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The Impact Of Energy Consumption, Economic Growth, FDI and Urbanization On Co2 Emissions: Empirical Evidence From Egypt

Abeer Rashdan [1]
Faculty of Economics and Political science-Future University, Egypt
Email: Abeer.Rashdan@fue.edu.eg

Wafaa Ibrahim [2]
Faculty of economics and political science, Cairo University, Egypt

Abstract: Climate change has become one of the most significant environmental pressures affecting sustainable economic growth for all countries around the world. Although Egypt's historical share of global emissions is not high; it is estimated at 0.6% of global emissions, Egypt is recognized as highly vulnerable to climate change impacts especially in agricultural production and higher temperatures effects. The study aims to investigate the impact of energy consumption, economic growth, FDI, and urbanization on CO2 emissions in Egypt. The research employs a VAR testing method (vector auto-regression). The method used required the Error Correction Model (short run and long run) for the period (1990-2021). The results were very controversial: both FDI and urbanization have a statistically positive impact on CO2 emissions, while energy consumption and economic growth have a significant negative effect in the long run. However, all four variables have no impact on carbon dioxide emissions in the short run.

Keywords: *Energy consumption, Urbanization, Carbon dioxide, Egypt*

JEL Codes: *Q43, Q48*

[1] ORCID iD 0000-0002-8703-3926
[2] ORCID iD 0000-0001-7858-7057

Introduction

Climate change has become one of the most significant environmental pressures affecting sustainable economic growth for all countries around the world. According to the Global Risk Report 2022, failure to mitigate climate change ranks among the most severe risks on a global scale for the severity survey over the long term (10 years). Consequently, there has been an increasing interest in climate change among economists and policymakers. The growing volume of economic activities has been the main driver of global warming through the heavy use of primary fossil fuel products (e.g., coal, oil, and gas). No doubt, economic growth is considered an essential factor in every sector's growth for underdeveloped and developed nations to achieve sustainable economic progress (Wang et al., 2018). Meanwhile, rising global temperatures have become a persistent threat to the process of sustainable development due to large amounts of industrial waste and the burning of fossil fuels such as crude oil, natural gas, and coal during production (Erdoğan, 2019).

However, the emission of CO2 has both economic and environmental consequences. According to Stern (2006), "global warming due to the accumulation of greenhouse gases (GHG), the main one being carbon dioxide (CO2), is the main threat to humanity.". Momentum studies were found using CO2 emissions to describe the relationship between these two variables. Some studies confirmed the validity of the Environment Kuznets Curve (Ang (2007), Grossman and Krueger (1996), Friedl and Getzner (2003)). Then a new review of the importance of energy consumption by Kraft and Kraft (1978) suggested that higher economic growth required higher energy consumption. The Granger causality test is used to establish the relationship between economic growth and energy consumption. Followed by studies that use both emissions of CO2 and energy consumption as determinants of economic growth that were initiated by Ang (2007) and Soytas et al. (2007).

It is a global crisis, not less severe than an economic one. Nevertheless, the Arab region contributes less than 5 percent to the worldwide greenhouse gas emissions, as shown in Figure (1), Appendix (1). The drastic situation is that the region is one of the foremost vulnerable to the potential ravages of climate change. Recently, the region has suffered from rising average temperatures, leading to hotter summers and more frequent heat waves. Reduced rainfall in coming years will worsen the situation further, and the region opts to water shortages and water stress. Weather patterns are becoming more unpredictable as seven Arab countries are at the top of the 22-water stress index 2023 (Egypt, Lebanon Qatar, Syria Algeria, Kuwait, and Jordan) as shown in Figure (2). The region is subject to growing extremes in terms of unusual meteorological events, droughts and floods, and growing variability of river flows and recharge rates of groundwater aquifers.

Followed by the emergence of new factors and debatable arguments till the time of writing these lines of the trade-off between a clean environment and sustainable economic development. Inevitably economic activity increases energy consumption and carbon emissions which are the root causes of the greenhouse effect and climate change. It is more reasonable that economic development in most countries accelerates economic growth, which makes more sense than any environmental concerns especially the early stages of modernization. Developing countries are in need for more energy to achieve high economic growth, to be able to provide a better standard of living, which are much higher priorities than environmental issues.

On the development pace, urbanization is a natural phenomenon. An increase in attention has been given to the impact of urbanization on the use of CO2 and energy. The result confirms such a relationship for various countries and regions of the world, both developed and developing (Abbasi, 2020; Ali, 2010; Wang, 2021). These studies confirmed that the influence of urbanization on economic growth in both higher and middle-income countries is significant and positive, while it is small for low-income countries. It has also been shown that the impact of urbanization is gradual and that each stage of urbanization has a different impact on economic growth. The growing factors that affect the environmental quality are still interconnected, it is not just growth-energy nexus, but rather energy consumption, the level of urbanization, and to what extent FDI inflows into the economies. All the factors do not operate at a separate pace but rather have an integrated relationship in some way with the other factors.

Egypt's historical share of global emissions is not high; it is estimated at 0.6% of global emissions. (Climate change and development 2022). According to Egypt's First Biennial Updated Report (BUR) 2018, "Egypt's economic and emissions growth is still tightly linked to each other, as reflected in total GHG emissions from 1990 to 2019, which grew 163% in absolute terms and 47% per capita. Just between 2005 and 2015, emissions increased by about 31%, from 248 Mt CO2eq in 2005 to 325 Mt CO2eq in 2015". Egypt is also recognized as highly vulnerable to climate change impacts, ranking 104 out of 185 countries in the 2021 ND-GAIN Index.

Egypt has witnessed high population growth with rapid urbanization. The UN estimates that "Egypt's population will reach 159.9 million by 2050, up from 102 million in 2020, with 55.6% of the total population living in cities by 2050" (Climate Change and Development 2022). That means cities provide more services to an additional 41.4 million, rising demand for electricity, water and food, health, and education. If this speed of urbanization growth rate combined with a lack of climate-smart planning systems could lead to informal settlements, limited access to infrastructure, and limited access to clean water, and housing, which highly increases the risk of climate change impacts.

