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Operational Risk, Climate Change, and Economic Growth in Iran

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ABSTRACT

Economic growth is one of the most critical goals in all countries. Economic growth can enhance public welfare, reduce poverty, and alleviate unemployment. Knowing the factors affecting economic growth is essential, but recognising the obstacles can be more critical and practical. Iran is constantly exposed to various risks due to its location in one of the world's most significant and turbulent regions, the Middle East. On the other hand, Iran's hot and arid geographical location has led this country to be directly influenced by climate change. The main objective of the present research is to investigate the effect of operational risk and climate change on economic growth in Iran from q1:2014 to q4:2021 using the time-varying parameter vector autoregression (TVP-VAR). The research results reveal that any operational risk improvement positively affects Iran's economic growth. Furthermore, international sanctions have a significant impact on operational risk and, thus, a negative effect on economic growth in Iran; Therefore, it is suggested to Iranian policymakers to alleviate international tensions, especially with the influential countries in the global economic scene, to improve the operational risk, increase foreign investments, enhance the business environment, reduce the cost of business transactions and accordingly, increase the economic growth and development of the country. On the other hand, the climate change crisis has had an adverse effect on economic growth in Iran. It is thus suggested that policymakers consider climate change as a critical and urgent issue in legislation.

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1. Introduction

Economic growth is a central goal for governments worldwide, as it plays a pivotal role in reducing poverty and enhancing living standards, particularly in developing nations. However, numerous risks, including operational risk and the critical issue of climate change, can significantly impact a country's economic growth (Bloom, 2009; Danielsson et al., 2022). Operational risk, encompassing aspects such as labor market challenges, trade and investment concerns, logistics issues, and crime and security threats, has a complex relationship with economic growth. High levels of operational risk tend to harm growth, whereas low levels initially have a positive effect, which may eventually turn negative. International risks, including capital flows, investments, and exports, also impact growth and challenge monetary policy independence. Identifying and analyzing these risks is crucial for fostering investment and economic growth. Neglecting these risks can result in uncertainty, inefficiency, stagnation, and even crises. Investors in the stock market must assess a country's economic, financial, and political stability to mitigate investment risks. Furthermore, climate change poses a formidable global challenge. It leads to adverse consequences such as rising global temperatures, melting polar ice, increased sea levels, and shifting weather patterns. Iran, located in a predominantly arid and semi-arid climate zone, faces significant climate change risks (Dell et al., 2012). The impacts of climate change extend beyond agriculture, affecting industrial production, overall investment, political stability, institutional status, soil quality, water resources, and sea levels (Ahir et al., 2019; Bloom, 2009). Iran's economic growth has been inconsistent in recent years, with fluctuations between positive and negative rates. International sanctions, which hinder foreign investment opportunities and oil revenue returns, have contributed to this instability. Comparatively, Turkey has maintained a more consistent average growth rate. Iran faces a high level of operational risk, particularly in crime and security, as well as investment risk, ranking low on the global scale. The environmental crisis, exemplified by a substantial increase in carbon dioxide emissions since the 1990s, poses a grave concern for both Iran and the global economy. Iran's rankings in the Climate Change Performance Index (CCPI) and the Climate Change Risk Index (GCRI) indicate a challenging environment. In light of these challenges, the primary objective of this research is to examine the seasonal and 2014-2021 economic growth in Iran, considering both operational risk and climate change. The time-varying parameter vector autoregression (TVP-VAR) method will be employed to delve deeper into these complex dynamics. This paper represents a pioneering effort in measuring the operational risk index for the Iranian economy. It also incorporates contemporary climate indices like the climate risk index and climate change performance index. Methodologically, it adopts an innovative approach by employing the time-varying parameter vector autoregression (TVP-VAR) due to its dynamic nature.

The structure of the paper is organized as follows: Section 2 outlines the theoretical underpinnings of the research. Section 3 conducts a comprehensive review of relevant literature. Section 4 delineates the methodology employed and introduces the model. Section 5 comprises the presentation and analysis of the research findings. Finally, Section 6 offers the conclusions drawn from the study and provides pertinent policy recommendations.

2. Theoretical foundations

2. 1. Economic Growth and Operational Risk

Many economists argue that understanding how economic growth and development occur goes beyond factors like the labor force, population growth, and capital accumulation alone. Relying solely on models that focus on capital accumulation, such as the classical growth model, may not provide a comprehensive understanding of today's economic realities. Therefore, it is crucial to consider variables that indicate economic instabilities, such as risks. Economic risk refers to the potential impact of macroeconomic conditions on a company's investments and prospects, both domestically and internationally. These risks can encompass fluctuations in exchange rates, shifts in government policies or regulations, political instability, or the imposition of economic sanctions. Economic risks encompass various aspects, including the labor market, trade and investment, logistics, crime and security, as well as political and financial risks. Different types of risks influence economic growth through various channels, such as their impact on the construction, finance, industry, and banking sectors. Of particular significance is their effect on investment and capital flight. In essence, the rise in risk and the potential for various financial and economic crises can have long-lasting detrimental effects on macroeconomic performance, particularly on economic growth (Zareh et al., 2021; Tehrani et al., 2020). Fig (1) shows the relationship between short-term and long-term economic risk and growth.

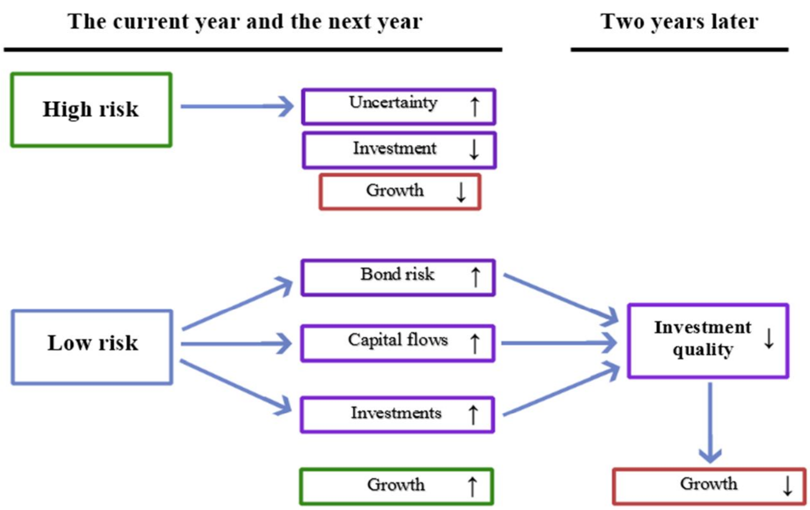

Fig 1. The Relationship between risk and economic growth

Source: Bloom, 2009; Ahir et al., 2019

Different economic and non-economic risks have varying impacts on economic growth, depending on their level. These effects can be categorized into two main groups: high-level risk and low-level risk. When risk is at a high level, it introduces uncertainty into the economy. This heightened uncertainty erodes investor confidence, leading to a decrease in economic growth. This negative impact is supported by various theories and studies (Brunnermeier & Pedersen, 2009; Bloom, 2009; Ahir et al., 2019). Conversely, when risk is at a lower level, it initially fosters optimism in the economy. Economic agents become more willing to take risks, leading to increased investment. Consequently, economic growth experiences an upturn in the short term. However, over time, as risk persists, the availability of suitable investment opportunities diminishes, causing investment risk to rise. This dynamic makes the financial system more fragile, ultimately resulting in a boom-bust cycle and a subsequent decline in economic growth. This phenomenon is supported by research and insights from scholars like Danielsson et al. (2009) and Săvoiua & Ğaicu (2014).

