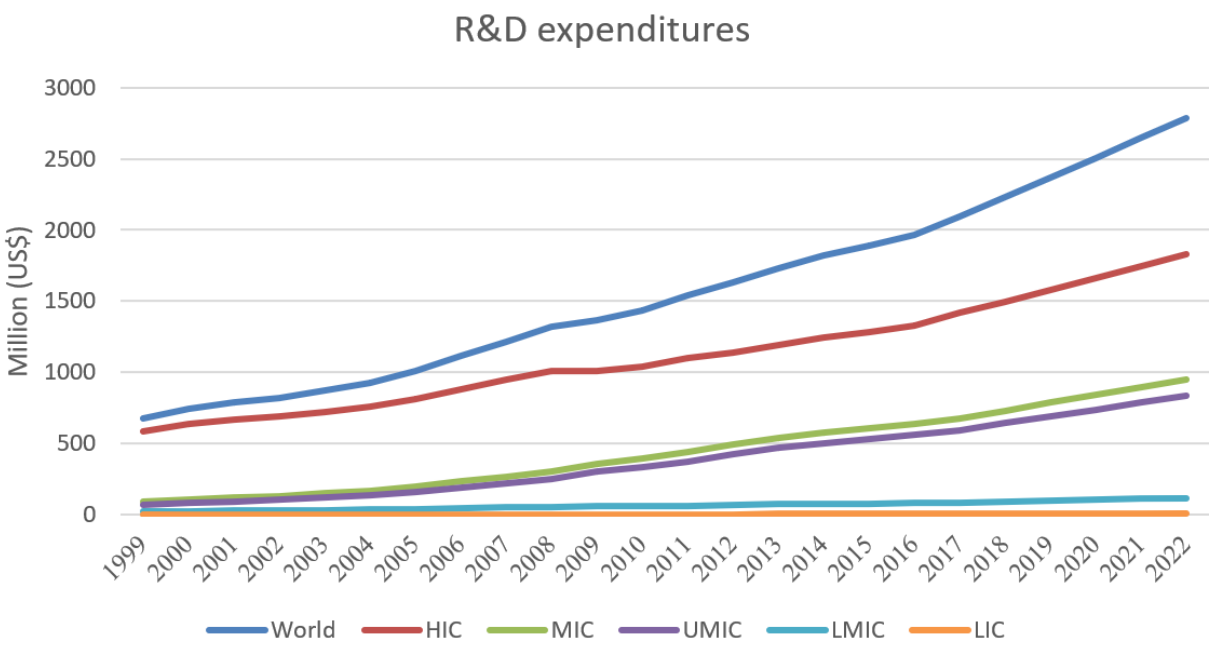

Figure 3. Trend of R&D expenditures.

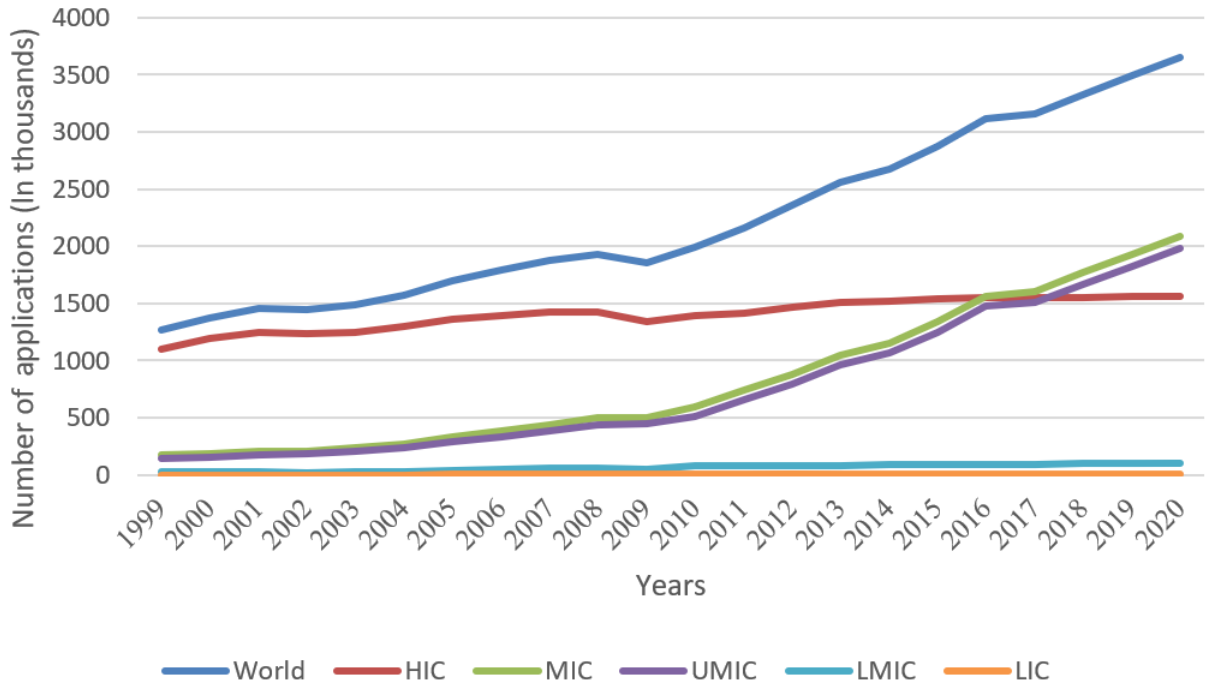

Figure 4. Trend of patent applications.