According to the UNDP report 2023 “Potential Impacts of Climate Change on the Egyptian Economy” Egypt is highly at risk where agricultural production is estimated to decrease to 47% by 2060, with reductions in agriculture-related employment of up to 39%, food prices increase by 16 to 68%. Welfare losses in agriculture in 2060 are estimated to range from 40 to 234 billion Egyptian pounds. Increased concentrations and heat stress could result in approximately 2,000 to 5,000 more deaths per year, with an equivalent loss of 20 to 48 billion EGP per year. Higher temperatures could reduce annual tourist revenues by 90 to 110 billion EGP. Given the risks that climate change poses for Egypt, it is very important that adaptation risks that are already apparent and risks that will most likely become greater under climate change be promptly addressed.

Based on the above-mentioned, the key goal of the study is to figure out the short and long-term relationship between environmental degradation caused by carbon dioxide (CO2) emissions and energy consumption, economic growth, FDI, and urbanization. To assess the relationships between these four variables, the VAR testing method (vector auto-regression) was used. The method used required the Error Correction Model (short run and long run). The results were very controversial: both FDI and urbanization have a statistically positive impact on CO2 emissions, while energy consumption and economic growth have a significant negative effect in the long run. However, all four variables have no impact on carbon dioxide emissions in the short run. The evolution of the five variables can be tackled in Appendix (1). The paper is organized as follows: The next section describes the related literature review. Section 3 outlines the econometric model approach and describes the used data. Section 4 discusses the empirical results. Section 5 concludes and offers some policy implications.

Literature Review

The literature review is still very debatable regarding the impact and the direction (unidirectional, bidirectional, neutral) of the effect of economic growth, energy consumption, FDI, and urbanization on CO2 emission. The review of the literature can be divided into four components. Worth noting, that the variables are highly interconnected and cannot be separated regarding their impact on CO2.

Literature review of the effect of FDI and CO2

Foreign direct investment (FDI) is a significant component in promoting economic progress and advancement in emerging nations. It enhances economic integration and internationalization globally through financial flows, trade technology, and resource modelling (Mohanty et al., 2019). It also has a positive impact on the economy by being viewed as one of the fundamental variables promoting economic development. FDI inflows remain an important source of boosting economic growth and technology transfer for most developing countries. However, the perspective of the pollution haven hypothesis (PHH) argues that FDI inflows may result in the production of polluted goods in poor economies.

However, FDI is considered very crucial for developing economies since it is associated with rapid economic growth, employment creation, industrialization process, and improvement in the standard of living (Balsalobre-Lorente et al. 2019). For all these reasons, developing economies are competing for more FDI inflows (Blanco et al. 2013). Based on that, the relationship between FDI and environmental pollution is still very debatable. On one hand, FDI inflows to developing countries result from their lax environmental regulations, hence more FDI inflows will lead to more environmental degradation in the host countries following the assumption of the pollution haven hypothesis PHH (Copeland and Taylor 1994). The weak pollution controls provide a competitive advantage to developing countries pushing the argument that developing countries may intentionally keep their environmental controls weak to become the stronger candidate for FDI inflows (Ashraf et al. 2022). Another narrative argues that Lax Environmental Control in developing countries could benefit consumers in developed countries hence they will enjoy the consumption of pollution-intensive goods at cheaper prices (Gill et al. 2018).

On the other hand, FDI brings technological improvements to the host country, leading to better environmental quality (Abbasi and Riaz 2016; Saud et al. 2019). It also argued that highly restrictive environmental policies of developed countries can push their firms to introduce clean energies, subsequently resulting in lower marginal costs and higher productivity in these economies (Porter and Van Der Linde 1995). While other view shows that when the respective economies exceed certain threshold levels of schooling, FDI reduces pollution emissions it moves to “the pollution halo hypothesis”. So, transforming from pollution heaven to pollution halo depends on the level of human capital of the developing country. Khan et al. (2023) confirm the existence of PHH for the selected 108 sample economies, when schooling levels exceed certain limits, the PHH turns into a pollution

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halo hypothesis where more FDI starts contributing to better environmental quality in developing countries.

Abdouli, et al. (2017) investigate the causal relationship between environmental quality, FDI and economic growth for 17 MENA. Their results emphasise the existence of a unidirectional causality from FDI to economic growth, a bidirectional causality between economic growth and CO2 emissions, also a bidirectional causality between FDI and CO_2 emissions. Lee (2013) explored a complex relationship between foreign direct investment, CO2 emissions and economic growth using data about the BRIC countries from 1971 to 2009 using a panel co-integration approach. The empirical evidence supports the existence of unidirectional causality from FDI to economic growth and from economic growth to CO2 emissions. In the same stream, Pao and Tsai (2010) investigate the causal links between FDI and CO2 emissions for a panel of BRIC countries. The results using Granger causality tests indicate the existence of strong bidirectional causality between the two variables over the period 1992–2007. However, developing countries need renewable energy investments of about $1.7 trillion each year but attracted only $544 billion in clean energy FDI in 2022 (UNCTAD 2023).

Literature review of the effect of energy consumption on CO2

High energy use worsens the environmental quality because the conformist source of energy creates GHGs in the atmosphere. Several studies have tackled the link between energy consumption and CO2 emission. According to (Alam et al. 2012; Apergis and Payne 2009), Regarding the relationship between energy consumption and economic growth, in the process of production energy is not a significant input factor influencing economic growth unlike the traditional inputs capital and labour which gives the view of no direct causal relationship exists between the two variables. Therefore, energy-saving policies can be implemented to decrease CO2 emissions without affecting economic growth. Omri (2013) analysed the link between economic growth, energy use, and environmental degradation (1990 - 2011) for the MENA region, the finding revealed that energy policies are responsible for affecting the connection between energy use and economic growth. In Soysa and Sari (2009) study, the results validate the bidirectional causality between energy consumption and CO_2 emissions using the Granger causality test to identify the two-way linkages between energy consumption, economic growth, and carbon emissions in Turkey over the period (1960–2000). The same findings were confirmed by Arouri et al. (2012) an investigation on the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 MENA countries over the period (1981–

2005), and results confirmed the bidirectional causality between carbon emissions and energy consumption.

