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*Research article*

# Do international capital flows, institutional quality matter for innovation output: the mediating role of economic policy uncertainty

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**Abstract:** The determinants of innovation output in empirical literature have been extensively investigated by considering diverse sets of variables. Still, the impact of economic policy uncertainty on innovation output is yet to unleash. The study investigates the association between EPU and innovation output to mitigate the existing research gap, considering a panel of 22 countries over 1997–2018. The study employs a dynamic panel quantile regression and system-GMM specification causality test to discover elasticity and directional association both in the long and short run. Study findings disclosed negative statistically significant effects running from EPU to innovation output except innovation measured by R&D.; moreover, institutional quality and FDI expose positive and statistically significant association with innovation output. In directional causality, unidirectional causality runs from EPU and FDI to innovation output, whereas bidirectional causality establishes between institutional quality and innovation output.

**Keywords:** innovation output; economic policy uncertainty; institutional quality; dynamic panel quantile regression

**JEL Codes:** O31, O36, Q68

## 1. Introduction

Since Solow (1957) pioneering work, the critical role of technological advancement in fostering a nation's long-term wealth creation and competitive advantage has been recognized. While growing literature has explored numerous analytical connections between innovation and firm-or market-specific characteristics, systematic empiric research investigating how policy impacts innovation practices are scarce. Politics is essential to innovation since policymakers make legislative and regulatory decisions that often alter the economic climate in which innovative companies work, which eventually affects a nation's innovation progress. Innovation is a special expenditure in intangible, long-term properties that would generate income in the future. Owing to its longer investment time horizon and higher tail risk, it is distinct from normal investment intangible assets such as capital expenditures. Besides, economic conditions influencing innovation vary from those affecting normal investment. See Alesina and Perotti (1996), Bloom et al. (2007), Julio and Yook (2012), and Gulen and Ion (2016).

Innovation has played a decisive role in many countries' economic and social growth and has been one of the key methods for solving big global challenges. It is the primary source of economic development, increased production, the cornerstone of competitiveness, advancement in healthcare and, thus, essential for alleviating poverty. Innovation is highly reliant on general economic circumstances, government, schooling, and infrastructure. However, the scratch of the global financial crisis challenges economic growth and the innovation environment badly hurt. Innovation output in the economy can detect in manifolds, such as knowledge creation, technological capabilities, and information dissemination with the assistance of Research and development.

Innovation is the prerequisite for economic growth, especially in a dynamic environment. It is because innovation breed ample possibilities for growth through firm-level and aggregated level development in the economy. Countries with higher innovation output can possess sustainable economic growth characterized by escalating the standard of living and per capita income. Therefore, promoting innovation in the economy is critically addressed in the empirical literature and establishes key macro determinants that drive innovation output. In a study, Malik (2020) disclosed that investment in education, institutional quality, and trade openness helps accelerate innovation output and foreign direct investment negatively impacted innovation output. Innovation output role in the economy can be addressed in the manifold, including acceleration of economic activities allowing industrialization (Dincer, 2019), assist in achieving sustainable economic growth, especially in developing nations (Lee et al., 2016), and competitive position in international trade (Hartono and Kusumawardhani, 2019).

Empirical literature displays a growing number of studies established the key macro determinants that are critically important for fostering innovation output in the economy, such as investment in education (Brunello et al., 2007; Villalba, 2007; Bosworth, 2009), institutional quality (Marcelin and Mathur, 2014; Hartono and Kusumawardhani, 2019), financial development (Pan et al., 2019), trade openness (Dotta and Munyo, 2019; Kacani, 2020), economic growth, foreign investment (Cheung and Ping, 2004; Stiebale and Reize, 2008; Khachoo and Sharma, 2016).

The motivation of the study is to gauge the impact of economic policy uncertainty, foreign direct investment and institutional quality on national innovation output. The study considered a panel of 22 nations for the period 1997–2018, and several econometrical tools were applied in exploring the association in empirical assessment. Study findings documented that economic policy uncertainty induces an economy for investing in knowledge innovation through research and development. Furthermore, innovation in the economy has immensely guided by better institutions, implying that Protection for knowledge creation creates a comfortable ambience for innovativeness in the economy.

The present study contributes to the existing literature threefold. First, with our best knowledge, the first-ever empirical study focuses on investigating the influence of economic policy uncertainty on innovation output in the economy, covering a large data sample with the study's spine. However, in recent times, Tajaddini and Gholipour (2020) perform a study focusing on the impact of EPU on innovation output. Second, empirical literature regarding innovation output and macro determinants reveals that studies have measured, in most cases, by utilizing one proxy variable. In reality, taking considered one proxy measure despite several different measures were available. In that case, to some extent, the previous verdicts are one-directional and biased in the sense of selection of proxy of innovation output. Following the present literature, this study considers four proxies to detect the impact of EPU, institutional quality, and foreign capital flows on innovation output. It is firmly believed that selecting diverse measures assesses the ultimate impact of target variables and assists in strategic thinking for future policy formulation and implementation. Third, exploring fresh evidence nexus between EPU and innovation output, the study applies a nonlinear framework and a conventional linear estimation. Nonlinear estimation enables the decomposition of total effects in terms of positive and negative shocks in the economy's explanatory variables. Asymmetry in empirical estimation induces critically thinking among researchers and policymakers over believe in perceive notions.

This article adopts the following structure. Section 2 deals with the literature review in detail, focusing on EPU effects on innovation output, government quality effects on innovation output, and international capital flows' influence on innovation output. Section 3 concentrated on explaining the variables definition and econometrical methodology of the study. Results of econometrical model estimation and their interpretation report in Section 4. Finally, findings and policy implications are exhibited in Section 5.

## 2. Literature review

Industrial revaluation brings radical changes in the economy through technological transformation and disruption of normal business activities in different areas including, marketing, the health care industry, financial activities and human involvement. According to Schwab and Sala-i-Martín (2016), Revolution is the outcome of accumulated effects from innovation output in the economy. Innovation familiarizes the rethinking process in the economy by diffusion of innovative products, processes, and ideas and maximising economic resource scarcity (Dutta et al., 2018). Moreover, the emergence of new technologies intensifies industrial output manifold by reducing complexity in the production process, efficient supply chain system, administrative efficiency, and digital integration in the overall business activities.

Innovation outputs immensely contribute to the economy, including public research institute development, knowledge innovation practice in the universities, international tie-up between domestic and international researchers, and growth-driven factors evolution (Solow, 1956; Schumpeter, 2013; Leoncini, 2017; Wu et al., 2017). However, in a study, Janoskova and Kral (2019) explained that the impact of innovation output immensely varies from country to country due to the selection of different proxies for measuring the presence of innovation output in the empirical equation.

Extensive literature has been fueled by recognizing the drivers of creativity. In the early years, invention analysis adopted Schumpeter's (1934) study in terms of "change in the type of the output function", which is close to the concept of technical change by Solow (1957). Later, innovation is also related to economic growth theories that describe global economies' growth dynamics by drawing attention to endogenous technological transition (Romer, 1990).

Referring to innovation output in empirical literature tow line of thoughts are available, i.e., the first line of empirical studies have been investigated to explore the key determinants induces innovation output focusing macro-economic data, see for instance (firm level data, see for instance (Kotha et al., 2011); (Oltra and Flor, 2003); (Sudolska and Łapińska, 2020)). The second line of empirical studies has explored the effects of innovation output in the economy; see, for instance, (Wong et al., 2005; Karnizova and Li, 2014; Law et al., 2020; Huang and Zhang, 2020; Huang and Xu, 1999).

### *2.1. Economic policy uncertainty and innovation output*

Several studies have emphasized the relevance of government policy as a determinant of technological progress. However, the basic results of these studies varied due to the different meanings of the invention. Innovation is a slippery term, however. For in-position, economists have described it as applying an invention or implementing a new tool or principle. Still, patent lawyers consider it to discover a tool or concept and not its eventual application. Scholars from diverse areas have sought, through the perspectives of their disciplines, to clarify innovation. Economists have, for their part, characterized the effect of economic forces, in particular the position of commodity values, relative cost factors and supply constraints. Jacob (1966) shows that the intensity of technological expansion is unswervingly related to progress in demand; Nelson et al. (1967) advocate that the speed of dissemination is wholly related to the industry's affordability or market. Policy uncertainty and national innovation output nexus attract researchers in empirical studies. A study establishes adverse effects running from policy uncertainty to innovation activities in the economy. Furthermore, they posit that policy uncertainty hurts the economy's incentive to innovation.

Tajaddini and Gholipour (2020) performed a study to establish the nexus between economic policy uncertainty, expenditure in R&D and innovation output for the period 1996–2015 with a pane of 19 countries. The study applied random effects, fixed effects and GMM estimation. Study findings revealed that EPU is positively linked to innovation output and R&D expenditure in the economy. They postulated that during economic uncertainty, both government and firms invest a substantial amount for innovation to mitigate potential effects, thus creating a pleasant environment supporting innovation and positive externalities.

### *2.2. Nexus between International capital flows and innovation output*

FDI will affect technological advancement in host countries with different mechanisms: forward and backward linkages, strategic impact, established consequences, human resources development, and brain-led information diffusion (Berger & Diez, 2008). The role of international capital flows for fostering national innovation have been investigated in the empirical literature and established positive association see, for instance (Borensztein et al., 1998; Crescenzi et al., 2007). In a study, Bertschek (1995) explained that innovation output increases due to international foreign capital and intense competition. Hence, domestic business firms invest considerable money and time for innovation, eventually augmenting national innovation capacity. In contrast, Filippetti et al. (2017) found that the economy invests for surging innovation capacity to attract foreign investors and increase adsorption capacity in the economy. Inflows of FDI help expand adsorption capacity through human capital development, knowledge sharing, and physical infrastructure development.

Developing countries attract foreign capital in the economy for availing modern and advanced technology to increase their innovation capabilities. Besides, FDI can bring spillover effects and eliminate externalities, thus accelerating technological progress and innovative activities in the economy. A study conducted by Andrijauskiene and Dumčiuvienė (2019) to assess foreign investment's existing controversy boosts national innovation capacity in the economy. The study utilized a pane of 28 European countries for the period 2013–2016. Study findings revealed that international foreign capital flows and import intensity positively promote innovation activities in the economy.

