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Information and Communication Technology (ICT), Energy Volatility, and Output Volatility Nexus: A Global Panel Data Analysis

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ABSTRACT The current research contributes to the literature by evaluating the influence of Information and Communication Technology (ICT), energy volatility, and output volatility on global economies over the time period 1971-2020. The analysis was based on panel dataset for 154 nations. For empirical analysis, the study used pooled OLS, fixed effects, and random effects models including 2SLS and GMM methods. Moreover, to ensure the stability of the findings, the study ran a series of robustness analyses. The results suggested that ICT mitigates economic instability and output volatility. Energy use volatility, on the other hand, yielded considerable positive and statistically significant outcomes and augmented output volatility. This study provides important policy recommendations for implementing ICT-enabled technologies. Moreover, it is advised that the government should promote ICT technologies which result in lower volatility and protracted development of the economy.

INDEX TERMS energy consumption volatility, Information and Communication Technology (ICT), output volatility, panel data

I. INTRODUCTION

Every competitive economy relies on stable economic growth to achieve the aim of a high standard of living and long-term economic growth. It impacts the nation's current and future well-being. Globally, economists and decision-makers showed a growing interest in the idea of output volatility during the past few decades. Output volatility (OV) represents the GDP fluctuations in the economy. Economists are concerned about high OV because several studies showed that it has a negative effect on economic growth or is associated with the lower growth [1]. OV has high welfare costs, especially in the poor countries.

Considerable research explored the different triggers of the OV. Various research connects OV with trade openness [2], economic growth [3], inflation volatility [4], and environmental degradation [5] along with the financial development [6]. Similarly, literature also pointed out the other determinants of the OV as well, such as terms of trade uncertainty [6], government type [7], and population [7], [8].

The world has changed dramatically in recent decades as the ICT revolution has displayed its expansion into diverse levels, such as organization, country as well as sector level [9]. Considerable research has been conducted to contribute ICT penetration to economic growth [10], [11]. According to a thorough review by [10], many developing nations used their comparative advantage of being behind the developed nations to spur economic development. It was made possible by the notable advancements in internet-based IT. [12] pointed out that the technological

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progress could influence business cycles in the open economy.

No study directly looked into the clout of ICT on the OV so far. However, there are certain ways which show that ICT contributes to decrease in OV. Due to ICT, there is enhancement in electronic devices and lessening asymmetric information which cause reduction in transaction cost and it would result to create efficient market in the economy which leads to lower OV. Likewise, network externalities also reduce OV by increasing the number of subscribers which increase the market competition as well as efficient market creation. Moreover, due to ICT, financial economy goes higher through which the productivity and investment increases. It helps to build the political and strategic relationships within countries which support to counter the instability, leading to reduce the OV. Likewise, with ICT, the effectiveness of education improves which aids literacy movement along with enhancing the scope of education by facilitating mobile learning. It also facilitates the research and scholarly communication which results in the improvement of resource allocation, leading to lower OV. However, there is a strong need to check the impact of ICT on OV.

Besides, energy would be seen as a basic intermediate and a production-accelerating factor which plays a central role in economic growth, development, and industrial growth. The studies, such as [13] and [14] found out the uni-direction causality among energy consumption and the GDP growth, while [15] and [16] found out the bi-directional causality among the GDP and the energy consumption. Additionally, some studies concluded that there is no casual association between the GDP growth and the energy consumption [17].

However, previous research focused on the relationship between GDP growth of the economy and energy consumption, but it totally ignores the unpredictable fluctuations among OV and energy consumption volatility. In this regard, limited evidence determined the impact of volatility of energy consumption on the OV. For instance, [18] explored that there is a largest reduction in the macro-economic volatility due to the highly energy consumption in United States. It is also important for the policymakers to know the relationship between the volatility of energy consumption and the OV.

The current investigation was specifically designed to explore the linkage between energy consumption volatility, ICT, and OV. It employed a novel concept called energy consumption volatility which was never employed in any of the previous researches. Secondly, this study employed an index of ICT, based on different measures of ICT. Thirdly, the study was not limited to a single country's analysis. Rather, it presented a global picture of the analysis involving a large number of countries over the time period from 1971 to 2020. The current research gathered the data from World Bank (2021). Finally, it used a variety of essential econometric methodologies to investigate the better empirical results along with robustness analysis to ensure the integrity of the data and empirical results.

The research questions of the study are as follows:

(i) Is energy consumption volatility have supportive impact on OV?

(ii) Is ICT impact OV in a favorable way?

(iii) Do different proxies of ICT have similar effects on OV?

(iv) Is the relationship between "OV and energy consumption volatility" and "OV and ICT" sensitive to inclusion of additional determinants of OV?

The current study is organized in the following pattern. Section 1 is based on the introduction. Whereas, section 2 provides extensive, theoretical, and empirical previous literature on energy consumption, ICT, and OV linkages. Section 3 encompasses the analytical framework and econometric methodology. Section 4 presents theory of variables used sources of data and descriptive analysis of the data. Section 5 demonstrates empirical findings of the study. The last section 6 comprises the conclusion, limitations, and policy recommendations of the study.

II. LITERATURE REVIEW

This section is divided into two sub-sections. Section 2.1 reviews the literature on ICT and OV, while section 2.2 reviews the literature on energy use and OV, respectively.

A. INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) AND OUTPUT VOLATILITY

Modern economic growth theories focus on the contribution of innovation and technology development to the growth. These theories also indicate that ICT investments are crucial to economic development. The question arises that how does ICT effect the developing and emerging economies? There are various ties between ICT and economic output in both advanced and emerging economies. Firstly, with E-government adoption, ICT expenditure reduces firms operating costs. Secondly, ICT assists in preparation and advising services. Thirdly, it enhances the access to pertinent data. Fourthly, ICT may be leveraged to lower travel expenses and processing fees. Although, these facilities are not exclusive to emerging markets, they regularly offer services which were previously unavailable in both digital and non-digital markets.

Empirical studies show that ICT contributed mixed results to the economic growth. For instance, [19] and [20] concentrated on the potentials of ICT in US and verified that ICT contributed positively to US economic growth. They found that the spike in use of IT capital as well as faster increased efficiency in computer production account for roughly two-thirds of the acceleration in the increase in productivity during the two halves of the 1990s. [21] concluded for Finland that ICT contributes three times more to the economic growth than electricity and electricity's impact on growth was smaller than ICTs in the United States.

Similarly, some researchers believe that broadband and internet can contribute to economic growth by lowering market attrition and the mandatory information price of entry into the market [22], [23]. However, [24] discovered that ICT measures promote both regional and global economic financial growth. In contrast, ICT negatively impacts the economic growth as well. For instance, [25] tested the association among ICT accumulating capital and total factor production (TFP) emergence across U.S. manufacturing companies and discovered that ICT has a reverse bias elasticity. Moreover, [26] discovered that ICT influences the growth of economy via a variety of routes including FDI and spillover effects. ICT also helps to promote the economic growth in many advanced and newly developed economies but not in emerging economies. However, the relationship between ICT and

OV was overlooked in the literature. The role of ICT in managing OV is critical as its usage overcome transaction costs, information asymmetries and enhances economic efficiency [27].

B. ENERGY CONSUMPTION AND OUTPUT VOLATILITY

Energy's position in the growth of economy was a contentious issue in the literature. Energy inputs are intermediate in conventional neo-classical growth models, while land, labor, and capital are considered as basic variables, implying that energy consumption and production are neutral. Ecological models, on the other hand, indicate that electricity plays a significant role in income generation. Numerous investigations were conducted to explore the link amongst the energy and the economy in several countries with many of them focusing on the utilization of energy from the renewable sources [28], [29]. [30] explored the relationship amongst renewable energy consumption, ecological footprint, and the urbanization. It was investigated that energy consumption leads to the economic growth in the economy and all the factors whether its urbanization, growth of the economy or the financial evolution. All these factors promote to environmental destruction. Other researchers, on the other hand, sign up for the conservative assumption that economic growth affects the energy usage. For instance, [28] found the long-run existence relationships among energy-related inflows and the economic growth. Similar results were validated by [30]. However, [31] investigated the volatility of oil and energy prices from January 1945 to August 2005 and discovered that crude oil, natural gas, and refined oil prices were more unpredictable than all domestically manufactured items.

Another deficiency, throughout the literature, is that certain previous studies focused on the association amongst energy consumption and GDP growth, completely ignoring how volatile fluctuations in energy use affect GDP volatility. Resultantly, there is a scarcity of empirical evidence on the consequences of energy consumption volatility on OV. However, policymakers need to understand the relationship among energy consumption volatility and OV. From this perspective, [32] empirically investigated the relationship between real GDP volatility and the energy consumption volatility in the UK and found out the significant impact. The results of the Markov regime-switching model revealed that energy consumption volatility plays a substantial role in determining GDP volatility behaviour. Understanding the swings in energy consumption is a necessity to explore how production growth fluctuates over time, in this regard. It is also worth seeing if the impacts of energy consumption volatility on GDP volatility differ in low- and high-volatility environments.

The explanation above makes it abundantly evident that there is little discussion in the literature pertaining to ICT and energy volatility affects OV. OV is a hot topic for the policymakers as well as the economists. To summarize the above discussion, ICT has mixed effect on OV. However, no evidence proves the impact of energy volatility on OV. Since there is little or no empirical research on this subject globally, the current study filled an essential gap in existing research by contributing to the discussion of OV, energy consumption volatility, and ICT. This study is not dependent on a certain period and also presents a global perspective of analysis employing a vast number of nations.