2. 2. Economic Growth and Climate Change

Climate change involves long-term shifts in temperature and weather patterns. While natural factors like solar cycles can influence climate, since the 1800s, human activities, particularly the burning of fossil fuels such as coal, oil, and gas, have become the primary driver of climate change. The impact of climate change on economic growth has been explored through theoretical and experimental studies. There are several suggested channels through which climate change affects the economy. Firstly, climate change disrupts ecosystems through events like floods, droughts, erosion, species extinction, and adverse weather conditions, which can harm economic growth. Secondly, resources are diverted to mitigate the negative consequences of global warming, reducing the resources available for investment in physical infrastructure, research and development, and human capital. From a theoretical standpoint, the link between climate change and economic growth can be established at both micro and macro levels. At the macro level, it affects both production levels (e.g., agricultural output) and the economy's capacity to foster growth and productivity by influencing investment and institutional factors. At the micro level, various factors, including workforce health and productivity, come into play. Nordhaus (1991) introduced a fundamental framework that integrated climate change into the economic system, leading to the development of the Regional Integrated model of Climate and Economy (RICE). Integrated Assessment Models (IAMs) are employed to evaluate the impact of global climate change by incorporating dynamic descriptions of energy and economic systems, weather systems, and the resulting climate impacts. These models have been widely used to assess climate policies and combine economic activities with simplified weather systems. Linking Earth System Models (ESMs) with socioeconomic frameworks is a challenging but essential task for conducting scientific research on climate change impacts. Some researchers have adopted endogenous growth frameworks to analyze the macroeconomic effects of climate change. These studies explore how climate change-induced reductions in output or production can influence consumption and savings decisions, ultimately leading to significant long-term economic consequences (Ikefuji & Horii, 2012; Barro, 2015; Müller-Fürstenberger & Schumacher, 2015; Bakkensen & Barrage, 2016; Akao & Sakamoto, 2018). Lecocq and Shalizi (2007) from the sustainable rural and urban development team of the World Bank believe that the impact of climate change on economic growth in developing countries is as follows: extensive economic activities → emission of greenhouse gases → increase in the concentration of pollutants → climate changes → physical and ecological impacts (ultimate damages) on various economic systems → ultimately damages to activities and reduction in economic growth. Fig (2) shows the effect of climate change on economic growth according to the study of Hideg et al. (2022) and Barker (2001).

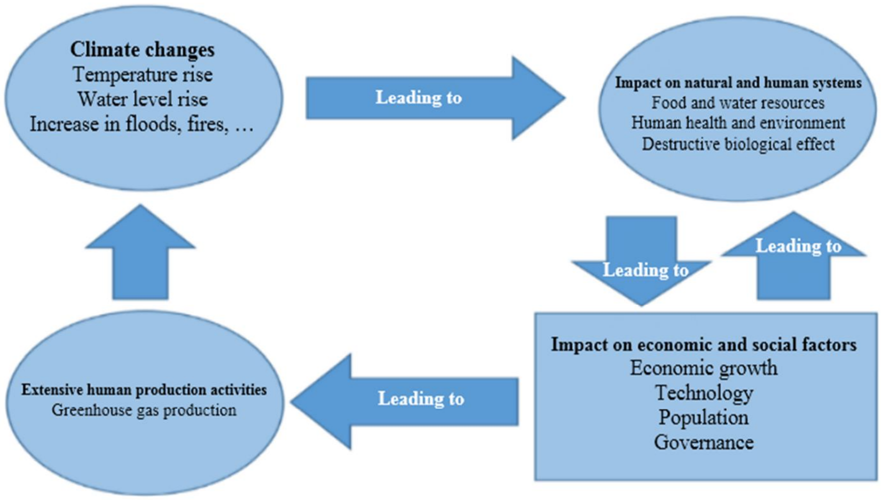

Fig 2. The Effect of climate change on economic growth

Source: Hideg et al. (2022) and Barker (2001)

3. Literature Review

A series of studies have explored the intricate relationship between various types of risk and economic growth, shedding light on different aspects:

Wang et al. (2022) focused on renewable energy and its impact on economic growth within OECD member countries, finding that increasing renewable energy use positively affects economic growth when national risks are moderate or low. Sun et al. (2021) investigated investment and investment risk across 34 Asian countries, revealing that lower investment risks are associated with accelerated economic growth. Meyer and Mothibi (2021) studied the impact of rank risk index on South Africa's economic growth, highlighting a two-way relationship where increased risk leads to decreased investment and economic growth. Liu et al. (2020) delved into political risk and its effects on economic growth across 113 countries, noting that reduced political risk can stimulate economic growth, especially in less developed nations. Akadiri et al. (2020) examined geopolitical risk's impact on Turkey's economic growth, concluding that geopolitical risk negatively affects both short- and long-term economic growth. Dinh et al. (2019) explored the relationship between foreign direct investment, risk, and economic growth in developing countries, finding that lower risk levels lead to increased foreign direct investment and economic growth in the long term. Ge et al. (2022) considered foreign private investment and environmental sustainability in developed and developing countries, revealing that higher foreign private investment positively correlates with economic growth in environmentally sustainable nations. Ferreira et al. (2020) emphasized the importance of addressing climate change. They found that reducing climate change has a significant positive impact on sustainable economic growth in OECD member countries. Rahman et al. (2020) investigated the effects of carbon dioxide emissions and population density on economic growth in South Asian countries, concluding that both factors negatively affect economic growth. Kahn et al. (2019) examined the long-term effects of climate change on the global economy and found that even a small annual increase in global temperature could lead to a substantial decrease in global economic growth. Kompas et al. (2018) analyzed the impact of global warming on GDP and economic growth in 139 countries, demonstrating that increasing global warming negatively affects economic growth across all nations. Additionally, a 4^0C increase in global warming by 2100 could result in a significant economic loss. Notably, while these studies have explored various aspects of risk and climate change, there appears to be a gap in research examining the influence of operational risk on economic growth. Additionally, the use of climate change performance and climate change risk variables in the present research distinguishes it from prior studies in this field.

4. Research Methodology and Data

4. 1. Model Specification and Data

According to the studies of Wang et al. (2022), Sun et al. (2021), Ge et al. (2022), and Ferreira et al. (2020), model (1) is introduced:

$$EG_t = \beta_0 + \beta_1 K_t + \beta_2 L_t + \beta_3 TFP_t + \beta_4 OR_t + \beta_5 CCP_t + \beta_6 CR_t + \varepsilon_t \quad (1)$$

The model’s variables (1) are fully presented in Table (1).

Table 1. Data Definition

Symbol	Name of variable	Unit	Source
EG	Economic Growth	%	World Bank, Business Monitor (Fitch Solutions)
K	Gross Fixed Capital Formation	US$ (2015)	World Bank, Business Monitor (Fitch Solutions)
L	Labor Force	Person	World Bank, Business Monitor (Fitch Solutions)
TFP	Total Factor Productivity	%	Solow Residual Method
OR	Operational Risk Index	0-100	Business Monitor
CCP	Climate Change Performance Index	0-100	German Watch
CR	Climate Risk Index	0-120	German Watch

Source: Research results

In this research, the primary focus is on the economic growth rate, which serves as the dependent variable, as outlined in Table 1. The study adopts the Solow growth model, which comprises three key components:

Capital Accumulation: This aspect, derived from recent global research (e.g., Wang et al., 2022; Sun et al., 2011; Meyer and Mothibi, 2021), encompasses the formation of gross fixed capital. Gross fixed capital formation represents the acquisition of produced assets by producers for their use, minus any disposals of production assets.