Following the same stream of results, Helair et al. (2019) studied the top Three emitters in Africa (Egypt, Algeria, and South Africa over the period (1971-2015). Results show that energy consumption and economic growth have positive and significant impacts on carbon dioxide (CO2) both in the long and short run in the three countries.

Literature review of the effect of Economic Growth on CO_2

The link between economic growth and CO2 emission has been analysed extensively in the last decades, the direction the strength of the relation may vary according to the level of development. In study of Ghosh (2010) documents two-way links between CO_2 emissions and economic growth in India over the period (1971–2006). In more recent research, Ajmi, Hammoudeh, Nguyen, and Sato (2015)investigated the relationships between energy consumption, carbon dioxide (CO_2) emissions and gross domestic product (GDP) in the G7 countries. Their study shows the presence of a bi-directional causality and bidirectional time-varying causality between energy consumption and CO2 emissions in the United States.

Sbia, Shahbaz, and Hamdi, (2014) investigated the relationship between foreign direct investment, carbon emissions and economic growth in the case of the UAE covering the period of 1975–2011 of an Autoregressive distributed lag (ARDL) methodology. The Relationship between carbon emissions and economic growth is bidirectional. Lau et al. (2014) have examined the relationship between economic growth, and CO2emission in the presence of foreign direct investment and trade openness in Malaysia from 1970 to 2008 using the Granger causality methodology to test the interrelationships of the variables, their study shows the presence of a bi-directional causality between CO2 and economic growth, and FDI and economic growth.

Regarding the MENA region, Fakhri et al. (2015) investigated the impact of CO_2 emissions on per capita growth, energy consumption, life expectancy and urbanization in MENA countries during the period (1990 – 2010). The empirical results show that the CO_2 emission is explained by energy consumption and economic growth per capita which exert positive and significant effects. Nevertheless, growth-generating economic potential is in non-polluting sectors and not generators of greenhouse gases in the long run.

However, no clear cut of the relationship between economic growth and CO2; it can be divided into three groups. The first conventional view emphasizes the significant positive relation (Deschênes and Greenstone, 2007, Zilberman et al., 2004; Hope, 2006; Mendelsohn et al., 2000a, b; Tol, 2002b). While others view its negative impact (Dell, Jones, and Olken (2008); Serdeczny et al. (2017); Akram (2013); Abidoye and Odusola (2015); Mearns, Katz, and Schneider (1984); Moriondo, Giannakopoulos, and Bindi (2011). More controversial is the third group where both negative and positive impacts exist (Colacito et al. (2014); Zilberman et al. (2004)). These arguments depend on the channels of transforming the effect whether negative or positive, full of adequation determinants that must be fully integrated before jumping to the precise conclusion.

Literature review of the effect of Urbanization on CO_2

Urbanization is a social and economic phenomenon that is increasing across the globe, people are migrating from rural to urban areas in search of better life and social welfare. "A growing urban population (estimated to be 41.4 million by 2050) will put additional strain on urban-area service provision and deepen the exposure of assets and people to climate risks, with those risks disproportionately borne by most vulnerable population" (Climate and Development Report 2022). Even though urbanization is frequently linked to higher pollution levels, it can also help with environmental benefits. For instance, through economies of scale in the availability of restroom facilities. More specifically, together with those associated with greater earnings, urban Economic operations could result in two distinct environmental consequences: industrialization and increased levels of consumption. First, the switch to contemporary fuels is accelerated by urbanization. This modifies resource usage patterns. Secondly, cities give greater chances to attain economies of scale and to make better use of natural resources than rural areas do, hence the manner that cities are planned is crucial. In the interest of sustainable development maybe there is a benefit.

Numerous empirical research works have examined the effects of urbanization on environmental quality across various socioeconomic levels and nations. The results show that urbanization has a varying impact on carbon emissions, either notably positively or negatively. Based on a panel set of 69 nations that were analyzed for the determinants of CO2 emissions (1985-2005) for two income groups of high income, middle income, and low income, Sharma (2011) findings show that urbanization does not enhance carbon emissions but rather wealth. The analysis demonstrates that while urbanization has a negative impact on CO2 emissions across all sub-samples, trade openness, GDP per capita, and energy consumption all have a favourable impact on CO2 emissions. An alternative interpretation of the

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threshold is provided by Martinez et al. (2011), who examine the connection between urbanization and CO2.

The finding was an inverted U-shaped relationship, indicating that at a given point carbon emission became negative when urbanization reaches beyond a certain point, then emissions remain stagnant. Hanif (2018) study examined the impact of energy consumption and urbanization in East Asia and in the Pacific region using panel data on 12 developing countries for the period 1990 to 2014. The results, also based on the GMM, showed that energy consumption and urbanization are both significant factors in the increase in carbon emissions in these regionsOn the other side, Poumanyvong et al, (2012) investigate the influence of urbanization on energy consumption and CO_2 emissions across 99 countries (1975-2005). The results reveal that the impact of urbanization on energy consumption and CO2 emissions varied with the nature of development. Urbanization influences carbon emissions positively for all income groups, however, the effect is glaring in middle-income countries

Data and methodology

The study employs secondary data that were sourced from World Bank (2022) Development Indicators. The data sourced are urban population as a proxy for urbanization, GDP per capita (constant 2017 international $) as a proxy for economic growth, CO2 emissions (kg per PPP $ of GDP) as a proxy for carbon emissions, and energy use (kg of oil equivalent per capita) as a proxy for energy consumption, Foreign direct investment, net inflows (% of GDP) as a proxy of FDI. All the previous variables for the period (1990-2021).

The model will be written as follows:

$$\begin{aligned}\Delta Co2\, emission_t &= \rho u_{t-1} + \beta_1 \Delta FDI_{t-1} + \beta_2 \Delta GDP_{t-1} + \beta_3 \Delta Enegy\, use_{t-1} + \beta_4 \Delta ur\\ &+ \sum_{i=2}^{m} (\gamma_i \Delta FDI_{t-i} + \lambda_i \Delta GDP_{t-1} + \alpha_i \Delta Enegy\, use_{t-1} + \theta_i \Delta urban)\\ &+ \sum_{j=1}^{k} \psi_j \Delta Co2\, emission_{t-j} + v_t,\end{aligned}$$

The research employs the VAR Test approach to capture the short and long-run relationship between the variables in hand, and ECM models will be used to determine the directions and strength of interdependence.