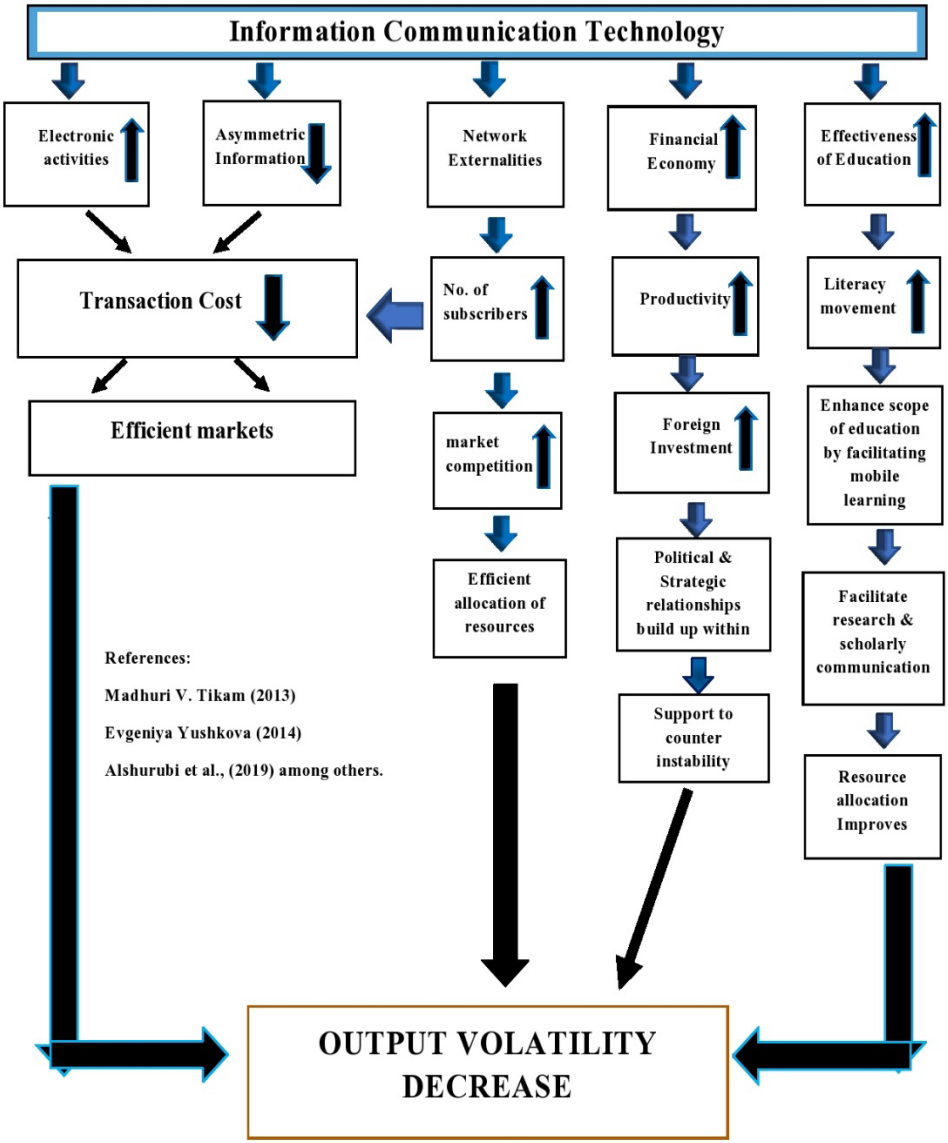

Figure 1. Flow chart of ICT and OV

III. METHODOLOGY

A. MODEL SPECIFICATION AND DATA

The importance of new technological developments, information, and discoveries are continually increasing. A country's wealth is determined by its national output. Resultantly, the fluctuations in output are critical to a country's prosperity and development. This

study focused on energy consumption volatility and ICT as determinants of OV. The data collection spans 50 years from 1971 to 2020 and includes 154 countries.

Standard deviation (SD) of the per capita GDP was the benchmark metric of the volatility [33], [34], [35]. In the empirical literature, it is also very common to use log of GDP to measure the growth in order to determine the volatility [36], [37]. However, in the current research, the standard deviation of GDP per capita was taken to measure the OV. OV can be created by taking the 3-year standard average of Gross Domestic Product (GDP). Following the discussion of the theoretical framework, the study now reports empirical requirements of all the models used in this study in this section. The relationship between "OV and energy consumption volatility" and "OV and ICT" can be expressed as a panel equation.

$$\text{Output Volatility} = \alpha_1(\text{DP})_{it} + \alpha_2(\text{OV})_{it-1} + \alpha_3 SD(TO)_{it} + \alpha_4 \text{SD}(\text{INF})_{it} + \alpha_5 \text{SD}(\text{EC})_{it} + \alpha_6(\text{ICTIndex})_{it} + \mu_{it} + \varepsilon_{it}$$

Where i= Countries 1,2,…..,217, t= time period.

Where output volatility is the standard deviation of the per capita GDP, GDP is the measure of the growth which is measured through per capita GDP. The current study used the lag of the dependent variable as well, so it is denoted as $\alpha_2(\text{OV})_{it-1}$. SD (TO) and, SD (INF) as standard deviation for trade openness and standard deviation of inflation, respectively. SD (EC) is the standard deviation of the energy consumption. ICT is a novel concept so, the current study used three common measures of ICT. The first was fixed telephone subscription, the second one was mobile cellular subscription, and the third one was individuals using the internet. These proxies were used in index form. The data was used in subscription per 100 of these proxies and index was calculated by simple mean value of these three measures. In the model, the term μ represents the specific countries effect, while ε is said to be the error term. Likewise, terms i and t denote the country and time period, respectively.

In the above equation, the impact of GDP on OV is denoted as α_1, the impact of lag of OV on OV is α_2, impact of trade openness on OV is α_3, impact of inflation on OV is α_4, and the impact of energy consumption volatility on OV is α_5 and α_6 is the impact of ICT on OV.

It would be determined whether the development of financial intermediaries has an impact of the real and the monetary sectors on output volatility or not. Therefore, for this purpose the volatility of trade was used as well as volatility of inflation in the current empirical research.