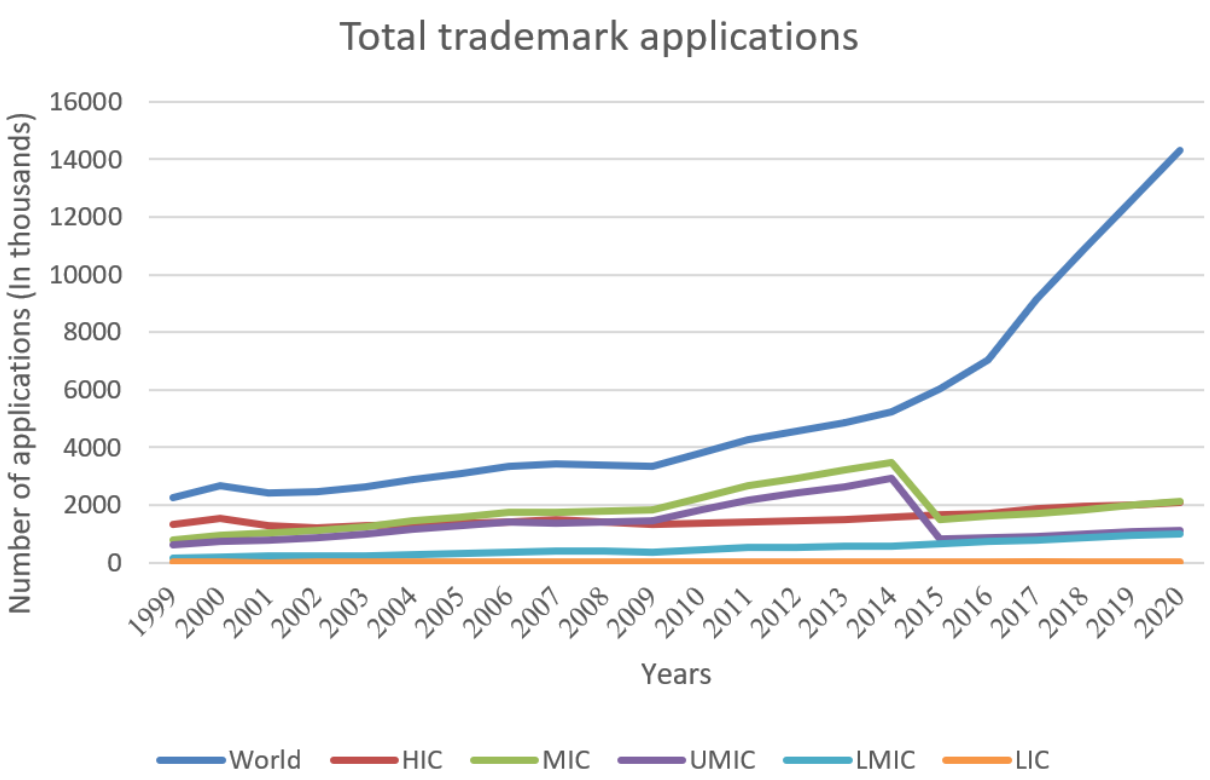

Figure 5. Trend of trademark applications.

Figure 2 represents the increase in remittances to various global income groups from 1999 to 2022 (World Bank, 2024). Remittances were $758.94 billion globally in 2022; out of them, 578.41 billion were received by middle-income countries (World Bank, 2024). The figure also highlights the significant disparity in remittance inflows between MICs and the global average. Compared to HICs and LICs, MICs received over three times as much in remittance inflows. On the other hand, the economic expansion of countries, particularly in MICs, has been boosted by unprecedented innovation in recent years (Kaplinsky & Kraemer-Mbula, 2022). Past studies considered different proxies, such as R&D investment, patents, trademarks, scientific publications, etc., to represent innovation. In contrast, this study considers three distinct factors and combines them into an index using the "principal component analysis (PCA)" as a proxy for innovation in MICs. The R&D expenditures, patents, and trademark applications show a rising trend in MICs (Figures 3, 4, and 5). It reveals that during the past twenty-three years, there has been a considerable upswing in innovation growth.

Considering the above discussion, including the hypotheses and data trends of the selected variables, it is determined that the interactive effect of remittances and innovation (R&D, patents, trademarks) on economic growth in MICs is hesitant and needs more research. Very few current studies have presented insights into the distinct impact of remittances and innovation on economic growth in different contexts worldwide. Still, a noteworthy deficiency exists in the number of thorough studies examining their interactions outside the restricted setting of MICs. It is crucial to comprehend the connections between remittance inflows and innovation because of these nations' essential roles in the global economy. To close this gap, this study investigates how innovation and remittances interact to drive economic growth in MICs.

The following are the novel contributions of this research to the body of literature. First, using long-term panel data, this study offers a fresh literature contribution by exploring the moderating role of remittances in the innovation-growth nexus in MICs. While previous studies mainly examine remittances as a direct growth driver, they often miss its moderating role within the innovation-growth dynamic. By reframing remittances as a moderating factor, this study reveals how remittances can either amplify or limit innovation's impact on growth, addressing a

critical gap in the literature. Henceforth, this research makes a noteworthy contextual contribution in MICs by being the first to examine this moderating relationship. Therefore, this study indicates that MICs can enhance global economic growth through remittances and innovation by effectively utilizing 75% of the worldwide population. Second, to the authors' best knowledge, this research is perhaps the first study to apply PCA to create an innovation index consisting of three essential proxies (R&D, patents, and trademarks) for innovation. Prior research has confined the investigation to focusing on one variable by employing one indicator, such as patent, trademark, or R&D expenditure; this distorts the accurate picture of innovation. Another major limitation of more superficial innovation indicators is that they do not give a holistic view of the phenomenon; therefore, a more comprehensive, composite measure of innovation is a more accurate picture of the multifaceted part many innovation measures play in the present economic growth. Third, this research uses the PCSE, FGLS, and D-H causality estimation methods to address the issues of cross-sectional dependency and heteroskedasticity. This methodological combination is rare in the existing literature, as it confirms the robustness and reliability of the results. In the fourth place, policymakers in MICs might use the results to help them make good rules for their own institutions about remittances and new ideas.