An initial step of the analysis, before the mentioned methodology, is to validate the stationarity assumption. Stationarity assumption is tested using the Augmented Dickey-Fuller (ADF) test. The ADF test is one of the

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cited unit root tests in the literature and is commonly used. The ADF test is applied to determine whether the data series is stationary (has no unit root) or not, by calculating the respective statistics and p-values in the main level. In the case that all variables are non-stationary at level, we move to the first difference, this means that they are integrated in order I.

Descriptive Analysis

This section aims to illustrate, as in Table (1), the descriptive statistics of the variables used in this study. Overall, the total number of observations was about 37. Also, we found that urbanization has the highest variation among the variable, whereas carbon emissions, urban population growth (annual %) and urban population (% of total population) have the lowest standard deviations. Table (2) shows the correlation results. A strong positive correlation existed between urban population growth (annual %) and urban population (% of the total population), whereas a weak negative correlation between carbon emissions and foreign direct investment, net inflows (% of GDP) is observed (-0.127).

Table (1): Descriptive Statistics (n=37)

Variable Name	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
urban population (% of total population)	42.658	43.954	43.04078	0.36521
CO2 emissions (kg per PPP $ of GDP)	0.20262	0.421419	0.291246	0.054431
energy use (kg of oil equivalent) per $1,000 GDP	76.13808	96.93892	88.94266	4.865712
GDP per capita growth (annual %)	-1.2839	5.078168	2.185448	1.501507
foreign direct investment, net inflows (% of GDP)	-0.20454	9.348567	2.400157	2.114176

Table (2): Correlation Matrix (n=37)

	urban population (% of total population)	CO2 emissions (kg per PPP $ of GDP)	energy use (kg of oil equivalent) per $1,000 GDP	GDP per capita growth (annual %)	foreign direct investment , net inflows (% of GDP)
urban population (% of total population)	1				
CO2 emissions (kg per PPP $ of GDP)	0.303	1			
energy use (kg of oil equivalent) per $1,000 GDP	0.616**	0.297	1		
GDP per capita growth (annual %)	-0.091	-0.041	0.202	1	
foreign direct investment, net inflows (% of GDP)	0.182	-0.172	0.578**	0.631**	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Stationarity Test

Table (3) displays the results of the ADF test. From the results, it can be concluded that all variables are not stationary at its level with confidence level of 95%. A suggested remedy to this is to take the first difference and re-conduct the test. The result in this case is in favour of stationarity with confidence level of 95%. So, we can conclude that all variables are co-integrated of order 1.

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Table (3): Augmented Dickey-Fuller (ADF) test for unit root variable

Variable	ADF	p-value
CO2 emission	-1.6322	0.4563
ΔCO2 emission	-6.082***	0.0000
Energy use	-2.528	0.1200
ΔEnergy use	-6.137***	0.0000
GDP growth	0.01748	0.9536
ΔGDP growth	-3.752***	0.0075
Urban population	2.598	0.9999
ΔUrban population	-6.514***	0.0000

*10%, **5%, ***1% significance. ADF t-statistic reported.

Note: The ADF tests include an intercept. The appropriate lag lengths were selected according to the Schwartz Bayesian criterion.

Cointegration and ECM Models

First, we examine the long-run unbiasedness and efficiency based on cointegration. Second, examining the short-run unbiasedness and efficiency based on an error correction model (ECM).

Cointegration Tests

To check cointegration of the CO2 emission and all other variables,[3] the Johansen test is conducted. For choosing the appropriate lag length number of criterions can be applied. The appropriate lag length is 1 according to all criterion, as clear in Table (4).

[3] According to the above augmented dickey fuller (ADF) test it is clear that two series are integrated of order I.

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Table (4): Lag length criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-134.7024	NA	0.004263	8.731402	8.960423	8.807316
1	-43.68041	37.84771*	6.45e-06*	1.708451*	5.066709* *	2.959118
2	14.24039	76.02105	1.02e-05	2.547475	5.979153	3.382530
3	52.08811	147.9108	7.04e-05	1.744493	5.408833	5.060510
4	77.66479	17.58397	1.39e-05	4.605025	6.517897	3.302646

Considering, one lag and considering a constant in the cointegration relation, the results are presented in Table (4) and Table (5). The Johansen trace and the maximal eigenvalue test together prove that there is a cointegration vector, i.e. there is a long-run relationship between Co2 emission, and each of energy consumption, economic growth, FDI and urbanization, then, error correction model must be applied.

This vividly shows that in the long run interest rate has a negative impact on market index. The relationship is found statistically significant at the 10% level. The result is implying that in Bangladesh in the long run, a one percent increase in interest rate contributes 13.20 % decrease in market index.

Table (5): Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.691057	71.18145	60.06141	0.0043
At most 1	0.394762	33.59434	40.17493	0.1961

Trace test indicates 1 co-integrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table (6): Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized		Max-Eigen	0.05	

No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.691057	37.58712	30.43961	0.0055
At most 1	0.394762	16.06827	24.15921	0.4159

Table 7 presents the findings regarding the long-run impacts of different factors on CO2 emissions in the Egyptian context. The results indicate the following relationships, which are statistically significant at a 95% confidence level:

- Energy Use: There is a long-run negative impact of energy use on CO2 emissions. Specifically, a one-unit increase in energy use leads to a decrease of 0.045 units in CO2 emissions.
- Foreign Direct Investment (FDI): There is a long-run positive impact of FDI on CO2 emissions. A one-unit increase in FDI contributes to an increase of 0.127 units in CO2 emissions.
- GDP per Capita Growth: There is a long-run negative impact of GDP per capita growth on CO2 emissions. A one-unit increase in GDP per capita growth leads to a decrease of 0.125 units in CO2 emissions.
- Urban Population: There is a long-run positive impact of urban population on CO2 emissions. A one-unit increase in the urban population contributes to an increase of 0.88 units in CO2 emissions.

These findings provide important insights into the relationships between energy use, FDI, GDP per capita growth, urban population, and CO2 emissions in Egypt. They suggest that reducing energy use and promoting sustainable economic growth can help mitigate CO2 emissions, while urbanization and FDI may contribute to increased emissions.