Further evidence was revealed in the study of Kiselakova et al. (2020). They postulated that economic growth appeared as a critical determinant for surging the national innovation capacity in EU nations. They advocated that government expenditure on R&D can boost innovation capacity through the innovation of knowledge by promoting scientific research.

A study conducted by Ustalar and Şanlisoy (2016) applying nonlinear ARDL for evaluating asymmetric shocks of FDI on innovation performance in Turkey from 1984 to 2017. The study revealed that positive and negative shocks in FDI are positively linked to innovation performance in the long and short run. Furthermore, they witnessed that FDI impact on innovation output is prominent in foreign-owned firms than domestic firms. The same line of thought is available in the study of Loukil (2016). In a study, Cheung and Ping (2004) cited that the crowding-out impact of FDI on local firms is that domestic companies could like joint ventures with foreign investors as getting technology from abroad associate substitutes for establishing an innovative atmosphere. It appears that firm interest in R&D activities forces competitors to look after their innovation capability by enhancing firm's efficiency.

With firm-level data, foreign capital flows impact on innovation have been extensively investigated in empirical literature see, for instance (Cheung and Ping, 2004; Stiebale and Reize, 2008; Wignaraja, 2008; Fang and Mohnen, 2010; GAO et al., 2010; Wang and Wu, 2016; Antonakakis et al., 2017). Literature postulated that FDI inflows in the industry accelerate production possibility through technological advancement, knowledge sharing, and efficient production process and produce market intense among firms available in the industry. Positioning the market and availing competitive benefits, firms have been induced to innovate products and processes. Innovation output at the firm's level can be recognized twofold. First, FDI channelized firms expertized to firms in the host economy from home countries. Second, exchanging advanced knowledge boost the host firm's existing potentials and bring the best through innovative activities. Hence, firms introduce new products and services with existing ones (Bertschek, 1995).

Furthermore, Blomström and Kokko (1998) advocated that technological transfer through FDI accelerates innovation activities because FDI presence in the industry acts as a reward factor for firms by eradicating the externalities. In the study, Li et al. (2016) familiarized that outward foreign investment catalyses innovation output for domestic firms. They also identified that the influence of outward FDI on innovation output is guided by absorption capacity, foreign presence, and competition intensity in the local industry.

Nyeadi and Adjasi (2020) evaluate the foreign capital impact on innovation output in the industry using world bank enterprise data in Sub-Saharan African countries. They applied the tow stage regression model to divulge the nature of association and elasticity of FDI on innovation output. Empirical estimation disclosed innovation output at frim level positively augmented in Nigeria, but insignificant effects appear in South Africa. Capital flows in the international area have been producing two-way benefits, i.e., both home and host economy receiving positive output due to inward and outward foreign investment. Masso et al. (2010) revealed a higher innovation output induced by outward investment in domestic and foreign firms. They also observed foreign-owned enterprises channelized income to knowledge innovation that local enterprises.

**Table 1.** Summary findings-nexus between international capital flows and innovation output.

| | Positive effects | Negative effects | Neutral effects |
|---|---|---|---|
| Country-level data | Cheung and Ping (2004) Masso et al. (2013); Islam et al. (2018); Sivalogathasan and Wu (2014); Kinoshita (1998); Blind and Jungmittag (2004); | Loukil (2016); Arun and Yıldırım (2017) | Chen (2007); Loukil (2016) |
| Firm-level data | Nyeadi and Adjasi (2020); Yilun (2020); Girma et al. (2008);Cheung and Ping (2004) | | |

*2.3. Governance quality and innovation output*

The institutional theory suggested that countries possess a robust institutional framework, efficient legal environment, democratic practices, and public confidence to reduce international transaction costs, market performance efficiency, trusted environment, and fair, competitive environment. Moreover, efficient institutions' presences induce innovativeness in the economy irrespective of the firm and aggregated levels. Hence allows more money flow in knowledge innovation that is research and development. Ultimately, investment in R&D produces more innovation opportunities in the economy.

Researchers and policymakers have invested considerable time into establishing the linkage between institutional quality and innovation in the economy (Koçak, 2017; Villanueva, 2019; Sattar and Mahmood, 2011; Kang et al., 2017). Innovation output in the economy seeks a friendly environment such as a strong regulatory framework, policy focused on innovation activities at firms and aggregated levels, and financial incentives for investing in research and development. In a study, Carlin and Soskice (2008) postulated that augmenting the speed of innovation output in the economy government persuasion is inevitable because lethargic government intention, higher tax burden and disinclination to formulate national innovation policy discourage firms from investing in R&D, eventually national innovation output gradually diminished in the long-run(Crafts, 2006).

In a study, Rodríguez-Pose and Di Cataldo (2015) investigate the impact of quality institutions on national innovation output in the European region during 1997–2009. The study revealed that managing institutional quality assists in increasing government quality and regional cooperation. Hence national innovation output capacity is enhanced. Furthermore, they suggested that corruption in government officials significantly indulges the national innovation output adversely. Government quality is considered a credible attribute for formulating long-term national innovation strategies, channelling economic resources in productive investment areas, and pursuing the effective implementation of monetary and fiscal strategies in the economy. In a study, Farole et al. (2011) advocated that ineffective and uncontrolled government institutions hinder the process of national innovation. They also postulated that the capacity to design and effectively implement national innovation strategies immensely relies on the institution's decentralization. The lower degree of institutional delegation produces a discomfort situation in the economy.

Wang et al. (2020) have conducted a study for gauging the effects of bank finance and institutional quality on technological innovation in BRIC nation for the period by applying Westerlund (2007) cointegration and CS-ARDL. Study findings exposed a stable long-run relationship between bank finance, institutional quality, and innovation output. Furthermore, regarding individual effects on innovation, the study documented positive effects from bank finance and institutional quality to technological innovation at the national level. They postulated that developed institutions protect citizens' interests and provide a pleasant ambience to foster open innovation. In the same flow, Wu et al. (2020) observed that an unstable political state and corruption weaken the capacity to generate innovation output.

On the other hand, the legal framework for protecting intellectual property rights augments and strengthens technological innovation in the economy. Similar findings are also available in the study of Tebaldi and Elmslie (2013). Hence, Institutional efficiency increases businesses' confidence in the government's capacity to implement policies and execute regulations, eventually stimulating innovation. Similarly, Varsakelis (2006) argued that creativity's motives are relevant in corruption, public accountability, and political stability. One of the most critical aspects representing systemic efficiency is corruption.

In contrast, several researchers, including Aldieri et al. (2020); Ervits and Zmuda (2018); Anokhin and Schulze (2009), exposed innovation output effects on government quality. In a study, Aldieri et al. (2020) observed that investment in R&D activities assists in thriving institutions' quality by lessening inefficiency and swelling operational innovativeness.

#### 2.3.1. Conceptual and hypothesised model of hypothesis testing

Innovation promotes productivity in a country, provides a significant competitive advantage and is widely accepted as a driving force for long-term economic growth. Thus, getting the desired momentum from innovation, in the empirical literature, the determinants of innovation output extensively investigated and exposed the key factors for augmenting innovation output in the economy. This study's focus is not on the determinants of the critical facts but rather on establishing the elasticity and directional relationship between EPU, IQ, FDI, and innovation output. The following Figure 1 exhibits the possible directional causalities to be tested in the study.

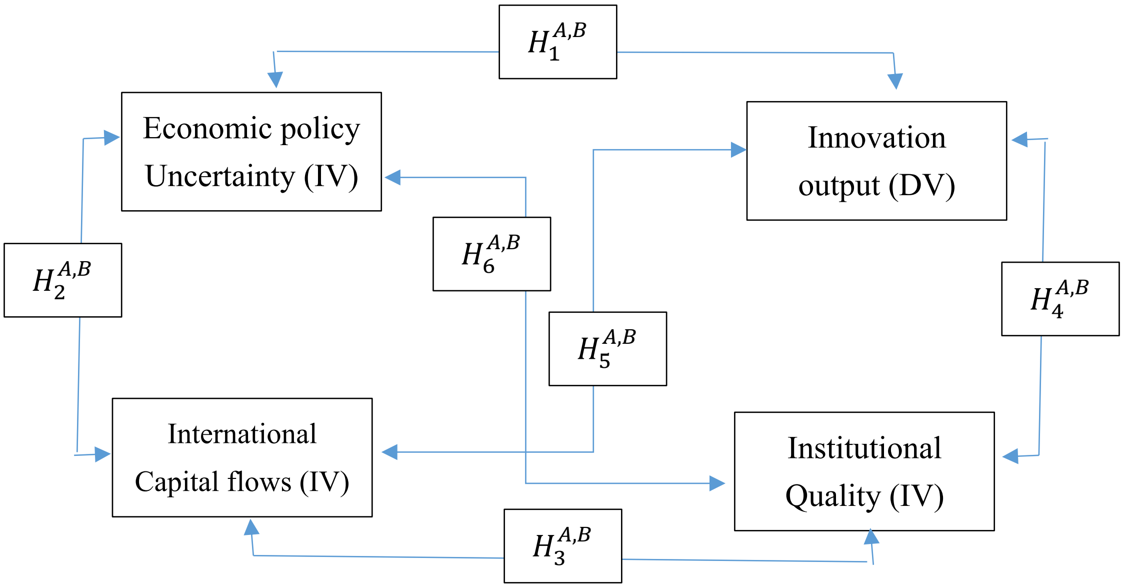


**Figure 1.** Possible directional causalities.

$H_1^{A,B}$: Economic Policy Uncertainty does not granger cause innovation output and vice-versa
$H_2^{A,B}$: Economic Policy Uncertainty does not granger cause FDI and vise-versa
$H_3^{A,B}$: Institutional quality not granger cause FDI and vise-versa
$H_4^{A,B}$: Institutional quality, not granger cause Innovation output and vice-versa
$H_5^{A,B}$: FDI not granger cause Innovation output and vice-versa
$H_6^{A,B}$: Economic Policy Uncertainty does not granger cause Institutional Quality and vise-versa

## 3. Data and methodology of the study

To evaluate the impact of EPU, Institutional quality and foreign capital flow on innovation output for the span from 1997–2018 with a panel of 22 countries. The selection of sample countries primarily relies on data availability.

