Quantifying Climate Risks: SVAR Analysis on Inflation and Economic Growth in Egypt

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Abstract:

Climate change poses a critical challenge in our era. In this study, we use quantitative methodology to examine the effect of natural disasters on inflation and GDP growth caused by weather. Using time series data for Egypt spanning the period 1965-2021. Based on Structural Vector Autoregression (SVAR), the analysis reveals that inflation and growth respond very modestly to weather-related natural disasters but differ regarding the direction and magnitude of climate shocks. Temperature shocks, storms, and floods lead to a decrease in inflation rates, while earthquakes increase inflation rates. While flood shocks appear to lead to a permanent increase in real Gross Domestic Product (GDP) growth, the effects of temperature, storms, and earthquakes are more volatile and less persistent in the long run. In the case of temperature shocks, the growth slowdown extends beyond seven years from the shock. At this point, real GDP growth is lower by approximately 3.8 percentage points than if the temperature shock had not occurred.

Keywords: climate risks, inflation, economic growth, SVAR.

Jel Classification: Q54, E31, O44, C32

الملخص:

إن تغير المناخ هو التحدي الحاسم في عصرنا. في هذه الدراسة، نحقق بشكل تجريبي باستخدام منهجية كمية في تأثير الكوارث الطبيعية المتعلقة بالطقس على تضخم أسعار المستهلك والنمو الاقتصادي، باستخدام بيانات سلاسل زمنية لمصر خلال الفترة ١٩٦٥-٢٠٢١. يُظهر التحليل القائم على متجه الانحدار الذاتي الهيكلي Structural Vector Autoregression SVAR أن التضخم والنمو يستجيبان بشكل متواضع جداً للكوارث الطبيعية المتعلقة بالطقس، ولكنهما يختلفان من حيث الاتجاه والحجم للصدمات المناخية. فتؤدي صدمات درجات الحرارة أو العواصف أو الفيضانات إلى انخفاض معدلات التضخم، لكن الزلازل تؤدي إلى ارتفاع معدلات التضخم. فبينما يبدو أن صدمة الفيضانات تؤدي إلى زيادة دائمة في نمو الناتج المحلي الإجمالي الحقيقي، فإن تأثير درجات الحرارة، والعواصف، والزلازل يكون أكثر تقلبًا وأقل استمرارًا على المدى الطويل. ففي حالة صدمة درجات الحرارة، يصل تباطؤ النمو إلى ما بعد ٧ سنوات منذ الصدمة، وعند هذه النقطة يكون نمو الناتج المحلي الإجمالي الحقيقي أقل بنحو ٣.٨ نقطة مئوية مما لو لم تحدث صدمة درجة الحرارة.

الكلمات الرئيسية: المخاطر المناخية، التضخم، النمو الاقتصادي، SVAR.

1 Introduction and Background:

The global economy and financial markets confront significant uncertainty due to climate change, a complex and ever-changing issue. These shocks include a variety of natural phenomena, such as earthquakes, storms, extreme temperatures, and drought. These climate shocks have significant and prolonged impacts on various economic variables, which poses an increasing challenge to world countries in supporting sustainable economic growth.

The frequency and severity of weather-related natural disasters have increased as global temperatures have risen to extremes. Droughts, extreme heat, and devastating storms are all on the rise due to human-caused climate change, whichas serious implications for ecosystems, human health, and the economy (Cevik & Jalles, 2023).

Weather shocks could impact economic activity through various channels, including diminishing labor productivity and agricultural and industrial output and reducing investment and output. Prominent evidence in this regard was introduced by (Cevik & Jalles, 2023), reviving what was previously confirmed by (Acevedo et al., 2020; Dell et al., 2012), which confirms the increasing importance of investigating climate-related shocks on economic activity.

Egypt, a key MENA emerging economy, is experiencing diverse impacts of climate shocks, including agriculture, industry, and infrastructure sectors. However, certain regions are exposed to climate shocks more severely than others. It is critical to understand how climate shocks affect Egypt's inflation and economic development to direct efforts towards mitigating those impacts and strengthen the economy's resilience.

However, literature experiencing a lack of research that comprehensively addresses these issues, as most economic studies have addressed the impacts of severe climate shocks such as floods, droughts, and fires while not giving the same importance to less severe climate shocks such as extreme temperatures and rainfall pattern changes, which can also have significant and lasting effects on economic variables. Moreover, literature has focused on developed countries rather than developing countries, despite the importance of studying climate shocks on both sides. More in-depth, most studies lacked focus on institutions and policies that could play a pivotal role in influencing the severity of the effects of these shocks.

This study seeks to fill this research gap by analyzing the various effects of climate shocks on inflation and growth indicators in Egypt, considering the institutional dimension and the effects of economic policies, with the goal of better understanding the effects of climate change on the Egyptian economy and guiding economic policies in this regard.

What effect do climate shocks have on Egypt's inflation and growth dynamics? This is not a straightforward issue, given that climatic shocks have contradictory effects on supply and demand while having a pervasive impact. Using a Structural Vector Autoregression (SVAR) approach, this research examines the impact of temperature extremes, floods, earthquakes, and storms on various inflation and GDP metrics in Egypt between 1962 and 2021. A more precise analysis is developed by paying attention to many indicators, such as core inflation and food inflation, and by integrating key crucial control factors. It is believed that the conclusions arising from this study would provide deeper insight into how to deal with climate concerns and support sustainable economic growth in Egypt and other nations with similar circumstances. By providing this context, the study contributes significantly to ongoing research into the effects of climatic shocks on Egypt's economy and efforts to steer economic policy toward improving economic well-being.

2 Literature Review

It is widely acknowledged that climate change poses serious economic threats, particularly economic growth and inflation. Several literature, including (Gupta et al., 2023; Zhang, 2023), have looked at the connection between climate change, inflation and economic growth, showing the possible detrimental effects of climate change on economic expansion.

According to (Winsemius et al., 2016), even after accounting for GDP growth, the influence of socioeconomic expansion on flood risk in Southeast Asia is even bigger. Considering both climate change and economic growth is crucial for accurate risk assessments, and this finding implies that socioeconomic considerations play a major role in influencing flood risk. They found that in Southeast Asia, the impact of societal growth on flood risk was significantly larger after controlling for GDP growth. This study suggests that socioeconomic factors play a significant role in influencing flood risk and that including both climate change and economic growth is vital for proper risk estimates. Using a dynamic general equilibrium model, (Eboli et al., 2010) investigated the relationship between climate change and economic expansion. Their findings further highlight these elements' interdependence by showing that climate change's effects are expected to affect economic growth.

Climate change might have far-reaching effects on the economy, including but not limited to dampening growth. In light of recent events, such as the COVID-19 pandemic, climate change, and the financial sector, (Monasterolo et al., 2020) highlighted the significance of compound risk. They highlighted that productive capacity, production, and GDP losses can arise from climate-induced hazards.

