Journal of Open Innovation: Technology, Market, and Complexity

MDPI

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 were extensively investigated by considering diverse sets of variables. Still, the impact of economic policy uncertainty on innovation output is yet to unleash. To mitigate the existing research gap, the study investigated the association between *EPU* and innovation output, considering a panel of 22 countries over 1997–2018. The study employed a dynamic panel quantile regression and system-GMM specification causality test for discovering elasticity and directional association both in the long-run and the 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* exposed positive and statistically significant association with innovation output. In terms of directional causality, unidirectional causality running from *EPU* and *FDI* to innovation output was established, whereas bidirectional causality was established between institutional quality and innovation output.

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

Citation: Qamruzzaman, M.; Tayachi, T.; Mehta, A.M.; Ali, M. Do International Capital Flows, Institutional Quality Matter for Innovation Output: The Mediating Role of Economic Policy Uncertainty. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 141. https://doi.org/10.3390/joitmc7020141

Received: 3 May 2021
Accepted: 20 May 2021
Published: 24 May 2021

1. Introduction

Since Solow's [1] pioneering work, the critical role of technological advancement in fostering a nation's long-term wealth creation and competitive advantage was recognized. While growing literature explored numerous analytical connections between innovation and firm- or market-specific characteristics, systematic empiric research investigating how policy impacts innovation practices is scarce. Politics are 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 a normal investment intangible asset such as capital expenditures. Besides, economic conditions influencing innovation vary from those affecting normal investment. See Alesina and Perotti [2], Bloom, et al. [3], Julio and Yook [4], and Gulen and Ion [5].

Innovation plays a decisive role in many countries' economic and social growth and is one of the key methods for solving big global challenges. It is the primary source of economic development and increased production as well as the cornerstone of competitiveness and advancement in healthcare; thus, it is 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 was 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 in the economy.

Innovation is the prerequisite for economic growth, especially in a dynamic environment. It is because innovation breeds 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 key macro determinants are established that induce innovation output in the economy. In a study, Malik [6] disclosed that investment in education, institutional quality, and trade openness helps accelerate innovation output, and foreign direct investment established a negative impact on innovation output. Innovation output role in the economy can be addressed in the manifold, including acceleration of economic activities allowing industrialization [7], assistance in achieving sustainable economic growth, especially in developing nations [8], and competitive positions in international trade [9].

Empirical literature displays a growing number of studies that established the key macro determinants that are critically important for fostering innovation output in the economy, such as investment in education [10–12], institutional quality [9,13], financial development [14], trade openness [15,16], economic growth, and foreign investment [17–19].

The present study contributes to the existing literature threefold. First, with our best knowledge, the first-ever empirical study focused 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 [20] performed a study focusing on the impact of *EPU* on innovation output. Second, empirical literature regarding innovation output and macro determinants reveals that studies measured data, in most cases, by utilizing one proxy variable and considering one proxy measure despite several different measures being available. In that case, the previous verdicts, to some extent, were one-directional and biased in the sense of selection of proxy of innovation output. Following the present literature, this study considered 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 that is the nexus between *EPU* and innovation output, the study applied a nonlinear framework and a conventional linear estimation. Nonlinear estimation enabled the decomposition of total effects in terms of positive and negative shocks in the economy's explanatory variables. Asymmetry in empirical estimation induces critical thinking among researchers and policymakers over belief in perceived 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 concentrates on explaining the variables' definitions and the econometrical methodology of the study. Results of econometrical model estimation and their interpretation are reported 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, health care industry, financial activities, and human involvement. Revolution, according to Schwab and Sala-i-Martín [21], 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 enables the economy to maximize economic resource scarcity [22]. Moreover, the emergence of new technologies intensifies industrial output manifold by reducing complexity in the production process as well as with efficient supply chain systems, administrative efficiency, and digital integration in the overall business activities.

Open innovation immensely contributes 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 of evolution [23–26]. However, in a study, Janoskova and Kral [27] explained that the impact of open innovation immensely varies from country to country due to the selection of different proxies for measuring the presence of innovation in the empirical equation.

Extensive literature was 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 [1]. Later, innovation was also related to economic growth theories that described global economies' growth dynamics by drawing attention to endogenous technological transition [28].

Referring to innovation output in empirical literature, a collection of thoughts are available, e.g., the first line of empirical studies investigated the key determinants that induced innovation output, focusing on macro-economic data or firm level data (see, for instance, [29–31]). The second line of empirical studies explored the effects of innovation output in the economy (see, for instance, [32–36]).

2.1. Open Innovation and Macro Fundamentals

It is alleged that manufacturing is moving towards a modern age of "open innovation" [37], a period of profitable corporate R&D policies in which external sources of information and resources help to complement intramural R&D [38,39]. As is commonly supposed, a new, all-encompassing framework of practices is arising out of modularity, online creation, and broad distribution of content. As far as infrastructure and product structures are concerned, this could have large effects on delivery of innovative services and activities [40,41]. This world is full of all sorts of beautiful possibilities, only waiting to be unlocked by the practice of accessible innovation. As a result, open innovation may, to a certain degree, be understood within the framework of structural limits on long-term research and development within, including continuing competency accumulation of in-house and the establishment of in-house enablers [42]. The mode of corporate management is the issue, and business agility is the solution [39].

Open innovation implementation includes: proximity and close relationships with higher education institutions; existence of a governance system to mediate relationships with knowledge actors outside the regional system; mechanisms of a relationship network and knowledge absorptive capacity by the firms constituting the regional innovation systems; and provision of public support [43]. Knowledge procurement from domestic organizations has little bearing on financial results and has a negative impact on firms' R&D [44]. Information learning from international nations, on the other hand, results in superior success and assists companies in unlocking their breakthrough capacity [45].