### *3.1. Innovation output: As a dependent variable*

In practical, measurement of innovation output in the economy is utterly difficult, due to researchers in empirical literature have utilized diversified proxy such as R&D expenditure (Coluccia et al., 2019; Knott and Vieregger, 2018; Maradana et al., 2017), resident patents application (Wusiman and Ndzembanteh, 2020; Maradana et al., 2017), license, and new product development. The study measures innovation output with four proxies; see Table 2 for detailed definitions, produce conclusive findings, and ensure robust empirical estimation.

**Table 2.** Definition of innovation output with reference.

| Indicators | Definition | Reference |
|---|---|---|
| R&D | Research and development expenditure: expressed as a percentage of real gross domestic product. | (Coluccia et al., 2019; Knott and Vieregger, 2018; Maradana et al., 2017) |
| patents application | Patents filed by residents: expressed in numbers per thousand population. | (Wusiman and Ndzembanteh, 2020; Maradana et al., 2017; Tebaldi and Elmslie (2013); Lee et al. (2016); Rodríguez-Pose and Wilkie (2019) |
| | Patents filed by non-residents: expressed in numbers per thousand population | (Maradana et al., 2017) |
| HTX | High-technology exports: expressed as a percentage of real gross domestic product | (Maradana et al., 2017) |

### *3.2. Economic policy uncertainty (EPU)*

In the empirical literature, to measures economic policy uncertainty, a growing number of researchers utilizes the index of EPU (e.g. (Gulen and Ion, 2016; Gholipour, 2019; Tajaddini and Gholipour, 2020), which is introduced by Baker et al. (2013). EPU for major countries and regions globally and the data can be obtained from the Economic Policy Uncertainty database[1]. It includes uncertainties regarding tax, spending, monetary and regulatory policy by the government that is calculated from 3 (three) components, i.e., the frequency of economic policies appear in the newspaper, the number of expired code, the extent of forecaster disagreement over future inflation, and government purchases.

### *3.3. Institutional quality (IQ)*

The existing empirical literature has produced two lines of evidence while incorporating institutional quality in the empirical model. First, several studies considered single indicators that measure an aspect of institutional quality. For instance, Li and Resnick (2003); Aizenman and Spiegel (2006); Levchenko (2007); Habib and Zurawicki (2002); Wijeweera and Dollery (2009); Gani (2007). Second, another group of researchers used a composite proxy indicator, constructed by considering proxy measures extracted from WGI. See for instance Asamoah et al. (2016); Le et al. (2016); Law et al. (2014); Poelhekke and van der Ploeg (2010); Globerman and Shapiro (2002); Daude and Stein (2007).

Following existing literature, see Asamoah et al. (2016), Asiedu (2013), Buchanan et al. (2012), Daude and Stein (2007). This study utilized a governance dataset developed by the Worldwide Governance Indicators (WGI). WGI reports indicators for six governance dimensions, i.e., Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, the rule of law, and Control of Corruption, mostly known as Kaufmann et al. (2010).

[1]https://www.policyuncertainty.com/.

In a study, Globerman and Shapiro (2002) have argued that these indices are positively correlated. Thus it is complicated to use them all in a single regression equation. Table 3. presents correlations on the six indicators described above. It is apparent that a strong correlation available among the variables, as suggested by Globerman and Shapiro (2002) and Daude and Stein (2007).

**Table 3.** Pair-wise correlation of Institutional quality proxies (WGI).

| | *v* | *ps* | *GE* | *RQ* | *L* | *CC* |
|---|---|---|---|---|---|---|
| v | 1 | | | | | |
| ps | 0.725652 | 1 | | | | |
| GE | 0.518462 | 0.582931 | 1 | | | |
| RQ | 0.678391 | 0.640665 | 0.73532 | 1 | | |
| L | 0.709744 | 0.509499 | 0.879439 | 0.799107 | 1 | |
| CC | 0.338795 | 0.725775 | 0.837552 | 0.492579 | 0.792911 | 1 |

As a result, Following existing literature, see, for instance, Asamoah et al. (2016) Globerman and Shapiro (2002), the study performed principal components of the six indicators of governance using employing factor analysis and construct Instructional quality index (IQ). The results of PCI are exhibited in Table 4.

**Table 4.** Principle component analysis.

| Eigenvalues: (Sum = 6, Average = 1) | | | | | | |
|---|---|---|---|---|---|---|
| Number | Value | Difference | Proportion | Cumulative Value | Cumulative Proportion | |
| 1 | 4.048765 | 2.833551 | 0.6748 | 4.048765 | 0.6748 | |
| 2 | 1.215214 | 0.821663 | 0.2025 | 5.263979 | 0.8773 | |
| 3 | 0.393551 | 0.217447 | 0.0656 | 5.657529 | 0.9429 | |
| 4 | 0.176104 | 0.075909 | 0.0294 | 5.833633 | 0.9723 | |
| 5 | 0.100195 | 0.034023 | 0.0167 | 5.933828 | 0.9890 | |
| 6 | 0.066172 | --- | 0.0110 | 6.000000 | 1.0000 | |
| Eigenvectors (loadings): | | | | | | |
| Variable | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| V | 0.340148 | −0.510462 | 0.722309 | −0.146329 | −0.118082 | 0.258152 |
| PS | 0.304139 | 0.641847 | 0.420379 | 0.555728 | 0.087919 | 0.047428 |
| GE | 0.468207 | 0.080609 | −0.303192 | 0.009098 | −0.825799 | 0.018228 |
| RQ | 0.397804 | −0.427150 | −0.428263 | 0.519370 | 0.353108 | 0.285403 |
| L | 0.480680 | −0.091251 | 0.016122 | −0.136876 | 0.237931 | −0.827656 |
| CC | 0.428112 | 0.360804 | −0.161111 | −0.617406 | 0.339245 | 0.405347 |

## 3.4. *International capital flows*

Domestic capital accumulation plays a critical role in innovation output in the economy. The role of FDI in the process of capital accumulation is positively appreciated in literature. Furthermore, the effects of FDI on innovation also evaluated and established diverse directions depending upon the selection of innovation output proxies; the impact of FDI varies accordingly. The possible channel to augment innovation output through FDI can address. First, the intensification of R&D expenditure in the industry. Second, technological advancement through FDI ensures the optimization of scarce resources, forcing firms to innovate in their product lines and service. Third, the emergence of foreign companies inject forces for domestic firms for innovation. Therefore, the impact of FDI on innovation output is inhabitable. Following the present state relationship between innovation output and FDI, the study also considers FDI intensity measuring as FDI inflows as a percentage of GDP.

Apart from independent variables as explained above, the study considers three control variables: financial development measured by domestic credit to the private sector as a percentage of GDP, trade openness proxy by total trade as a percentage of GDP, and the growth rate GDP. Considering all variables in the study, the generalized regression is presented below in Equation (1).

$$In\ IO_{it}^{1} = \emptyset_i + \alpha \quad lnIO_{i,t-1} + \beta_1 lnEPU_{i\,t} + \beta_2 lnGQ_{i\,t} + \beta_3 lnICF_{i\,t} + \beta_4 lnTO_{i\,t} + \beta_5 lnFD_{i\,t} + \beta_6 lnY_{it} + \epsilon_{it} \quad (1)$$

*3.5. Panel unit root and Cross-sectional dependency test*

In the panel data, due to the globalization and association of the world economies, the cross-sectional issue becomes prominent and neglecting the issue can cause inefficient and incorrect regression outcomes (Qamruzzaman and Jianguo, 2020). We thus start the study by performing the CSD test of Pesaran (2004). This analysis uses the CSD augmented unit root test from Pesaran Pesaran (2007). CSD is not considered by the unit root tests focused on first-generation econometrics. However, CADF and CIPS unit root tests from Pesaran Pesaran (2007) search for stationarity and examine the heterogeneity of the panel results. CADF and CIPS are common strategies in current literature that resolve the problem of heterogeneity and CSD controls.

*3.6. Dynamic quantile regression analysis*

This study utilizes the dynamic panel quantile regression technique familiarized by Koenker (2004) for addressing the panel data properties known as heterogeneity. In recent times, PQR has been extensively used in empirical estimation due to the unique privilege offered over the conditional mean regression assessment. First, PQR can handle significant variations between predicted and unobserved variables and minimize spurious estimation (Akram et al., 2020). Second, data distribution may not cause model estimation, implying that PQR efficiently handles and offers efficient estimation with nonnormality distribution in the data set (Cheng et al., 2019). Third, PQR is capable of managing heterogeneity and cross-sectional issues in the data set. From a policy point of view, It is also interesting for policy prospects to assess the coefficient’s value at the extreme of the distribution.

The dynamic panel quantile regress with individual fixed effects, following Huang et al. (2020), and it is system specification as follows:

$$y_{it} = \partial_{it} + \vartheta y_{it-1} + \beta X_{it} + \mu_{it,} \qquad i = 1 \ldots..N, t = 1 \ldots\ldots.T \quad (2)$$

where $y_{it}$ is the dependent variable, $\vartheta$ specify the individual fixed effects and is time-varying, $y_{it-1}$stands for lagged of the dependent variable, $X_{it}$ for the explanatory variables in the equation, and $\mu$ random error term. The coefficient estimation with target $\tau^{th}$ can be derived from Equation (3):

$$Q_{y_{it}}(\tau|y_{it-1}, X_{it}) = \partial_{it} + \vartheta(\tau)y_{it-1} + \beta(\tau)X_{it} \quad (3)$$

Hence, the successive model for the study presents below

$$Q_{y_{it}}(\tau|X_{it}) = \partial_{it} + \vartheta(\tau)y_{it-1} + \beta(\tau)EPU_{it} + \pi(\tau)IQ_{it} + \alpha(\tau)FDI_{it} + \gamma(\tau)FD_{it} + \xi(\tau)TO_{it} + \zeta(\tau)Y_{it} + \mu_i \quad (4)$$

Performing PQR in the empirical estimation, the conventional OLS does not work efficiently (Zhang et al., 2015). Thus, Koenker (2004) offers a panel term for mitigating the unknown individual fixed effects. The objective functions are as follows for the destination.

$$\underset{\beta}{argmin} \sum_{m-1}^{M}\sum_{n-1}^{N}\sum_{t-1}^{T} w_M \rho_{\tau m}\big[Y_{it} - \beta(\tau)EPU_{it} - \pi(\tau)IQ_{it} - \alpha(\tau)FDI_{it} - \gamma(\tau)FD_{it} - \xi(\tau)TO_{it} - \zeta(\tau)Y_{it} - \mu_{i,}\big] + \theta\sum_{i-1}^{N}|\mu| \quad (5)$$

where $\rho_t y = y(\tau - 1_{(y<0)})$ is standard check function, $1_A$ explain indicator function of set A, $Y_{it}$ Denotes the innovation output in the economy, M stands for quantiles index, $W_M$ traces the mth location in the estimation, and $\mu$ captures individual fixed effects, respectively.