The rest of this paper's structure is as follows: Section 2 includes a literature review. Section 3 deals with methodology and data. Results from the empirical research are discussed in section 4. Section 5 includes the conclusion, relevant policy suggestions, limitations, and future research prospects.

2. LITERATURE REVIEW

Numerous studies have partially scrutinized the affiliation between remittances, innovation, and economic growth. To explore studies, we review the relevant literature.

2.1. Remittances and Economic Growth

This theoretical literature applies endogenous growth theory to analyze the affiliation between remittances and economic growth (Deonanan & Ramkissoon, 2018). The endogenous growth theory differed from conventional methods by exploring the inherent qualities of remittances as endogenous capital that may support self-sustaining development processes. Yadeta and Hunegnaw (2022) assert that the endogenous growth theory offers a strong structure for comprehending how remittances foster human capital development, technical advancement, and innovation, ultimately leading to immediate consumption, investment, and steady development. Theoretically, remittance inflows can impact long-term economic growth significantly; this research synthesizes this basis.

According to earlier studies, remittances and economic growth have a strong and positive association. For instance, between 1999 and 2013, Meyer and Shera (2017) studied the impact of remittances on GDP growth in six European nations with high remittance receipt rates. The analysis discovered a robust and positive relationship between growth in the chosen countries and remittances. Similarly, Salahuddin and Gow (2015) investigated the affiliation between GDP growth and migrant remittances across four Asian economies using panel data spanning 1977 to 2012. The analysis found a strong, positive long-term relationship between the specified nations' economic development and remittances. Between 1975 and 2011, Deonanan and Ramkissoon (2018) repeatedly examined the impact of remittances on the economic growth of eleven Caribbean nations. In seven countries, they found evidence of various long-term causal relationships between the variables.

Equally, Azizi, Aftabi, Azizkhani, and Yektansani (2024) studied the effect of remittances on the economic growth of 113 developing nations from 1990 to 2015, using data from 113 countries. The researchers revealed that remittances enhanced growth in developing nations with substantial human capital but not in those with poor human capital. Zardoub and Sboui (2021) examined how FDI, Official Development Assistance (ODA), and remittances affected GDP growth in 41 developing nations between 1990 and 2016. Research indicated that unclear money flows have an impact on economic expansion. Bucevska and Naumoski (2023) found that FDI and remittances influenced

the economic growth of eight South-East European nations between 2008 and 2021. According to the study, remittances and economic growth have a reciprocal causal link.

In contrast, the literature currently in publication recognizes inconsistent results. For example, according to Cazachevici et al. (2020) statistical analysis of 538 evaluations of 95 research studies in middle- and low-income countries revealed that 40% of the studies had no effect, 20% had a negative impact, and 40% suggested a considerable influence of remittances on economic growth. Accordingly, Siddique et al. (2012) examined the connection between remittances and economic growth in Bangladesh, India, and Sri Lanka using a Granger causality test using a Vector Autoregression (VAR) framework. The findings showed a two-way causal relationship in Sri Lanka and no direct correlation in India. Similarly, Tchekoumi and Nya (2023) examined the affiliation between migrant remittances and economic growth in six Central African Economic and Monetary Community (CEMAC) zone nations from 1990-2018 using the Panel Smooth Transition Regression (PSTR) and Generalized Method of Moments (GMM) methods. The results displayed a nonlinear connection in two regimes with a threshold effect. Remittances significantly and positively influence economic growth under the first regime, while negative impacts occur under the second regime.

However, existing literature reveals mixed outcomes, with some studies showing a positive impact of remittances on growth by increasing income, alleviating poverty, and improving human capital, while others discover negative effects, such as dependency, reduced labor participation, or inefficient allocation of resources. Remarkably, a significant gap persists: none of the existing research examines the moderating role of remittances within the innovation-growth affiliation. This omission overlooks the potential for remittances to act as a stabilizing or enhancing force within the innovation process, particularly in MICs where financial constraints can limit the growth effects of innovation. Prior studies tend to treat remittances and innovation separately or focus solely on their direct impacts on growth, thus missing the complex interplay that remittances may have in strengthening or dampening innovation-driven growth. Without exploring this moderating role, the literature lacks a dynamic understanding of how remittances might affect innovation outcomes in various economic conditions or institutional settings, leaving an incomplete picture of growth dynamics in remittance-dependent economies. Addressing this gap could reveal decisive insights into optimizing remittances to enhance innovation-driven growth, providing targeted policy directions for MICs.

2.2. Innovation and Economic Growth

Innovation is essential for long-term economic growth. Researchers explore the connection between innovation and economic growth. For instance, Ulku (2004) discovered the link between economic growth, innovation, and R&D for thirty nations using the GMM method and data from 1981 to 1997. The study found that R&D stimulated innovations, and such discoveries supported consistent rises in GDP. The researcher discovered a significant connection between the preferred variables. Hasan and Tucci (2010) documented the association between economic growth and innovation, applying data from 1980 to 2003 from 58 nations. Their research showed that home enterprises of countries with high-caliber patents also experience quicker economic growth. Pece et al. (2015) examined data from three CEE nations from 2000 to 2013 using various innovation proxies (trademarks, R&D, and patents) to determine the affiliation with GDP expansion. They discovered a significant link between the chosen variables using the Ordinary Least Squares (OLS) approach. Haldar, Sucharita, Dash, Sethi, and Padhan (2023) revealed that innovation significantly influences growth up to the highest income quantile in sixteen emerging economies from 2000 to 2018, including energy consumption, Information and Communication Technology (ICT), etc., by the Driscoll-Kraay, GMM, and fixed-effects methods.