Labor Force: Following the World Bank's definition, the labor force includes individuals aged 15 and above who actively contribute their labor to produce goods and services within a given timeframe. It encompasses those who are currently employed, those actively seeking employment, and individuals entering the job market for the first time.

Productivity of Production Factors: This parameter is related to the Solow model. In simple terms, it refers to the productivity of production factors within the Solow framework. Residual Solow represents a portion of the economy's production that cannot be attributed to capital and labor accumulation.

Additionally, the research employs the operational risk index to quantitatively assess operational challenges across 201 countries and regions worldwide. This index assigns scores ranging from zero (indicating high risk) to 100 (indicating low risk) based on specific criteria. Operational risk is characterized by four primary indicators, as illustrated in Fig 1.

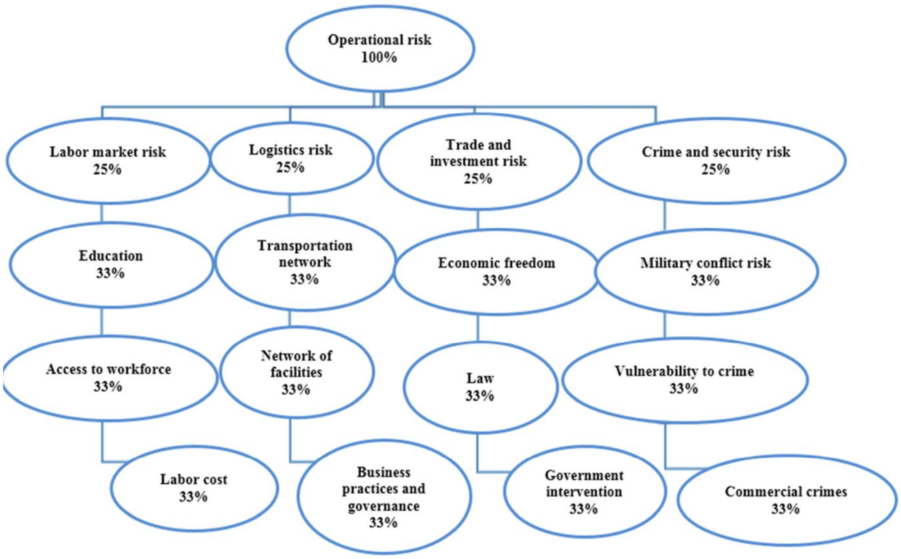

Fig 1. Components of operational risk

Source: Business Monitor

The CCPI has been created by weight from the combination of four indicators; of the total 100% weight of the climate change index, 40% depends on greenhouse gas emissions, 20% on renewable energy, 20% on energy consumption, and 20% on countries' climate policies (Climate Change Performance, 2022). Fig (3) conceptually shows the CCPI.

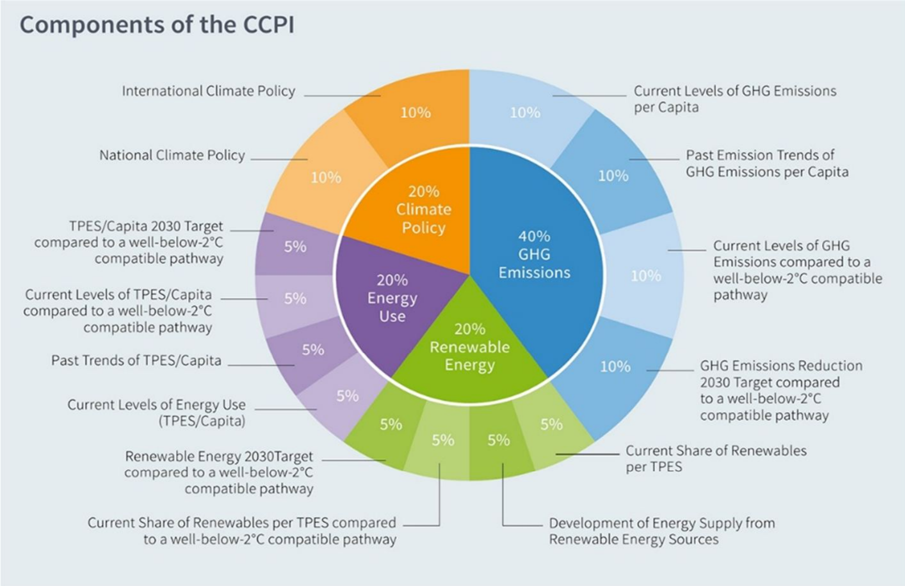

Fig 3. Components of the CCPI

Source: German Watch

On the other hand, the climate risk index is a combination of four indicators: the number of deaths, the number of deaths per 100,000 people, the total loss due to climate change per purchasing power parity in US dollars, and the loss per unit of GDP caused by climate change, which, like the previous climate variable, has a score of 0 for high risk and a score of 120 for low risk.

4. 2. Research Methodology

Due to the presence of structural breaks and cyclic variations in Iran's economic time series data, there is a need for an econometric model that can effectively account for these effects within shorter time intervals like years, months, and seasons. TVP (Time-Varying Parameter) models, including TVP-VAR, offer this flexibility because they incorporate time-varying coefficients. Traditional models struggle to accurately estimate parameters when dealing with structural breaks and cyclic variations in economic data, which are common in Iran's economic time series. TVP-VAR models, relying on the Kalman filter for estimating time-varying coefficients, provide a way to model these real-world complexities effectively. In contrast to the vector autoregression (VAR) model, TVP-VAR allows for the calculation of variable coefficients that change over time. This is crucial because economic conditions undergo structural changes and cyclical variations. The TVP-VAR model robustly and accurately captures the nature of these temporal changes in economic structure. To estimate the TVP-VAR model, a stochastic fluctuations approach proposed by Primiceri in 2005 can be used, and it can be estimated using Markov Chain Monte Carlo (MCMC) within the Bayesian inference framework. To introduce the TVP-VAR model, let's first consider a structural VAR model as follows:

$$Ay_t = Q_1 y_{t-1} + \cdots + Q_p y_{t-p} + u_t . T = P + 1. \dots . T \tag{2}$$

Where y_t represents the $n \times 1$ vector of the observed variables, A and $Q_1 \dots Q_p$ are the $n \times n$ matrix of parameters, and $u_t \sim \left(0. \sum_u\right)$ is the $n \times 1$ vector of structural shocks, shown as follows:

$$\Sigma = \begin{bmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \sigma_2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_n \end{bmatrix} \tag{3}$$

We determine the simulation relationship between structural shocks in a recursive form. Suppose that A is a lower triangular matrix whose elements on the primary diameter are equal to one:

$$A = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{2.1} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n.1} & \cdots & \alpha_{n.n-1} & 1 \end{bmatrix} \tag{4}$$

In equation (2), there is a problem of determining a unique value for the parameters in the model; because the coefficients are unknown, and the variables may affect each other simultaneously (Bredin & O'Reilly, 2004). We rewrite equation (2) as an adjusted VAR model to estimate the parameters.

$$y_t = B_1 y_{t-1} + \cdots + B_p y_{t-p} + A^{-1} \sum{}_t \varepsilon_t. \varepsilon_t \sim (0. I_n) \quad (5)$$