2.2. Economic Policy Uncertainty and Innovation

Several studies 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 described it as applying an invention or implementing a new tool or principle. Still, patent lawyers consider it to discover a tool or concept without considering its eventual application. Scholars from diverse areas sought, through the perspectives of their disciplines, to clarify innovation. Economists, for their part, characterized the effect of economic forces, in particular, the position of commodity values, the relative cost factors, and the supply constraints. Jacob [46] showed that the intensity of technological expansion is unswervingly related to progress in demand. Nelson et al. [47] advocated that the speed of dissemination is wholly related to the industry's affordability or market. Policy uncertainty and national innovation output attract researchers in empirical studies. A study established adverse effects running from policy uncertainty to innovation activities in the economy. Furthermore, they posited that policy uncertainty hurts the economy's incentive for innovation.

A study was performed by Tajaddini and Gholipour [20] for establishing the nexus between economic policy uncertainty, expenditure in R&D, and innovation output for the period 1996–2015 with 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 with the motive to mitigate potential effects, thus creating a pleasant environment and supporting innovation and positive externalities.

2.3. Nexus between International Capital Flows and Innovation

In host countries, *FDI* affects technological advancement with different mechanisms: forward and backward linkages, strategic impact, established consequences, human resources development, and brain-led information diffusion (Berger and Diez, 2008). The role of international capital flows for fostering national innovation was investigated in the empirical literature and established positive association (see, for instance, [48,49]). In a study, Bertschek [50] explained that innovation output increases in the economy due to international foreign capital and intense competition. Hence, to survive in the domestic business, firms invest considerable money and time for innovation, eventually augmenting national innovation capacity. In contrast, Filippetti, et al. [51] found that the economy invests in 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 effects, thus accelerating technological progress and innovative activities in the economy. A study conducted by Andrijauskiene and Dumčiuvienė [52] to assess foreign investment's existing controversy boosted national innovation capacity in the economy. The study utilized a total 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. [53]. They postulated that economic growth appears 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 was conducted by Ustalar and Şanlisoy [54] 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 both in the long-run and the short-run. Furthermore, they witnessed that *FDI* impact on innovation output is more prominent in foreign-owned firms than domestic firms. The same thoughts were addressed in the study of Loukil [55]. In a study, Cheung and Ping [17] cited that the crowding-out impact of *FDI* on local firms is that domestic companies could use joint ventures with foreign investors to get 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 the firm's efficiency.

With firm-level data, foreign capital flows impact on innovation were extensively investigated in empirical literature (see, for instance, Cheung and Ping [17,18,56–59]). A study postulated that *FDI* inflows in the industry accelerate production, possibly through technological advancement, knowledge sharing, and efficient production processes, and produce market intensity among firms available in the industry. Positioning the market and availing competitive benefits, firms were induced to innovate products and processes. Innovation output at the firm's level can be recognized twofold. First, *FDI* channelized firms and expertized to firms in the host economy from home countries. Second, the exchange of advanced knowledge boosted the host firm's existing potentials and brought the best through innovative activities. Hence, firms introduce new products and services with existing ones [50].

Furthermore, Blomström and Kokko [60] 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. A study by Li et al. [61] conveyed that outward foreign investment is a catalyst and augments 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 [62] evaluated 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 estimations disclosed innovation output at firm level was positively augmented in Nigeria, but insignificant effects appeared in South Africa. Capital flows in the international area produce two-way benefits, e.g., both home and host economies receive positive output due to inward and outward foreign investment. Masso et al. [63] revealed a higher level of innovation output induced by outward investment in domestic and foreign firms. They also observed foreign-owned enterprises channelized income to knowledge innovation in local enterprises. Summary findings focusing the nexus between international capital and innovation output display in Table 1.

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

	Positive Effects	Negative Effects	Neutral Effects
Country-level data	Cheung and Ping [17]; Masso et al. [64]; Islam et al. [65]; Sivalogathasan and Wu [66]; Kinoshita [67]; Blind and Jungmittag [68];	Loukil [55]; Arun and Yıldırım [69]	Chen [70]; Loukil [55]
Firm-level data	Nyeadi and Adjasi [62]; Yilun [71]; Girma et al. [72]; Cheung and Ping [17]		

2.4. Governance Quality and Innovation

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 firm level and aggregated level, allowing more money to flow in the knowledge innovation that is research and development. Ultimately, investment in R&D produces more innovation opportunities in the economy.

In recent periods, researchers and policymakers invested considerable time into establishing the linkage between institutional quality and innovation in the economy [73–75]. Innovation output in the economy seeks a friendly environment, such as a strong regulatory framework, policy focused on innovation activities at firms level and aggregated level, and financial incentives for investing in research and development. In a study, Carlin and Soskice [76] 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 causing national innovation output to gradually diminish in the long-run [77].

In a study, Rodríguez-Pose and Di Cataldo [78] investigated 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 strategies for national innovation, channelizing 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. [79] 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 situation of discomfort in the economy.

Wang et al. [80] 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 [81] 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 running 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 ambiance to foster open innovation. In the same flow, Wu et al. [82] 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 [83]. Hence, institutional efficiency increases businesses' confidence in the government's capacity to implement policies and execute regulations, which eventually stimulates innovation. Similarly, Varsakelis [84] argued that creativity's motives are relevant in terms of 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. [85], Ervits and Zmuda [86], and Anokhin and Schulze [87], exposed innovation output effects on government quality. In a study, Aldieri, Barra, Ruggiero, and Vinci [85] observed that investment in R&D activities assists in thriving institutions' quality by lessening inefficiency and swelling operational innovativeness.

2.5. Motivation and Hypothesis Development

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, using the desired momentum from innovation, the empirical literature extensively investigated the determinants of innovation output and exposed the key factors for augmenting innovation output in the economy. This study's focus was not to determine the critical facts but rather to establish the elasticity and the directional relationship between *EPU*, *IQ*, *FDI*, and innovation output. The following Figure 1 exhibits the possible directional causalities tested in the study.