Table (6): Coefficients for Cointegration Equation

Cointegrating Eq:	CointEq1
CO2_EMISSIONS(-1)	**1.000000**
ENERGY_USE(-1)	**-0.044921**
	(0.01395)
	[-3.22091]
FOREIGN_DIRECT_INVESTMEN(-1)	**0.127489**
	(0.02719)
	[4.68922]
GDP_PER_CAPITA_GROWTH_(-1)	**-0.124638**
	(0.03657)
	[-3.40843]
URBAN_POPULATION(-1)	**0.876268**
	(0.12776)
	[6.85845]
C	**-33.98807**

Note: i) Standard errors in ( ) & t-statistics in [ ] ; ii) * indicates statistically significant at the 10% level
note: Standard errors in () & t-statistics in ();** sig. at 95% confident.

<u>Error Correction Models (ECM)</u>

Because of the non-stationarity of the variables of the study, the ECM is conducted to assess the short-run efficiency. The model estimates the following
equation:

$$\Delta Co2\ emission_t = \rho u_{t-1} + \beta_1 \Delta FDI_{t-1} + \beta_2 \Delta GDP_{t-1} + \beta_3 \Delta Enegy\ use_{t-1} + \beta_4 \Delta urban + \sum_{i=2}^{m} (\gamma_i \Delta FDI_{t-i} + \lambda_i \Delta GDP_{t-1} + \alpha_i \Delta Enegy\ use_{t-1} + \theta_i \Delta urban) + \sum_{j=1}^{k} \psi_j \Delta Co2\ emission_{t-j} + \nu_t,$$

where, u_{t-1} is the lagged value of error correction term and ν_t is a white noise error term, $\beta s, \lambda s, \alpha_s, \theta s\ , \psi s$ are the regression coefficients.

The model is estimated with the difference of appropriate lag length. Since the appropriate lag length is 1 then it will be lag 0 for the difference. The results are presented in Table (7). The estimated error correction coefficient indicates that a 5.9% deviation of the emission from its long-run equilibrium level is corrected each period in the short run. Also, from the t-value of the coefficients in the ECM test, it is clear that the difference of CO2 emission at time t in Egypt is not affected by the difference of any of the other variables at time t-1 only, with confidence 95%.

Table (7): Estimated error correction coefficient

Error Correction:	**D(CO2_EMISSIONS __KG_PER_PP)**
CointEq1	**-0.059540** **(0.02043)** **[-2.9143]**
D(CO2_EMISSIONS(-1))	**-0.056464** **(0.20026)** **[-0.28195]**
D(ENERGY_USE(-1))	**0.000189** **(0.00174)** **[0.10891]**
D(FDI(-1))	**-0.001549** **(0.00543)** **[-0.28517]**
D(GDP_PER_CAPITA_GROWTH(-1))	**0.002842** **(0.00483)** **[0.58895]**
D(URBAN_POPULATION(-1))	**-0.009141** **(0.08640)** **[-0.10580]**
C	**-0.000462** **(0.00624)** **[-0.07400]**

Standard errors in ( ) & t-statistics in [ ]

To test the strength of results, tests on residuals have applied. More specifically, vector error correction (VEC) Residual Tests for Autocorrelations, and heteroscedasticity are conducted. As shown in Figure 3, the residuals of VEC is almost white noise this support the strength of the

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model, as well the test of serial autocorrelation supported that no autocorrelation for the residuals for all lags as shown in Table (8).

Table (8): VEC Residual Serial Correlation LM Tests

Null Hypothesis: no serial correlation at lag order h

Lags	LM-Stat	Prob
1		
2	2.723729	0.6051
3	6.882035	0.1423
4	1.103399	0.8937
5	8.522975	0.0742
6	9.248521	0.0552
7	12.59792	0.0734
8	6.479183	0.1661
9	4.402898	0.3542
10	5.235848	0.2639
11	8.943339	0.0625
12	6.835428	0.1448
	4.719725	0.3173

Probs from chi-square with 25 df.

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Table (8): VEC Residual Serial Correlation LM Tests

Null Hypothesis: no serial correlation at lag order h

Lags	LM-Stat	Prob
1	2.723729	0.6051
2	6.882035	0.1423
3	1.103399	0.8937
4	8.522975	0.0742
5	9.248521	0.0552
6	12.59792	0.0734
7	6.479183	0.1661
8	4.402898	0.3542
9	5.235848	0.2639
10	8.943339	0.0625
11	6.835428	0.1448
12	4.719725	0.3173

Probs from chi-square with 25 df.

Conclusion

Climate change has become one of the most significant environmental pressures affecting sustainable economic growth for all countries around the world. Although COP27 included calls for greater climate justice which means that countries that contribute the least to climate change while suffering most of the brunt of its adverse impacts, should be treated fairly through sufficient and accessible means of implementation of transition to sustainable environmental goals .COP27 paved the way for new pathways for cooperation of identifying means for the future of energy, innovative financing, food and water security and enhancing support to vulnerable countries.

- Although Egypt is considered not highly emitter of CO_2. Egypt's government one of contributing of global effect of adaption and mitigate the climate change impacts. Egypt submitted its Intended Nationally Determined Contribution (INDC) in November 2015 to achieve the global targets set out in the UNFCCC's Paris Agreement. After Egypt signed the Paris Agreement on the 22nd of April 2016 and ratified it on 29th June 2017, the INDC was considered Egypt's first NDC.

Given Egypt's vulnerability to climate change impacts, particularly increasing heatwaves, this research aims to examine the extent to which energy consumption, economic growth, foreign direct investment (FDI), and urbanization affect CO2 emissions in both the short and long run. The results of the study are quite contradictory. While FDI and urbanization have statistically positive impacts on CO2 emissions, energy consumption and economic growth have significant negative effects in the long run.

Surprisingly, the findings indicate that a one-unit increase in energy use leads to a decrease of 0.045 units in CO2 emissions. This unexpected result challenges the conventional understanding that increased energy consumption contributes to higher emissions. As time passes and Egypt undergoes structural transformation, with reduced dependence on the agriculture sector, which is highly vulnerable to climate change, such as extreme heat and rainfall, transitioning to a low-carbon pathway could help Egypt prepare for an uncertain future while enhancing the competitiveness of Egyptian products.