The consequences of climate change on economic growth can be both direct and indirect. The effects of climate change on economic growth may be exacerbated by market inefficiencies and the business cycle (Akan, 2023; Devitt & Tol, 2012). This implies that the consequences of climate change on economic growth are complex and can be impacted by numerous factors. In addition, (Salas Reyes et al., 2021) examined climate change risk perception and communication using affective dimensions. In their literature evaluation, emotions and affect are crucial to understanding how people perceive and convey climate change hazards. According to the study, research on the affective components of risk perception and communication connected to a wider spectrum of climate change impacts is needed. Moreover, the economic risks associated with climate change have been studied extensively, and many studies have focused on both the potential negative implications and the role of adaptation and mitigation methods in reducing such risks. (Breitenstein et al., 2021) emphasized the need for the financial sector to better comprehend and handle environmental risks. The results highlight the importance of using sound risk management measures to mitigate climate-related financial risks. (Hiep Hoang & Minh Huynh, 2021) affirmed that better institutions can help soften the blow of climate change on economic expansion.

Literature also investigated another strand of relationships, including human health and extended impacts of climate and climate vulnerability (Asafo-Adjei et al., 2023). (Karki et al., 2020) examined inflation and economic growth.

The study shows that economic literature disagrees on inflation and economic growth. Further research is needed to understand inflation-economic growth dynamics in different circumstances (Jordan et al., 2023; Meinerding et al., 2023). In addition, an extensive literature study on climate security and its effects on East Asia was illustrated by (Sekiyama, 2022). In addition to immediate dangers posed by extreme weather events, resource shortages, climate migration, disruptions in food production, and geopolitical shifts are also identified as ways in which climate change raises the probability of war. The results highlight the significance of tackling climate security concerns in the region. (Ford & Pearce, 2010) a systematic literature review was conducted to assess climate change vulnerability in the western Canadian Arctic. The study highlights the need for a comprehensive understanding of climate change impacts on vulnerable regions. The findings underscore the gaps in knowledge and the need for further research to enhance climate change resilience in the western Canadian Arctic.

The literature implies that climate change threatens economic development and inflation. Climate change has several direct and indirect implications for the economy. However, the predominant literature has focused on advanced economies without giving their developing counterparts the attention they deserve. The scope of these studies is too narrow to account for all climatic threats while also failing to give the institutional dimension the attention it deserves. Understanding and tackling these risks is essential for climate-resilient economic development.

3 Data overview

To achieve the study's objective of measuring the impact of climate-related shocks on inflation and economic growth dynamics in Egypt, the study relies on annual time series data for Egypt covering the period from 1965 to 2021, with 57 annual observations. Inflation and economic growth will serve as the dependent variables in this analysis. Inflation is measured on an annual basis as the percentage change in the Consumer Price Index (CPI) following (Cevik & Jalles, 2023) as follows:

$$\pi_t = \left(\frac{CPI_t}{CPI_{t-12}}\right) * 100$$

Where π_t refers to the inflation level in Egypt at time t, based on the headline Consumer Price Index (CPI) and the Food CPI component in the Consumer Price Index, derived from the Global Inflation Database by (Ha et al., 2023). Economic growth is measured using the annual rate of change in real Gross Domestic Product (GDP) obtained from the World Development Indicators database of the World Bank. These data sources and measurements provide a solid foundation for the study's analysis of the impact of climate-related shocks on inflation and economic growth in Egypt over the specified period.

The frequency of weather-related natural catastrophes recorded in the Emergency Events Database (EM-DAT) is a proxy for climate shocks. Since 1900, the Centre for Research on the Epidemiology of Catastrophes (CRED) at the Catholic University of Louvain in Belgium has created the EM-DAT database, which contains information on the occurrence and consequences of over 22,000 large-scale natural disasters worldwide. It offers information on various categories focused on climate-induced events, including droughts, extreme temperatures[1], and storms. EM-DAT defines droughts as "an extended period of deficient rainfall relative to the statistical multi-year average for a region, resulting in a water shortage for people, animals, and plants." Extreme temperatures are generally characterized as "variations in temperature above (extreme heat) or below (extreme cold) normal conditions." Storms encompass weather phenomena, including extratropical storms, tropical cyclones, and thunderstorms. Climate shocks have been transformed into dummy variables, where these shocks take a value of 1 when a climate-related disaster occurs in Egypt in a particular year and zero otherwise. However, to develop a more detailed analysis, the intensity of climate-related natural disasters is also used, measured by the number of deaths per population. Including these variables is crucial for assessing the impact of climate-related shocks on Egypt's inflation and economic growth dynamics over the studied period.

The study herein utilizes the extant literature, as summarized by (Botzen et al., 2019; Cevik & Jalles, 2023). A set of control variables has been included in the analysis conducted in the present study, encompassing external debt

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[1] The main difference between extreme temperatures and droughts is that extreme temperatures are the result of short-term weather-related hazards, while droughts are the consequence of long-term climatic hazards.

balances, per capita real Gross Domestic Product (GDP), output gaps, trade openness (defined as the sum of exports and imports as a share of total GDP), levels of urbanization, the Financial Openness Index developed by (Chinn & Ito, 2006), the trade exchange rate index, and, lastly, the growth rate of the money supply. Data series were acquired from the International Monetary Fund's World Economic Outlook report, the World Bank's Global Development Indicators, and the Chinn-Ito database. An appendix in the study, **Table A- 1** describes the variables employed and their respective data sources.

4 Econometric Methodology

4.1 Model specification:

To measure the impact of climate-related shocks on inflation and economic growth dynamics in Egypt, a methodology based on Vector Auto Regression (VAR) will be employed. Since the critique by (Sims, 1980) in the early 1980s, VARs have evolved into standard tools for providing succinct insights into the response of macroeconomic variables to structural shocks. The popularity of VARs stems from their ease of use, as they are often more effective than complex simultaneous-equation models in predicting the dynamic effects of various types of random disturbances on the variables in the model. They are inherently unrestricted (Sims, 1980).

Here, VAR considers all interactions among variables, treating all variables as endogenous and models all variables as contemporaneously determined, ignoring structural relationships among variables. Due to its structural indeterminacy, VAR fails to account for structural relationships among variables. Different structural forms give the same reduced-form VAR, making it impossible to derive meaningful conclusions about the structural model from the reduced-form VAR without imposing restrictions (Gottschalk, 2001; Kilian & Lütkepohl, 2017). Structural Vector Autoregression (SVAR) addresses this identification problem in this context. Unlike VAR, SVAR considers the contemporaneous interactions among endogenous variables and allows structural shocks and impulse responses to be estimated. SVAR models use restrictions based on economic theory and/or prior beliefs to identify the system and obtain an economic interpretation of the response to shocks (Fielding et al., 2012; Kilian & Lütkepohl, 2017).