In equation (5), $B_i = A^{-1} Q_i$ for $i = 1 \ldots . p$. Also, we define B as $B_1 \ldots . B_n$ to show the modified form as follows:

$$y_t = X_1 B + A^{-1} \sum_t \ \varepsilon_t \quad (6)$$

where $X_t = I_n \otimes [1. y'_{t-1}. \ldots . y'_{t-p}]$ and $\otimes$ is the Kronecker product. All parameters are not time-varying. According to Primiceri (2005) and Nakajima and Watanabe (2011), we assume that all parameters $(B. A. \sum)$ change over time; Then, we rewrite equations (5) and (6) as follows:

$$y_t = B_1 y_{t-1} + \cdots + B_p y_{t-p} + \varepsilon_{t.}\ e_t \sim N(0. \Phi_t) \quad (7)$$

$$y_t = X_t B + e_t\ . t = p + 1. \ldots . n \quad (8)$$

Where y_t is the vector $(k \times 1)$ of the observed variables. $B_{1t}. \ldots . B_{pt}$ is the vector $(k \times k)$ of time-varying coefficients. Φ_t is the time-varying covariance matrix with dimensions $(k \times k)$; Also, Φ_t is calculated as $\Phi_t = A_t^{-1} \sum_t \sum_t \acute{A}_t^{-1}$, where A_t is the lower triangle matrix with diagonal elements equal to one, and $\sum t$ is also the diagonal matrix including the standard deviation of structural shocks. X_t has the same definition as before. All parameters are not time-varying. B_t is a line vector as $B_{1t}. \ldots . B_{pt}$, a_t is also a line vector of elements of matrix A_t. Finally, we define the elements of the vector $x_t = (x_{1t}. \ldots . x_{nt})$ as $x_{ji} = log\sigma_{ji}$. Time-varying parameters are assumed to follow a stochastic process (Nakajima & Watanabe, 2011; Primiceri, 2005):

$$\begin{array}{c} B_t \\ = B_{t-1} \\ + v_t \\ a \\ = a_{t-1} \\ + \xi \\ x_t \\ = x_{t-1} \\ + \eta_t \end{array} \qquad \begin{pmatrix} \varepsilon_t \\ v_t \\ \xi_t \\ \eta_t \end{pmatrix} \sim \mathrm{N} \left(0. \begin{pmatrix} I_n & 0 & 0 & 0 \\ 0 & \Sigma_B & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_X \end{pmatrix} \right) \quad (9)$$

where $t = p + 1. \ldots . n$ and $e_t = A_t^{-1} \sum_t \varepsilon_t$. I_n is a unitary matrix with n elements when $\sum_a . \sum_B$ and $\sum_x$ matrices are positive definite matrices. In the covariance matrix, $\sum_x$ $and\, is$ assumed to be diagonal, and shocks are uncorrelated between time-varying parameters. As can be seen, equations (8) and (9) are expressed in state-space form. State-space models include two equations: one is the state equation, here equation (9), which is sometimes called the transition equation, and the other is the measurement equation. The measurement equation describes the relationship between the observed variables (data) and the unobserved variables and shows the dynamic state equation of the state variables. The sum of these two equations is called the state-space model. According to Nakajima and Watanabe (2011), we assume that the state for time-varying parameters is equal to $B_{p+1} \sim N(v_{\beta 0} . \sum_{\beta 0})$, $a_{p+1} \sim N(v_{a0} . \sum_{a0})$, and $x_{p+1} \sim N(v_{x0} . \sum_{x0})$ (West & Harrison, 1997; Kim & Nelson, 1999; Harvey, 1989; Durbin & Koopman, 2001; Frühwirth-Schnatter, 1994; de Jong & de Jonge, 1995; Durbin & Koopman, 2002; Carter & Kohn, 1994).

5. Research Results

5. 1. Diagnostic Tests

The first step to estimate the vector autoregression model is to determine the optimal length of the interval, which is reported in Table (2). To determine the interval in TVP-VAR models, criteria such as the Akaike information criterion (AIC), Hannan-Quinn information criterion (HQ), Schwarz information criterion (SC), and final prediction error (FPE) have been used. According to the statistics of AIC, HQ, SC, and FPE, the length of interval two is determined for the model.

Table 2. Determining the optimal length of the interval of the model

Interval	AIC	HQ	SC	FPE
0	88.619	88.723	88.945	7.24e+29
1	73.250	74.084	73.250	1.68e+23
2	70.732*	67.397*	65.828*	1.83e+20*

Note: The * indicate the minimum value of the relevant statistic for selecting the optimal length

Source: Research results

In Table 3, the HEGY unit root test results are presented, considering the seasonality of the research variables. The HEGY unit root test, developed by Harris and others in 2009, holds significant importance in econometrics for several reasons. It excels in detecting unit roots, even when time series data exhibit structural breaks or non-linearities, which are common in economic data due to events such as policy changes and financial crises.

One notable advantage is that the HEGY test explicitly identifies structural breaks, enabling accurate modeling of changing economic behaviors. Compared to alternatives like the Augmented Dickey-Fuller test, the HEGY test offers higher statistical power, reducing the risk of failing to detect unit roots. It also accounts for variations in parameter estimation over different time periods, making it suitable for analyzing time series data with changing statistical properties. The flexibility of the HEGY test in addressing various forms of structural breaks and its empirical relevance in analyzing non-stationary economic data further underscore its significance in econometrics. Additionally, it plays a crucial role in policy analysis by assessing the long-term effects of policy changes on economic variables and establishing long-run relationships among variables in specific econometric models, which is essential for cointegration analysis. According to the obtained results, all the variables in the study are stationary. Consequently, the presence of spurious regression in the model is rejected, enabling further examination of the tests and model estimation.

Table 3. The HEGY unit root test

Variable	Type of Test	Test Statistics	Result	Stationarity
EG	Annual unit root	2.93 (0.043)	Absence of annual unit root	I(0)
	Six-month unit root	3.34 (0.029)	Absence of six-month unit root	I(0)
	Seasonal unit root	4.59 (0.000)	Absence of seasonal unit root	I(0)

Variable	Type of Test	Test Statistics	Result	Stationarity
K	Annual unit root	-2.95 (0.040)	Absence of annual unit root	I(0)
	Six-month unit root	-2.04 (0.050)	Absence of six-month unit root	I(0)
	Seasonal unit root	4.33 (0.000)	Absence of seasonal unit root	I(0)
L	Annual unit root	3.22 (0.001)	Absence of annual unit root	I(0)
	Six-month unit root	2.31 (0.049)	Absence of six-month unit root	I(0)
	Seasonal unit root	4.72 (0.000)	Absence of seasonal unit root	I(0)
TFP	Annual unit root	-2.61 (0.050)	Absence of annual unit root	I(0)
	Six-month unit root	3.10 (0.004)	Absence of six-month unit root	I(0)
	Seasonal unit root	4.99 (0.000)	Absence of seasonal unit root	I(0)
OR	Annual unit root	-2.53 (0.044)	Absence of annual unit root	I(0)
	Six-month unit root	-3.40 (0.000)	Absence of six-month unit root	I(0)
	Seasonal unit root	7.80 (0.000)	Absence of seasonal unit root	I(0)
CCP	Annual unit root	-4.67 (0.001)	Absence of annual unit root	I(0)
	Six-month unit root	-5.97 (0.005)	Absence of six-month unit root	I(0)
	Seasonal unit root	10.93 (0.000)	Absence of seasonal unit root	I(0)
CR	Annual unit root	-5.92 (0.000)	Absence of annual unit root	I(0)
	Six-month unit root	-6.40 (0.000)	Absence of six-month unit root	I(0)
	Seasonal unit root	8.82 (0.000)	Absence of seasonal unit root	I(0)

Note: The values inside () in test statistics indicate the probability level.