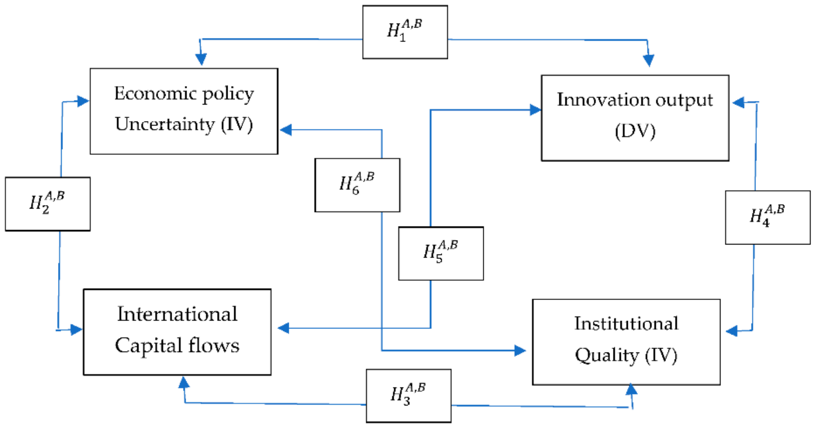

Figure 1. Possible directional causalities. $H_1^{A,B}$: Economic policy uncertainty does not cause innovation output and vise-versa; $H_2^{A,B}$: Economic policy uncertainty does not cause *FDI* and vise-versa; $H_3^{A,B}$: Institutional quality does not cause *FDI* and vise-versa; $H_4^{A,B}$: Institutional quality does not cause innovation output and vise-versa; $H_5^{A,B}$: *FDI* does not cause innovation output and vise-versa; $H_6^{A,B}$: Economic policy uncertainty does not 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 were studied for the span from 1997–2018 with 22 countries. The selection of sample countries primarily relied on data availability.

Innovation output (dependent variable): In practice, measurement of innovation output in the economy is utterly difficult due to researchers in empirical literature having utilized diversified proxies such as R&D expenditure [88–90], resident patents application [90,91], licenses, and new product development. In the study, innovation output was measured with four proxies; see Table 2 for detailed definitions, conclusive findings, and 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.	[88–90]
patents application	Patents filed by residents: expressed in numbers per thousand population.	[90–92]
	Patents filed by non-residents: expressed in numbers per thousand population.	[90]
HTX	High-technology exports: expressed as a percentage of real gross domestic product.	[90]

Economic policy uncertainty (*EPU*): In the empirical literature, to measure economic policy uncertainty, a growing amount of research utilizes the index of *EPU* (e.g., [5,20,93]), which was introduced by Baker et al. [94]. In terms of major countries and continents, the *EPU* makes economic prediction models available internationally, and the economic policy uncertainty holds the data for certain regions. To be interpreted as including economic policies such as tax, spending, money supply, and regulation, economists express their reservations about inflation in the newspaper in that way, e.g., in terms of uncertainty such as frequency, numbers of expirations, how many economists differ about potential price inflation, how much money the government is going to buy, and estimates of the spending power of the authorities, among other things.

Institutional quality (*IQ*): The existing empirical literature 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 [95], Aizenman and Spiegel [96], Levchenko [97], Habib and Zurawicki [98], Wijeweera and Dollery [99], and Gani [100]. Second, another group of researchers used a composite proxy indicator constructed by considering proxy measures extracted from WGI; see, for instance Asamoah et al. [101], Le et al. [102], Law et al. [103], Poelhekke and van der Ploeg [104], Globerman and Shapiro [105], and Daude and Stein [106].

Following existing literature, such as Asamoah, Adjasi, and Alhassan [101], Asiedu [107], Buchanan et al. [108], and Daude and Stein [106], this study utilized a governance dataset developed by the Worldwide Governance Indicators (WGI).

In a study, Globerman and Shapiro [105] 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 was apparent that a strong correlation was available among the variables, as suggested by Globerman and Shapiro [105] and Daude and Stein [106].

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, Adjasi, and Alhassan [101], Globerman and Shapiro [105]), the study performed principal components of the six indicators of governance employing factor analysis and constructing the instructional quality index (*IQ*). The results of PCI are exhibited in Table 4.

Table 4. Principle component analysis.

Eigenvalues: (Sum = 6, Average = 1)						
				Cumulative	Cumulative	
Number	Value	Difference	Proportion	Value	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

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 were also evaluated, and diverse directions depending upon the selection of innovation output proxies were established; the impact of *FDI* varies accordingly. The possible channel to augment innovation output through *FDI* can be addressed, firstly with the intensification of R&D expenditure in the industry, secondly with technological advancement through *FDI* to ensure optimization of scarce resources, forcing firms to figure out innovativeness in their product lines and service, and thirdly with the emergence of foreign companies injecting forces for domestic firms for innovation. Therefore, the impact of *FDI* on innovation output is inhabitable. Following the current relationship between innovation output and *FDI*, the study also considered *FDI* intensity measuring *FDI* inflows as a percentage of GDP.

Apart from independent variables as above explained, the study considered 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 growth rate GDP. Considering all variables in the study, the generalized regression is presented below in Equation (1).

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

Panel unit root and cross-sectional dependency test: In the panel data, due to globalization and association of the world economies, the cross-sectional issue becomes prominent, and neglecting the issue can cause inefficient and incorrect regression outcomes [109]. We thus started the study by performing the CSD test of Pesaran [110]. This analysis uses the CSD augmented unit root test from Pesaran Pesaran [111]. CSD is not considered by the unit root tests focused on first-generation econometrics. However, CADF and CIPS unit root tests from Pesaran Pesaran [111] search for stationarity and examine the panel results' heterogeneity. CADF and CIPS are common strategies in current literature that resolve the problem of heterogeneity and CSD controls.