Therefore, this study employs the SVAR framework because it compensates for the limitations of the VAR technique. Economic theories do not specify the precise factors or variables determining inflation and economic growth (Sala-I-Martin, 1997). Thus, the empirical model applied in this study is the $SVAR_{(p)}$ model, which illustrates the relationship between inflation rates, economic growth, climate-related natural disasters, and other explanatory economic variables. The $SVAR_{(p)}$ model can be expressed as follows:

$$AZ_t = A_0 + C(L)Z_{t-1} + B\varepsilon_t \qquad \text{Equation 1}$$

Where: A is a (k×k) matrix of structural coefficients, Z_t is a $(k \times 1)$ vector of endogenous variables (comprising climate-related natural disasters, external debt, individual's share of real GDP, output gap, trade openness, urbanization, trade exchange rate, financial openness, and money supply growth) at time t, A_0 is a $(k \times 1)$ vector of intercept terms, $C(L)$is a $(k \times k)$ matrix of lag polynomials of order L representing the impulse response function of elements of Z_t, Z_{t-1} is a $(k \times 1)$ vector of lagged endogenous variables, B is a $(k \times k)$ matrix capturing the linear relationships between structural shocks and those in the reduced form, ε_t is a $(k \times 1)$ vector of structural innovations. The structural innovations are uncorrelated and normally distributed. The reduced-form VAR model is determined by multiplying Equation 1 by the inverse of the matrix A, which is A-1.

$$Z_t = v + D(L)Z_{t-1} + u_t \qquad \text{Equation 2}$$

Where $v = A^{-1}A_0$, $D(L) = A^{-1}C(L)$, $u_t = A^{-1}B\varepsilon_t$. u_t is a $(k \times 1)$ vector of uncorrelated, serially distributed innovations in reduced form, which can be normally distributed but may be contemporaneously correlated with each other. Here, the relationship between the reduced-form innovations u_t, the final interest variables, the structural innovations ε_t, and so on, can be represented as follows:

$$Au_t = B\varepsilon_t \qquad \text{Equation 3}$$

Where A and B are square matrices that describe (1) the contemporaneous relationships between the variables and (2) the linear relationships between the reduced-form innovations. The reduced-form innovations u_t are not interpretable in an economic sense, as they are linear combinations of the structural shocks, while the unobserved structural shocks ε_t have an economic interpretation.

4.2 Structural identification:

As previously stated, constraints must be placed on matrices A and B to distinguish the structural shocks from the variance-covariance matrix computed in reduced form. Given that every equation in the unlimited VAR model employs the identical lag structure, the model in Equation 2 was estimated using Ordinary Least Squares (OLS) after the exact identification of the lag structure to remove serial correlation from the residuals. After estimating the reduced-form VAR using OLS, the next step in identifying the model is to assume the relative ordering of the variables. The ordering of the variables in the vector of endogenous variables plays a crucial role in the identification process because changing the order alters the structural innovations' relationship.

There are several identification options in the current literature, each with some advantages and disadvantages, with little guidance currently available to choose between them (Fry & Pagan, 2011). Relying on the identification scheme proposed by (Blanchard & Perotti, 2002), the assumption of no contemporaneous relationship informs the ordering of variables in the estimated model. The variables were introduced into the VAR model as follows: weather-related natural disasters (ND), the dependent variable [either the Headline Consumer Price Index (HCPI), the Food Consumer Price Index (FCPI), or the Gross Domestic Product Growth Rate (GDPG)], external debt (EDS), real per capita income (RGDPc), output gap (OG), trade openness (TO), urbanization (U), financial openness (FO), terms of trade (TOT), and finally, money supply growth (M2). This ordering imposes a triangular structure on the matrix A, and it can be represented in terms of reduced-form residuals and structural innovations as follows:

$$
= \begin{bmatrix} 1 & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\ a_{21} & 1 & \ddots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ a_{31} & a_{32} & 1 & \ddots & \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ a_{41} & a_{42} & a_{43} & 1 & \ddots & \cdots & \cdots & \cdots & \cdots & \vdots \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & \ddots & \cdots & \cdots & \cdots & \vdots \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & \ddots & \cdots & \cdots & \vdots \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 & \ddots & \cdots & \vdots \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 & \ddots & \vdots \\ a_{91} & a_{92} & a_{93} & a_{94} & a_{95} & a_{96} & a_{97} & a_{98} & 1 & 0 \\ a_{101} & a_{102} & a_{103} & a_{104} & a_{105} & a_{106} & a_{107} & a_{108} & a_{109} & 1 \end{bmatrix} \begin{bmatrix} u_i^{ND} \\ u_i^{HCPI} \\ u_i^{EDS} \\ u_i^{RGDPc} \\ u_i^{OG} \\ u_i^{TO} \\ u_i^{U} \\ u_i^{FO} \\ u_i^{TOT} \\ u_i^{M2} \end{bmatrix}
$$

Equation 4

$$
\begin{bmatrix} b_{11} & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\ 0 & 1 & \ddots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \ddots & 1 & \ddots & \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \ddots & 1 & \ddots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \ddots & 1 & \ddots & \cdots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \ddots & 1 & \ddots & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \ddots & 1 & \ddots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots & \ddots & 1 & \ddots & \vdots \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \ddots & 1 & 0 \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_i^{ND} \\ \varepsilon_i^{HCPI} \\ \varepsilon_i^{EDS} \\ \varepsilon_i^{RGDPc} \\ \varepsilon_i^{OG} \\ \varepsilon_i^{TO} \\ \varepsilon_i^{U} \\ \varepsilon_i^{FO} \\ \varepsilon_i^{TOT} \\ \varepsilon_i^{M2} \end{bmatrix}
$$

This implies that inflation, economic growth, external debt, real per capita income, output gap, trade openness, urbanization, financial openness, terms of trade, and money supply growth respond contemporaneously to changes in weather-related natural disasters. However, these natural disasters only respond to changes in these internal variables with a lag. Similarly, it is assumed that inflation and economic growth are contemporaneously affected by changes in weather-related natural disasters, external debt, real per capita income, output gap, trade openness, urbanization, financial openness, terms of trade, and money supply growth, but these variables respond to shocks in inflation and economic growth only with a delay.

After estimating the reduced form of the VAR and all the coefficients (a's and b's), the next step is to create matrices A and B, which are used to compute Impulse Response Functions (IRFs). IRFs are used to assess and track the time path of the impact of structural shocks on the endogenous variables of interest.

5 Empirical results:

5.1 Descriptive analysis:

Here, Table 1 and Table 2 present a concise statistical description of all the variables used and the correlation matrix between them. Table 1, along with

Figure A- 1 in the study's appendix, aims to describe the key features of the study's variables. For the dependent variables,

Figure A- 1 reveals significant fluctuations in Egypt's growth rates and inflation levels over the study period of 57 years. On average, the Egyptian economy grows at 4.7% annually, with overall prices increasing by approximately 10.4% and food prices rising by about 11.4% annually. This means that the Egyptian economy roughly doubles in size every 21 years, while food prices double every 8 years, and the general price level for all goods doubles every 10 years. This implies a continuous decline in the welfare of Egyptians due to the lack of proportional income growth and rising price levels.

The independent variables representing climate-related natural disasters have been expressed as dummy variables (whether a disaster occurred or not). Therefore, the average of the independent variables reflects the percentage of observations that take the value 1, meaning the percentage of observations that report the occurrence of a natural disaster. Based on this, the average of the overall natural disasters index is (0.353), meaning that 35.3% of the period used experienced natural disasters, equivalent to 20 years. This can be observed in

Figure A- 1. These natural disasters are categorized as follows: 4 years with temperature-related disasters, 6 years with earthquake-related disasters, 7 years with storm-related disasters, and finally, 11 years with flood-related disasters. The reason for the difference between the total number of climate-related natural disasters that occurred during the study period and the sum of the four specific types mentioned is the presence of years where more than one weather-related disaster occurred.