### *3.7. GMM-system based Panel Granger-causality test following (Shabani and Shahnazi, 2019)*

The study adopted the panel error correction model causality test discussed by Shabani and Shahnazi (2019) and Qamruzzaman and Jianguo (2020) in their research work to determine the directional causality between financial growth, trade transparency, cross-broader capital flows and renewable energy use. Panel Granger-System-GMM framework causality test is carried out in two phases. The long-run model estimation with Dynamic-OLS for the recovery of the residuals in the first stage. Second, the DOLS approximation residual is used as the first lagged error correction term, determining the model's long-run causality. The equations for the short-run and long-run causality estimation are presented below:

$$\Delta IO^1{}_{it} = \beta_{1i} + \sum_{k=1}^{m}\beta_{11ik}EPU_{it-k} + \sum_{k=1}^{m}\beta_{12ik}FCF_{it-k} + \sum_{k=1}^{m}\beta_{13ik}IQ_{it-k} + \sum_{k=1}^{m}\beta_{14ik}FD_{it-k} + \sum_{k=1}^{m}\beta_{15ik}TO_{it-k} + \sum_{k=1}^{m}\beta_{16ik}Y_{it-k} + \zeta_{1i}ECT_{it-1} + e_{1it} \quad (6)$$

$$\Delta IO^2{}_{it} = \beta_{2i} + \sum_{k=1}^{m}\beta_{21ik}EPU_{it-k} + \sum_{k=1}^{m}\beta_{22ik}FCF_{it-k} + \sum_{k=1}^{m}\beta_{23ik}IQ_{it-k} + \sum_{k=1}^{m}\beta_{24ik}FD_{it-k} + \sum_{k=1}^{m}\beta_{25ik}TO_{it-k} + \sum_{k=1}^{m}\beta_{26ik}Y_{it-k} + \zeta_{2i}ECT_{it-1} + e_{2it} \quad (7)$$

$$\Delta IO^3{}_{it} = \beta_{3i} + \sum_{k=1}^{m}\beta_{31ik}EPU_{it-k} + \sum_{k=1}^{m}\beta_{32ik}FCF_{it-k} + \sum_{k=1}^{m}\beta_{33ik}IQ_{it-k} + \sum_{k=1}^{m}\beta_{34ik}FD_{it-k} + \sum_{k=1}^{m}\beta_{35ik}TO_{it-k} + \sum_{k=1}^{m}\beta_{36ik}Y_{it-k} + \zeta_{3i}ECT_{it-1} + e_{3it} \quad (8)$$

$$\Delta IO^4{}_{it} = \beta_{1i} + \sum_{k=1}^{m}\beta_{41ik}EPU_{it-k} + \sum_{k=1}^{m}\beta_{42ik}FCF_{it-k} + \sum_{k=1}^{m}\beta_{43ik}IQ_{it-k} + \sum_{k=1}^{m}\beta_{44ik}FD_{it-k} + \sum_{k=1}^{m}\beta_{45ik}TO_{it-k} + \sum_{k=1}^{m}\beta_{46ik}Y_{it-k} + \zeta_{4i}ECT_{it-1} + e_{4it} \quad (9)$$

The optimal lag, i.e., m is 2, in the equation determined by following Akaike's information criterion (AIC) and the lagged ECT stances for error correction term for assessing long-run causality, and $e_{it}$ For the error term. According to (Soto, 2009; Combes and Ebeke, 2011), a causality test using the GMM framework can handle endogeneity problems and produce unbiased and consistent results over OLS-based estimation.

The generalized method of moments (GMM) is an econometric methodology used in panel data estimation with endogenous regressors. In the empirical literature, there are two types of GMM estimations were used; the first difference GMM estimation proposed by Arellano and Bond (1991) and the system GMM estimation proposed by Arellano and Bover (1995) and further development performed by Blundell and Bond (1998). The first difference GMM estimation suffers from week instruments and small sample sizes when endogenous variables are close to a random walk (Blundell and Bond, 1998). The emergence of system-GMM estimation overcome the weakness in the first difference GMM estimation (Arellano, 2003; Baltagi, 2008a; Baum et al., 2007; Han et al., 2014). The System-GMM performs estimating in two system equations. First, the original levels equation with a suitable lagged first difference as instruments and the first difference equation with suitable lagged level as instruments. The application of system-GMM reduces the finite sample biased and increases consistency in estimation (Blundell and Bond, 1998). Therefore, we perform system-GMM estimation by using the prior developed Equation (6–9).

The short-run and long-run causality, after system GMM estimation, will be identified by applying a standard Wald test. The null hypothesis of no causality will be rejected if the coefficients of $\beta_{11}$ to $\beta_{46}$= 0 and the coefficient of ECT statistically significant ascertain the existence of long-run causality in the equation.

## 4. Empirical model estimation and interpretation

### *4.1. Panel unit root test, cross-sectional dependency, and cointegration test*

Before proceeding to empirical estimation, we execute panel unit root tests to understand the order of integration and panel cointegration test for revealing variables the long-run association between innovation output, economic policy uncertainty, international capital flows, and institutional qualities.

Table 5 displays the results of the panel unit root test following Levin et al. (2002). Im et al. (2003), and ADF-Fisher Chi-square under the assumption of trend and constant and trend. Study findings revealed that all the variables are stationary after the first difference. Furthermore, we observed that EPU and trade openness in some cases revealed stationary at a level. However, stationary after second difference did not establish by either variable.

**Table 5.** Results of panel unit root test.

| | Levin, Lin & Chu t | | Im, Pesaran and Shin W-stat | | ADF - Fisher Chi-square | |
|---|---|---|---|---|---|---|
| | t | t&c | t | t&c | t | t&c |
| *Panel–A: Al level* | | | | | | |
| $IO_1$ | −3.64761 | −0.78612 | −1.22451 | 0.09848 | 67.6154* | 62.0605** |
| $IO_2$ | −3.83741 | 0.05830 | −0.81470 | 0.35825 | 50.8792 | 45.4126 |
| $IO_3$ | −0.14883 | −0.69151 | 2.15688 | 0.51934 | 29.3162 | 38.6531 |
| $IO_4$ | 0.57653 | −0.72930 | 4.07206 | 0.39678 | 24.0641 | 37.8156 |
| EPU | −3.12516 | −13.1761 | −1.77977** | −13.1458*** | 57.7772* | 239.231*** |
| FDI | −4.09827 | −3.71423 | −4.63286 | −4.04347 | 94.6937*** | 90.9217** |
| GQ | −11.9196 | −11.4280 | −8.17511 | −6.66912 | 145.876*** | 117.500*** |
| TO | −2.02767 | −2.4830*** | −0.09504 | −1.76042** | 39.1578 | 62.7599** |
| FD | −5.73119 | −4.60698 | −1.60488 | −4.52428 | 59.4054 | 96.4665*** |
| Y | −8.29232 | −17.8708 | −7.52229 | −17.0503 | 140.154*** | 313.235*** |
| *Panel–B: After the first difference* | | | | | | |
| IO1 | −7.6887*** | −7.6792*** | −7.9772*** | −7.7281*** | 158.417*** | 134.759*** |
| IO1 | −5.5504*** | −7.6046*** | −7.8154*** | −7.6033*** | 152.665*** | 122.011*** |
| IO1 | −6.4886*** | −5.2531*** | −6.6955*** | −4.5475*** | 125.526*** | 98.9149*** |
| IO1 | −4.3618*** | −4.0317*** | −5.5702*** | −4.5224*** | 107.494*** | 94.3955*** |
| EPU | −13.1761*** | −9.9788*** | −13.1458*** | −9.8047*** | 239.231*** | 170.517*** |
| FDI | −13.8269*** | −10.8702*** | −13.7930*** | −10.5625*** | 248.373*** | 181.749*** |
| GQ | −19.6733*** | −16.2543*** | −16.4528*** | −13.0629*** | 300.986*** | 222.669*** |
| TO | −12.0092*** | −10.9891*** | −10.0961*** | −7.7624*** | 183.420*** | 138.739*** |
| FD | −4.6069*** | −6.1071*** | −4.5242*** | −4.5863*** | 96.4665*** | 96.7494*** |
| Y | −17.8708*** | −15.0786*** | −17.0503*** | −14.3586*** | 313.235*** | 243.824*** |

Note: Significance level is indicating at 1%, 5% and 10% with ***, ** & *, respectively.

Furthermore, the variable’s integration also gauges by accomplishing the second generation unit root test: CIPS and CADF, and their results are displayed in Table 6. At level series estimation, it appears that a few variables are stationary under both CIPS and CADF estimation. Still, after the first difference, all the variables exhibit stationary properties in both estimations.

The study evaluates the cross-sectional dependency of the variables (see Table 7). The cross-sectional dependency results reject the null hypothesis of cross-sectional independence at a 1% level of significance, implying that a variable’s shock in one cross-section may spread in other variables in the panel countries. Hence, all the variables in the area are cross-sectionally dependent.