Dynamic quantile regression analysis: This study utilized the dynamic panel quantile regression technique familiarized by Koenker [112] for addressing the panel data properties known as heterogeneity. In recent times, PQR was extensively used in empirical estimation due to the unique privilege offered over the conditional mean regression assessment. First, PQR can handle all significant variations between predicted and unobserved variables and minimize spurious estimation [113]. Second, data distribution may not cause model estimation, implying that PQR efficiently handles and offers efficient estimation with non-normality distribution in the data set [114]. 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 regressed with individual fixed effects, following Huang et al. [115], and its system specification is as follows:

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

where y_{it} is the dependent variable, ϑ specifies the individual fixed effects and is time-varying, y_{it-1} stands for lagged dependent variable, X_{it} for the explanatory variables in the equation, and μ random error term. The coefficient estimation with target τth 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 is presented 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 [116]. Thus, Koenker [112] offers a panel term for mitigating the unknown individual fixed effects. The objective functions are as follows for the destination.

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

where $\rho_t y = y\left(\tau - 1_{(y<0)}\right)$ is standard check function, 1_A explains 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 μ captures individual fixed effects, respectively.

GMM-system based Panel Granger-causality test (following [117]): The study adopted the panel error correction model causality test discussed by Shabani and Shahnazi [117] and Qamruzzaman and Jianguo [109] in their research work to determine the directional causality between financial growth, trade transparency, cross-broader capital flows, and renewable energy use. The panel Granger-system-GMM framework causality test was carried out in two phases. The long-run model estimation with dynamic OLS was carried out for the recovery of the residuals in the first stage. Second, the DOLS approximation residual was used as the first lagged error correction term, determining the model's long-run causality. The equations for short-run and long-run causality estimations 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 was 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 [118,119], a causality test using the system GMM framework can handle endogeneity problems and produce unbiased and consistent results over OLS-based estimation.

In the estimation of panel data with endogenous regressors, the generalized method of moments (GMM) is a widely used econometric technique. The first difference GMM estimation proposed by Arellano and Bover [120] and the method GMM estimation proposed by Arellano and Bond [121] and further developed by Blundell and Bond [122] are the two forms of GMM estimations used in the empirical literature. When endogenous variables are similar to a random walk, GMM estimation suffers from a short instrument and limited sample size [123]. The development of system-GMM estimation overcame the drawbacks of first-order GMM estimation [123–126]. The use of system-GMM decreases finite sample bias and improves estimation accuracy. As a result, we estimated system-GMM using previously established Equations (6)–(9).

The standard Wald test was performed for detecting the causality between institutional quality, international capital flows, *EPU*, and the proxies of innovation output both in the long-run and short-run. The lagged coefficient of *ECT* specifies the long-run causal association in the empirical model. In this regard, the coefficients have to be negative and statistically significant.

4. Results

4.1. Panel Unit Root Test, Cross-Sectional Dependency, and Cointegration Test

Before proceeding to empirical estimation, we executed panel unit root tests to understand the order of integration and panel cointegration tests for revealing variables in the presence of long-run associations between innovation output, economic policy uncertainty, international capital flows, and institutional qualities. Table 5 displays the panel unit root test results following Levin et al. [127], Im et al. [128], and ADF-Fisher Chi-square under the assumption of trend and constant and trend. Study findings revealed that all the variables were stationary after the first difference. Furthermore, we observed *EPU* and trade openness in some cases were revealed to be stationary at a level. However, them being stationary after the second difference was not established by either variable.

Table 5. Results of panel unit root test.

	Levin, Lin, and 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						
IO^1	−7.6887 ***	−7.6792 ***	−7.9772 ***	−7.7281 ***	158.417 ***	134.759 ***
IO^1	−5.5504 ***	−7.6046 ***	−7.8154 ***	−7.6033 ***	152.665 ***	122.011 ***
IO^1	−6.4886 ***	−5.2531 ***	−6.6955 ***	−4.5475 ***	125.526 ***	98.9149 ***
IO^1	−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 ***

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

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

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 ***

Significance level is indicated at 1% with ***.

The study evaluated the cross-sectional dependency of the variables (see Table 7). The cross-sectional dependency results rejected the null hypothesis of cross-sectional independence at a 1% level of significance, which implies that a shock in a variable in one cross-section may spread in other variables in the panel countries. Hence, all the variables in the area were cross-sectionally dependent.

Table 7. Cross-sectional dependency test.

	LM_{BP} [129]	LM_{PS} Pesaran [110]	LM_{adj} Pesaran et al. [130]	CD_{PS} Pesaran [131]
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 indicated at 1% with ***.

In addition to CDS, in the following section, the study intended to evaluate heterogeneity following the framework familiarized by Pesaran and Yamagata [132]. The estimation results are displayed in Table 8 with two coefficients, i.e., Δ and *adj*.Δ. The study findings established the availability of heterogeneous properties in the selected data set by rejecting the null hypothesis of homogeneity at a 1% level of significance.

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 ***

*** denotes statistically significant at 1%.

Table 9 exhibits the results of the panel cointegration test following the framework proposed by Pedroni [133–135] in the panel B and the Kao [136] residual cointegration test in the panel B. Ten test statistics in model (1), eight test statistics in model (2), nine test statistics in model (3), and seven test statistics in model (4) were statistically significant at a 1% level of significance. The study customarily resulted in the presence of long-run cointegration in all four empirical models. Furthermore, the analysis performed the Kao residual cointegration test (see panel B) and ascertained 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 ***

Significance level is indicated at 1% and 5% with *** and ** respectively.