Table 1: Descriptive statistics for variables, 1965 - 2021

	Unit of measurement	*Obs.*	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*	*Normality test*
Dependent Variable:								
Real GDP growth	(annual %)	57	4.9656	4.7445	2.541	-1.607	13.28	[8.6507]**
Headline CPI	(annual %)	57	10.414	10.065	6.349	-1.676	29.51	[3.0600]
Food CPI	(annual %)	52	12.215	11.437	7.649	-0.199	38.66	[10.448]***
Independent Variable:								
Natural disaster (Overall)	(dummy)	57	0.3529	0	0.481	0	1	[9.8622]***
Temperature natural disaster	(dummy)	57	0.0702	0	0.258	0	1	[314.13]***
Storm natural disaster	(dummy)	57	0.1228	0	0.331	0	1	[75.753]***
Earthquakes natural disaster	(dummy)	57	0.1053	0	0.309	0	1	[113.51]***
Floods natural disaster	(dummy)	57	0.1929	0	0.398	0	1	[23.419]***
Control Variables:								
External debt stocks	(% of GNI)	57	49.834	36.675	33.68	13.99	132.7	[8.0345]**
GDP per capita	(Constant LCU)	57	22226	20826	9411	9184	39789	[3.5575]
GDP per capita (log)		57	9.9103	9.9439	0.464	9.125	10.59	[4.0682]
Output gap	(% of Potential GDP)	57	0.0279	-0.0290	2.719	-8.239	7.511	[4.5574]
Trade openness	(% of GDP)	57	46.912	45.911	12.25	29.26	74.46	[2.8180]
Urban	(% of the population)	57	42.866	42.946	0.944	39.69	43.95	[42.031]***
Financial openness	(0 - 1)	52	0.3414	0.1635	0.391	0	1	[6.6017]**
Terms of trade	(Constant LCU)	57	4.7e+10	4.2e+10	3.4e+10	-2.5e+1 0	1.5e+11	[7.0629]**
Terms of trade (log)		57	24.419	24.921	3.368	0	25.86	[5752.9]***
M_2	(annual %)	57	17.249	16.239	9.554	1.538	51.42	[15.753]***

***Note*:** - ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table 2: Correlation matrix between variables, 1965 - 2021

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
GDP growth	**(1)**	1										
Headline CPI	**(2)**	0.283[b]	1									
Natural disaster	**(3)**	-0.123	-0.022	1								
External debt	**(4)**	0.369[a]	0.575[a]	-0.059	1							
ln GDP_c	**(5)**	-0.121	0.164	0.225[c]	-0.171	1						
Output gap	**(6)**	0.089	0.099	-0.177	0.073	0.024	1					
Trade openness	**(7)**	0.415[a]	0.411[a]	0.013	0.464[a]	0.086	-0.157	1				
Urban	**(8)**	0.415[a]	0.461[a]	0.056	0.638[a]	0.346[a]	-0.309[b]	0.554[a]	1			
Financial openness	**(9)**	-0.164	-0.376	0.125	-0.565[a]	0.624[a]	0.174	0.050	-0.329[b]	1		
ln Terms of trade	**(10)**	-0.023	0.017	0.078	0.015	-0.207	-0.087	0.127	0.027	0.014	1	
M_2	**(11)**	0.417[a]	0.454[a]	-0.044	0.511[a]	-0.015	-0.359[a]	0.436[a]	0.638[a]	-0.503[a]	0.042	1

***Note*:** - a, b, and c indicate significance at 1%, 5% and 10%, respectively.

Moving on to the control variables, we find that the average external debt as a percentage of total national income is 36.7%. Additionally, the per capita real income increased from 9,184 pounds in 1965 to 39,789 pounds in 2021, equivalent to an average monthly income of 3,300 pounds in 2021, which is a very modest income level. The output gap is 0.03% of the potential GDP, indicating a very small gap and suggesting that the Egyptian economy is operating close to its maximum production capacity. Egypt is also not very economically open, with an average trade-to-GDP ratio of 46.9%, and it is financially not very open, with an average of 0.164. Moreover, 42.9% of the total population lives in urban areas. Finally, the average broad money supply growth rate is 16.2%, which is relatively high and may partially explain the high inflation rates.

Table 2 shows a weak and statistically non-significant negative correlation between the climate-related natural disasters variable and the dependent variables (real GDP growth and inflation). The correlation is -12.3% with GDP growth and -2.2% with inflation. This suggests that real GDP growth and inflation rates are not significantly affected by climate-related shocks, meaning that climate shocks do not lead to substantial changes in growth or inflation rates. This could be attributed to climate-related natural disasters in Egypt mostly occurring in remote and sparsely populated areas, especially in border provinces, oases, or sparsely populated desert regions. Additionally, the size and impact of these natural disasters are generally small, and they do not reach the magnitude of large-scale natural disasters that significantly impact the national economy, such as the 1992 earthquake disaster.

5.2 Unit Root Test:

The first step in the standard analysis involves verifying the stationarity of the time series and determining the degree of integration for each series within the model to avoid spurious regression. The unit root test is considered one of the most important and widely used methods for testing stationarity. As (Fuller, 1976) has illustrated, unit root tests are not necessarily robust, and it is preferable to employ multiple tests. Therefore, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, which are commonly used in applied research, will be used to detect stationarity and verify the strength and stability of the results (Robust). Table 3 presents the stationarity results.

The stationarity results from the ADF and PP tests indicate a consensus that all variables were stationary at the level, meaning they have become integrated of order I(0). However, three indicators deviate from this: external debt balances, per capita real income, and the financial openness index, which were non-stationary at the level but became stationary at the first difference, signifying that they are integrated of order I(1). Consequently, the first differences of these three variables will be taken to transform them into stationary variables for further analysis.