Source: Research results

Considering the level of significance of the unit root test in all research variables, the null hypothesis of the HEGY test in all three annual, semi-annual, and seasonal tests at a 5% error level has been rejected. Therefore, there is no unit root, and all variables are stationary at a significant level; as a result, there is no need for a cointegration test, however, to ensure that the model has no problem. Now, the stability test of the vector autoregression model will be investigated through the polynomial inverse root circle test. The results of this test can be seen in Fig (4).

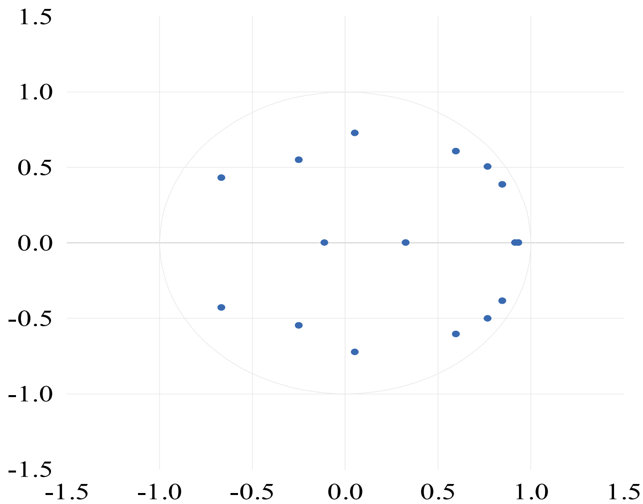

Fig 4. Polynomial inverse root circle test

Source: Research results

As can be seen from Figure (4), there is no root outside the unit circle, so the TVP-VAR model satisfies the conditions of stability, and as a result, it is confirmed that the model coefficients are not false. The final diagnostic tests before presenting and analysing the impulse response functions of the TVP-VAR model are the serial correlation and variance heterogeneity tests, reported in Table (4).

Table 4. The results of serial correlation and variance heterogeneity tests

Serial Correlation Test				Variance Heterogeneity Test		
Interval	**Degree of Freedom**	**F-Statistic**	**Probability**	**Statistic**	**Degree of Freedom**	**Probability**
1	49	4.082	0.163	810.262	49	0.250
2	49	1.550	1.180			
3	49	1.125	0.158			

Source: Research results

As can be seen from Table (4), the probability of both serial correlation and variance heterogeneity tests is higher than 5%; as a result, the null hypothesis of the absence of serial correlation and the absence of variance heterogeneity, respectively, is not rejected and is confirmed.

5. 2. Impulse Response Functions in the TVP-VAR Model

Figures (5) to (11) show the graphs of the impulse response functions of the TVP-VAR model. These are three-dimensional graphs showing the vertical axis, the shock of the variables, and the horizontal axes of periods (0 to 12) and time (2014 to 2021).

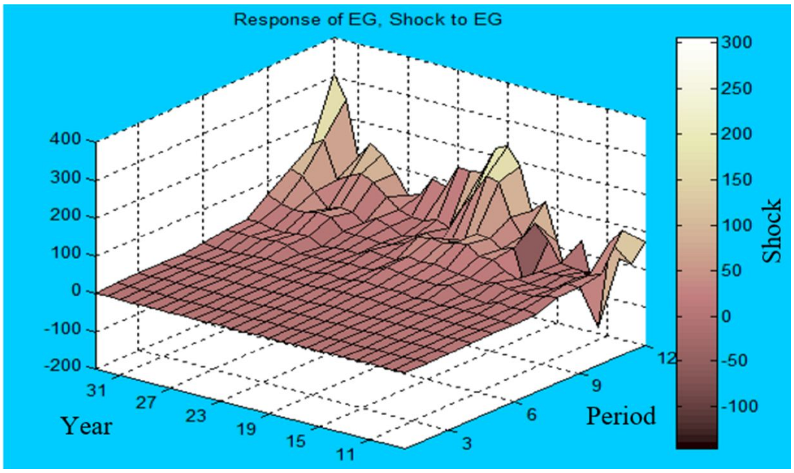

Fig 5. Analysis of the impulse response of economic growth shock on economic growth

Source: Research results

According to Fig (5), the short-term increase in Iran's economic growth rate (periods 0 to 6) didn't have a significant impact on the country's economic growth. However, in the long term (periods 9 and 12), except for the initial years of the research (2014 and 2015), it had a positive effect on Iran's economic growth. Various factors have influenced Iran's economic growth, with one of the most significant being international sanctions. The positive shock observed after 2015 can be attributed to the Iran nuclear agreement.

Following the election of Donald Trump as the President of the United States and the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA), secondary sanctions were reimposed on Iran, leading to a decline in Iran's economic growth rate in 2018 (between periods 19 and 27 on the horizontal axis). During this period, the effect of the impulse response of the economic growth shock on economic growth decreased. However, starting from period 27 onwards, which marks the end of Donald Trump's presidency and the Democrats taking office, there was a positive shift in nuclear negotiations, raising hopes for a return to the JCPOA. This created a positive economic atmosphere in Iran, leading to an increase in the economic growth rate, which became positive in the graph. Iran's economy has distinctive features, including a significant presence of the government in sectors like hydrocarbons, agriculture, and services, as well as heavy reliance on oil revenues. While there's relative diversity for an oil-exporting country, Iran's economic growth has historically been subject to fluctuations. The nation has faced challenges, including economic sanctions, oil price fluctuations, and the COVID-19 pandemic. In 2021, Iran experienced economic recovery, especially in the oil and services sectors, which contributed to a 5% annual growth rate. However, the agricultural sector saw a decline of 1.2% due to drought and energy shortages. The Iranian government has grappled with budgetary challenges, primarily because of low oil revenues and high expenditures. Tax revenues increased by 60%, and government expenditures grew by 58%, resulting in high inflation. Iran's budget deficit reached 6.8%

of GDP in the first half of 2021, primarily financed through bond issuance since planned asset sales did not materialize. Inflation continued to rise due to various factors, significantly impacting economic growth. Iran's economic growth prospects are subject to both positive and negative risks. These include economic and non-economic factors related to oil market dynamics, geopolitical tensions, epidemics, and climate change. Additionally, a potential increase in global tensions could raise oil prices, leading to higher financial revenues and increased oil exports, thereby boosting economic growth. Conversely, downside risks stem from the possibility of a worsening coronavirus epidemic, increased effects of climate change, heightened geopolitical tensions, and the global impact of events like the Ukraine war on food prices and Iran's food imports.