Furthermore, acknowledging the results of the CD test (see Table 7) and the second-generation panel unit root test, i.e., CIPS and CADF (see Table 6), the study probed the long-run association between innovation output, *EPU*, foreign capital flows, and institutional quality following cointegration framework familiarized by Westerlund [81]. There is ample evidence supporting the presence of stable long-run cointegration in models (1), (2), (3), and (4) (see Table 10). The test statistics of groups and panels established statistically significant results, which enabled 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 with 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 ***

Significance level is indicated at 1% with ***.

4.2. Heterogeneous Effects of EPU, IFCI, and 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 11 reports the result of GMM estimation under the assumption of pooled and fixed effects. In a study, Baltagi [137] pointed out that control of period affects analysis and generates spurious output. Therefore, following Zhu et al. [138] and Huang, Zhu, and Zhang [115], 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			
IO^1 (−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			
IO^1 (−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 of GDP			
IO^1 (−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			
IO^1 (−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 * (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)

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

Panel A of Table 11 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 ambiance of national innovation output hinders an increase of the degree of *EPU*. More specifically, a 10% increase of EUP can cause reeducation of IOs in the economy by 0.14% in model (1), by 3.41% in model (2), and by 4.24% in model (3). Therefore, it is established that innovation output at an aggregated level could intensify by offering a creative atmosphere by reducing the *EPU* level. Institutional quality exhibited a positive linkage with innovation output. All the coefficients were statistically significant at a 1% level of significance. Findings advocate 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 boosted 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 projected an adverse link 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) customarily resulted in positive association. With the growing pace of globalization, the open innovation strategy is also expanding as never before. Generally, firms expand globally as a consequence of home based "ownership advantages" to be exploited in foreign markets [139]. Thus, firms restrict their R&D activity close to their home countries and shift to host economies [140,141].

The following section deals with empirical model estimation by performing dynamic PQR, and the results are displayed in Table 12 based on various proxy measures of innovation outputs. The study considered lower quantiles including 10th, 20th, 30th, 40th, and 50th and higher quintiles including 60th, 70th, 80th, and 90th. The key findings from dynamic PQR are stated below:

Table 12. Results of dynamic quantile regression: innovation output measured by patents filed by residents.

	0.15	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**
Patents Filed by Residents									
EPU	−0.033 *** (−10.8904)	−0.024 *** (−10.685)	−0.151 *** (−14.440)	−0.098 *** (−5.314)	−0.282 *** (−0.808)	−0.549 *** (−51.624)	−0.869 *** (−72.207)	−0.126 *** (−23.034)	−0.216 *** (−44.273)
GQ	−0.012 (−0.349)	−0.023 (−0.341)	0.045 ** (20.107)	0.144 *** (40.071)	0.341 *** (60.916)	0.321 *** (57.154)	0.415 *** (85.1441)	0.575 *** (90.385)	0.655 *** (124.122)
FDI	0.092 (24.1888)	0.071 (12.0263)	0.015 (10.324)	0.042 *** (15.3877)	0.188 *** (25.1344)	0.362 *** (57.6469)	0.287 *** (45.2408)	0.747 *** (82.8658)	0.748 *** (84.6123)
FD	0.087 (09.717)	0.128 *** (21.181)	0.139 *** (22.322)	−0.276 (−0.641)	−0.0161 (−1.128)	−0.0312 (−1.942)	−0.0183 (−0.916)	0.0028 (0.143)	0.0167 (0.582)
TO	−0.021 (−10.4593)	−0.098 (10.7667)	−0.018 (10.0791)	0.222 *** (32.204)	0.257 *** (37.6046)	0.346 *** (45.474)	0.513 *** (65.0282)	0.5307 *** (68.7167)	0.564 *** (67.739)
Y	0.022 *** (9.235)	0.025 *** (10.232)	0.0304 *** (10.6885)	0.081 *** (10.849)	0.277 *** (31.7818)	0.335 *** (44.9051)	0.361 *** (45.197)	0.479 *** (56.278)	0.475 *** (56.389)
IO^1 (−1)	1.115 *** (109.595)	1.069 *** (101.521)	1.106 *** (101.871)	1.137 *** (112.464)	1.179 *** (117.971)	1.230 *** (126.452)	1.151 *** (113.759)	1.119 *** (115.282)	1.154 *** (121.714)
IO^1 (−2)	−0.1032 (−0.9036)	−0.0602 (−0.6554)	−0.1008 (−1.0823)	−0.1344 (−1.4678)	−0.1741 (−2.6201)	−0.2245 (−2.9386)	−0.1529 (−1.8683)	−0.1329 (−1.7573)	−0.1759 (−3.272)
EPU	−0.015 *** (−9.014)	−0.029 *** (−9.774)	−0.328 *** (−43.842)	−0.381 *** (−48.554)	−0.421 *** (−52.014)	−0.622 *** (−78.511)	−0.734 *** (−87.214)	−0.763 *** (89.914)	−0.833 *** (−97.251)
GQ	−0.095 (−0.001)	−0.012 (−0.047)	−0.056 (0.121)	0.025 *** (8.557)	0.091 *** (11.245)	0.254 *** (35.484)	0.312 *** (42.785)	0.417 *** (52.784)	0.451 *** (55.842)
FDI	−0.003 (−0.001)	−0.001 (−0.007)	0.014 *** (0.007)	0.213 *** (34.215)	0.156 *** (27.512)	0.186 *** (29.754)	0.212 *** (31.745)	0.384 (42.845)	0.313 (42.75)
FD	−0.019 (−0.008)	−0.024 (−0.041)	0.019 *** (6.142)	0.027 *** (8.021)	0.142 *** (21.054)	0.387 *** (47.207)	0.417 *** (52.774)	0.523 *** (64.784)	0.516 *** (64.857)
TO	0.013 (0.002)	0.015 (0.004)	0.006 (0.007)	0.014 *** (8.012)	0.018 *** (7.051)	0.257 *** (37.845)	0.262 *** (38.154)	0.322 *** (43.512)	0.411 *** (52.75)
Y	0.023** (9.854)	0.024 *** (7.852)	0.147 *** (21.745)	0.168 *** (29.845)	0.174 *** (26.773)	0.137 *** (25.441)	0.123 *** (23.154)	0.206 *** (31.842)	0.283 *** (37.845)
IO^1 (−1)	1.057 *** (110.145)	1.054 *** (112.574)	1.076 *** (117.862)	1.643 *** (185.945)	1.062 *** (110.855)	1.548 *** (175.007)	1.062 *** (110.845)	1.403 *** (154.254)	1.046 *** (110.845)
IO^1 (−2)	−0.027 (−0.0215)	−0.0023 (−0.451)	−0.0057 (−0.5512)	−0.0029 (−0.8415)	−0.0091 (−0.5512)	−0.0005 (−0.8451)	−0.0054 (−0.0541)	−0.0081 (−0.5531)	−0.0040 (−0.1201)
R@D									
EPU	0.016 *** (8.124)	0.023 *** (9.845)	0.055 *** (10.452)	0.067 *** (11.421)	0.164 *** (22.751)	0.184 *** (28.341)	0.267 *** (37.154)	0.265 *** (36.754)	0.495 *** (55.845)
GQ	−0.002 (−0.005)	−0.0015 (0.004)	−0.0046 −(0.005)	0.027 *** (5.341)	0.244 *** (35.754)	0.351 *** (46.742)	0.134 *** (24.761)	0.313 *** (43.751)	0.398 *** (48.974)
FDI	−0.0043 (−0.008)	−0.0038 (0.004)	−0.005 (0.005)	0.016 *** (6.045)	0.087 *** (10.541)	0.026 *** (5.742)	0.118 *** (22.841)	0.642 *** (75.845)	0.577 *** (66.844)