In addition to CDS, in the following section, the study intends to evaluate heterogeneity following the framework familiarized by Pesaran and Yamagata (2008). The estimation results display in Table 8 with two coefficients, i.e., Δ and adj.Δ. study findings establish the availability of heterogeneous properties in the selected data set by rejecting the null hypothesis of homogeneity at a 1% level of significance.

**Table 6.** CIPS and CADF unit root tests.

| | CIPS | | | | CADF | | | |
|---|---|---|---|---|---|---|---|---|
| | At level | | Δ | | At level | | Δ | |
| | C | C&T | C | C&T | C | C&T | C | C&T |
| $IO^1$ | −2.523*** | −2.777*** | −7.254*** | −4.987*** | −2.476 | −2.171 | −6.262*** | −4.206*** |
| $IO^2$ | −2.009 | −2.426 | −3.555*** | −7.818*** | −2.075 | −2.428 | −5.614*** | −3.044*** |
| $IO^3$ | −2.147 | −2.519*** | −6.945*** | −5.931*** | −2.762*** | −2.107 | −3.637*** | −5.830*** |
| $IO^4$ | −2.631*** | −2.100 | −7.449*** | −3.442*** | −2.168 | −2.506*** | −5.507*** | −5.933*** |
| $EPU$ | −2.066 | −2.724*** | −6.232*** | −4.553*** | −2.887*** | −2.948*** | −4.773*** | −4.138*** |
| $FCF$ | −2.157 | −2.307 | −8.644*** | −6.384*** | −2.722*** | −2.548*** | −6.451*** | −8.820*** |
| $IQ$ | −2.983*** | −2.864*** | −3.758*** | −4.548*** | −2.678*** | −2.413 | −3.021*** | −8.207*** |
| $FD$ | −2.426 | −2.303 | −8.303*** | −4.456*** | −2.448 | −2.231 | −4.031*** | −3.160*** |
| $TO$ | −2.988*** | −2.895*** | −3.878*** | −4.826*** | −2.096 | −2.357 | −3.168*** | −5.139*** |
| $Y$ | −2.639*** | −2.132 | −6.482*** | −7.804*** | −2.025 | −2.675*** | −5.167*** | −3.945*** |

Note: Significance level is indicating at 1%, 5% and 10% with ***, ** & *, respectively.

**Table 7.** Cross-sectional dependency test.

| | $LM_{BP}$ (Breusch and Pagan, 1980) | $LM_{PS}$ Pesaran (2004) | $LM_{adj}$ Pesaran et al. (2008) | $CD_{PS}$ Pesaran (2006) |
|---|---|---|---|---|
| $IO^1$ | 1935.008*** | 79.2776*** | 78.75381*** | 13.7594*** |
| $IO^2$ | 1818.087*** | 73.8379*** | 73.3141*** | 3.2761*** |
| $IO^3$ | 1387.307*** | 53.7962*** | 53.2724*** | 19.8086*** |
| $IO^4$ | 451.0266*** | 19.1012*** | 18.6965*** | 4.7713*** |
| $EPU$ | 2415.723*** | 101.6425*** | 101.1187*** | 44.1026*** |
| $FCF$ | 378.6877*** | 6.8715*** | 6.3472*** | 5.5946*** |
| $IQ$ | 5071.172*** | 225.1852*** | 224.6614*** | 71.2119*** |
| $FD$ | 1896.105*** | 77.4677*** | 76.9438*** | 19.9392*** |
| $TO$ | 1791.999*** | 72.6242*** | 72.1041*** | 24.4197*** |
| $Y$ | 526.0243*** | 13.7257*** | 13.2196*** | 15.2867*** |

Significance level is indicating at 1%, 5% and 10% with ***, ** & *, respectively.

**Table 8.** Result of heterogeneity.

| | IO | IQ | IQ | IO | EPU | FCF | IQ | FD | TO | Y |
|---|---|---|---|---|---|---|---|---|---|---|
| Δ | 25.315*** | 15.874*** | 22.875*** | 25.881*** | 9.745*** | 26.445*** | 57.844*** | 22.154*** | 44.594*** | 19.314*** |
| Adj. Δ | 32.654*** | 18.945*** | 25.841*** | 32.751*** | 11.856*** | 29.845*** | 75.842*** | 32.541*** | 55.214*** | 22.761*** |

Note: *** denotes statistically significant at a1%.

Table 9 exhibits the results of the panel cointegration test following the framework proposed by Pedroni (2004); Pedroni (1999); Pedroni (2001) in panel-B, and Kao (1999) residual cointegration test in the panel-B. ten test statistics in the model (1), eight test statistics in the model (2), nine test statistics in the model (3), and seven test statistics in the model (4) are statistically significant at a 1% level of significance. Study results customarily the presence of long-run cointegration in all four empirical models. Furthermore, the analysis performed the Kao residual cointegration test (see panel-B) and ascertain the long-run cointegration.

**Table 9.** Results of Panel cointegration.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *Panel-A: Pedroni residual cointegration test* | | | | |
| Panel v-Statistic | 2.6128*** | 1.8788 | 2.1876*** | 2.1924*** |
| Panel rho-Statistic | −4.8664*** | −4.4506*** | −5.1337** | −2.0018*** |
| Panel PP-Statistic | −8.2396*** | −7.6187 | −8.7829 | −4.1809*** |
| Panel ADF-Statistic | 2.6128*** | −2.473** | −3.6422*** | −0.2883 |
| Panel v-Statistic | −0.2543 | −0.8711 | 0.2151 | −0.3393 |
| Panel rho-Statistic | −4.5921*** | −4.3971*** | −5.0832*** | −2.8298** |
| Panel PP-Statistic | −7.6674*** | −7.4689*** | −9.8478*** | −5.7774*** |
| Panel ADF-Statistic | −3.4287*** | −3.1302*** | −4.9905*** | −1.8863** |
| Group rho-Statistic | −2.0634*** | −1.6598** | −2.1839** | −0.4156 |
| Group PP-Statistic | −7.1695*** | −6.6909*** | −9.0761*** | −5.0879*** |
| Group ADF-Statistic | −3.1406*** | −2.2952** | −4.2216*** | −0.2049 |
| *Panel-B: Kao residual cointegration test* | | | | |
| ADF | −2.9726*** | −1.5814*** | −2.8971*** | −5.8228*** |

Note: Significance level is indicating at 1%, 5% and 10% with ***, ** & *, respectively.

Furthermore, acknowledging the results of the CD test (see Table 7) and second-generation panel unit root test, i.e., CIPS and CADF (see Table 6), the study probe the long-run association between innovation output, EPU, foreign capital flows, and institutional quality following cointegration framework familiarized by Westerlund (2007). There is ample evidence supporting the presence of stable long-run cointegration in models (1), (2), (3), and (4) (see Table). The test statistics of the Group and panel established statistically significant results, which enable us to reject the null hypothesis of "no cointegration" in the equation. The results advocated that studied variables have a long-run association and also prevail long-run impact on national innovation output.

**Table 10.** Westerlund (2007) Cointegration.

| Model | Gt | Ga | Pt | Pa |
|---|---|---|---|---|
| $IO^1 = \int EPU, FCF, IQ$ | −11.24*** | −7.884*** | −14.221*** | −14.775*** |
| $IO^1 = \int EPU, FCF, IQ$ | −4.257*** | −15.228*** | −7.115*** | −12.338*** |
| $IO^1 = \int EPU, FCF, IQ$ | −9.351*** | −6.887*** | −8.208*** | −21.084*** |
| $IO^1 = \int EPU, FCF, IQ$ | −14.710*** | −10.247*** | −9.887*** | −12.571*** |

Note: Significance level is indicating at 1%, 5% and 10% with ***, ** & *, respectively.

### 4.2. Heterogeneous effects of EPU, IFCI, IQ on innovation output

In this section, the study first implemented the GMM estimation techniques to evaluate the effects of economic policy uncertainty, international capital flows, and institutional quality on innovation output. Table reports the Result of GMM estimation under the assumption of pooled and fixed effects. In a study, Baltagi (2008b) pointed out that control of period effects in analysis and generated spurious output. Therefore, following Zhu et al. (2016) and Huang et al. (2020), we focused on two-way fixed effects in the estimation, which is reported in column [3].

**Table 11.** GMM estimation results.

| | **Pooled** | **One-way fixed effect** | **Two-way fixed-effect** |
|---|---|---|---|
| *Panel-A: innovation output measured by* Patents filed by residents | | | |
| IO1(-1) | 0.9996***(257.061) | 0.9609***(69.6812) | 0.9736***(66.4595) |
| EPU | −0.0141***(−4.4838) | −0.0341**(−3.3423) | −0.0424**(−7.0031) |
| GQ | 0.0211(3.2586)*** | 0.0442**(2.3268) | 0.036***(4.5702) |
| FCF | −0.036**(−9.6265) | 0.074**(5.905) | 0.0102***(4.1886) |
| FD | 0.013**(5.255) | 0.0024*(2.0807) | 0.0452**(4.1831) |
| TO | −0.0125**(−3.3731) | 0.0348***(3.6717) | 0.0995*(3.6197) |
| Y | 0.0446*(5.8144) | 0.0134**(5.4075) | 0.0075**(5.7135) |
| *Panel-B: innovation output measured by* Patents filed by non-residents | | | |
| IO1(-1) | 1.0081**(181.6619) | 0.8082**(26.4778) | 0.8197**24.6688 |
| EPU | −0.021**(−12.1323) | 0.096**(8.465) | −0.026**(−6.7479) |
| GQ | −0.0012(−1.0577) | −0.0004(−0.3704) | −0.0028(−0.6915) |
| FDI | −0.0059*(−1.6542) | 0.0269***(2.8861) | 0.0268***(3.7632) |
| FD | −0.002(−0.1233) | 0.0587**(2.1663) | 0.0107***(3.1615) |
| TO | −0.011(−0.7543) | 0.1054(1.1831) | −0.0024(−0.0229) |
| Y | 0.0193(1.4586) | 0.012(0.7359) | −0.0032(−0.1737) |
| *Panel-C: innovation output measured by R&D expenditure as a percentage GDP* | | | |
| IO1(-1) | 0.9814***(188.653) | 0.8979 (43.705) | 0.932 (41.8286) |
| EPU | 0.087***(−3.938) | 0.043***(3.068) | 0.013***(7.4366) |
| GQ | −0.0281**(−2.460) | −0.0271***(−4.496) | −0.014***(−5.3751) |
| FDI | −0.047(−1.839) | −0.0009 (−0.203) | −0.011 (−0.3866) |
| FD | 0.024***(3.692) | −0.0094 (−0.626) | 0.03 (0.2268) |
| TO | −0.076(−1.825) | 0.0711*** (2.949) | 0.082 (2.9296) |
| Y | 0.025(0.744) | −0.015 (−1.159) | −0.021 (−0.2111) |
| *Panel-D: innovation output measured by High-technology exports* | | | |
| IO1(-1) | 0.9853*** (205.8377) | 0.8884*** (38.0057) | 0.8759*** (30.5931) |
| EPU | 0.004*** (4.6644) | 0.0063*** (3.6973) | 0.0047** (3.3398) |
| GQ | −0.0001 (−0.255) | −0.0005 (−1.1538) | −0.0004 (−0.2717) |
| FDI | 0.0052*88 (3.5556) | 0.0039 (0.6361) | 0.005 (0.7557) |
| DCP | 0.0284*** (3.5891) | −0.0181 (−0.8703) | −0.0252 (−1.0907) |
| TO | −0.0012 (−0.2458) | 0.1005*** (2.833) | 0.0633 (1.5956) |
| Y | −0.0003 (−0.0726) | −0.0082 (−1.4378) | −0.0136** (−2.0668) |