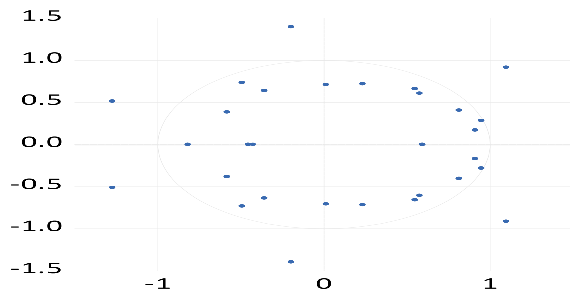
Table 3: Unit root test results

Variables	***Augmented Dickey-Fuller***			***Phillips-Perron***			***Results***
	Intercept	*Intercept & trend*	*None*	*Intercept*	*Intercept & trend*	*None*	
Real GDP growth	-4.3338[a]			-4.3448[a]			I(0)
Headline CPI	-3.4455[b]			-3.4109[b]			I(0)
Food CPI	-3.6703[a]			-3.6267[a]			I(0)
Natural disaster (Overall)	-6.5890[a]			-6.5877[a]			I(0)
Temperature natural disaster	-6.0482[a]			-6.0377[a]			I(0)
Storm natural disaster	-7.2000[a]			-7.4264[a]			I(0)
Earthquakes natural disaster	-6.8738[a]			-6.8828[a]			I(0)
Floods natural disaster	-5.4872[a]			-5.4872[a]			I(0)
External debt stocks	-1.1814	-1.5315	-0.4946	-1.4641	-1.7173	-0.6850	I(1)
D(External debt stocks)	-5.7209[a]			-5.7588[a]			
GDP per capita (log)	-0.7658	-0.8613	3.1096	-0.7217	-1.4375	5.5862	I(1)
D(GDP per capita (log))	-4.3663[a]			-4.3796[a]			
Output gap	-4.4888[a]			-3.3121[b]			I(0)
Trade openness	-2.6260[c]			-2.2859	-2.2122	-0.6581	I(0)/I(1)
D(Trade openness)				-5.9643[a]			
Urban	-3.8011[a]			-3.9419[a]			I(0)
Financial openness	-1.2175	-1.0938	-0.5827	-1.4534	-1.5101	-0.8358	I(1)
D(Financial openness)	-6.0586[a]			-6.1954[a]			
Terms of trade (log)	-3.2563[b]			-5.7955[a]			I(0)
M_2	-3.2332[b]			-3.1233[b]			I(0)
Critical Values	***ADF***			***PP***			
%1	-3.7696	-4.4407	-2.6743	-3.7529	-4.4163	-2.6694	
%5	-3.0049	-3.6329	-1.9572	-2.9981	-3.6220	-1.9564	
%10	-2.6422	-3.2547	-1.6082	-2.6388	-3.2486	-1.6085	

***Note*: -** a, b, and c indicate significance at 1%, 5% and 10%, respectively.

After confirming the stationarity of the time series used in the analysis, an SVAR model was estimated with a lag order of two, as selected using the Schwartz Information Criteria (SC) test. The model also passed diagnostic tests for normal distribution and the absence of autocorrelation. In addition to the unit root tests, the stationarity of variables was further validated through the graphical representation of AR roots, as depicted in Figure 1. It is evident in the figure that all eigenvalues are smaller than one and fall within the unit circle. This signifies that the SVAR model is covariance stationary and satisfies the stability condition (Lütkepohl, 2005).

Figure 1: Inverse roots of AR characteristic polynomial:



5.3 Structural impulse responses:

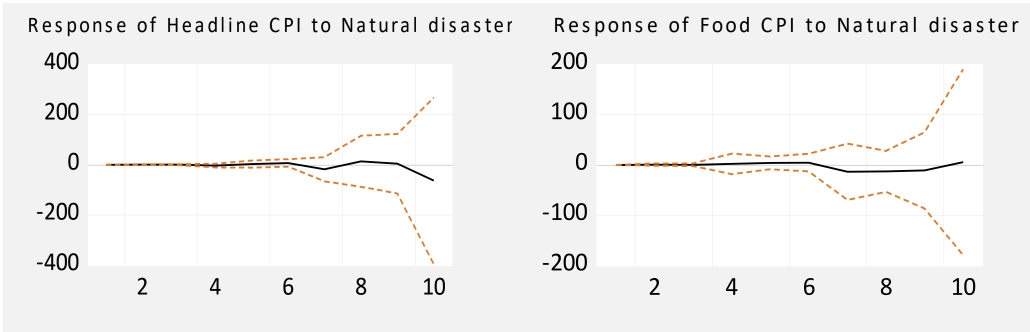
The starting point for our empirical analysis is to estimate the impact of climate shocks of four types, namely temperature-related shocks, storms, earthquakes, and floods, on the inflation indicators employed, namely the headline Consumer Price Index (CPI) and the Food Consumer Price Index (CPI), during the period 1965-2021 in Egypt. Subsequently, the estimation of climate shocks on economic growth during the same period will follow.

5.3.1 Climate Shocks and Inflation:

Figure 2 presents Impulse Response Functions (IRF) models for the main inflation and food inflation due to climate-related natural disaster shocks alongside 95% confidence intervals. Figure 3 displays IRF models for the main inflation and food inflation for four types of climate-related natural disaster shocks: temperature-related, storms, earthquakes, and floods. Meanwhile,

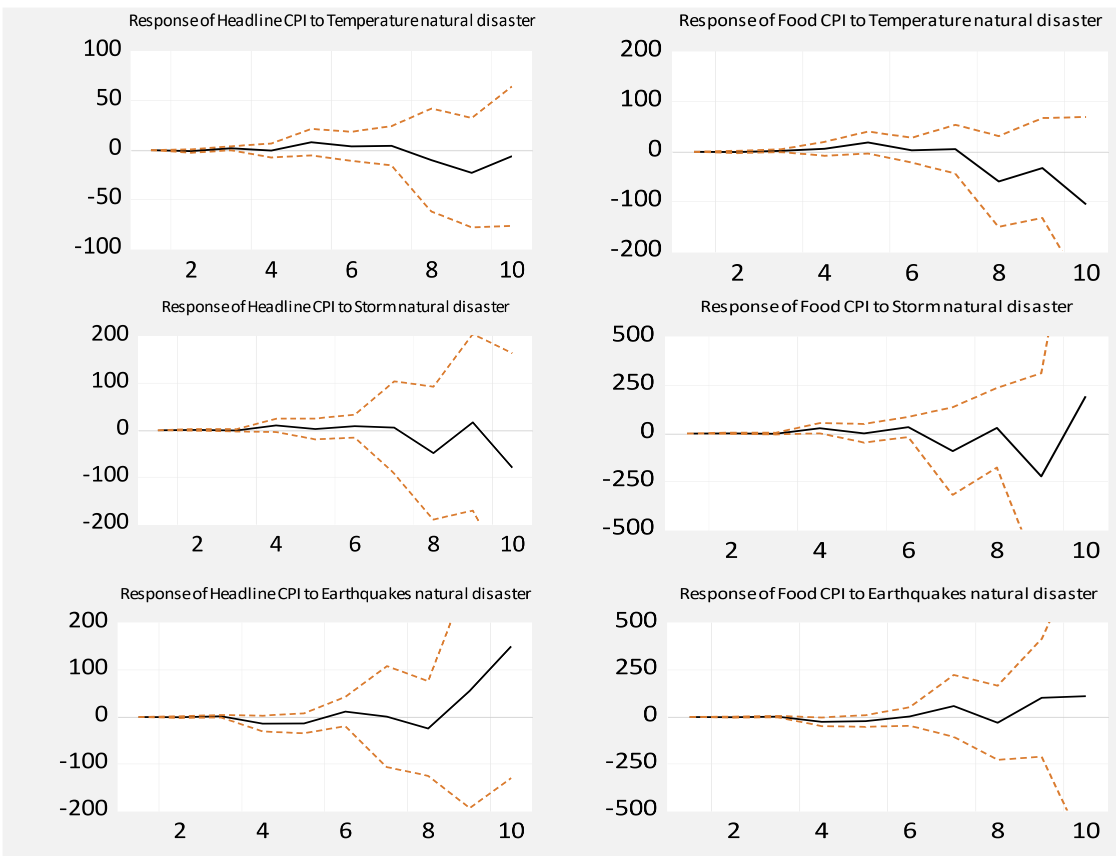
Table A- 2 provides the numerical results of the resulting IRF models.