IV. DATA AND VARIABLE DESCRIPTION

To describe the effects of ICT and energy consumption volatility on OV, the panel data set was used. Panel data, used in the current reseach, included 154 global countries over the time period from 1971 to 2020. The data was gathered from World Development Indicator (WDI) for the empirical analysis. The summary of the data sources of all the variables used in the construction of other variables are reported in the following table.

TABLE I

SUMMARY OF DATA SOURCES OF VARIABLES

Variables	Denoted by	Measured in
Dependent Variable		
Output Volatility	OV	Standard deviation of GDP per capita, measured in the constant 2010 US dollars
Focused Variables		
Energy Use Volatility	EUV	Standard deviation of energy use which is measured in kg of oil equivalent per capita
Fixed telephone subscription	FTS	Per 100 people
Mobile Cellular Subscription	MCS	Per 100 people
Individuals using the Internet	IUI	Per 100 people
Control Variables		
GDP per capita	GDPPC	Constant 2010 US dollars
Volatility of Trade Openness	VTO	Standard deviation of trade openness measured in % of GDP
Volatility of Inflation	VINF	Standard deviation of consumer price index measured in 2010 = 100
Other Variables for Sensitivity		
Life expectancy at birth	LE	Years
Current account balance	CAB	percentage of GDP
Fertility rate, total	FERR	Births per women
Population growth	AGRS	Percentage of GDP
Agriculture, forestry, and fishing, value added	POPG	Annual percentage
General government final consumption expenditure	GC	Percentage of GDP
CO2 emissions	CO2	Metrics tons per capita
Nitrous oxide emissions	NO	Thousand metric tons of CO2 equivalent
Methane emissions	ME	Kt of CO2 equivalent
Total greenhouse gas emissions	GGE	Kt of CO2 equivalent

The descriptive statistics offered in this part include information about the two measures of central tendency, mean and median, minimum values of the variables as well as the maximum values of the variables. Moreover, standard deviation was used to reflect the data dispersion and the total number of observations. The descriptive analytics finding for all variables are shown in the table below.

TABLE II
DESCRIPTIVE STATISTICS

Variables	Obs.	Mean	Median	Std. Dev.	Minimum	Maximum
Dependent Variable						
Output volatility	4233	487.55251	186.3893	1218.547	0.568753	27799.44
Focused Variables						
Energy Use Volatility	4233	85.50767	38.86661	149.1675	0.010218	2111.344
ICT Index	4233	25.39657	14.71435	27.48578	0.00000	126.4974
Control Variables						
GDP per capita	4233	14009.68	5322.385	17666.05	276.0559	111968.3
Volatility of Trade Openness	4233	5.351086	3.572547	6.031967	0.000175	113.0318
Volatility of Inflation	4233	4.207171	2.468004	10.84574	2.57e-10	296.8047

The mean and the median values of the OV are 487.55251 and 186.3893 respectively, while standard deviation is 1218.547. The minimum value of the OV is 0.568753 and the maximum value of the OV is 27799.44. Mean value of the energy use volatility and ICT index are 85.50767 and 25.3965, respectively. While, the median of energy use volatility and ICT index are 38.86661 and 14.71435, respectively. The standard deviation of energy use volatility and ICT index are 149.1675 and 27.48578, respectively. Moreover, the minimum value of the energy use volatility and ICT index are 0.010218 and 0.000, respectively. While, the maximum value of energy use volatility and ICT index are 2111.344 and 126.4974, respectively.

Correlation is a statistical approach for determining the direction and degree of a linear relationship between two variables and explaining it. This is crucial to understand to process the issue of the multi-collinearity.

TABLE III
CORRELATION MATRIX

	Variables	1	2	3	4	5	6
1.	Output Volatility	1.0000					
2.	GDP Per Capita	0.3330	1.0000				
3.	Energy Use Volatility	0.2150	0.4337	1.0000			
4.	ICT Index	0.1424	0.5654	0.2673	1.0000		
5.	Volatility of Trade Openness	0.1801	-0.0520	0.1151	0.0137	1.0000	
6.	Volatility of Inflation	0.0246	-0.0038	-0.0061	-0.0101	0.0022	1.0000

Table III exhibits the results of correlation matrix and it is stated that output volatility is positively correlated with the GDP per capita, volatility of energy use, ICT index, volatility of trade openness, and volatility of inflation. As the correlation coefficient of any variable is positive, representing that the OV would also increases.

V. RESULTS AND DISCUSSION

This section discusses the results that how ICT and volatility of energy consumption could affect the OV. Different econometric techniques were used for this purpose referenced in section 3. The current study used the panel data regressions for the analysis including pooled ordinary least square technique, fixed effect technique, random effect technique, two stage least square as well as the generalized method of moments technique. To ensure that the findings were stable, the current study employed sensitivity analysis. The whole estimation was done with 154 countries and the study also used famous statistical packages of Stata 15. The data was taken from world development indicator for the analysis.

A. POOLED ORDINARY LEAST SQUARE NEXUS

The pooled ordinary least square technique is estimated by simple OLS regression which is overly restrictive in that it specifies the constant intercept as well as coefficients assumptions. Error terms describe how things change over time and between entities. When the model is properly and correctly evaluated but the independent variables are not correlated with the residuals, than OLS can be used to estimate it.