Furthermore, unlike the typical literature on developing countries, the research reveals that a one-unit increase in GDP per capita growth leads to a decrease of 0.125 units in CO2 emissions. This finding suggests that as Egypt experiences economic growth, it is also making progress in reducing its carbon emissions, which is not commonly observed in similar contexts.

- Given the conventional stream of literatures; one-unit increase in the urban population contributes 0.88 units increases in CO_2 emission. A step forward in the effort of adaptation of climate change, Egypt has launched an initiative in Solutions Day of the 27th UN Climate Change Conference, the initiative is set to be integrated with Egypt’s initiative Haya Karima (Decent Life), stressing that such integration will help prepare the countryside for green transformation with value $1.8 billion. In tandem with the efforts of COP28 where The COP process’ second Urban Ministerial will anchor COP28’s Multilevel Action, Urbanization and Built Environment Day. The high-level event will convene a diverse set of ministers, local and regional leaders, financial institutions, and non-government stakeholders to agree on a suite of multilevel, Paris-aligned actions for cooperation in the UNFCCC space, focused on joint policy and finance for sustainable urbanization across sectors including buildings, waste, transport, water, energy, and nature.

- Regarding the impact of FDI, a one-unit increase in the FDI contributes 0.127 units increases in CO_2 emission. Following the mainstream of most developing countries, most of FDI inflows concentrated in extracting sectors (Oil). Egypt in its path to sustainable development in power sector will conduct the Renew Suez Canal Economic Zone Green Hydrogen Plant Project with estimated cost $ 8billion. According to world investment report the Egypt's rank (7th out of the Top 10 developing economies by international investment in renewable energy, as Share of renewable energy in total project value (%) is 14% as it shows in Figure (8). The Sharm El Sheikh Guidebook for Just Financing (2022) was launched through the coordination of the Government of Egypt in partnership with a broad range of stakeholders, including UNCTAD. The Guidebook highlights the need to minimize the risk of climate-action-related ISDS cases and suggests options for IIAs (Inventory Approval System) to proactively promote and facilitate investments that are conducive to climate change objectives (UNCTAD; world investment report 2023).These results must consider due to its controversial argument. However, all the four variables have no impact on carbon dioxide emission in the short run.

- Whilst the COP26 in Glasgow was all about target setting, COP27 was all about implementation. COP27 focused the light on the backdrop of inadequate ambition to curb greenhouse gas emissions. The UN's Intergovernmental Panel on Climate Change (IPCC) addressed that CO2 emissions need to be cut 45% by 2030 compared to year 2010 levels to limiting temperature rise to 1.5 degrees Celsius by the end of this century. A report published by UNFCCC ahead of COP27 shows that whilst countries are bending the curve of global greenhouse gas emissions efforts remain insufficient to limit global temperature rise to 1.5 degrees Celsius by the end of the century.

- Looking forward the continuing efforts from COP27 to COP28 as the first Global Stocktake (GST) of the Paris Agreement, can be the turning point. The main targets are Fast-tracking the energy transition and slashing emissions before 2030, transforming climate finance, by delivering on old promises and setting the framework for a new deal on finance, and Putting nature, people, lives, and livelihoods at the heart of climate action. COP28 presents an opportunity to fast-track the energy transition by building the energy system of the future, while rapidly decarbonizing the energy system of today to keep 1.5°C.

Policy Recommendations

- Deploy Cross-cutting adaptation policies; Egypt must develop a National Adaptation Plan with detailed costs, implementation, and metrics. In addition to Coordinate and enhance monitoring and data collection efforts in support of implementing adaptation measures. Provide ready full plan for the potential for increased migration to urban areas from rural areas. Working on international cooperation and financing opportunities for adaptations.
- Build a “Safety First” culture and raise community awareness, taking into consideration that climate change constitutes a long-term phenomenon.
- Reinforce Egypt’s competitiveness and economic growth by working on low carbon transition, as market preferences shift toward greener and lower carbon content products and policies.
- Egypt has a potential opportunity for decarbonization especially in the energy sector as Egypt scored 79, above the MENA regional average of 66.73, in the assessment of sustainable energy policies by more focus attention on using natural gas for meeting and increasing levels of renewable energy.
- The no-regret approach to decarbonization is very ambitious as Egypt has significant flexibility to take immediate action to re-evaluate the long-term decarbonization pathway beyond 2030.
- The best player is the government which should play a steering role to clarify its priorities towards climate investments that would induce the private sector participation.
- Strengthening the National Information Exchange System: all the stakeholders must take responsibility and action for combating the challenges.
- Establishing incentive policies to expand the use of electric cars
- Expand the use of natural gas, especially in the petrochemical industry
- The National Council for Climate Change studies various ways to encourage local manufacturing of renewable energy lamps
- Encouraging civil society institutions to calculate carbon emissions for various activities.
- Activating interactive map projects to study the impact of climate on the construction of new cities

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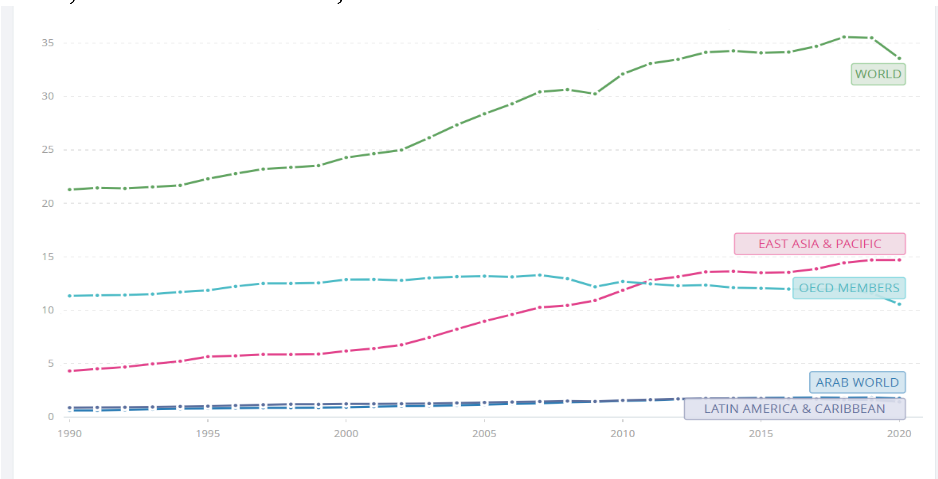
Appendix (1)