In contrast, Feki and Mnif (2016) examined information from 35 developing countries between 2004 and 2013. The researchers discovered two additional characteristics that were crucial for gauging entrepreneurship. Innovation was one of the factors that could foster growth. They also identified that technological innovation had a long-term beneficial stimulus on growth and a short-term detrimental one. Data from 1983 to 2007 for 18 OECD countries were

studied by Bucci, Carbonari, Gil, and Trovato (2021) who found that greater patenting engagement led to a rise in growth in certain nations. Data from 1995 to 2019 in the European Union (EU) were utilized by Acheampong, Dzator, Dzator, and Salim (2022) to examine the link between some factors and economic growth. The study found that innovation using a dynamic system-generalized approach of moment significantly increased GDP and energy usage linearly. Manzoor Ahmad and Zheng (2023) demonstrated a pro-cyclical construction between innovation and economic growth in 36 OECD economies using the GMM technique.

However, the present literature discloses various findings, with many studies identifying positive and negative relationships between innovation and growth. The previous studies have primarily focused on high-income or low-income economies, leaving a notable gap regarding middle-income countries (MICs). This lack of research on MICs presents a significant limitation, as the economic structures, resource availability, and institutional frameworks of MICs differ substantially from those of other income groups, potentially affecting how innovation affects growth. Without investigating MICs specifically, current research overlooks the unique challenges and opportunities these countries face in leveraging innovation for growth. This gap in the literature results in an incomplete understanding of innovation's role across different economic contexts, especially in MICs, where growth dynamics may be influenced by factors like emerging industrial bases, moderate financial development, and varying degrees of institutional support. Addressing this research gap is essential for developing targeted insights and policies to enhance innovation-led growth in middle-income economies.

3. MATERIALS AND METHODS

3.1. Data

Multiple sources are used to gather secondary data. The study employs a panel dataset encompassing 25 middle-income countries from 1999 to 2021. Other MICs are not considered for this analysis because of the lack of data for certain independent variables. Therefore, this study employs the convenience sample method to select middle-income nations, as data on crucial variables from sources is unavailable after 2021. Most data are estimated using logarithmic specifications (L) because the study is so simple. The logarithm form preserves smoothness for all variables, guards against outliers, lessens the impact of autocorrelation and heteroskedasticity, and avoids incorrect regressions. Table 1 lists the specifics of the data and sources.

Table 1. Description of data.

Vars	Description	Obs.	Mean	Max.	Min.	SD	Source
EG	Economic growth represents the gross domestic product (GDP) in US$ current purchasing power parity (PPP)	575	11.08	13.30	8.93	0.87	WDI (2024)
FR	Foreign remittances in US$ current PPP	575	9.24	11.07	6.04	0.72	
INNO	The innovation index determines the R&D % of GDP, patent applications (Residents), and trademark applications (Residents).	575	0.00	5.47	-3.07	1.54	
FDI	Foreign direct investment in US$ current PPP	575	9.51	11.83	6.67	0.87	
LIEX	Life expectancy at birth, life expectancy, total (Years)	575	1.86	1.90	1.73	0.03	
LBO	% of total population ages 15+ as labor force participation	575	1.77	1.90	1.60	0.07	
POG	Population growth (Annual %)	575	0.46	0.66	0.02	0.14	
FD	Financial development (Composite) index by the international monetary fund (IMF)	575	-0.53	-0.13	-1.27	0.25	IMF (2024)
CS	Capital stock in US$ current PPP	575	11.98	14.08	9.28	0.91	PWT 10.01

Note: All variables are reported as common logarithms.

3.2. Rationale for Variables

Remittances, innovation, and economic growth are the crucial variables for this paper. Here, the dependent variable in this study is economic growth (LEG), following the approach of Hammar and Belarbi (2021) and Islam, Rahaman, and Chen (2024). On the other hand, this study uses remittances (LFR) as an independent variable, a widely recognized measure of GDP growth referred to by Meyer and Shera (2017). We use an innovation index as another independent variable, constructed through PCA using three key proxies: R&D, patents, and trademarks, rather than relying on a single innovation measure. Researchers usually utilize R&D expenditures as a revealing measure of innovation (Minović & Jednak, 2021; Nguyen, Pham, & Tram, 2020) with a predominant emphasis on patents as an alternative metric (Mahmood Ahmad et al., 2020; Bucci et al., 2021; Burhan, Singh, & Jain, 2017; Feki & Mnif, 2016; Hashmi & Alam, 2019; Saleem, Shahzad, Khan, & Khilji, 2019; Ulku, 2004) while a smaller subset incorporates trademarks (Acheampong et al., 2022) as an additional proxy for innovation assessment. However, encountering approximately seven innovation proxies in the existing literature, determining the most suitable indicators for evaluating economic growth in middle-income nations poses a challenge. Consequently, this study addresses the issue by constructing the index. The literature lacks evidence for an innovation index that includes these three main innovation proxies.