TABLE IV
POOLED ORDINARY LEAST SQUARE RESULTS OF OUTPUT VOLATILITY AS DEPENDENT VARIABLE

Variables	Output Volatility
GDP per capita	0.0149*** (16.21)
Lag of Output Volatility	0.432*** (55.10)
Energy Use Volatility	0.237** (2.60)
ICT Index	-1.349* (-2.52)
Volatility of Trade Openness	16.14*** (7.76)
Volatility of Inflation	22.77*** (19.05)
R-Square	0.5871
F-Statistics	1001.44
F-Probability	0.0000
No of observations	4233

***p<0.01, **p<0.05, *p<0.1

Table IV represents the results of pooled (OLS) technique of the estimated equation reported in chapter 03. There is a positive connection between GDP per capita and the OV. The results showed that the 1% increase in the GDP per capita would lead to an increase in the OV by 0.0149 unit. OV is substantially a long-lasting concept. Therefore, the current study used panel data set in the analysis. Higher GDP tends to increase OV. It may be the cause that the channel included in GDP enhancement is very volatile which results in OV. The lag of OV was used in this research which has a significant and positive impact on the OV. Same results were concluded by [5], [38]. It

indicates that the 1% increase in the lag of OV would lead to increase in the OV by 0.432 units.

There is considerable positive and significant impact of energy consumption volatility on the OV. The results indicated that the 1% increase in the volatility of energy consumption would lead to increase in the OV by 0.237 units. The growth in the output is highly volatile if there are variations in the consumption of the energy. ICT suggested that there is a negative impact of OV as it reduces the output stability. It would also result in the decrease of the production in the economy. ICT is a novel concept and three common proxies were used to calculate the ICT index here. Due to increase, the technology there is a reduction in asymmetric information which cause to lessen the transaction cost which would create the efficient market in the economy which leads to lower the OV. The results indicated that the 1 unit increase in the ICT index would lead to decrease in the OV by 1.349 units.

Volatility of trade shows instability in the real sector. From the estimated result, it was found that the volatility of trade has a positive and significant impact. As the results indicated that the OV would be increased due to the deterioration and the interference in real sectors. Same results were concluded by [5], [36], [39], and [40]. According to them, due to the trade openness in the economy, the volatility would be increased which may lead to the external shocks in the economy. It indicates that the 1% increase in the volatility of trade openness would lead to increase in the OV by 16.14 units. Volatility of inflation shows the instability in the monetary sector. The findings showed that the volatility of inflation has a positive and significant impact on the OV. The results indicated that the OV would be increased due to the deterioration and the interference in monetary sectors. Same results were concluded by [36]. It indicated that the 1% increase in the volatility of inflation would lead to increase in the output volatility by 22.77 units.

Moreover, the findings revealed that the value of R- square is 0.5871 which indicates that there is 58% variation in the dependent variable that is output volatility due to the independent variables in the analysis. The total number of observations are 4233, while the value of the F- statistics is 1001.44 and the probability of the F-statistics is 0.0000.

B. FIXED EFFECTS AND RANDOM EFFECTS RESULTS OF OUTPUT VOLATILITY

The intercept does not change for all the countries in the pooled OLS model. Likewise, in the cross sections, the coefficients remain identical. Due to the limitation of this assumption, sometimes the deformation among the variables is being faced. Therefore, other techniques, such as fixed effect and the random effect technique are employed for the analysis. The results of fixed effect and random effect techniques are reported in table V. Firstly, the fixed effect model results in column (1) are considered.

The findings of the fixed effect model suggested that there is consistency in the results. The results indicated that with 1% increase in the GDP per capita, lag of OV, volatility of energy consumption, and volatility of trade and volatility of inflation would lead to an increase in the OV by 0.0222, 0.418, 0.0907, 17.37, and 24.94 units, respectively. By contrast, ICT reduces the output stability. It would also result in the decrease of the production which creates the asymmetric information in the economy. The results indicated that

the 1% increase in the ICT index would lead to decrease in the OV by 3.011 units. The results were correctly estimated in the analysis. Moreover, the findings revealed that the value of R- square is 0.5818, total no of observations are 4233, while the value of the F- statistics is 747.19 and the probability of the F- statistics is 0.0000.

TABLE V
FIXED EFFECT AND RANDOM EFFECT RESULTS OF OUTPUT VOLATILITY

Variables	(1)	(2)
	Fixed Effects Model	Random Effects Model
Output Volatility		
GDP per capita	0.0222*** (7.90)	0.0149*** (16.21)
Lag of Output Volatility	0.418*** (51.77)	0.432*** (55.10)
Volatility of Energy Use	0.0907 (0.71)	0.237** (2.60)
ICT Index	-3.011*** (-4.27)	-1.349* (-2.52)
Volatility of Trade Openness	17.37*** (7.05)	16.14*** (7.76)
Volatility of Inflation	24.94*** (20.08)	22.77*** (19.05)
R-Square	0.5818	0.5871
Chi2(6)	------	6008.61
Prob > Chi2	------	0.0000
F-Statistics	747.19	------
F-Probability	0.0000	------
No of Observations	4233	4233

***p<0.01, **p<0.05, *p<0.1

The Random effect model results are considered presented in the column 2. When there is an increase in the number of observations, then it would also affect the unknown parameters in the fixed effect model. To tackle this situation, the random effect regression is selected.