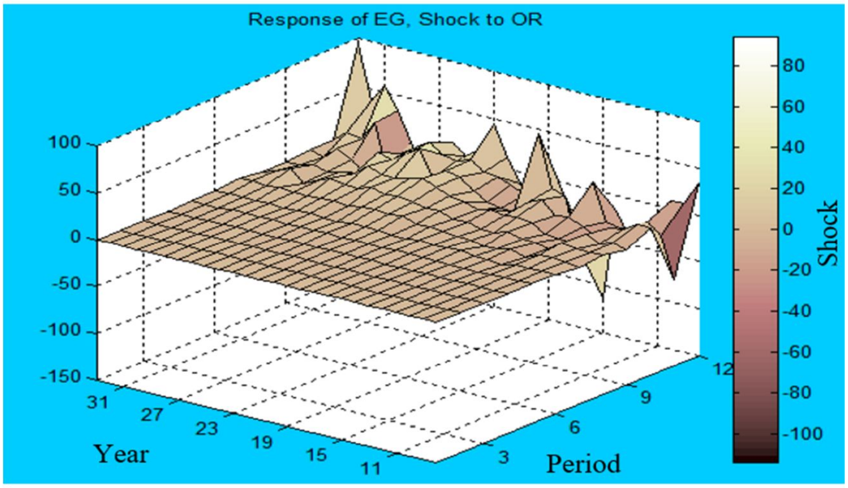

Fig 6. Analysis of the impulse response of operational risk shock on economic growth

Source: Research results

Fig (6) provides an analysis of the impact of an operational risk shock on economic growth in Iran. Operational risk encompasses four distinct risk categories: labor market risk, trade and investment risk, logistics risk, and crime and security risk. Consequently, operational risk serves as a comprehensive measure of a country's overall economic condition. Iran, situated in the challenging Middle East region, contends with an array of risks and uncertainties. These include factors such as international sanctions, the presence of terrorist groups in neighboring areas, extensive international negative portrayals of Iran's internal situation and poverty, inadequate investments in transportation infrastructure across land, sea, and air, and strict labor market regulations. These factors collectively contribute to elevated levels of trade and investment risk, crime and security risk, logistics risk, and labor market risk in Iran.

As depicted in Figure (6), during the short term (periods 0 to 6), the operational risk shock's impact on economic growth appears to be relatively modest. However, in the long term, except for the initial years of the research (from 2014 to mid-2015), operational risk had an adverse effect on Iran's economic growth. Following the reduction of sanctions, the operational risk shock generated a positive impact on economic growth. This cumulative effect became more pronounced in the later years of the study, particularly in 2020 and 2021. Iran's strained relationships with the United States and key regional players like Saudi Arabia have led to its isolation from the international community and have weakened its overall business environment. Notable risks include trade barriers and regulatory constraints. Iran faces restrictions that prohibit foreign participation in specific sectors, high tax rates, strict labor laws, allegations of corruption, a weak legal framework, and the dominance of state-owned enterprises, all of which have created challenges for businesses operating within the country. Despite offering substantial investment opportunities in sectors such as hydrocarbons, infrastructure, and consumer industries, Iran remains inaccessible to Western investors due to ongoing U.S. sanctions. This restriction is expected to persist as long as these sanctions remain in effect.

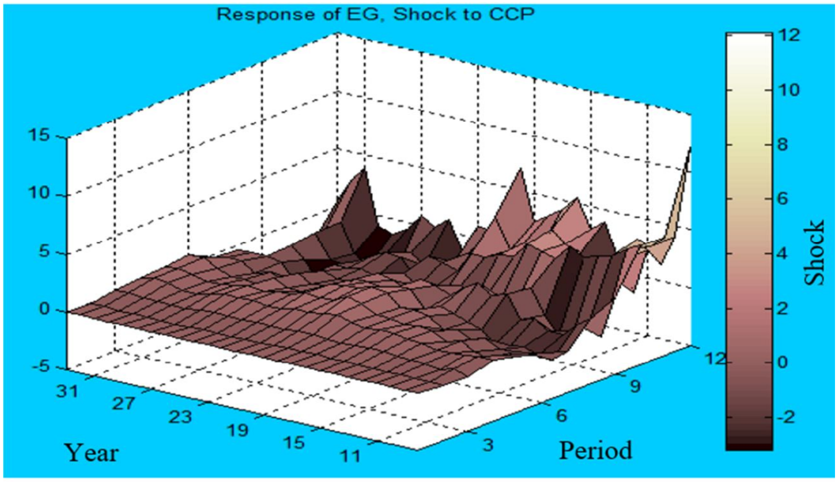

Fig 7. Analysis of the impulse response of the CCPI shock on economic growth

Source: Research results

Fig (7) illustrates the impact of the Climate Change Performance Index (CCPI) shock on economic growth in Iran. Notably, the shock resulting from the CCPI had a predominantly negative effect on Iran's economic growth across most stages, leading to a reduction in economic growth. This negative influence can be explained through a chain of causation: extensive economic activities lead to the emission of greenhouse gases, which subsequently elevate pollutant concentrations, ultimately resulting in climate changes. These climate changes, in turn, bring about physical and ecological consequences, ultimately causing damage to various economic systems and consequently reducing overall economic growth. Climate change encompasses enduring alterations in temperature and weather patterns. While some of these changes may arise naturally, such as variations in solar cycles, the primary driver of climate change since the 1800s has been human activities, primarily linked to the combustion of fossil fuels like coal, oil, and gas. Both theoretical and empirical studies have proposed multiple channels through which climate change affects economic growth.

Firstly, climate change disrupts ecosystems through events like floods, droughts, erosion, species extinction, and adverse weather conditions, all of which have detrimental consequences for economic growth. Secondly, the allocation of limited resources to mitigate the adverse impacts of global warming diverts resources away from investments in physical infrastructure, research and development, and human capital, further hampering economic growth. From a theoretical perspective, the relationship between climate change and economic growth can be substantiated from both micro and macro viewpoints. On a macro level, this effect becomes evident in terms of production levels, such as agricultural production, as well as in the economy's capacity to foster growth and enhance productivity through its influence on investments and institutional factors. Meanwhile, on a micro level, this relationship unfolds through various factors, including the health and productivity of the workforce.

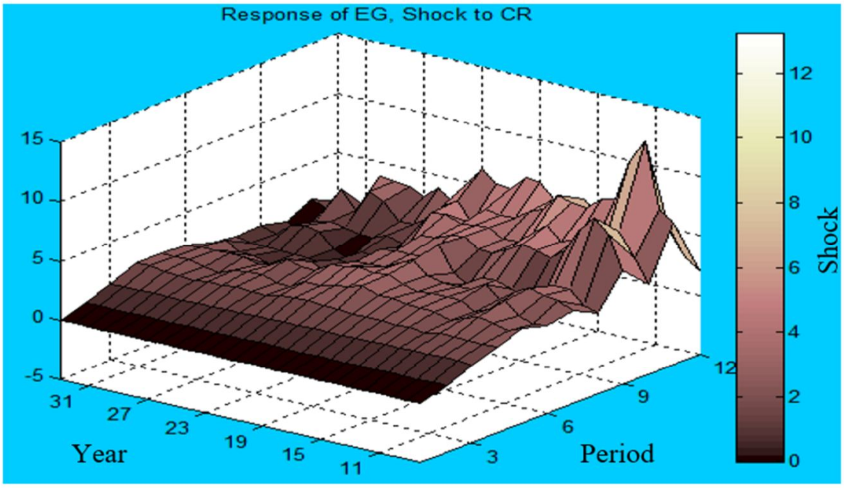

Fig 8. Analysis of the impulse response of climate change risk index shock on economic growth

Source: Research results

Fig (8) presents an analysis of the impulse response of the Climate Change Risk Index shock on economic growth in Iran. This analysis reveals that the effect of this shock on economic growth is initially positive during the early years but gradually turns negative over time. The Climate Change Risk Index comprises two key variables: GDP loss and damage caused by climate change, as well as mortality resulting from climate change. The initial positive effect observed in the early years can be attributed to increased production of goods and services, which leads to economic growth. However, as time progresses, the detrimental environmental consequences of this increased production begin to outweigh the positive economic impact, resulting in a decline in the economic growth rate. Several prominent economic growth models are commonly employed to analyze the effects of climate change on economic growth. These include the Solow-Swan model, the Ramsey-Cass-Koopmans model, and to a lesser extent, the Mankiw, Romer, and Weil (MRW) model (1992). Across all three models, assuming a fixed savings rate, it has been consistently determined that climate change exerts a negative influence on production, leading to a reduction in investment. In the long term, this diminished investment results in decreased capital stock and per capita consumption, leading to a decline in total demand and ultimately negatively impacting the GDP. In an endogenous growth model, the situation can further deteriorate if reduced investment, due to the effect of capital accumulation, hampers technical progress, impedes improvements in labor productivity, or impedes the accumulation of human capital. These factors collectively contribute to the adverse economic effects of climate change on long-term economic growth.