The model includes multiple control variables to enhance internal reliability and prevent study bias by establishing a causal link between variables. Foreign direct investment (FDI) is a key driver of economic growth, often representing the flow of capital, technology, and management expertise into a country. This variable is widely used in empirical research to capture the impacts of inbound foreign investments on economic outcomes, with studies by Muhammad and Khan (2021) and Saidi, Mani, Mefteh, Shahbaz, and Akhtar (2020) emphasizing its role in fostering growth, innovation, and productivity. Including FDI as a variable allows for examining its effect on economic indicators by accounting for how external investments contribute to the host country's overall economic landscape. Life expectancy (LLIEX) is an essential indicator of a population's health and well-being, reflecting the quality of healthcare, nutrition, and living conditions in a country. Researchers, including Kunze (2014) and Azomahou, Boucekkine, and Diene (2009) used life expectancy to assess the relationship between health improvements and economic outcomes, as longer life expectancy often contributes to a more productive workforce and enhanced human capital. Financial development (LFD) is a crucial determinant of economic growth, capturing the efficiency, depth, and accessibility of financial institutions and markets within an economy. Researchers such as Abeka, Andoh, Gatsi, and Kawor (2021) and Islam and Alhamad (2022) employed financial development as a variable to understand its role in facilitating capital accumulation, improving resource allocation, and supporting investment and innovation. Capital stock (LCS) signifies the total accumulated assets used in production, serving as a fundamental input for economic growth and productivity. Researchers like Su, Zhou, Nakagami, Ren, and Mu (2012) included capital stock as a variable to evaluate its contribution to output, reflecting the availability of machinery, infrastructure, and technology that drove efficiency and expansion. Including capital stock (LCS) permits a deeper understanding of how physical capital investment influences economic performance and supports sustained growth. Following the precedent set by researchers such as Lechman and Kaur (2015) and Kumari (2018) we employ the labor force (LLBO) as another control variable in our analysis. This metric comprehensively measures a country's productive capacity and potential to contribute to economic growth and development. Population growth (LPOG) is another control variable in our analysis, as it reflects the changing demographics of a country. As supported by the work of Peterson (2017) and Sibe, Chiatchoua, and Megne (2016) population growth can significantly influence economic activity, labor supply, consumption patterns, and investment demand, all of which have implications for financial development. However, some countries display negative population growth data. When calculating a country's logarithm value, we convert the minimal number of such negative values into a positive value by adding 1.

3.3. Empirical Model

The Solow growth model will be the basis of this study, which explains long-run economic growth by looking at remittances and innovation. The study's main idea comes from both real-world research and endogenous growth theory. It says 'there is a significant correlation between remittances, innovation, and economic growth." With the remittances, innovation, and other control factors that impact economic growth, we expand "the neoclassical aggregate production (output) function" in this work. Therefore, economic growth (EG) is a function of remittances (FR), innovation (INNO), and a set of control variables (Z). This statement is expressed in the intentional equation below:

$$EG = \int(FR,\ INNO,\ Z) \quad (1)$$

Adding the logarithm of each side of Equation 1 converts the equation into a linear one. This research uses the subsequent static baseline regression models for remittances and innovation to analyze economic growth in MICs. Therefore, the coefficient notation yields the following basic equation for economic growth:

$$LEG_{it} = \beta_0 + \beta_1 LFR_{it} + \beta_2 LINNO_{it} + \gamma Z_{it} + \mu_t + \varepsilon_{it} \quad (2)$$

Where t = the number of years, i = the number of nations, and β shows the coefficients of the predictors. LEGit (Log gross domestic product) is the dependent variable, while LFRit and LINNOit are the explanatory independent variables. Z_{it} is the control variable matrix, including LFDIit, LLIEXit, LFDit, LCSit, LLBOit, and LPOGit. μ_t and εit are the unidentified time-specific properties and the error term, respectively.

The CSD test detects cross-sectional dependency (CSD) in the panel dataset. The CSD is found in this study using the Pesaran (2004) CSD test. We use second-generation unit-roots testing in light of the traditional test's inconsistent results. For example, Pesaran, Smith, and Yamagata (2009) CIPS and Pesaran (2007) CADF. After making sure that the variables are linked by cointegration, we use panel Kao cointegration tests to check if the variables are also linked over the long term.

However, after confirming the panel data's expected properties, especially the presence of cross-sectional dependency and cointegration among variables, the Prais-Winsten regression model with PCSE is utilized to estimate Equation 2. We use the PCSE method to address CSD and heteroskedasticity, ensuring more reliable standard errors and reliable estimates for our panel data analysis. The FGLS approaches are utilized to ensure consistency in results, with the practical and homoscedastic FGLS method being employed for robustness analysis in cases of heteroskedastic existence. If the outcome is heteroscedastic, we rewrite Equation 3 by dividing both sides of Equation 2 by δ_i.

$$\frac{LEG_{it}}{\delta_i} = \frac{\beta_0}{\delta_i} + \frac{\beta_1 LFR_{it}}{\delta_i} + \frac{\beta_2 LINNO_{it}}{\delta_i} + \frac{\gamma Z_{it}}{\delta_i} + \frac{\mu_t}{\delta_i} + \frac{\varepsilon_{it}}{\delta_i} \quad (3)$$

We simplify Equation 3 and report in Equation 4, which we utilize as the main reference equation in a homoscedastic and efficient manner for the econometric study.

$$LEG_{it}^* = \beta_0^* + \beta_1 LFR_{it}^* + \beta_2 LINNO_{it}^* + \gamma Z_{it}^* + \mu_t^* + \varepsilon_{it} \quad (4)$$

The "Dumitrescu and Hurlin (2012)" panel causality check is eventually used to identify the pattern of causation among variables. All coefficients in this evaluation should change across multiple cross-sections. In this analysis, all coefficients are projected to vary across different cross-sections. Equation 5 provides a quick synopsis of the D-H model.

$$Y_{it} = \beta_i + \sum_{i=1}^{k} \alpha_i Y_{i,t-k} + \sum_{i=1}^{k} \delta_i X_{i,t-k} + \varepsilon_{it} \quad (5)$$

Here, the constant is denoted by β_i, the coefficient slope by δ_i, and the lag parameter by α_i. The null hypothesis and alternative hypotheses are defined in detail in Equation 6.

$$H_0: \delta_i = \delta_i = 0, H_i: \{\delta_i = 0, \forall_i = 1, 2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots N\ \delta_i \neq 0, \forall_i = N_1 + 1,\ N_1 + 2, \ldots\ldots\ldots\ldots . N \quad (6)$$

An alternate hypothesis suggests that panel data can identify at least one causative link, even though every cross-section shows non-homogenous Granger causality.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. CSD Test and Panel Unit-Root (URT) Test Results

Initially, we utilize the cross-sectional dependency (CSD) test by Pesaran (2004). Table 2 lists the CSD empirical findings. The findings show that CSD is present in certain variables because of shared factors such as macroeconomic prospects, globalization, and national economic aspirations.