The findings showed that due to 1% increase in the per capita GDP, lag of OV, Volatility of energy consumption, and volatility of trade and volatility of inflation would lead to an increase in the output volatility by 0.0149, 0.432, 0.237, 16.14 and 22.77 units, respectively. Additionally, ICT is considered to be volume up and the speed of capital inflows. The results concluded that the 1% increase in the ICT index would lead to decrease OV by 1.349 units. Overall, ICT mitigates the economic instability and the OV. In terms of the model selection, the Hausman test was used under the assumption that the fixed effects model's null hypothesis was adequate. The model has p< 0.1, indicating that fixed effects model is more recommended over random effects model. However, the value of R- square is 0.5871 and the total number of observations are 4233, while the value of the Chi-square is 6008.61 and the probability of the Chi-square is 0.0000.

C. TWO STAGE LEAST SQUARE RESULTS

The problem of endogeniety exists in the estimated model of the current study. Since there are contemporaneous links between ICT, energy consumption volatility, and OV. Moreover, when the problem of endogeniety arises then OLS results get biased. Therefore, this problem would be tackled by applying the two stage least

square estimation. In order to carry 2SLS, the lagged value of the endogenous variable was employed as instrumental variable. Therefore, in empirics, the lag of ICT Index was used as instrumental variable.

TABLE VI
TWO STAGE LEAST SQUARE (2SLS) RESULTS

Variables	Output Volatility
GDP per capita	0.0150401*** (16.29)
Lag of Output Volatility	0.4312033*** (55.05)
Energy Use Volatility	0.2350334* (2.59)
ICT Index	-1.454228* (-2.69)
Volatility of Trade Openness	16.16851*** (7.76)
Volatility of Inflation	22.80299*** (19.07)
R-Square	0.5870
Chi-square(6)	6005.09
Probability > Chi-square	0.0000
No of observations	4224

***p<0.01, **p<0.05, *p<0.1

The conclusions of 2SLS were reported in Table VI. The lag of ICT Index was employed as an instrumental variable in the empirical investigation. The findings revealed that 1% increase in the GDP per capita would lead to increase in the OV by 0.0150401 units. [9] came up with the opposite results. According to them, GDP growth is negatively linked with the OV. The results of lag of OV, energy consumption volatility, volatility of trade and volatility of inflation shows that with 1% increase in the lag of OV, energy consumption volatility, volatility of trade and volatility of inflation, the OV would increase by 0.4312033, 0.2350334, 16.16851, and 22.80299 units, respectively.

On the other hand, ICT index comes up with the opposite results. The findings showed that the 1% increase in the ICT index would lead to decrease the OV by 1.454228 units. Moreover, the value of R-square is 0.5870 and total number of observations are 4224, while the value of the Chi-square is 6005.09 and the probability of the Chi-square is 0.0000.

D. ONE-STEP GENERALIZED METHOD OF MOMENTS (GMM) RESULTS

To address issues of potential endogeneity, omitted variables, measurement error, and heteroscedasticity in the study, one-step GMM is used. To eliminate time invariant effect, system GMM includes lag of dependent variable as independent variable. So, the lag of ICT Index was used as the instrumental variable in the conducted research.

TABLE VII
ONE-STEP GENERALIZED METHOD OF MOMENTS (GMM) RESULTS

Variables	Output Volatility
GDP per capita	0.0150*** (5.98)
Lag of Output Volatility	0.431*** (4.83)
Energy Use Volatility	0.235 (1.78)

Variables	Output Volatility
ICT Index	-1.454** (-2.81)
Volatility of Trade Openness	16.17*** (4.16)
Volatility of Inflation	22.80*** (4.41)
R-Square	0.5870
Chi-square (6)	1266.36
Probability > Chi-square	0.0000
No of observations	4224

***p<0.01, **p<0.05, *p<0.1

Table VII reported the results of GMM. Conclusion implies that due to 1% increase in the GDP per capita, lag of OV, energy use volatility, volatility of trade and volatility of inflation, it would lead to increase in the OV by 0.0150, 0.431, 0.235, 16.17, and 22.48 units, respectively. By contrast, empirical analysis shows the negative relationship of the ICT on OV as it reduces the output instability. The results indicated that due to 1% increase in the ICT index, it would lead to decrease in the OV by 1.454 units. The value of R- square is 0.5870, total number of observations are 4224, while the value of the Chi-square is 1266.36 and the probability of the Chi-square is 0.0000.

E. SYSTEM GENERALIZED METHODS OF MOMENT (GMM) RESULTS

System GMM is used to tackle the endogeneity problem in the data. To eliminate time invariant effect, system GMM includes lag of dependent variable as independent variable. Therefore, the lag of ICT Index was used here as the instrumental variable in the research.

TABLE VIII
SYSTEM GENERALIZED METHOD OF MOMENTS (GMM) RESULTS

Variables	Output Volatility
GDP per capita	0.0430*** (13.75)
Lag of Output Volatility	0.0761*** (4.97)
Energy Use Volatility	0.550 (1.37)
ICT Index	-10.02*** (-8.52)
Volatility of Trade Openness	90.02*** (7.53)
Volatility of Inflation	161.7*** (31.00)
AR (2)	0.029
Sargan Test	0.625
Instruments	134
Groups	154
No of observations	4233

***p<0.01, **p<0.05, *p<0.1

Table VIII concluded the results of system GMM. Conclusion implies that due to 1% increase in the GDP per capita, lag of OV, energy use volatility, volatility of trade and volatility of inflation, it would lead to increase in the OV by 0.0430, 0.0761, 0.550, 90.02, and 161.7 units, respectively. By contrast, empirical analysis shows the negative relationship of the ICT on OV as it reduces the output instability. The results

indicated that due to 1 percent increase in the ICT index, it would lead to decrease in the OV by 10.02 units. However, the value of Arellano Bond (AR) test is 0.029 and the value of Sargan test is 0.625. Moreover, the number of instruments are 134, while number of groups are 154. Lastly number of observations are 4233.