Table 12. *Cont.*

	0.15	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
FD	0.0013 (0.007)	0.029 (5.021)	0.032 (5.124)	0.042 *** (6.751)	0.186 *** (28.315)	0.210 *** (32.541)	0.483 *** (59.314)	0.721 *** (83.214)	0.751 *** (88.845)
TO	0.0062 (0.004)	0.021 (5.142)	0.038 (0.599)	0.074 *** (11.452)	0.257 *** (36.745)	0.262 *** (37.552)	0.322 *** (43.854)	0.451 *** (56.754)	0.544 *** (65.254)
Y	−0.0063 (−0.1141)	−0.0099 (−0.417)	−0.0054 (−0.712)	−0.004 (−0.541)	0.034 *** (5.152)	0.045 *** (5.345)	0.132 *** (23.451)	0.283 *** (38.214)	0.287 *** (39.745)
IO^1 (−1)	1.215 *** (132.45)	1.357 *** (144.751)	1.267 *** (133.754)	1.252 *** (134.251)	0.933 *** (98.311)	0.222 *** (35.334)	0.160 *** (25.845)	0.065 *** (11.745)	0.072 *** (3.542)
IO^1 (−2)	−0.0078 (−0.875)	−0.0011 (−0.647)	−0.0092 (−0.812)	−0.0049 (−0.745)	−0.0052 (−0.667)	−0.0044 (−0.554)	−0.0045 (−0.754)	−0.0077 (−0.557)	−0.0055 (−0.664)
					Export				
EPU	−0.056 *** (−8.512)	−0.018 *** (−5.142)	−0.029 *** (−5.214)	−0.145 *** (−45.214)	−0.178 *** (−75.214)	−0.164 *** (−12.512)	−0.295 *** (−8.314)	−0.194 *** (−77.312)	−0.271 *** (−12.512)
GQ	−0.0032 (−0.6614)	−0.0001 (−0.0541)	0.062 *** (−5.314)	0.015 *** (12.512)	0.018** (5.154)	0.024 *** (4.614)	0.029 *** (12.374)	0.096 *** (21.612)	0.233 *** (23.641)
FDI	−0.0051 (−0.6671)	−0.0012 (0.4423)	−0.0019 (−0.4421)	0.046 *** (12.314)	0.191 *** (32.415)	0.281 *** (8.194)	0.318 *** (23.845)	0.356 *** (55.314)	0.426 *** (45.214)
FD	0.018 *** (5.315)	0.019 *** (12.367)	0.024 *** (2.452)	0.087 *** (11.361)	0.028 *** (25.142)	0.132 *** (32.845)	0.252 *** (45.315)	0.461 *** (45.677)	0.527 *** (75.612)
TO	0.0013 (0.6614)	0.0021 (0.5512)	0.028 *** (5.314)	0.268 *** (45.761)	0.121 *** (25.314)	0.128 *** (55.314)	0.211 *** (75.612)	0.275 *** (55.314)	0.341 *** (65.842)
Y	0.014 *** (5.312)	0.011 *** (9.314)	0.0084 *** (5.614)	0.262 *** (75.612)	0.171 *** (21.351)	0.186 *** (45.612)	0.289 *** (29.751)	0.329 *** (44.123)	0.376 *** (56.812)
IO^1 (−1)	1.058 *** (25.314)	1.031 *** (75.612)	1.034 *** (45.315)	1.133 *** (55.751)	1.083 *** (75.612)	1.059 *** (85.751)	1.067 *** (11.512)	1.478 *** (85.315)	1.788 *** (55.314)
IO^1 (−2)	−0.006 (−0.552)	−0.0043 (−0.3315)	−0.0035 (−0.4475)	−0.0024 (−0.2241)	−0.0042 (−0.5585)	−0.0023 (−0.6631)	−0.006 (0.5574)	−0.0018 (0.3312)	−0.0076 (0.8842)