Note: () is for t-stat, significance level is indicating at 1%, 5% and 10% with ***, ** & *, respectively.

Panel-A of Table displays results with Innovation output measured by Patents filed by residents. For EPU effects on innovation output, the study revealed a negative association, implying that the ambience of national innovation output hinders an increase of the degree of EPU. More specifically, a 10% increase of EUP can causes reeducation of IOs in the economy by 0.14% in the model [1], by 3.41% in the model [2], and 4.24% in the model [3]. Therefore, it is established that innovation output at an aggregated level could intensify by offering an innovative atmosphere by reducing the EPU level. Institutional quality exhibits a positive linkage with innovation output, and all the coefficients are statistically significant at a 1% significance level. Findings advocate that institutional quality induces innovation activities in the economy by offering a stable and well-functioning legal framework and governmental efficiency. In particular, a 10% progress in institutional quality can boost innovation output in the economy by 0.211% in model [1], by 0.442% in model [2], and by 0.36% in model [3], respectively. Furthermore, foreign capital flows in the economy project adverse linked to innovation output of the empirical model with the Pooled assumption (a coefficient of −0.036); nonetheless, empirical model estimation with one-way fixed effects (a coefficient of 0.074) and two-way fixed effects (a coefficient of 0.0102) customary the positive association.

The following section deals with empirical model estimation by performing dynamic PQR, and their results are displayed in Table-based on various proxy measures of innovation outputs. The study has considered lower quantile includes 10th, 20th, 30th, 40th, and 50th and higher quintiles include the 60th, 70th, 80th, 90th. The key findings from dynamic PQR are stated below:

First, the regression coefficients of economic policy uncertainty hereafter EPU on innovation output expose a mixed association level with a statistically positive and negative impact running towards different proxied innovation output. Negative statistically association reveals for innovation measures by *PAR* (see panel-A in Table), innovation measures by *PAnR* (see, Panel-B in Table), and innovation measures by *HTE* (see panel-D in Table) in all quantiles, as expected, that suggesting the instable state of economy discourages innovativeness in the economy. Furthermore, EPU creates tension in the economy, which act as adverse determinants of investment confidence reduction and thus aggregated level output immensely interrupted by lowering innovation practices in the economy. These findings are also supported by Gholipour (2019), Clarke (2001), Hall (2002) but oppose the other direction findings available in the study of Tajaddini and Gholipour (2020). Moreover, results show statistically significant positive links between EPU and investment in R&D per capital (see Panel-C in Table 11), indicating that EPU induces innovativeness in the economy. These findings are in line with Bloom (2014); Kraft et al. (2018). Usually, uncertainties limit business actives in the economy; however, knowledge-based, high-tech, and innovation-oriented industries persistently seek and immensely rely on R&D outputs.

Furthermore, developed countries with advanced industries and large companies are always intended to capitalize on business completive advantages; thus, continual investment for innovation through R&D is a strategic position even in a state of uncertainty. Van Vo and Le (2017) postulates that investment in R&D is the key to the firm's survival with economic uncertainty by exploiting the competitive advantages. He also advocates that increased investment in R&D creates ample opportunities for the firm in sustainable development and prospects.

*Second*, the nexus between institutional quality and innovation output exhibits a negative association but statistically insignificant results in lower quantiles: 15$^{th}$, 20$^{th}$ and 30$^{th}$. Positive statistically significant exposes in higher quantities, which is desirable. The verdict is applicable for each model estimation, moreover in line with empirical studies of Canh et al. (2019), Tebaldi and Elmslie (2013), Kwan and Chiu (2015), Sala-i-Martin (2001). The availability of quality institutions in the economy augmented knowledge accumulation and diffusion, suggesting the interlinkage between political stability and invention in the patent application(Gradstein, 2004). Furthermore, the Protection of intellectual property and legal framework is a motivating factor in enhancing the economy's innovation output (Chen and Puttitanun, 2005).

Knowledge creation through investing in R&D activities, employment development, skills improvements, and technological innovation in the system. Financial systems, particularly bank-based financial institutions, persistently seeking product and services diversification to enjoy competitive market advantages. Thus investment in R&D becomes one of the key strategic concerns. However, government persuasion and motivation play a pivotal role in encouraging investment for knowledge innovation through instructional participation. Furthermore, Trust, knowledge-sharing, and shared economic benefits benefit from democratic legal and political systems that ensure freedom of speech and secure innovators' interests. Dakhli and De Clercq (2004) argue that the economy has a lower degree of social behaviours, implying that stock civics norms and social restrictions adversely caused in exporting high-technology goods.

*Third,* the coefficients of international capital inflows are positively associated with innovation output measured by four proxies. In particular (see panel-A in Table), the coefficient of FDI inflows is positive and statistically significant in all quantiles from 40th to 90th, suggesting that national innovation outputs in terms of the patent application by residents are augmented through continual receipts of international capital in the economy. This finding aligns with Cheung and Ping (2004), Li et al. (2016). Furthermore, innovation outputs measured by patent applications by non-resident expose a positive association with FDI from $30^{th}$ to $90^{th}$ quantiles, and all the coefficients are statistically significant at a 1% level. The effects of FDI on R&D as a proxy of innovation output in the economy exhibits negative statistically insignificant association in lower quantiles, i.e., $15^{th}$, $20^{th}$ and $30^{th}$, whereas, positive statistically significant relationship establishes in higher quantiles that is $40^{th}$, $50^{th}$, $60^{th}$, $70^{th}$,$80^{th}$ and $90^{th}$, respectively (see, Panel-C in Table). Study findings are supported by Jian (2007). Moreover, innovation output in high-tech exports exposes negative links with FDI, but statistically insignificant and positive impacts divulge in higher quantiles, i.e., from $30^{th}$ to $90^{th}$. This finding is supported by Yilun (2020); Cheung and Ping (2004).

These findings suggest that the developed economy is primarily occupied with high-tech industries. Thus, inflows of FDI accelerates the growth of high-tech industries by channelizing long term investment. The economy has been experiencing the effects of FDI, especially on innovation output in technological innovation, by establishing backwards-forward interlinkage, completive effects and knowledge dissemination(Berger and Diez, 2008). FDI is believed to put in required resources, innovative technology, marketing strategies, and management expertise for domestic businesses and create secondary spillovers useful for the domestic economy. A pull effect may occur due to the MNC's proprietary information leakage or domestic firms' response to international firms' arrival. Spillovers correlated with cross-industry impacts, which may theoretically impact domestic businesses' competitiveness in the same industry, can also affect employment and consumer access and efficiency in upstream and downstream sectors.

*Fourth*, the Result of financial development espouses positive statistically significant effects on the upper quantiles' innovation output from 30th to 90th. This vine of association can observe in all four proxies of innovation output. Study findings align with Zhu et al. (2020), Hsu et al. (2014). Regarding financial development effects on innovation output, Hsu et al. (2014) postulate that the emerging economy has been experiencing more prominent impacts because channelizing and reallocating economic resources tempt innovative tasks in the economy. Furthermore, stockholders' investment protection act as a catalyst for thriving national innovation(Aghion et al., 2009). Adequate financing from technological, infrastructural development boosts innovational propensity, establishing a well-functioning financial sector as a critical factor for development by the path of innovation. Moreover, financial development by strengthening financial systems encourages investments in entrepreneurial innovation development, which eventually accelerate economic growth (Meierrieks, 2014).