F. SENSITIVITY ANALYSIS OF OUTPUT VOLATILITY AND ENERGY CONSUMPTION BY INCORPORATING ICT INDICATORS

The findings of the robustness were examined in this section of the investigation. To ensure that the findings were stable, a series of robustness assessments were run. Some extra control variables were added to assess the sensitivity of the results. Columns 1 to 11 in Table IX (a, b) include life expectancy at birth, current balance account, total fertility rate, population growth, value added of forestry, fishing and agriculture, final consumption of general government expenditure, CO2 emissions, emissions of nitrous oxide, methane emissions, and the total greenhouse gas emissions at alternative control variables, respectively. These additional control variables are included one by one to assess the robustness of findings.

TABLE IX(A).
RESULTS OF SENSITIVITY ANALYSIS AND RESULTS OF OUTPUT VOLATILITY AND ENERGY CONSUMPTION BY INCORPORATING ICT INDEX

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Output Volatility					
GDP per capita	0.0149*** (16.21)	0.0147*** (14.89)	0.0117*** (19.55)	0.0149*** (15.75)	0.0130*** (14.70)	0.0150*** (16.23)
Lag of Output Volatility	0.432*** (55.10)	0.432*** (55.04)	0.482*** (49.87)	0.432*** (55.03)	0.450*** (53.22)	0.432*** (55.08)
Energy Use Volatility	0.237** (2.60)	0.235** (2.59)	0.321*** (5.29)	0.236** (2.59)	0.252** (3.05)	0.214* (2.30)
ICT Index	-1.349* (-2.52)	-1.554** (-2.58)	-0.911** (-2.84)	-1.451* (-2.48)	-1.769*** (-3.44)	-1.185* (-2.14)
Volatility of Trade	16.14*** (7.76)	16.18*** (7.77)	8.755*** (6.54)	16.15*** (7.76)	14.24*** (7.63)	16.20*** (7.78)
Volatility of Inflation	22.77*** (19.05)	22.79*** (19.05)	14.03*** (11.96)	22.77*** (19.04)	16.51*** (13.02)	22.78*** (19.05)
Life expectancy at birth	---	1.363 (0.71)	---	---	---	---
Current Account Balance	---	---	0.302 (0.43)	---	---	---
Fertility rate, total	---	---	---	-3.390 (-0.38)	---	---
Agri, forestry, and fishing	---	---	---	---	-3.996** (-3.17)	---
Population Growth	---	---	---	---	---	9.973 (1.09)
R- Square	0.5871	0.5871	0.6533	0.5871	0.5810	0.5872

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Output Volatility					
F- Statistics	1001.44	857.55	1002.87	857.43	750.25	858.51
F- Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No of Observations	4233	4229	3734	4229	3795	4232

***p<0.01, **p<0.05, *p<0.1

TABLE IX(B)
RESULTS OF SENSITIVITY ANALYSIS AND RESULTS OF OUTPUT VOLATILITY AND ENERGY CONSUMPTION BY INCORPORATING ICT INDEX

Variables	(7)	(8)	(9)	(10)	(11)
	Output Volatility				
GDP per capita	0.0155*** (16.25)	0.0137*** (12.61)	0.0149*** (16.12)	0.0149*** (16.15)	0.0151*** (16.20)
Lag of Output Volatility	0.431*** (54.33)	0.432*** (54.64)	0.432*** (54.88)	0.431*** (54.87)	0.431*** (54.57)
Energy Use Volatility	0.197* (2.14)	0.141 (1.34)	0.235* (2.57)	0.235* (2.57)	0.224* (2.43)
ICT Index	-1.472** (-2.69)	-1.331* (-2.45)	-1.336* (-2.45)	-1.337* (-2.45)	-1.404* (-2.57)
Volatility of Trade	16.43*** (7.78)	15.27*** (7.19)	16.06*** (7.50)	16.13*** (7.54)	18.39*** (8.07)
Volatility of Inflation	22.84*** (18.79)	22.43*** (18.70)	22.80*** (18.97)	22.79*** (18.96)	23.27*** (19.12)
Population Growth	-2.510 (-1.14)	---	---	---	---
CO2 Emissions	---	6.931* (2.01)	---	---	---
Nitrous Oxide Emissions	---	---	0.000003 (-0.02)	---	---
Methane Emissions	---	---	---	0.00003 (0.27)	---
Total Greenhouse gas Emissions	---	---	---	---	0.000003 (0.20)
R- Square	0.5870	0.5858	0.5869	0.5869	0.5870
F- Statistics	835.60	843.68	851.01	851.04	844.94
F- Prob.	0.0000	0.0000	0.0000	0.0000	0.0000
No of Observations	4124	4183	4201	4201	4170

***p<0.01, **p<0.05, *p<0.1

Table IX (a) and 9(b) show the empirical analysis with the inclusion of additional variables. The direction and the significance of the relationship between the

independent variables including volatility of energy use and ICT and the dependent variable which is OV are consistent with the baseline model when additional variables were included in the analysis. It was discovered that no matter how many extra variables are introduced, the base model results remain the same. Overall, the findings concluded that the variables of the current research are robust. Moreover, these findings are not sensitive to the inclusion of the control variables.