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

First, the regression coefficients of economic policy uncertainty after *EPU* on innovation output exposed a mixed level of association with a statistically positive and negative impact running towards different proxies of innovation output. Negative statistical association was revealed for innovation measures by *PAR* (see panel A in Table 12), innovation measures by *PAnR* (see panel B in Table 12), and innovation measures by *HTE* (see panel D in Table 12) in all quantiles, as expected, suggesting the instable state of the economy discourages innovativeness in the economy. Furthermore, *EPU* creates tension in the economy, which acts as an adverse determinant of investment confidence reduction, and, thus, the aggregated level output is immensely interrupted by lowering innovation practices in the economy. These findings are also supported by Gholipour [93], Clarke [142], and Hall [143] but oppose the findings available in the study of Tajaddini and Gholipour [20]. 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 [144] and Kraft et al. [145]. Usually, uncertainties limit business activities in the economy; however, knowledge-based, high-tech, and innovation-oriented industries persistently seek and immensely rely on R&D outputs. Oakey [146] advocated that investment in R&D allows a higher degree of industrial openness and transforms a high technology and intensive industry.

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 the state of uncertainties.

Van Vo and Le [147] postulated that investment in R&D is the key to the firm's survival with economic uncertainty by exploiting the competitive advantages. The study also advocated that increased investment in R&D creates ample opportunities for the firm in sustainable development and prospects. However, as open innovation is now a predominant paradigm for the knowledge-based economy [148], the cultural need for open innovation dynamics is in a rocket shooting process for companies and non-profit organizations and is able to reduce the cost of open innovation dynamics, known as innovation complexity or open innovation paradox [149]

Second, the nexus between institutional quality and innovation output exhibited a negative association but statistically insignificant results in lower quantiles: 15th, 20th, and 30th. Positive statistical significance was exposed in higher quantities, which is desirable. The verdict is applicable for each model estimation, in line with empirical studies of Canh et al. [150], Tebaldi and Elmslie [83], Kwan and Chiu [151], and Sala-i-Martin [152]. 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 [153]. Furthermore, the protection of intellectual property and legal framework acts as a motivating factor in enhancing the economy's innovation output [154].

Knowledge creation through investing in R&D activities enhances employment development, skills improvements, and technological innovation in the system. Financial systems, particularly bank-based financial institutions, persistently seek 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 [155] argued that the economy has a lower degree of social behaviors, implying that stock civics norms and social restrictions are adversely caused in exporting high-technology goods.

Third, the coefficients of international capital inflows were positively associated with innovation output measured by four proxies. In particular (see panel A in Table 12), the coefficient of *FDI* inflows was 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 is in line with Cheung and Ping [17] and Li, Strange, Ning, and Sutherland [61]. Furthermore, innovation outputs measured by patent applications by non-resident exposed a positive association with *FDI* from 30th to 90th quantiles, and all the coefficients were statistically significant at a 1% level. The effects of *FDI* on R&D as a proxy of innovation output in the economy exhibited negative statistically insignificant association in lower quantiles, i.e., 15th, 20th, and 30th, whereas a positive statistically significant relationship was established in higher quantiles, that is, 40th, 50th, 60th, 70th, 80th, and 90th, respectively (see panel C in Table 12). Study findings are supported by Jian [156]. Moreover, innovation output in terms of high-tech exports exposed negative links with *FDI* but statistically insignificant and positive statistically impacts divulged in higher quantiles, i.e., from 30th to 90th. This finding is supported by Yilun [71] and Cheung and Ping [17].

These findings suggest that the developed economy is primarily occupied with high-tech industries. Thus, inflows of *FDI* accelerate the growth of high-tech industries by channelizing long-term investment. The economy is experiencing the effects of *FDI*, especially in innovation output in technological innovation, by establishing backward-forward interlinkage, completive effects, and knowledge dissemination [157]. *FDI* is believed to put in required resources, innovative technology, marketing strategies, and management expertise for domestic businesses and creates secondary spillovers useful for the domestic economy. A pull effect may occur due to the MNC's proprietary information leakage or the domestic firms' response to international firms' arrival. Spillovers correlate with cross-industry impacts, which may theoretically impact domestic businesses' competitiveness in the same industry and can also affect employment, consumer access, and efficiency in upstream and downstream sectors.

Fourth, the result of financial development espoused positive statistically significant effects on the upper quantiles' innovation output from 30th to 90th. This association was observed in all four proxies of innovation output. Study findings are in line with Zhu et al. [158] and Hsu, et al. [159]. Regarding financial development effects on innovation output, Hsu, Tian, and Xu [159] postulated that the emerging economy is experiencing more major impacts because channelizing and reallocating economic resources tempt innovative tasks in the economy. Furthermore, stockholders' investment protection acts as a catalyst for thriving national innovation [160]. Adequate financing from technological and infrastructural development boosts innovational propensity, establishing a well-functioning financial sector to be a critical factor for development by the path of innovation. Moreover, financial development by offering to strengthen financial systems encourages investments in entrepreneurial innovation development, which eventually accelerates economic growth [161].

In the following section, the study moved to gauge the directional association between economic policy uncertainty, institutional quality, *FDI*, and innovation output by performing previously established Equations (6)–(9). The results of both long-run and short-run causalities are displayed in Table 13, and a summary of short-run causalities is reported in Table 14.

Long-run causality was evaluated by scrutinizing the coefficient of lagged error correction term and ascertaining long-run causality; the coefficient needed to be negative and statistically significant. Study finding revealed several causal estimations: the coefficient of lagged error correction terms was statistically significant at 1% and 5% levels, principally in the causal model with innovation output as the dependent variable in the respective equation. Study findings suggested that economic policy uncertainty, institutional quality, and *FDI* are critically important for fostering innovativeness in the economy. Furthermore, the feedback hypothesis was 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. Moreover, the open innovation phase did not take place in isolation but relied on many players and entailed a series of institutions capable of supporting and improving this process [162]. Literature suggested that the position of the government and its public funding can stimulate open innovation among actors in the external environment [163,164].