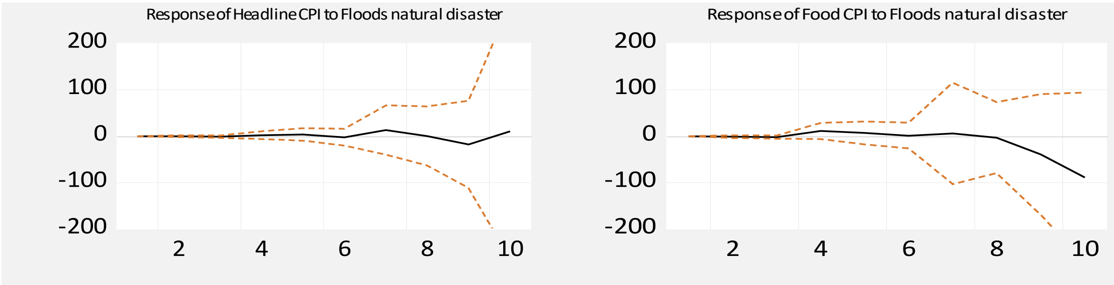
Figure 2: Baseline Impact of Climate Shocks on Inflation: Headline and Food Inflation



Note: Response to Structural VAR Innovations ± 2 S.E.

Figure 3: Baseline Impact of sub-Climate Shocks on Inflation: Headline and Food Inflation





Note: Response to Structural VAR Innovations ± 2 S.E.

As evident in the Impulse Response Functions (IRF) graphs, the solid lines represent the response function to shocks, while the dashed lines represent the confidence intervals, with their width representing approximately two standard errors. These dashed lines thus indicate a 95% confidence interval. The horizontal axis represents the number of years that have passed after the occurrence of the shock, while the vertical axis measures the response of the inflation level (percentage).

Figure 2 and Figure 3 show that both main and food inflation respond very modestly to climate shocks, especially in the short and medium terms. They exhibit different directions and magnitudes of response to climate shocks, as measured by a binary weather-related natural disaster occurrence variable for a particular year. On the overall level of climate-related natural disasters in Figure 2, the occurrence of a climate-related natural disaster leads to a modest increase in main inflation in the first year, followed by a decrease in main inflation until the third year, after which it increases again in the medium term but decreases to its lowest level in the long term, around 10 years later. As for food inflation, a climate-related natural disaster leads to a gradual increase over the medium term, but it reaches its lowest level after about 7 years.

At the level of sub-disasters (temperature-related, storms, earthquakes, and floods), it is observed that the response pattern of both main inflation and food inflation to these shocks is roughly symmetric in terms of direction. For temperature-related, earthquake, and flood-related natural disasters, the occurrence leads to a slight decrease in main inflation and food inflation below their initial levels in the first year, unlike storm-related natural disasters, which lead to an increase in main inflation and food inflation above their initial levels in the first year. Subsequently, there is a variation in the response to shocks from these four types of disasters during the second and third years. However, in the end, these effects converge almost from the fourth year for both main inflation and food inflation. Over the long term, inflation rates decline significantly below their initial levels before the disaster, except for natural disasters resulting from earthquakes, which lead to a substantial response in the long term, reaching 150.1 for main inflation and 110.5 for food inflation in the tenth year.

Hence, it becomes evident that the state of the economy plays a significant role in shaping the impact of weather-related disasters on core inflation and food inflation. However, the long-term magnitude and pattern depend on the precise nature of the shock. The wide-scale weather events analyzed in our study serve as shocks at the national level for two reasons: either the shock itself is widespread, or economic relationships related to trade and/or market integration ultimately disseminate the shock throughout Egypt.

5.3.2 Climate Shocks and Growth:

In Figure 4, an Impulse Response Function (IRF) model is presented for the growth of the total real GDP concerning the total natural disaster variable. In contrast,

Figure *5* presents IRF models for the growth of total real GDP for four types of weather-related natural disasters (temperature-related, storms, earthquakes, and floods) alongside 95% confidence intervals. It has been observed that the initial response of economic growth to climate shocks is positive in the short and medium terms for both the overall climate shocks and the four specific types of weather-related disasters. However, it eventually turns negative starting from the seventh year.

As for the four sub-disasters, the size and pattern of the response show variability over the long term. While flood shocks lead to a permanent increase in real GDP growth, the impact of temperature-related, storm-related, and earthquake-related shocks is more volatile and less sustained over the long term. In the case of temperature-related shocks, the growth slowdown extends beyond 7 years from the shock. The real GDP growth is approximately 3.8 percentage points lower than it would have been without the temperature shock. Both storm waves and earthquake shocks result in a slight decline in growth in the first year after the shock, but the impact size is variable and less persistent over time.

These results reflect Egypt's demographic, structural, financial, and institutional differences, which may hinder its ability to adapt to and mitigate the consequences of climate shocks. In particular, it should be noted that the overall weather-related impact is likely to obscure significant differences in the impact of different types of natural disasters on real GDP growth across sectors.

Figure 4: Baseline Impact of Climate Shocks on Growth

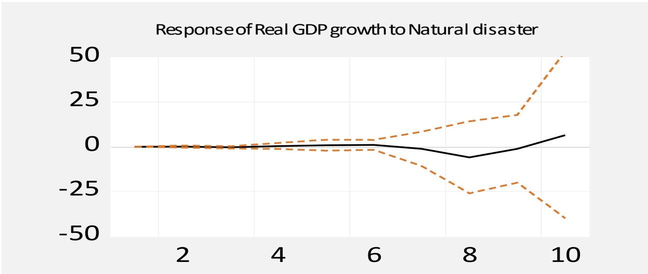
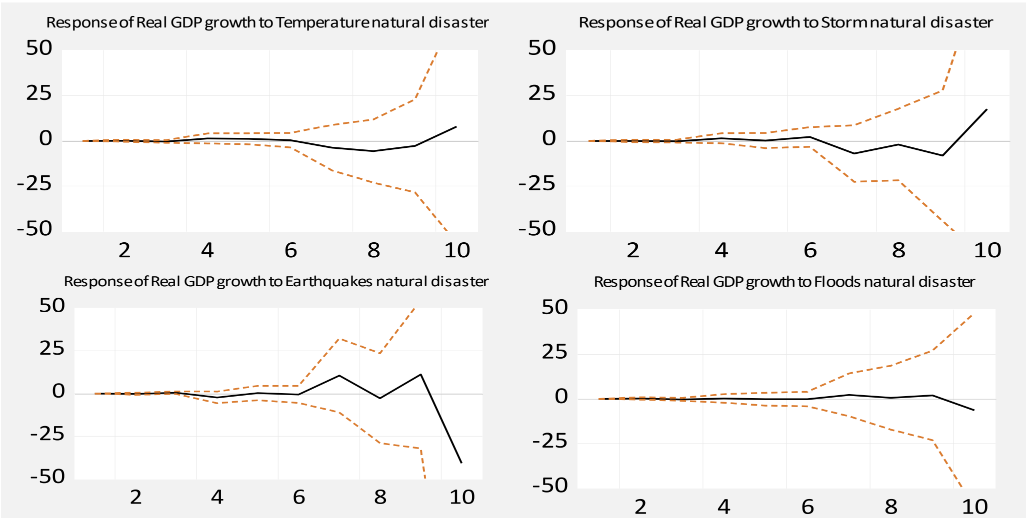


Figure 5: Baseline Impact of sub-Climate Shocks on Inflation: Headline and Food Inflation



Note: Response to Structural VAR Innovations ± 2 S.E.