**Table 12.** Results of dynamic Quantile regression: Innovation output measured by Patents filed by residents.

| | **015** | **0.20** | **0.30** | **0.40** | **0.50** | **0.60** | **0.70** | **0.80** | **0.90** |
|---|---|---|---|---|---|---|---|---|---|
| *Patents filed by residents* | | | | | | | | | |
| EPU | −0.033*** | −0.024*** | −0.151*** | −0.098*** | −0.282*** | −0.549*** | −0.869*** | −0.126*** | −0.216*** |
| | (−10.8904) | (−10.685) | (−14.440) | (−5.314) | (−0.808) | (−51.624) | (−72.207) | (−23.034) | (−44.273) |
| GQ | −0.012 | −0.023 | 0.045** | 0.144*** | 0.341*** | 0.321*** | 0.415*** | 0.575*** | 0.655*** |
| | (−0.349) | (−0.341) | (20.107) | (40.071) | (60.916) | (57.154) | (85.1441) | (90.385) | (124.122) |
| FDI | 0.092 | 0.071 | 0.015 | 0.042*** | 0.188*** | 0.362*** | 0.287*** | 0.747*** | 0.748*** |
| | (24.1888) | (12.0263) | (10.324) | (15.3877) | (25.1344) | (57.6469) | (45.2408) | (82.8658) | (84.6123) |
| FD | 0.087 | 0.128*** | 0.139*** | −0.276 | −0.0161 | −0.0312 | −0.0183 | 0.0028 | 0.0167 |
| | (09.717) | (21.181) | (22.322) | (−0.641) | (−1.128) | (−1.942) | (−0.916) | (0.143) | (0.582) |
| TO | −0.021 | −0.098 | −0.018 | 0.222*** | 0.257*** | 0.346*** | 0.513*** | 0.5307*** | 0.564*** |
| | (−10.4593) | (10.7667) | (10.0791) | (32.204) | (37.6046) | (45.474) | (65.0282) | (68.7167) | (67.739) |
| Y | 0.022*** | 0.025*** | 0.0304*** | 0.081*** | 0.277*** | 0.335*** | 0.361*** | 0.479*** | 0.475*** |
| | (9.235) | (10.232) | (10.6885) | (10.849) | (31.7818) | (44.9051) | (45.197) | (56.278) | (56.389) |
| IO1(−1) | 1.115*** | 1.069*** | 1.106*** | 1.137*** | 1.179*** | 1.230*** | 1.151*** | 1.119*** | 1.154*** |
| | (109.595) | (101.521) | (101.871) | (112.464) | (117.971) | (126.452) | (113.759) | (115.282) | (121.714) |
| IO1(−2) | −0.1032 | −0.0602 | −0.1008 | −0.1344 | −0.1741 | −0.2245 | −0.1529 | −0.1329 | −0.1759 |
| | (−0.9036) | (−0.6554) | (−1.0823) | (−1.4678) | (−2.6201) | (−2.9386) | (−1.8683) | (−1.7573) | (−3.272) |
| | | | | | | | | | |
| EPU | −0.015*** | −0.029*** | −0.328*** | −0.381*** | −0.421*** | −0.622*** | −0.734*** | −0.763*** | −0.833*** |
| | (−9.014) | (−9.774) | (−43.842) | (−48.554) | (−52.014) | (−78.511) | (−87.214) | (89.914) | (−97.251) |
| GQ | −0.095 | −0.012 | −0.056 | 0.025*** | 0.091*** | 0.254*** | 0.312*** | 0.417*** | 0.451*** |
| | (−0.001) | (−0.047) | (0.121) | (8.557) | (11.245) | (35.484) | (42.785) | (52.784) | (55.842) |
| FDI | −0.003 | −0.001 | 0.014*** | 0.213*** | 0.156*** | 0.186*** | 0.212*** | 0.384 | 0.313 |
| | (−0.001) | (−0.007) | (0.007) | (34.215) | (27.512) | (29.754) | (31.745) | (42.845) | (42.75) |

*Continued on next page*

| | 015 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 |
|---|---|---|---|---|---|---|---|---|---|
| *Patents filed by residents* | | | | | | | | | |
| FD | −0.019 | −0.024 | 0.019*** | 0.027*** | 0.142*** | 0.387*** | 0.417*** | 0.523*** | 0.516*** |
| | (−0.008) | (−0.041) | (6.142) | (8.021) | (21.054) | (47.207) | (52.774) | (64.784) | (64.857) |
| TO | 0.013 | 0.015 | 0.006 | 0.014*** | 0.018*** | 0.257*** | 0.262*** | 0.322*** | 0.411*** |
| | (0.002) | (0.004) | (0.007) | (8.012) | (7.051) | (37.845) | (38.154) | (43.512) | (52.75) |
| Y | 0.023** | 0.024*** | 0.147*** | 0.168*** | 0.174*** | 0.137*** | 0.123*** | 0.206*** | 0.283*** |
| | (9.854) | (7.852) | (21.745) | (29.845) | (26.773) | (25.441) | (23.154) | (31.842) | (37.845) |
| IO1(−1) | 1.057*** | 1.054*** | 1.076*** | 1.643*** | 1.062*** | 1.548*** | 1.062*** | 1.403*** | 1.046*** |
| | (110.145) | (112.574) | (117.862) | (185.945) | (110.855) | (175.007) | (110.845) | (154.254) | (110.845) |
| IO1(−2) | −0.027 | −0.0023 | −0.0057 | −0.0029 | −0.0091 | −0.0005 | −0.0054 | −0.0081 | −0.0040 |
| | (−0.0215) | (−0.451) | (−0.5512) | (−0.8415) | (−0.5512) | (−0.8451) | (−0.0541) | (−0.5531) | (−0.1201) |
| R@D | | | | | | | | | |
| EPU | 0.016*** | 0.023*** | 0.055*** | 0.067**** | 0.164*** | 0.184*** | 0.267*** | 0.265*** | 0.495*** |
| | (8.124) | (9.845) | (10.452) | (11.421) | (22.751) | (28.341) | (37.154) | (36.754) | (55.845) |
| GQ | −0.002 | −0.0015 | −0.0046 | 0.027*** | 0.244*** | 0.351*** | 0.134*** | 0.313*** | 0.398*** |
| | (−0.005) | (0.004) | −(0.005) | (5.341) | (35.754) | (46.742) | (24.761) | (43.751) | (48.974) |
| FDI | −0.0043 | −0.0038 | −0.005 | 0.016*** | 0.087*** | 0.026*** | 0.118*** | 0.642*** | 0.577*** |
| | (−0.008) | (0.004) | (0.005) | (6.045) | (10.541) | (5.742) | (22.841) | (75.845) | (66.844) |
| FD | 0.0013 | 0.029 | 0.032 | 0.042*** | 0.186*** | 0.210*** | 0.483*** | 0.721*** | 0.751*** |
| | (0.007) | (5.021) | (5.124) | (6.751) | (28.315) | (32.541) | (59.314) | (83.214) | (88.845) |
| TO | 0.0062 | 0.021 | 0.038 | 0.074*** | 0.257*** | 0.262*** | 0.322*** | 0.451*** | 0.544*** |
| | (0.004) | (5.142) | (0.599) | (11.452) | (36.745) | (37.552) | (43.854) | (56.754) | (65.254) |
| Y | −0.0063 | −0.0099 | −0.0054 | −0.004 | 0.034*** | 0.045*** | 0.132*** | 0.283*** | 0.287*** |
| | (−0.1141) | (−0.417) | (−0.712) | (−0.541) | (5.152) | (5.345) | (23.451) | (38.214) | (39.745) |
| IO1(−1) | 1.215*** | 1.357*** | 1.267*** | 1.252*** | 0.933*** | 0.222*** | 0.160*** | 0.065*** | 0.072*** |
| | (132.45) | (144.751) | (133.754) | (134.251) | (98.311) | (35.334) | (25.845) | (11.745) | (3.542) |
| IO1(−2) | −0.0078 | −0.0011 | −0.0092 | −0.0049 | −0.0052 | −0.0044 | −0.0045 | −0.0077 | −0.0055 |
| | (−0.875) | (−0.647) | (−0.812) | (−0.745) | (−0.667) | (−0.554) | (−0.754) | (−0.557) | (−0.664) |
| Export | | | | | | | | | |
| EPU | −0.056*** | −0.018*** | −0.029*** | −0.145*** | −0.178*** | −0.164*** | −0.295*** | −0.194*** | −0.271*** |
| | (−8.512) | (−5.142) | (−5.214) | (−45.214) | (−75.214) | (−12.512) | (−8.314) | (−77.312) | (−12.512) |
| GQ | −0.0032 | −0.0001 | 0.062*** | 0.015*** | 0.018** | 0.024*** | 0.029*** | 0.096*** | 0.233*** |
| | (−0.6614) | (−0.0541) | (−5.314) | (12.512) | (5.154) | (4.614) | (12.374) | (21.612) | (23.641) |
| FDI | −0.0051 | −0.0012 | −0.0019 | 0.046*** | 0.191*** | 0.281*** | 0.318*** | 0.356*** | 0.426*** |
| | (−0.6671) | (0.4423) | (−0.4421) | (12.314) | (32.415) | (8.194) | (23.845) | (55.314) | (45.214) |
| FD | 0.018*** | 0.019*** | 0.024*** | 0.087*** | 0.028*** | 0.132*** | 0.252*** | 0.461*** | 0.527*** |
| | (5.315) | (12.367) | (2.452) | (11.361) | (25.142) | (32.845) | (45.315) | (45.677) | (75.612) |
| TO | 0.0013 | 0.0021 | 0.028*** | 0.268*** | 0.121*** | 0.128*** | 0.211*** | 0.275*** | 0.341*** |
| | (0.6614) | (0.5512) | (5.314) | (45.761) | (25.314) | (55.314) | (75.612) | (55.314) | (65.842) |
| Y | 0.014*** | 0.011*** | 0.0084*** | 0.262*** | 0.171*** | 0.186*** | 0.289*** | 0.329*** | 0.376*** |
| | (5.312) | (9.314) | (5.614) | (75.612) | (21.351 | (45.612) | (29.751) | (44.123) | (56.812) |
| IO1(−1) | 1.058*** | 1.031*** | 1.034*** | 1.133*** | 1.083*** | 1.059*** | 1.067*** | 1.478*** | 1.788*** |
| | (25.314) | (75.612) | (45.315) | (55.751) | (75.612) | (85.751) | (11.512) | (85.315) | (55.314) |
| IO1(−2) | −0.006 | −0.0043 | −0.0035 | −0.0024 | −0.0042 | −0.0023 | −0.006 | −0.0018 | −0.0076 |
| | (−.552) | (−0.3315) | (−0.4475) | (−0.2241) | (−0.5585) | (−0.6631) | (0.5574) | (0.3312) | (0.8842) |

Note: (1) Items in parentheses are t values. (2) ** and *** indicate the statistical significance at the 5% and 1% levels, respectively.

In the following section, the study gauges the directional association between economic policy uncertainty, institutional quality, FDI and innovation output by performing a prior established equation (6–9). The results of both long-run and short-run causalities display in Table 13, and a summary of short-run causalities reports in Table 14, respectively.