The short-run causality test results revealed several directional causalities running in the empirical estimation (see Table 12); however, the study intended to address causal effects running from *EPU*, *IQ*, and *FDI* to innovation outputs. Considering the nature of the causal direction, the study reported causalities into two groups.

First, there was evidence in favor of supporting feedback hypothesis, suggesting bidirectional relationships in the assessment. The study divulged feedback hypothesis was 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 was proxied by patent applications by residents (PATr) and non-residents (PATnr), innovation output and *FDI* [*IO*←→*FDI*), and economic growth and innovation output [*IO*←→*FDI*]. Second, the study unveiled 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 established that innovation output in the economy guided macro fundamental performance. However, innovation output induced the economy's aggregate performance.

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 ***

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

Table 14. Summary of Granger causality test.

Causality	[1]	[2]	[3]	[4]
$IO \leftarrow \neq \rightarrow EPU$	←	←	←	←→
$IO \leftarrow \neq \rightarrow IQ$	←→	←→	NA	NA
$IO \leftarrow \neq \rightarrow FDI$	←	→	→	←→
$IO \leftarrow \neq \rightarrow FD$	←	←	←	←
$IO \leftarrow \neq \rightarrow TO$	←	←	NA	NA
$IO \leftarrow \neq \rightarrow Y$	←→	→	←→	NA
$EPU \leftarrow \neq \rightarrow IQ$	NA	NA	NA	←
$EPU \leftarrow \neq \rightarrow FDI$	←→	←→	→	→
$EPU \leftarrow \neq \rightarrow FD$		←→	→	←
$EPU \leftarrow \neq \rightarrow TO$	←	←→	←	←
$EPU \leftarrow \neq \rightarrow Y$	→	←→	NA	NA
$IQ \leftarrow \neq \rightarrow FDI$	NA	←	←	←
$IQ \leftarrow \neq \rightarrow FD$	←→	←	→	→
$IQ \leftarrow \neq \rightarrow TO$	→	←	←→	←
$IQ \leftarrow \neq \rightarrow Y$	←	←	←→	→
$FDI \leftarrow \neq \rightarrow FD$	←	←	←	←
$FDI \leftarrow \neq \rightarrow TO$	←→	←	NA	←
$FDI \leftarrow \neq \rightarrow Y$	←	←→	←	←→
$FD \leftarrow \neq \rightarrow TO$	←	←→	←→	←
$FD \leftarrow \neq \rightarrow Y$	NA	←	←	←
$TO \leftarrow \neq \rightarrow Y$	→	→	→	→

Note: ←→ specifies bidirectional causality, "←/→" denotes unidirectional causality, and NA specifies no causality.

5. Findings and Policy Suggestions

The study intended 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 established a negative statistically significant association with innovation output measured by patent application from residents, non-residents, and high-tech exports. In contrast, a positive statistically significant association was revealed with innovation output measured by investment in R&D. These findings suggested that the impact of *EPU* was not conclusive because diverse proxy selection produced either directional association. However, in terms of final output through innovation, it was 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 the state of uncertainty accelerates investment in R&D, indicating that figuring out the alternative ways of getting rid of uncertainty and availing market opportunity creates shocks in the economy.

Institutional quality divulged a positive statistically significant association with innovation output in all four tested models in the higher quantities. These findings suggested an effective legal framework and efficiency in managing investor rights protection act as motivating factors for innovation. Furthermore, regulated government behavior 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 a market climate conducive to innovation capabilities.

Finally, regarding foreign capital flows and innovation output, study findings established a positive statistically significant association that was desirable based on existing literature. *FDI* is a source of technology transfer along with knowledge sharing mechanisms. Arun and Yıldırım [69] advocated that *FDI* intensifies innovative activities both at the firms level and in the aggregate level through appreciating employees' tendency for innovation and injecting pressure on domestic firms to cope with MNCs the knowledge innovation as an output of investment in R&D. The foreign cooperation among firms [165,166] that seems to exist in particular developing markets should be correlated with open innovation [167]. This international cooperation, which also benefits businesses in the acquisition and the development of advanced technology, raises and coordinates open innovation in the economy [168,169].

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 mitigate the state of uncertainty in the economy. It is crucial that both investors' 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 behavior and participation in the market should be focused on innovation output. That means actions towards investor's rights and protection, a strongly regulated framework, and institutional efficiency induce the 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 bring innovativeness in their operations. Still, it is a regulatory obligation to offer a pleasant ambiance for both participants in the economy.

The present study is not flawless, indicating the inherent limitation of the study. The present form only considered panel data with a sample of 22 countries, and the empirical finding might document different elasticities with the inclusion of more countries in the panel. An empirical study with a single country may reveal diverse direction as well. Therefore, the future study can be initiated with a larger panel and more proxy variables, e.g., constructing an innovation output index (IOI) by performing principal component analysis.

Author Contributions: Conceptualization, M.Q. and T.T.; methodology, M.Q. and A.M.M.; software, M.A. and T.T.; formal analysis, M.Q., T.T. and M.A.; data curation, M.A.; writing—original draft preparation, M.Q., T.T., M.A. and A.M.M.; writing—review and editing, M.Q. and T.T.; visualization, M.A. and T.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available in with reasonable request to corresponding author of the study.

Acknowledgments: We would like to express our heartfelt gratitude to the academic editor for his thoughtful suggestions. Furthermore, we would like to thanks the three esteem reviewers for their fruitful comments, which assists us immensely during the peer review process and increase the standard of the present manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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