Table 4: Structural Decomposition of Variance of Growth

Period	Response of Real GDP Growth				
	Overall	*Temperature*	*Storm*	*Earthquakes*	*Floods*
1	0.000000 (0.00000)	0.000000 (0.00000)	0.000000 (0.00000)	0.000000 (0.00000)	0.000000 (0.00000)
2	0.069015 (0.28705)	0.042068 (0.28667)	-0.060991 (0.34924)	-0.201447 (0.32743)	0.242101 (0.33893)
3	-0.378112 (0.33170)	-0.397792 (0.37170)	-0.195523 (0.39465)	0.406227 (0.37362)	-0.298612 (0.40834)
4	0.358834 (0.83954)	1.325125 (1.38484)	1.423154 (1.39033)	-2.304143 (1.69652)	0.208800 (1.19200)
5	0.820953 (1.53987)	1.069086 (1.53217)	0.119430 (2.09364)	0.200444 (2.10326)	-0.183183 (1.78568)
6	0.983343 (1.37869)	0.316909 (2.00047)	2.108055 (2.70570)	-0.596487 (2.48633)	-0.112970 (2.02277)
7	-1.203963 (4.80310)	-3.807830 (6.27009)	-7.062367 (7.81368)	10.45567 (10.8136)	2.233427 (6.01113)
8	-5.967606 (10.0924)	-5.685040 (8.76708)	-2.045287 (9.91193)	-2.812334 (13.1292)	0.663068 (8.95348)
9	-1.198926 (9.48359)	-2.783244 (12.8928)	-8.208593 (18.0604)	11.14061 (21.6565)	1.948328 (12.5571)
10	6.472507 (23.3084)	7.905494 (32.1293)	17.58861 (42.0851)	-40.74152 (76.4559)	-6.354679 (27.1866)

In general, the empirical analysis presented in this paper indicates that climate-related natural disasters have varying and conflicting effects on inflation and economic growth through multiple channels, such as (1) changes in agricultural production and food prices, (2) the dampening and reduction of economic activity through labor productivity, (3) reductions in wealth and income, thus affecting consumption and investment, and (4) the impact on transportation infrastructure and distribution costs. Moreover, these transmission channels differ significantly with the level of economic development and diversification across countries. We believe these results also reflect demographic differences, structural factors, and Egypt's limited financial and institutional capacity to adapt to and mitigate the effects of climate shocks. Accordingly, several important policy implications are in the wake of accelerating climate change. First, this will make inflation and growth dynamics more volatile, with potential ripple effects across all sectors of the economy. Second, the different inflation patterns and growth response to climate shocks will lead to further income and inflation disparities among various segments of society within the country. In other words, households with consumption baskets likely to experience inflation increases and income loss in the aftermath of natural disasters will be more severely affected compared to households with lower relative reliance on these products and whose income is not negatively impacted. Policymakers should also consider how shifting away from fossil fuels as a critical part of climate change mitigation efforts, often called the "green transition," will affect inflation and growth dynamics.

6 Results:

Climate change is the pivotal challenge of our era. In this paper, we empirically investigate the impact of weather-related natural disasters on consumer price inflation and economic growth using time series data for Egypt from 1962 to 2021. We employ a Structural Vector Autoregression (SVAR) framework to examine how climate shocks, such as temperature, floods, earthquakes, and storms, influence alternative measures of inflation and economic growth in Egypt over this period.

Our study reveals that both core inflation and food inflation respond very modestly to climate shocks, particularly in the short and medium terms. Moreover, our findings indicate that the initial response of economic growth to climate shocks is positive in the short and medium terms, but it turns negative beginning in the seventh year. These results appear to be at odds with the findings of a leading study (Cevik & Jalles, 2023), which demonstrated a substantial impact of climate shocks on both inflation and real GDP growth.

(Cevik & Jalles, 2023) encompassing 172 nations during the period 1970-2020, found pronounced variations in the impact of climate shocks on inflation and growth based on income levels, economic conditions, and financial capacity at the time of the shock. It is natural that when working with a large number of countries, the aggregate impact of sectoral data tends to be strong, particularly when the sample includes nations highly susceptible to earthquakes, storms, floods, and extreme temperature fluctuations.

7 Conclusion:

Conversely, our present paper constitutes a single-country case study focusing on Egypt. The divergent results can be attributed to climate-related natural disasters in Egypt primarily occurring in remote and sparsely populated areas, notably in border provinces, oases, and desert regions. The magnitude of these natural disasters tends to be relatively low, and their impact and reach are limited. As such, most of these natural disasters do not rise to the level of widespread, economy-wide disasters, such as the 1992 earthquake disaster. Nonetheless, both studies concur that inflation and economic growth differ in direction and magnitude across various climate-related disasters.

Temperature shocks, storms, and floods during the study period resulted in decreased inflation rates, whereas earthquakes led to increased inflation rates. While flood shocks appear to yield a sustained increase in real GDP growth, the impact of temperature, storms, and earthquakes is more volatile and less enduring over the long term. In the case of temperature shocks, the growth slowdown extends beyond seven years from the shock. Real GDP growth is approximately 3.8 percentage points lower than if the temperature shock had not occurred.

It is essential to recognize that the empirical results presented in this paper represent the minimum impact of weather-related disasters in the wake of accelerated climate change. Consequently, there are several significant implications for economic policy. Firstly, these findings will render inflation and growth dynamics more volatile, with potential repercussions across all sectors of the economy. Secondly, the divergent patterns in how inflation and growth respond to climate shocks will lead to further disparities in the inflation level and income growth experienced by various segments of society within a country. In other words, households whose consumption baskets consist primarily of goods and services likely to witness inflation and income loss in the aftermath of natural disasters will be more adversely affected than households with relatively lower dependence on these products, whose incomes are not negatively impacted.

In our view, these results reflect demographic and structural differences and financial and institutional vulnerabilities in developing countries, including Egypt, when adapting to and mitigating the effects of climate shocks. Looking to the future, it is also imperative for policymakers to consider how the transition away from fossil fuels as a pivotal component of climate change mitigation efforts will affect inflation and growth dynamics.