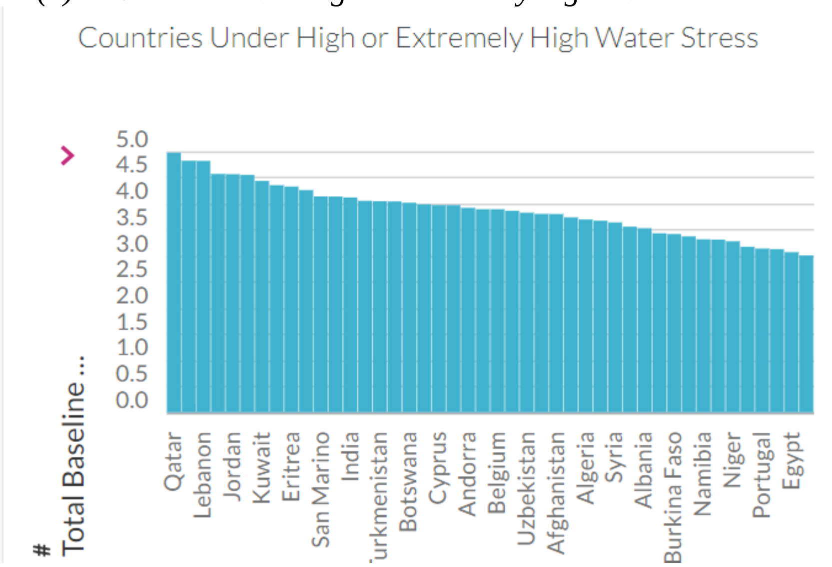
The evolution of the concerned variables

Figure (1) CO2 emissions (kt) - Arab World, World, Latin America & Caribbean, East Asia & Pacific, OECD members



Source:Worldbank.org

Figure (2) Countries Under high or extremely high water stress



Source: https://resourcewatch.org

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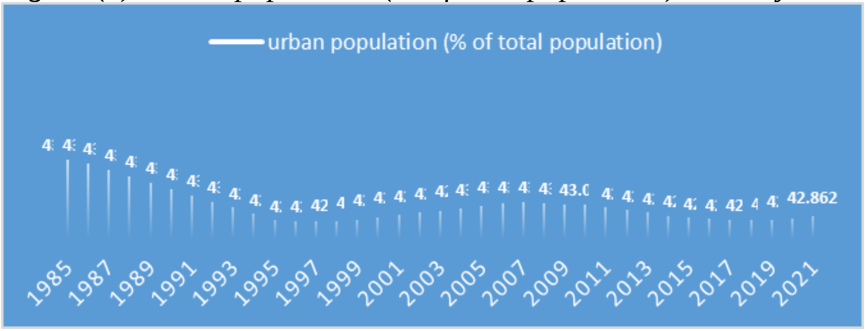
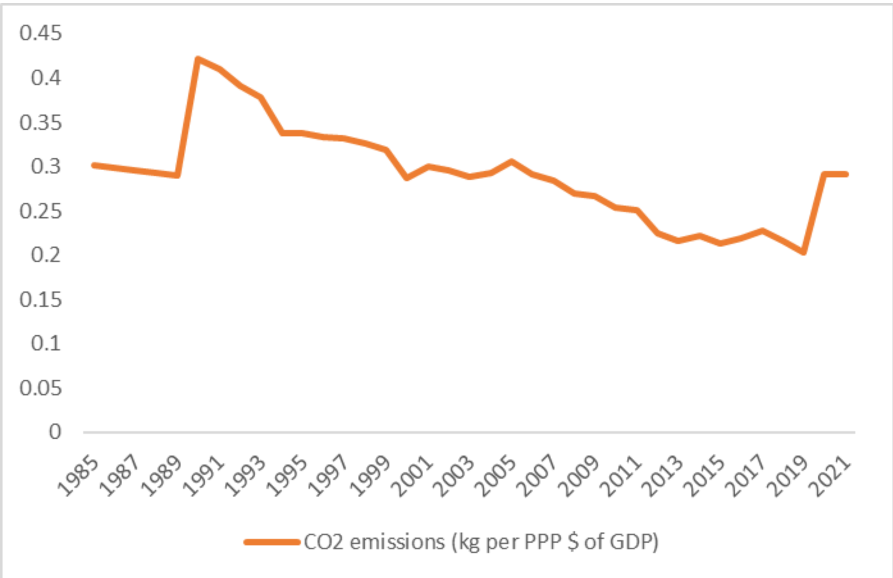
Figure (3): urban population (% of total population) across years



Source: World Development Indicators 2022.

Figure (3) depicts the urban population (% of the total population) in the period under observation. Apparently, the variable under consideration exhibits a downward trend across years with the lowest value occurring in 1997.

Figure (4): CO2 emissions (kg per PPP $ of GDP) across years



Source: world development indicators 2022.

Figure (4) depicts carbon emissions in the period under observation. Apparently, carbon emissions maintained a relatively flat growth. It's also clear that the variable under consideration experienced a sharp upward movement (peak) around 1990 but declined in the following year.