Table 2. CSD and URT test.

Variables	Pesaran CD	CADF		CIPS	
		At level	First difference	At level	First difference
LEG	76.80*	-2.27*		-2.267**	-3.913*
LFR	57.52*	-2.89*		-2.13***	-3.931*
LINNO	19.00*	-1.85	-3.34*	-2.09***	-4.614*
LFDI	40.09*	-2.35*		-2.86*	
LLIEX	63.28*	-1.85	-3.26*	-2.63*	
LFD	46.14*	-2.52*		-2.72*	
LCS	70.61*	-3.19*		-1.73	-2.43*
LLBO	1.33	-1.91	-2.68*	-1.47	-3.46*
LPOG	1.61	-2.55*		-2.25**	-2.17**

Note: * p<0.01, ** p<0.05, *** p<0.10.

Then, we use second-generation unit root tests (Cross-sectionally Augmented Dickey-Fuller-CADF and Cross-sectionally Augmented IPS-CIPS) due to cross-sectional dependence. Table 2 shows the unit root tests about the stationarity properties of the variables. The tests look at both the levels and first differences of the variables because it is possible to make stationary time series by looking at the differences of non-stationary ones.

4.2. Correlation Matrix and Collinearity Diagnostics

Table 3 displays the correlation matrix, indicating that most findings correlate with economic theory. At the 1% level, there is an optimistic and significant association between the economic growth (LEG) and all the explanatory variables except LPOG. The results show a positive and significant correlation between all variables (dependent, independent, and control), except for some exceptions.

Table 3. Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	VIF
(1) LEG	1.00									
(2) LFR	0.60*	1.00								1.85
(3) LINNO	0.86*	0.49*	1.00							4.05
(4) LFDI	0.87*	0.58*	0.80*	1.00						4.6
(5) LLIEX	0.18*	0.22*	0.07***	0.24*	1.00					1.14
(6) LFD	0.82*	0.41*	0.74*	0.76*	0.12*	1.00				2.82
(7) LCS	0.66*	0.48*	0.61*	0.53*	0.03	0.49*	1.00			1.74
(8) LLBO	0.19*	-0.12*	0.09**	0.24*	0.09**	0.22*	0.03	1.00		1.24
(9) LPOG	0.05	-0.05	-0.18*	-0.06	-0.03	0.01	-0.03	-0.01	1.00	1.1

Note: * p<0.01, ** p<0.05, *** p<0.10.

Table 3 also shows the outcomes of the multicollinearity test. The average variance inflation factor (VIF) values are 2.32, with all individual values below 4.7. Therefore, the correlation matrix and VIF test results indicate no multicollinearity issue in the model.

4.3. Panel Cointegration Outcomes

We examine the associations between the variables using a Kao residual panel cointegration technique. This method can recognize a long-term or cointegration relationship from the data, including CSD. However, the findings from Table 4 demonstrate the cointegration between the study's variables.

Table 4. Kao residual panel cointegration test.

Test	Statistic	p-value
Modified Dickey-Fuller t	- 4.32*	0.00
Dickey-Fuller t	-4.78*	0.00
Augmented Dickey-Fuller t	-4.30*	0.00
Unadjusted modified Dickey-Fuller t	-4.63*	0.00
Unadjusted Dickey-Fuller t	-4.89*	0.00

Note: * p<0.01.

4.4. Regression Results

Table 5 displays the results using the PCSE (columns 1 to 6) approach and the FGLS method as a robustness check (columns 7 to 9). Column 1 displays coefficients derived from PCSEs, while column 2 shows the results after adjusting for disturbance autocorrelation. In column 3, outcomes are presented following cross-panel correlation and autocorrelation corrections. Moving to column 4, the results are displayed post-control for heteroskedasticity. Columns 5 and 6 provide outcomes with the interactive effect of remittances and innovation (LFR_LINNO) exclusive and inclusive of year dummies, respectively. On the other hand, the coefficients derived from the FGLS method are presented in column 7, while columns 8 and 9 detail the interactive effects of remittances and innovation, with the year dummy excluded in column 8 and included in column 9.

The results confirm the expected association between remittances (LFR) and economic growth (LEG). Due to the positive and significant coefficient, remittances are crucial in promoting inclusive economic growth in MICs. The finding is reliable, based on the previous outcomes of Islam et al. (2024); Meyer and Shera (2017) and Zardoub and Sboui (2021). Most MICs support and foster a climate conducive to the export of laborers, which raises income, notably for MICs, and creates jobs while reducing poverty. Similarly, innovation (LINNO) positively impacts economic growth in MICs, which is statistically significant at the 1% level. The finding is parallel with Saleem et al. (2019); Hashmi and Alam (2019); Mahmood Ahmad et al. (2020); Ulku (2004); Bucci et al. (2021); Nguyen et al. (2020) and Acheampong et al. (2022).