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9 Appendix:

Table A- 1: Data description & Data source

Data	***Description***	***Source***
GDP growth	**The Gross Domestic Product growth rate;** expressed as a percentage per annum, refers to the annual rate of growth of the Gross Domestic Product at constant local currency prices. The figures are based on the fixed price of the United States dollar in the year 2010.	(WBI)
headline CPI	**Inflation, consumer prices (% annually);** reflects inflation as measured by the Consumer Price Index, which indicates the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may remain constant or vary over specific periods, typically on an annual basis. It is generally expressed using the Laspeyres formula.	(WBI)*
Natural disasters	**Natural disasters;** a hypothetical index that takes the value 1 when a disaster related to natural conditions such as extreme temperatures, storms, earthquakes, or floods occurs, while it takes the value 0 otherwise.	EM-DAT
Foreign debt	**External debt balances (% of gross national income);** this represents the amount of public debt guaranteed by the government, unguaranteed long-term private debt, the use of International Monetary Fund credit, short-term debt (all debts with an original maturity of one year or less), and overdue interest on long-term debt. Here, the total external debt balances are expressed as a percentage of gross national income.	(WBI)
GDP per capita	**Per capita gross domestic product (at constant local currency prices);** is obtained by dividing the real gross domestic product by the population at mid-year (expressed in natural logarithm form).	(WBI)
Output gap	**Output gap (% of potential output);** this is the difference between potential output (the optimal level in the absence of crises) and actual output. It is expressed as a percentage of potential output (optimal level). The output gap is typically calculated using the Hodrick-Prescott (HP) filter.	(WBI)*
Trade openness	**Trade (% of gross domestic product);** trade refers to the sum of exports and imports of goods and services, measured as a share of the gross domestic product. It is used to express the level of trade openness.	(WBI)
Urban	**Urban population (% of total population);** urban population refers to the people who reside in urban areas as defined by national statistical offices. It is expressed as a percentage of the total population.	(WBI)
Financial openness	**Financial openness index;** this is an index that measures the degree of openness of a country's capital account, based on binary dummy variables that regulate the scheduling of restrictions on cross-border	(Chinn-Ito)

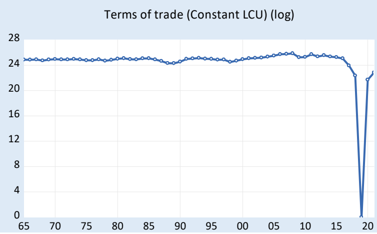
	financial transactions included in the International Monetary Fund's annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). This index is typically scaled between 0 and 1, with higher values indicating greater openness to cross-border capital transactions.	
Rate of trade	**Adjusted trade rate (at constant local currency prices);** the impact of trade rates is equal to the ability to import minus the exports of goods and services at constant prices. The data is expressed in the local currency's constant price (typically in natural logarithm form).	(WBI)
M_2 growth	**Broad money supply growth (% annually);** broad money supply includes currency outside banks, demand deposits (other than those of the central government), time deposits, savings, foreign currency deposits held by residents other than the central government, traveler's checks, and securities such as negotiable certificates of deposit and commercial paper. It is expressed as an annual percentage growth rate.	(WBI)

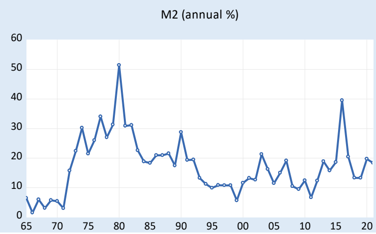
Note: - **WBI;** World Bank Indicators. - **EM-DAT;** Emergency Events Database. - **Chinn-Ito;** The Chinn-Ito Index, IMF's Annual Report on Exchange Arrangements & Exchange Restrictions (AREAER). * Authors calculations based on WBI.

Table A- 2: Structural Impulse Response Function results of Inflation:

Period	*Response of Headline CPI*					*Response of Food CPI*				
	Overall	*Temperature*	*Storm*	*Earthquakes*	*Floods*	*Overall*	*Temperature*	*Storm*	*Earthquakes*	*Floods*
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
2	0.718984	-1.049979	0.625232	-0.624361	-0.221876	1.019283	-0.554073	0.765391	-1.305546	-1.132128
	(0.85403)	(0.82693)	(1.01065)	(0.97640)	(1.02089)	(1.11843)	(1.17900)	(1.58999)	(1.36566)	(1.44833)
3	0.432787	1.722956	-0.479078	1.465150	-1.058780	0.146670	1.830075	-1.183702	1.817606	-2.018163
	(1.00191)	(0.99447)	(1.26037)	(1.32519)	(1.21216)	(1.33432)	(1.47350)	(2.06836)	(1.95568)	(1.75745)
4	-3.443481	-0.488906	10.26290	-14.33309	2.143634	3.441144	5.846776	27.37654	-25.94820	11.11355
	(3.46574)	(3.56090)	(7.06654)	(8.34230)	(4.21512)	(6.76802)	(6.95695)	(13.5213)	(11.4442)	(8.66073)
5	2.692096	7.952268	2.330837	-13.84157	3.730316	6.619977	18.43565	0.677378	-22.28860	6.896784
	(7.01297)	(6.67243)	(11.0831)	(10.6272)	(6.65369)	(8.40110)	(11.0258)	(24.1084)	(15.5841)	(12.2893)
6	7.257945	3.778273	8.472087	11.42365	-2.413926	7.384546	2.835036	33.04135	1.914845	1.098136
	(7.58857)	(7.36846)	(12.1915)	(15.6453)	(9.10630)	(9.53314)	(12.3841)	(26.0505)	(24.8418)	(13.8220)
7	-17.77386	4.350266	5.712087	0.631442	13.23859	-23.07446	4.971581	-91.11506	58.23793	5.772696
	(24.0058)	(9.95995)	(49.0341)	(53.7119)	(26.5945)	(26.3618)	(24.3163)	(113.561)	(82.2894)	(54.5248)
8	14.03231	-10.15468	-48.80412	-24.74675	0.328101	-21.83171	-59.63706	29.60615	-31.15128	-3.087716
	(50.8619)	(26.0724)	(70.6408)	(50.3934)	(31.7896)	(29.4736)	(45.3547)	(102.837)	(98.7449)	(38.1413)
9	4.420867	-22.97079	16.62038	55.08402	-17.70755	-18.35125	-32.80506	-221.9157	101.4231	-39.35082
	(59.0952)	(27.6739)	(93.8938)	(124.685)	(46.9861)	(46.7781)	(49.9322)	(266.951)	(156.534)	(64.8106)
10	-63.07541	-6.223774	-79.78140	150.1028	10.67601	9.511107	-105.4188	193.1068	110.5319	-88.85068
	(165.528)	(35.2689)	(121.689)	(140.230)	(137.126)	(149.507)	(87.4625)	(681.062)	(408.122)	(91.2785)

Figure A- 1: Study variables trends during the period 1965 - 2021


Terms of trade (Constant LCU) (log)
28
24
20
16
12
8
4
0
65
70
75
80
85
90
95
00
05
10
15
20


M2 (annual %)
60
50
40
30
20
10
0
65
70
75
80
85
90
95
00
05
10
15
20