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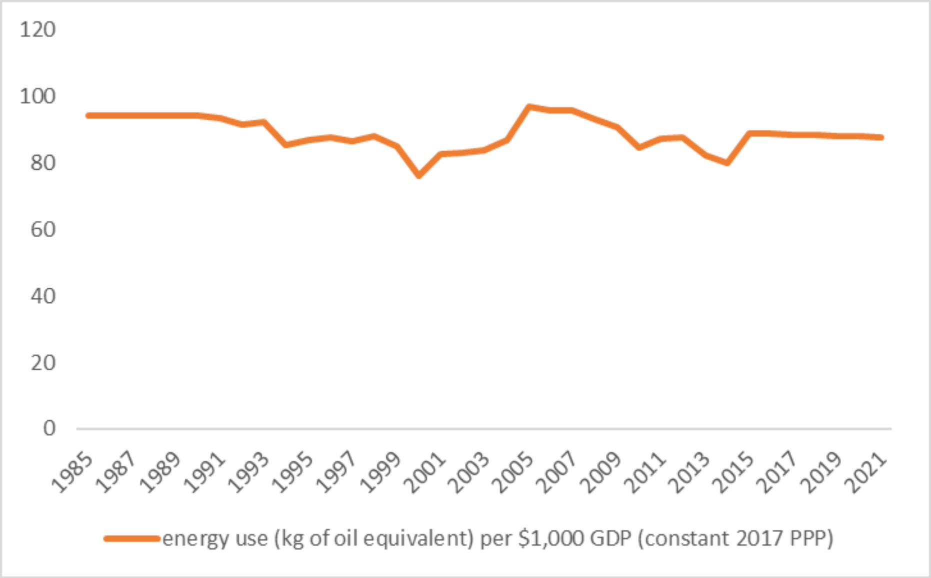
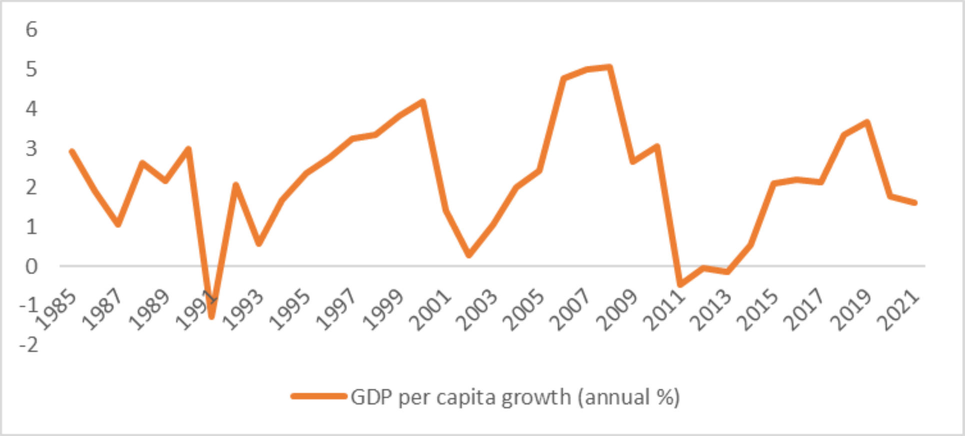
Figure (5): energy use (kg of oil equivalent) per $1,000 EGP across years



Source: world development indicators 2022.

Figure (5) depicts energy consumption in the period under observation. Apparently, energy consumption maintained a relatively flat growth with the highest value occurs in 2005 and the lowest one occurs in 2000.

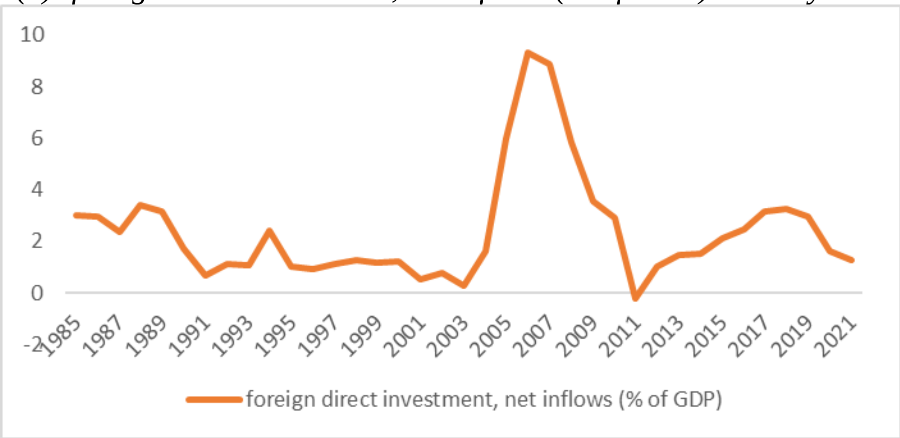
Figure (6): GDP per capita growth (annual %) across years



Source: World Development Indicators 2022.

Figure (6) depicts GDP per capita growth (annual %) in the period under observation. Apparently, GDP per capita growth (annual %) exhibits some up and down with the highest value occurring in 2008 and the lowest one occurs in 1991.

Figure (7): foreign direct investment, net inflows (% of GDP) across years

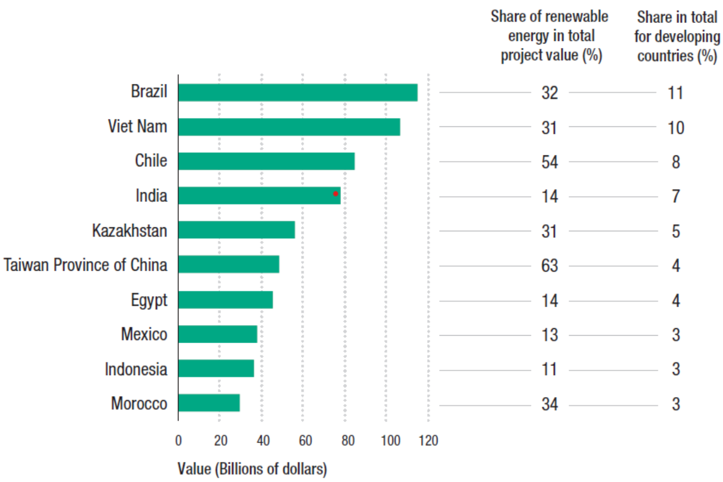


Source: World Development Indicators 2022

Figure (7) depicts foreign direct investment in the period under observation. Apparently, foreign direct investment maintained a relatively flat growth. It's also clear that the variable under consideration experienced a sharp upward movement (peak) around 2006 but declined in the following year.

Figure (8) Top 10 developing economies by international investment in

renewable energy, 2015–2022 (Billions of dollars and per cent)



Source: UNCTAD, based on information from The Financial Times, fDi Markets (www.fdimarkets.com), and Refinitiv SA.