We find a positive coefficient between FDI and EG in MICs at the 1% significance level in the control variables. The result is reliable based on the findings of Muhammad and Khan (2021) and Saidi et al. (2020). Similarly, the coefficient of life expectancy (LLIEX) indicates a positive and significant impact on economic growth, aligning with previous research by Kunze (2014) and Azomahou et al. (2009). This study reveals that financial development (LFD) significantly impacts EG. The findings are in line with those of Rahman, Khan, and Charfeddine (2020); Matei (2020); Abeka et al. (2021) and Islam and Alhamad (2022). The results, however, contradict Chowdhury (2016) findings, which indicated that financial development did not affect economic growth. The EG is consistently positively influenced by capital stock (LCS). According to a partially related conclusion by Su et al. (2012) capital stock encourages economic growth. Constantly, the labor force participation rate (LLBO) in economic growth fluctuates throughout time. Depending on some factors associated with development, such as gender and income level, LLBO has a varied impact on LEG. There is a U-shaped relationship between LEG and labor force participation (Kumari, 2018; Lechman & Kaur, 2015). Literature also reveals positive (Thaddeus et al., 2022) and negative (Yakubu, Akanegbu, & Jelilov, 2020) associations between labor force participation and economic growth. This study demonstrates that regional context and cultural factors positively influence labor force participation rates (LLBO) in MICs experiencing economic expansion. Furthermore, population growth (LPOG) is found to have a significant and positive impact on these economies. Similar conclusions about how LPOG promotes economic growth are made by Peterson (2017); Sibe et al. (2016) and Garza-Rodriguez, Andrade-Velasco, Martinez-Silva, Renteria-Rodriguez, and Vallejo-Castillo (2016). In terms of the economy, LPOG contributes significantly to inclusive economic growth. Most MICs encourage and maintain a favorable climate for exporting laborers, creating jobs, reducing poverty, and increasing revenue.

Table 5. PCSE and FGLS outcomes (DV: LEG).

Variable	PCSE						FGLS as robustness		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LFR	0.141*	0.0954*	0.0611*	0.0954*	0.148*	0.144*	0.141*	0.148*	0.144*
	(0.0205)	(0.0235)	(0.0187)	(0.0217)	(0.0187)	(0.0202)	(0.0196)	(0.0185)	(0.0191)
LINNO	0.242*	0.237*	0.129*	0.237*	0.775*	0.795*	0.242*	0.775*	0.795*
	(0.0115)	(0.0188)	(0.0170)	(0.0177)	(0.122)	(0.122)	(0.0134)	(0.0950)	(0.0945)
LFDI	0.260*	0.0722*	0.0823*	0.0722*	0.245*	0.241*	0.260*	0.245*	0.241*
	(0.0346)	(0.0138)	(0.0126)	(0.0123)	(0.0303)	(0.0330)	(0.0259)	(0.0243)	(0.0253)
LLIEX	1.130*	1.616*	1.595*	1.616*	1.130*	0.957*	1.130*	1.130*	0.957**
	(0.271)	(0.553)	(0.455)	(0.556)	(0.294)	(0.299)	(0.390)	(0.365)	(0.380)
LFD	0.616*	0.565*	0.731*	0.565*	0.472*	0.459*	0.616*	0.472*	0.459*
	(0.0535)	(0.0790)	(0.0673)	(0.0805)	(0.0697)	(0.0714)	(0.0678)	(0.0706)	(0.0711)
LCS	0.112*	0.223*	0.490*	0.223*	0.117*	0.115*	0.112*	0.117*	0.115*
	(0.0070)	(0.0220)	(0.0323)	(0.0376)	(0.00675)	(0.0066)	(0.0145)	(0.0142)	(0.0141)
LLBO	0.775*	1.063*	0.876*	1.063*	1.054*	1.081*	0.775*	1.054*	1.081*
	(0.132)	(0.264)	(0.246)	(0.236)	(0.148)	(0.149)	(0.160)	(0.164)	(0.164)
LPOG	0.917*	0.573*	0.620*	0.573*	0.998*	0.991*	0.917*	0.998*	0.991*
	(0.0594)	(0.131)	(0.0751)	(0.112)	(0.0717)	(0.0732)	(0.0726)	(0.0722)	(0.0716)
LFR_LINNO					-0.0541*	-0.0558*		-0.0541*	-0.0558*
					(0.0120)	(0.0121)		(0.0095)	(0.0094)
Constant	2.446*	1.939***	-0.613	1.939***	1.852*	2.257*	2.446*	1.852*	2.257*
	(0.432)	(1.175)	(1.128)	(1.166)	(0.427)	(0.426)	(0.760)	(0.711)	(0.739)
Year dummy	Yes	Yes		Yes		Yes	Yes		Yes
Observations	575	575	575	575	575	575	575	575	575
R-squared	0.925	0.989	0.998	0.989	0.928	0.929			
Number of countries	25	25	25	25	25	25	25	25	25
Wald statistics	23310	1835	3811	2484	66460	53370	7109	7394	7575

Note: * p<0.01, *** p<0.10.

We also confirm the association between remittances and innovation regarding substitutability or complementarity about economic growth in MICs. The experiment is based on the privilege of previous studies that remittances (emigration) foster innovation in the countries of origin and do not intensify the gaps in innovation levels between more and less developed nations, i.e., middle-income countries (Fackler, Giesing, & Laurentsyeva, 2020). Therefore, this study utilizes the PCSE and the FGLS methodologies to examine the interactive impacts of remittances and innovation on economic growth in MICs. However, this research reveals statistical significance at the 1% level and negative interaction effects across all estimate techniques. The negative interaction impacts specify the substitute connection between remittances and innovation in MICs. The findings indicate that remittances and innovation substitute for each other in MICs, contributing mutually to enhance growth. Therefore, this study explores the notion that remittances offer an alternative avenue for fostering innovation, thereby paving the way for sustainable growth in MICs.

The overall results indicate that remittances and innovation positively and significantly impact steady economic growth in MICs in the long term. Therefore, this study affirms that the synergy of remittances and innovation is crucial for MICs to attain their national goals and strategies for sustainable growth and seamless integration into the global economy. Furthermore, the long-term coefficients are determined by employing the PCSE and the FGLS, but they only offer direction and outcomes for the relationship. They are ineffective for determining any causal relationship. As a result, the investigation continues by analyzing the causal rapport between the selected variables, as shown in Table 6.