Fig (9) illustrates the impact of capital shock on economic growth. The analysis reveals that, with the exception of the periods before 2015, capital has consistently exerted a positive influence on economic growth in Iran across nearly all time periods. In general, economic growth is driven by an increase in the production of goods and services. Factors such as rising consumer spending, expanded international trade, and businesses augmenting their investments in capital expenditures can all contribute to the increased production of goods and services within an economy.

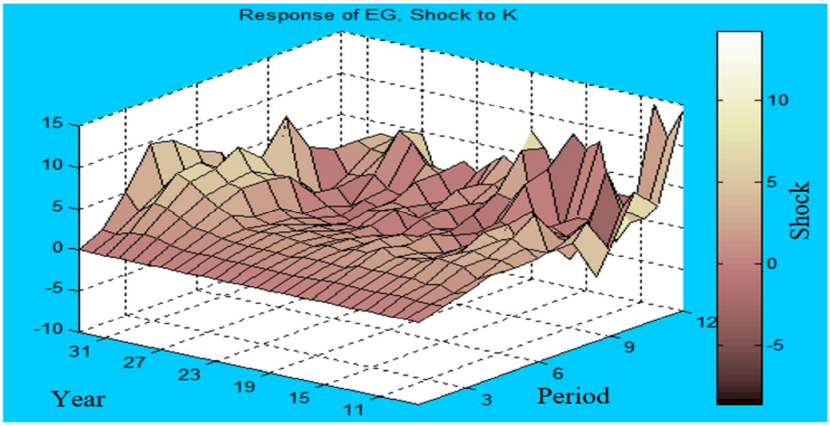

Fig 9. Analysis of the impulse response of capital shock on economic growth

Source: Research results

Despite facing international sanctions, Iran has demonstrated an ability to attract increased capital investment. The research findings indicate that any increase in capital investment, at any given point in time, has resulted in a positive economic growth shock in Iran. It's worth noting that in Iran, the public sector possesses a larger capital stock compared to the private sector. Both private and public sector capital stocks have a positive impact on economic growth, but the private sector's capital stock tends to be more productive and efficient, thus exerting a more pronounced influence on economic growth. Furthermore, several other significant factors influence capital stock in Iran, including the accumulation of domestic and foreign research and development capital, human capital, the ratio of physical capital stock to the labor force, indicators of commercial, economic, and political openness, the inflation rate, and the exchange rate. These factors collectively play a vital role in determining the productivity of all production factors and, consequently, their impact on economic growth.

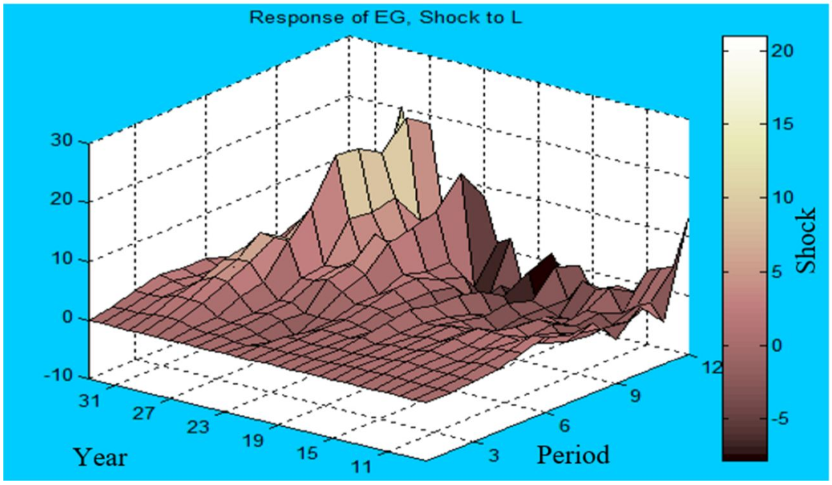

Fig 10. Analysis of the impulse response of the labour force shock on economic growth

Source: Research results

Fig (10) examines the impulse response of the labor force shock on economic growth in Iran. In the short term, the impact of the labor force on economic growth is not particularly pronounced, but over the long term, its effect becomes more evident. Between 2014 and 2015, during a period marked by unfavorable economic conditions resulting from sanctions, the labor force had a negative effect on economic growth. However, starting in 2015, this effect turned entirely positive, especially in the later years of the study, where it is highly noticeable. When discussing the labor force, it is crucial to consider both supply and demand aspects. Several key factors influence labor supply and demand:

Factors Affecting Labor Supply:

- **Population Size and Composition:** A larger population generally means a larger labor supply. The gender and age distribution within the population also play a critical role. Iran is currently facing a significant risk due to declining fertility rates and emigration of highly skilled individuals, which could exacerbate labor market risks in the near future.

- **Participation Rate in the Labor Force:** Not all individuals of working age are actively seeking employment; factors like retirement, student status, and homemaking affect labor force participation. The age at which individuals enter the labor market is influenced by economic conditions and education policies. Iran falls in between two extremes, with a relatively young labor force due to economic challenges and poverty, and some university students delaying entry into the labor market due to higher education policies. This dynamic could contribute to labor market risks in Iran.

Factors Affecting Labor Demand:

- **Capital:** Labor demand is closely tied to the availability of financial resources and capital. Both natural resources and human labor are primary factors in production, but the provision of goods and capital is also essential. In recent years, Iran has faced capital provision challenges due to international sanctions and banking-related financing issues, which have affected labor demand.
- **Size of the National Economy:** In many developing countries, limited population size and low demand for goods can hinder the creation of stable and competitive domestic industries. This, in turn, limits labor demand. Factors like natural resources, technology, government policies, and foreign investment also influence labor demand.

These various factors collectively impact the labor market in Iran, influencing its dynamics and contributing to the observed effects on economic growth.

Fig (11) depicts the impact of the productivity rate of production factors on economic growth in Iran during different periods. From the initial period (0 to 11, covering 2014 to late 2015), the shock related to the productivity rate of production factors had a negative effect on economic growth in Iran. This negative impact can be attributed to the relatively low levels of both capital and labor during this period. Between 2015 and 2017, the productivity rate of production factors began to positively influence economic growth. This shift towards a positive effect could be attributed to factors such as the reduction of sanctions, increased investment, and a decrease in unemployment during this timeframe.