VI. CONCLUSION AND POLICY IMPLICATIONS

The current study investigated the association between energy use volatility, ICT, and OV using the panel data of 154 nations for the time span of 50 years, that is, from 1971 to 2020. For this purpose, different econometric techniques were used, such as pooled OLS, fixed effects, random effects, two stage least squares, and generalized method of moments. The current investigation also applied endogeneity in the panel estimation. Moreover, to ensure that the findings were stable, a series of robustness assessments were also run.

The results suggested that energy consumption volatility yields considerable positive and statistically significant outcomes and has a distorted impact on OV. Energy volatility augments OV which contributes to macroeconomic instability. The growth in output is highly volatile if there are variations in the consumption of energy. It was discovered that when the macro-economy is extremely unreliable, then the volatility of consumption of energy substantially enhances the output volatility. Although, the volatility of consumption of energy was found to have a negligible influence on output volatility when macroeconomic activities are less volatile. ICT showed a favorable impact on output volatility as it reduces output instability. ICT helps to stabilize OV by reducing transaction costs and information asymmetries. When asymmetric information is reduced in an economy, the OV is also lowered. ICT plays a critical role in reducing OV by enhancing connectivity, supporting access to markets, improving economic efficiency, fostering innovation, increasing financial inclusion, and enabling data-driven policy choices. In such a situation economic resilience, diversification, and the capacity to absorb shocks tend to improve, leading to lower OV.

High OV has a negative impact on the growth of the economy. The findings for all of the nations covered in this empirical investigation were consistent in general. The current research suggests that ICT has an important role in mitigating economic instability, rather than energy use volatility.

A. POLICY RECOMMENDATIONS

This research offers following recommendations: First, to harness the potential of ICT to mitigate OV, it remains important to increase investment in ICT infrastructure including high-speed internet connectivity and stable power supply. Second, digital skills development needs to be increased by facilitating ICT literacy and training programs. Third, digital divide needs to be bridged by implementing ICT supporting strategies, especially in far-flung and marginalized areas. This may include options such as expanding internet connectivity, providing affordable access to ICT devices, and promoting digital literacy programs taking care of marginalized populations.

B. LIMITATIONS

The current study has some limitations. Firstly, the volatility of energy was measured through one proxy, however, future research can also use fossil fuel energy consumption and renewable energy consumption for empirical analysis. Secondly, due to the limitations and restrictions of the data, the current research used the unbalanced data methods. Thirdly, the current study included a global analysis but did not assimilate country specific and region specific analysis. Therefore, future research may extend this analysis by incorporating region and country wise analysis.

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APPENDIX

Albania	Dominican Republic	Korea, Rep.	Russian Federation
Algeria	Ecuador	Kosovo	Samoa
Angola	Egypt, Arab Rep.	Kuwait	Saudi Arabia
Antigua and Barbuda	El Salvador	Kyrgyz Republic	Senegal
Armenia	Equatorial Guinea	Latvia	Serbia
Australia	Estonia	Lebanon	Seychelles
Austria	Eswatini	Lesotho	Singapore
Azerbaijan	Ethiopia	Libya	Slovak Republic
Bahamas, The	Fiji	Lithuania	Slovenia
Bahrain	Finland	Luxembourg	Solomon Islands
Bangladesh	France	Malaysia	South Africa
Barbados	Gabon	Malta	South Sudan
Belarus	Gambia, The	Mauritius	Spain
Belgium	Georgia	Mexico	Sri Lanka
Benin	Germany	Moldova	St. Vincent and the Grenadines
Bhutan	Ghana	Mongolia	Sudan
Bolivia	Greece	Montenegro	Suriname
Bosnia and Herzegovina	Grenada	Morocco	Sweden
Botswana	Guatemala	Mozambique	Switzerland
Brazil	Guinea-Bissau	Myanmar	Tajikistan
Brunei Darussalam	Guyana	Namibia	Tanzania
Bulgaria	Haiti	Nepal	Thailand
Cabo Verde	Honduras	Netherlands	Timor-Leste
Cambodia	Hong Kong SAR, China	New Zealand	Togo
Cameroon	Hungary	Nicaragua	Tonga
Canada	Iceland	Niger	Tunisia
Chile	India	Nigeria	Turkey
China	Indonesia	North Macedonia	Ukraine
Colombia	Iran, Islamic Rep.	Norway	United Arab Emirates
Comoros	Iraq	Oman	United Kingdom
Congo, Dem. Rep.	Ireland	Pakistan	United States
Congo, Rep.	Israel	Panama	Uruguay
Costa Rica	Italy	Paraguay	Vanuatu
Cote d'Ivoire	Jamaica	Peru	Venezuela, RB
Croatia	Japan	Philippines	Vietnam
Cyprus	Jordan	Poland	Zambia
Czech Republic	Kazakhstan	Portugal	Zimbabwe
Denmark	Kenya	Qatar	
Dominica	Kiribati	Romania	

FLOWCHART OF TEST ANALYSIS