4.5. Results of the D-H Causality Test

The D-H causality test reveals thirty-six variables, thirty of which have bidirectional causality, and six have unidirectional causality at lag one (1). Table 6 only displays the outcomes of the causal relationships that pertain to the dependent variable (LEG), composed of six bidirectional and two unidirectional variables. The results show that all of the variables we chose, besides LINNO and LLIEX, have two-way causality with LEG (LFR↔LEG, LFDI↔LEG, LFD↔LEG, LCS↔ LEG, LLBO↔ LEG, LPOG↔ LEG). This means that LEG is affected by remittances, FDI, financial development, capital stock, labor force, and population growth. In contrast, LEG has a single-direction causality with innovation and life expectancy (LEG →LINNO, LEG →LLIEX).

Table 6. D-H causality test results.

SN	H_0	W-stat.	Zbar-stat.	Prob.	Result
1	LFR → LEG	4.241	9.020	0.000	LFR↔ LEG
	LEG → LFR	1.941	2.379	0.017	
2	LINNO → LEG	1.191	0.212	0.832	LEG →LINNO
	LEG → LINNO	2.182	3.074	0.002	
3	LFDI → LEG	2.599	4.278	0.000	LFDI ↔ LEG
	LEG → LFDI	3.439	6.703	0.000	
4	LLIEX → LEG	1.128	0.030	0.976	LEG → LLIEX
	LEG → LLIEX	3.278	6.238	0.000	
5	LFD → LEG	1.972	2.466	0.014	LFD↔ LEG
	LEG → LFD	5.559	12.826	0.000	
6	LCS → LEG	3.417	6.641	0.000	LCS ↔ LEG
	LEG → LCS	8.856	22.347	0.000	
7	LLBO → LEG	3.446	6.724	0.000	LLBO ↔ LEG
	LEG → LLBO	6.496	15.532	0.000	
8	LPOG → LEG	3.256	6.174	0.000	LPOG ↔ LEG
	LEG → LPOG	11.040	28.652	0.000	

On the contrary, the causal link between the rest of the twenty-eight variables is bidirectional except for four variables, which means they have a two-way causal affiliation between one another and vice versa. The rest of the four unidirectional variables are LFR→LFD, LFR→LLBO, LINNO→LFDI, and LINNO→LLBO), which means remittances cause financial development and labor force participation; innovation impacts FDI and labor force participation. The thirty feedbacks and six unidirectional causations confirm the accuracy of the PCSE and FGLS results and show their robustness. So, the series demonstrates the existence of causality between the chosen exposure and experimental variables, and the anticipated results are appropriate and trustworthy.

5. CONCLUSION

The study inspects the impact of remittances and innovation on economic growth, controlling for foreign direct investment, life expectancy, financial development, capital stock, labor force participation, and population growth in MICs. Before starting the estimate, we conduct necessary checks on our panel variables to ensure the findings are free of bias. The Kao residual cointegration test outcomes support the long-term connection between variables.

This unique study explores the potential for GDP growth through the interplay of remittances and innovation. To determine data stationarity, the study uses second-generation unit root tests. An appropriate cointegration test is employed to assess cointegration between the variables. Different econometric approaches (PCSE and FGLS) are used to discover the rapport between remittances, innovation, and economic growth. These methods can be used to get fair results after dealing with problems like cross-sectional dependence and heteroskedasticity. Furthermore, the robustness of "the heterogeneous panel D-H Granger causality test" validates the conclusions of the findings. As a result, the outcomes presented in this study are appropriate, reliable, and trustworthy. Mitigating concerns related to these factors offers a strategic approach to bolster financial permanence. In addition, our study adds to what has already been written by showing that variables have a strong and positive correlation, which means that they are linked in a way that makes the relationship stronger. Thus, this study reveals crucial contextual information for the MICs, which will add to the existing body of knowledge and serve as fresh proof.

Based on the findings, this research proposes several strategic suggestions for MICs to enhance remittance channels and reinforce innovation infrastructure: To begin, governments should improve remittance transfer systems by lowering transaction costs, making them easier to use, and making sure there are safe channels for money to flow in and out of the productive sectors. Secondly, investment in innovation infrastructure, including research funding, startup ecosystems, and tax incentives, is vital for fostering a culture of innovation and improving economic competitiveness. Thirdly, prioritizing skill enhancement programs and educational training is essential for building a workforce capable of driving innovation, including technical training, vocational programs, and collaboration between academic institutions and industries. Fourthly, public-private partnerships can speed up the implementation of new projects and make sure that remittance funds are sent to the right strategic areas by combining resources and expertise. Fifth, to improve financial inclusion, remittances need to be linked to formal financial systems. This can be done through targeted policies that encourage people to save, invest, and get credit for their business ideas. Sixth, robust governance frameworks ensure regulatory clarity, transparency, and stability in innovation and remittance utilization, promoting long-term sustainability. Finally, governments should balance fostering entrepreneurship with preserving macroeconomic stability through grants, mentorship, and incubation centers while implementing policies to safeguard economic resilience.

This study offers a few fresh insights. First, this study is pioneering the exploration of the moderating role of remittances in the innovation-growth nexus in MICs. Second, this study is the first to use PCA to construct an innovation index based on R&D, patents, and trademarks as main proxies for innovation. Third, while the existing studies use various approaches, this study utilizes PCSE, FGLS, and D-H causality assessment methods. Fourth, the results of this study can alert policymakers of MICs that intensify remittance inflows and foster innovation. These insights can catalyze economic growth by prompting strategic interventions.

This study is not without its limitations, despite the stunning results and its broad policy consequences. Based on data availability, the research includes just 25 of the middle-income countries. The study does not analyze countries with higher and lower-middle-income levels. Future research should consist of a more comprehensive analysis of upper middle-income, lower middle-income, or coastal areas. The study can be expanded to explore the symmetrical and asymmetrical effects of remittances, innovation, FDI, life expectancy, financial development, and labor force participation on GDP by increasing the sample size and time.

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