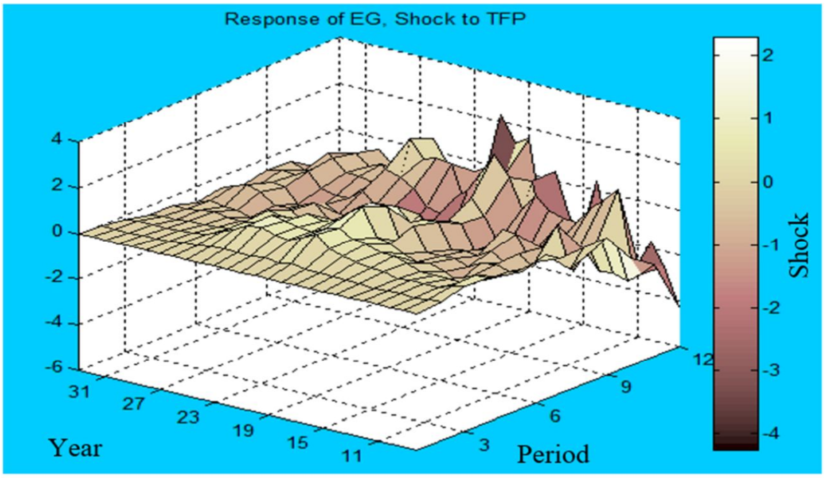

Fig 11. Analysis of the impulse response of the shock of productivity rate of production factors on economic growth

Source: Research results

From 2017 to 2021, the productivity rate of production factors continued to have a positive, albeit relatively modest, effect on economic growth in Iran. This effect may have been influenced by the reintroduction of U.S. sanctions during this period, although these sanctions did not reach the same level as before the 2015 international agreement.

In the context of economic models like the Solow-Swan model, any unexplained change in output growth, once the effect of capital accumulation is taken into account, is termed the 'Solow Residual.' This residual reflects external increases in total factor productivity during a specific period. Total factor productivity growth typically encompasses technological progress and any permanent efficiency improvements that interact with production factors over time. It may also include enhancements in management performance in both the private and public sectors of the economy. It's important to note that while the model acknowledges total factor productivity growth, it cannot be directly observed but must be estimated by comparing the effect of capital accumulation on growth with other contemporaneous factors over a given period.

The results related to the effect of operational risk on economic growth are consistent with the results of studies by Wang et al. (2022), Sun et al. (2011), Meyer and Mothibi (2021), Liu et al. (2020), Akadiri et al. (2020), Dinh et al. (2019), Heydari Heratmeh (2022), Reza Gholizadeh (2021), Zareh et al. (2021), and Sajjadieh Khajoi et al. (2021).

The results related to the effect of climatic variables on economic growth are consistent with the results of studies by Ge et al. (2022), Ferreira et al. (2020), Rahman et al. (2020), Kahn et al. (2019), Kompas et al. (2018), Panahi and Ismail Darjani (2020), Malekoutikhah and Farajzadeh (2020), and Kemroudi and Abunouri (2020).

6. Conclusions and Policy Recommendations

Economic growth is a crucial government objective for both developing and developed nations. It brings about several benefits such as improved living standards and increased real incomes, allowing for greater resource allocation to essential sectors like healthcare and education. This research aims to explore the impact of operational risk and climate change, measured by the CCPI and climate change risk index, on Iran's economic growth from Q1 2014 to Q4 2021 using the TVP-VAR model. The findings reveal that reducing operational risk positively influences economic growth in Iran. This is significant because Iran is situated in the challenging Middle East region, exposed to a multitude of risks and uncertainties. Factors such as international sanctions, the presence of terrorist groups, negative international perceptions, inadequate infrastructure investment in transportation, and strict labor laws contribute to high levels of trade and investment risk, crime and security risk, logistics risk, and labor market risk, collectively elevating operational risk.

The research divides Iran's economic performance into three distinct periods: before the nuclear agreement (Q1 2014 to Q2 2015), the nuclear agreement era (Q2 2015 to Q2 2018), and the post-U.S. withdrawal phase (Q2 2018 onwards). Operational risk shocks negatively impacted economic growth before the nuclear agreement, leading to a growth rate decline. During the agreement period, reduced sanctions, increased oil revenues, and foreign investments had a positive impact on economic growth, resulting in growth rate improvement. After the U.S. withdrawal in May 2018, operational risk shocks negatively affected Iran's economic growth, though not as severely as before the agreement. Furthermore, the research demonstrates that an improved CCPI and reduced climate change risk positively affect economic growth in Iran. A higher climate change risk index signifies improved climate conditions, leading to positive impacts on economic growth. However, the effect of climate change risk shocks on economic growth starts positively and gradually turns negative over time. The study emphasizes that extensive economic activities can contribute to increased greenhouse gas emissions, which, if left unaddressed, may lead to a climate change crisis, adversely affecting various economic systems and ultimately reducing economic growth.

Based on the research findings, the following recommendations are put forth to address operational risk and its components in order to enhance economic growth:

Leverage Skilled Graduates: Iran possesses a substantial pool of skilled graduates across various scientific disciplines. Investing in this educated workforce can mitigate migration risks and reduce labor market uncertainties. This, in turn, can boost economic growth by enhancing workforce productivity.

Promote Foreign Investment: Iran boasts a large and diverse economy with substantial potential for foreign investment. Reducing international tensions and trade and investment risks can attract foreign companies, fostering economic growth. This can also lead to increased exports of hydrocarbon products like oil and gas and facilitate the importation of technology.

Optimize Transportation Network: Iran's transportation network currently provides robust domestic and international connections to meet supply chain demands. Positioned along the east-west transit route, Iran can expand international relations, contributing to economic growth.

Enhance Security: Despite negative international portrayals, Iran experiences relatively low levels of violent crimes, ensuring the safety of foreign workers and commercial properties. By resolving international disputes and encouraging foreign investments, crime and security risks can be reduced, boosting economic growth.

Reform Labor Laws: High employment costs in Iran, stemming from stringent labor laws, can hinder productivity. Amending these laws to increase labor efficiency is recommended to enhance production and economic growth.

Facilitate Trade: High tariffs, customs delays, and corruption potential can burden importers and exporters. By revising laws and regulations and becoming part of international trade organizations, Iran can promote free trade, thus stimulating economic growth.

Leverage Asian Partnerships: Iran can benefit from long-term cooperation plans with Asian countries, particularly China and Russia. These partnerships can lead to increased technology imports, ultimately boosting productivity and economic growth.

Address Environmental Concerns: Iran's outdated technology and key industries contribute to increased environmental pollution, leading to environmental crises. To mitigate the impact of climate change and environmental issues on economic growth, the following recommendations are made:

- Reduce sanctions to enable the importation of environmentally friendly manufacturing technologies, reducing harmful pollutants and increasing production factor productivity.
- Implement tax incentives to encourage manufacturing companies to reduce environmental pollutants. Streamlined technology imports due to economies of scale can further reduce pollution and drive economic growth.

- Participate in international agreements like the Paris Agreement to tackle global climate crises through collective efforts.
- Enhance privatization efforts to increase labor and capital productivity and promote the adoption of cleaner technologies, thus contributing to economic growth.
- Implement pollution taxes on companies that harm the environment, similar to practices in Scandinavian countries. Reinvest these taxes to address environmental issues, such as providing environmental subsidies like free solar panels.
- Encourage companies to establish environmental research and development units to improve environmental efficiency and reduce greenhouse gas emissions. Make the creation of these units a legal requirement for companies.

Furthermore, future research should consider employing modern econometric methods, particularly spatial econometrics, to study the global impact of risk and climate change, given the international nature of these issues, involving multiple countries.

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Authors' contributions

All authors had contribution in preparing this paper.

Conflicts of interest

The authors declare no conflict of interest

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