**Table 13.** Result of System GMM specification Causality test.

| | Short−run causalities | | | | | | | Long−run |
|---|---|---|---|---|---|---|---|---|
| | IO | EPU | GQ | FDI | FD | TO | Y | $ECT_{(t-1)}$ |
| Panel−A: Innovation measured by patent application by a resident | | | | | | | | |
| IO | – | 13.7081*** | 10.8752*** | 10.926*** | 12.8905*** | 4.678* | 8.829*** | 15.942*** |
| EPU | 1.3682 | – | 0.614 | 7.635** | 3.977 | 8.1622*** | 0.532 | 9.745*** |
| GQ | 8.7453*** | 0.325 | – | 7.616** | 3.731 | 1.505 | 10.919*** | 4.754* |
| FDI | 0.2617 | 9.901*** | 3.9016 | – | 20.9642*** | 6.612** | 13.3424*** | 13.887** |
| FD | 2.3267 | 0.7983 | 11.611*** | 0.4477 | – | 6.436** | 2.403 | 1.084 |
| TO | 2.1109 | 4.338 | 10.4984*** | 4.1914 | 11.2344*** | – | 2.8532 | 2.845 |
| Y | 5.9068** | 5.683** | 2.9454 | 10.862*** | 1.8464 | 4.2914* | – | 45.214*** |
| Panel−A: Innovation measured by patent application by a resident | | | | | | | | |
| IO | – | 10.879*** | 11.427*** | 0.175 | 9.736*** | 21.386*** | 0.645 | 15315*** |
| EPU | 4.6264 | – | 7.181** | 10.115*** | 12.554*** | 7.7127*** | 0.3237 | 12.514*** |
| GQ | 8.1228*** | 0.4265 | – | 4.8791* | 12.522*** | 6.205*** | 12.461*** | 10.751*** |
| FDI | 8.1843*** | 64.251*** | 3.155 | – | 22.901*** | 12.276*** | 9.992*** | 5.315** |
| FD | 0.169 | 7.699** | 0.358 | 0.183 | – | 6.292* | 13.449** | 12.384*** |
| TO | 0.553 | 10.599*** | 0.384 | 0.017 | 11.025*** | – | 0.078 | 4.315 |
| Y | 12.512*** | 7.7828* | 0.5653 | 14.787*** | 0.0545 | 5.518* | – | 16.912*** |
| Panel−A: Innovation measured by R&D | | | | | | | | |
| IO | – | 12.747*** | 3.440 | 0.814 | 7.115*** | 2.745 | 11.497*** | 22.945*** |
| EPU | 1.253 | – | 0.293 | 0.072 | 15.912*** | 0.449 | 1.502 | 11.674** |
| GQ | 0.442 | 1.925 | – | 7.693** | 0.866 | 9.232** | 10.157** | 2.41 |
| FDI | 12.971*** | 10.687*** | 2.0653 | – | 36.529*** | 0.879 | 8.510** | 6.751** |
| FD | 0.4229 | 13.416*** | 8.636** | 0.555 | – | 5.328* | 13.042*** | 10.612*** |
| TO | 0.0063 | 0.0154 | 5.543* | 0.834 | 12.098*** | – | 0.653 | 3.451 |
| Y | 5.115* | 0.8508 | 5.035* | 0.9129 | 11.706** | 1.9331 | – | |
| Panel−A: Innovation measured by High−tech exports | | | | | | | | |
| IO | – | 10.5647*** | 0.1918 | 10.2354*** | 12.933*** | 0.624 | 0.0212 | 12.345*** |
| EPU | 13.318*** | – | 10.384*** | 0.046 | 13.1641*** | 0.541 | 1.483 | 15.945*** |
| GQ | 0.498 | 1.709 | – | 6.2187*** | 0.0001 | 5.246* | 0.033 | 9.614*** |
| FDI | 7.5818*** | 8.8561** | 0.2325 | – | 9.4897*** | 0.043 | 5.537* | 1.882 |
| FD | 0.7715 | 0.0091 | 5.805* | 0.9405 | – | 8.773** | 12.441*** | 2.485 |
| TO | 0.3746 | 0.0206 | 0.0249 | 5.028* | 0.2295 | – | 0.4367 | 3.481 |
| Y | 0.008 | 0.5157 | 5.905* | 5.297* | 0.5411 | 11.634*** | – | 16.841*** |

Long-run causality is evaluated by scrutinizing the lagged error correction term coefficient and ascertaining long-run causality; the coefficient must be negative and statistically significant. The study finding reveals several causal estimations. The lagged error correction terms coefficient is statistically significant at a 1% or 5% level, the principally causal model with innovation output as dependent variables in the respective equation. Study findings suggest that economic policy uncertainty, institutional quality, and FDI are critically important for fostering innovativeness in the economy. Furthermore, the feedback hypothesis is available for explaining the long-run causality between innovation output and EPU and innovation output and FDI in all four causality assessments. In contrast, innovation output and institutional quality established bidirectional association except in the model with R&D investment proxy for innovation output.

The short-run causality test results reveal several directional causalities running in the empirical estimation (see Table 14); however, the study intends to causal effects running from EPU, IQ, and FDI to innovation outputs. Considering the nature of the causal direction, the study reports causalities into two groups.

First, evidence in favour of supporting *feedback hypothesis* that is suggesting bidirectional relationships in the assessment. Study divulge feedback hypothesis is accessible for explaining the causal association between innovation output measured by High-tech exports and economic policy uncertainty [IO←→EPU], Innovation output and institutional quality [IO←→IQ] where institutional innovation proxied by patent applications by the resident (PATr) and non-residents (PATnr), innovation output and FDI [IO←→FDI), and economic growth and innovation output [IO←→FDI]. Second, the study unveils unidirectional causality running from economic policy uncertainty to innovation output [EPU→IQ], FDI to innovation output [FD→IQ], innovation output to FDI [IO→FDI], financial development to innovation output [FD→IO], and trade openness and innovation output [TO→IO]. Study findings establish that innovation output in the economy guided macro fundamentals' performance, but innovation output induces aggregate performance.

**Table 14.** Summary of granger causality test.

| Causality | [1] | [2] | [3] | [4] |
|---|---|---|---|---|
| IO ←≠→ EPU | ← | ← | ← | ←→ |
| IO ←≠→ IQ | ←→ | ←→ | NA | NA |
| IO ←≠→ FDI | ← | → | → | ←→ |
| IO ←≠→ FD | ← | ← | ← | ← |
| IO ←≠→ TO | ← | ← | NA | NA |
| IO ←≠→ Y | ←→ | → | ←→ | NA |
| EPU ←≠→ IQ | NA | NA | NA | ← |
| EPU ←≠→ FDI | ←→ | ←→ | → | → |
| EPU ←≠→ FD | | ←→ | → | ← |
| EPU ←≠→ TO | ← | ←→ | ← | ← |
| EPU ←≠→ Y | → | ←→ | NA | NA |
| IQ ←≠→ FDI | NA | ← | ← | ← |
| IQ ←≠→ FD | ←→ | ← | → | → |
| IQ ←≠→ TO | → | ← | ←→ | ← |
| IQ ←≠→ Y | ← | ← | ←→ | → |
| FDI ←≠→ FD | ← | ← | ← | ← |
| FDI ←≠→ TO | ←→ | ← | NA | ← |
| FDI ←≠→ Y | ← | ←→ | ← | ←→ |
| FD ←≠→ TO | ← | ←→ | ←→ | ← |
| FD ←≠→ Y | NA | ← | ← | ← |
| TO ←≠→ Y | → | → | → | → |

*Note: ←→ specifies bidirectional causality, "←/→" denotes unidirectional causality, and NA specify No-causality.*

## 5. Findings and policy suggestions

The study imputes to gauge the impact of economic policy uncertainty, institutional quality, and FDI on innovation output using a panel of 22 countries over 1997–2018. Results from dynamic panel quantile regression establish a negative statistically significant association with innovation output measured by patent application from residents, non-resident, and High-tech exports. In contrast, a positive, statistically significant association reveals with innovation output measured by investment in R & D R&D. these findings suggest that the impact of EPU is not conclusive because diverse proxy selection produces either directional association. However, in terms of final output through innovation, it is negatively affected due to instability in the economy's state, thus achieving steady growth in innovation output considering the aggregated economy prospect. It is recommended to establish economic stability by reducing uncertainty in the economy. Furthermore, investment in knowledge innovation during uncertainty accelerates investment in R&D, indicating that figuring out the alternative ways of getting rid of uncertainty and avail market opportunity creates shocks in the economy.

Institutional quality divulges a positive, statistically significant association with innovation output in all four tested models in the higher quantities. These findings suggest an effective legal framework and efficiency in managing investor rights protection act as motivating factors for innovation. Furthermore, regulated government behaviour and fair market policies create an appropriate environment for introducing high-tech industries. Therefore, it is crucial to explain the government's role in the sector. It does not intervene in the scientific study and development phase, preserving competitive market order in high-tech sectors and creating an economic structure and market climate conducive to innovation capabilities.

Finally, study findings of foreign capital flows and innovation output establish a positive statistically significant association that is desirable from existing literature. FDI is a source of technology transfer along with knowledge sharing mechanisms. Arun and Yıldırım (2017) advocate that FDI intensifies innovative activities both at the firms level and in the aggregate level through appreciating employees' tendency for innovation and injecting domestic firms to cope with MNCs' knowledge innovation as an output of investment in R&D.

Based on empirical findings, the following policy recommendations are suggested for fostering innovation output in the economy. (1), both fiscal and monetary policy formulation and their effective implementation should be targeted to mitigating the state of uncertainty in the economy. It is crucial that both investor's and inventors' degrees of confidence immensely rely on economic volatility. Thus, the government should protect investment rights and benefits, which eventually attract foreign investment. (2) Misrepresentation of government attitudes in the market injects discomfort for aggregate performance; therefore, government behaviour and participation should focus on innovation output. That means actions towards investor's rights Protection, a strongly regulated framework, and institutional efficiency induce industry to invest in innovation and support to reach sustainable growth. (3) Foreign investors' presence entices domestic firms to move out from conventional thinking and innovate in their operations. Still, it is a regulatory obligation to offer a pleasant ambience for both participants in the economy.

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## Conflicts of interest

The authors declare no conflict of interest.

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