ERF Working Papers Series

# Drought and Growth in Arab League Members, Iran and Turkey

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Economic Research Forum
منتدى البحوث الاقتصادية

Working Paper No. 1578
September 2022

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*This paper was originally presented during the ERF 28th Annual Conference entitled "Revisiting Macroeconomic Management in Times of Crisis and Beyond", held in March 26-30, 2022.*

[1] I am grateful to Mohamed Trabelsi and two anonymous referees for very helpful comments. The views expressed are mine and should not be interpreted as reflecting the views of Banque de France or the Eurosystem.

First published in 2022 by
The Economic Research Forum (ERF)
21 Al-Sad Al-Aaly Street
Dokki, Giza
Egypt
www.erf.org.eg

## Abstract

Water scarcity and droughts have long characterized the Middle East and North Africa, and climate change represents an additional challenge to this region's development prospects. Using macroeconomic and climate panel data for Arab League members, Iran and Turkey during the period 1960-–2018, this paper assesses the effects of sustained drought deviations from their historical norms on output growth in the region and shows that droughts decrease output growth in oil importing countries, with no or statistically weakly significant positive effects in oil exporting countries. These effects do not strengthen as the horizon increases and vanish after one year but do not revert in subsequent periods, leading to lasting losses in output level in oil importing countries. The agricultural sector and civil violence appear to be two of the transmission channels. The results advocate for carefully planned economic diversification in the region and shed light to associated risks.



**JEL classification:** E32, O11, O13, O40, Q54.

**Keywords:** Climate Change, Drought, Economic Growth, Business Fluctuations, Developing Countries, Middle East and North Africa



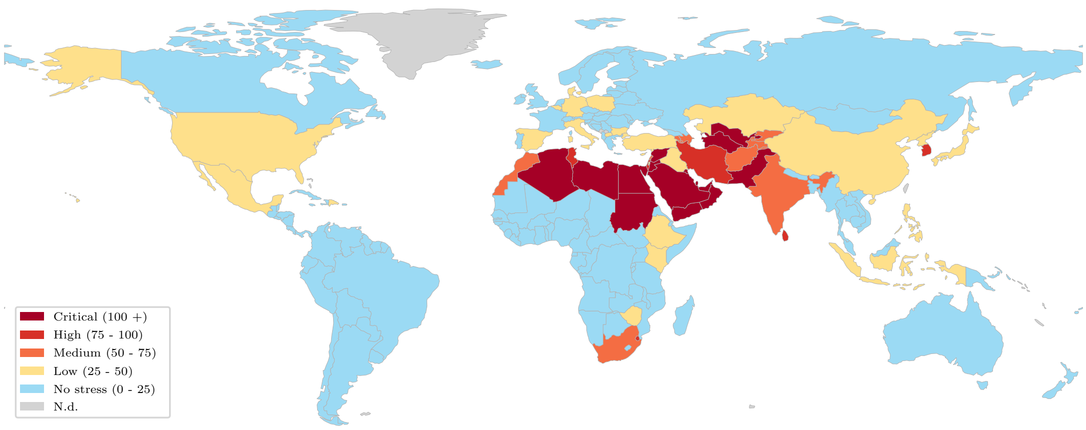
## ملخص

لطالما اتسمت منطقة الشرق الأوسط وشمال أفريقيا بندرة المياه والجفاف، ويأتي تغير المناخ ليمثل تحديا إضافيا لآفاق التنمية في هذه المنطقة. باستخدام بيانات لجنة الاقتصاد الكلي والمناخ لأعضاء جامعة الدول العربية وإيران وتركيا خلال الفترة 1960-2018، تقيم هذه الورقة البحثية آثار الانحرافات المستمرة للجفاف عن معاييرها التاريخية على نمو الإنتاج في المنطقة، وتظهر أن الجفاف يقلل من نمو الإنتاج في البلدان المستوردة للنفط، مع عدم وجود آثار إيجابية أو ضعيفة إحصائيا في البلدان المصدرة للنفط. ولا تتعزز هذه الآثار مع زيادة الأفق وتلاشيه بعد عام واحد ولكنها لا تعود لما كانت عليه فى فترات لاحقة، مما يؤدي إلى خسائر دائمة في مستوى الإنتاج في البلدان المستوردة للنفط. ويبدو أن القطاع الزراعي والعنف المدني هما من بين قنوات الانتقال لتلك البلدان. تدعو نتائج البحث إلى التنويع الاقتصادي المخطط له بعناية في المنطقة وتلقي الضوء على المخاطر ذات الصلة.

# 1 Introduction

Water scarcity has always been a defining element of Arab League members, Iran and Turkey's economic development. Figure 1 shows that the region experiences the most accute levels of water stress in the world, and that water stress reaches critical levels in a majority of its countries. Changing droughts patterns result from changing patterns in the combination of temperatures and precipitations and will continue evolving as the global climate changes. The region's challenging environment makes it particularly vulnerable to climate change, and adaptation efforts and policies are an absolute necessity to foster resilient economies and reinforce the foundations for inclusive growth and sustainable development. This is reflected in the fact that Egypt hosts COP27 in 2022 and the United Arab Emirates COP28 in 2023. A deeper understanding of the effects of droughts on the economy would allow to better elaborate and calibrate adaptation policies in the region.

Figure 1 – Water stress index (2018)




Note: The data are from FAO's AQUASTAT Database. The water stress index indicates freshwater withdrawal as a proportion of available freshwater resources (in %). The data are available at https://www.fao.org/aquastat/statistics/query/index.html.

This paper combines macroeconomic and climate data to empirically assess the effects of sustained droughts deviations from their historical norms on real GDP growth in Arab League member countries, Iran and Turkey. Dry climate conditions affect agricultural production, cattle mortality and infrastructure construction and maintainance costs, in addition to wide range of other impacts. This paper tests whether the assumption that droughts negatively affect GDP growth is confirmed by the data in the region. This paper also tests the assumption that oil-exporting countries' GDP growth is less affected by droughts. Several contries of the region rely particularly heavily on the oil sector and on oil exports. Since the supply is largely independent from climate conditions in the producing countries and the demand is exogenous, a higher dependence on this sector is expected to be associated with a lower effect of droughts on macroeconomic fluctuations.

A recent and growing empirical literature has sought to shed light on the macroeconomic effects of climate change using panel data. These studies have mainly focused on the relation between temperatures and output (Dell et al., 2012; Burke et al., 2015; Acevedo et al., 2020) and found a negative relation between these two variables. Kahn et al. (2021) consider instead temperatures deviation from their historical norms in order to focus on temperature *changes* instead of temperature *levels*. de Bandt et al. (2021) follow this approach and adopt an empirical strategy that allows to assess the effects of sustained temperature deviations from their historical norms on output growth. These papers usually control for precipitations, but results from this literature mainly indicate an absence of relation with output level or output growth. This can be explained by several issues arising when aggregating precipitation data at the country level (Damania et al., 2020). Little attention has been paid to the macroeconomic effects of changes in the combination of temperatures and precipitations.

This paper contributes to the literature in several ways. First, it assesses the macroeconomic effects of sustained changing patterns of drought conditions, a consequence of climate change that has been relatively neglected by macroeconomists. Second, it focuses on a region that will be greatly impacted by climate change despite having contributed little to historical $CO_2$ emissions (4.4 % of global historical $CO_2$ emissions according to data from Boden et al., 2017), preventing therefore reverse causality concerns in the empirical strategy. Third, it sheds light on potential transmission mechanisms and heterogenous effects by taking into account the diversity across countries in the region.

To assess the relation between sustained drought deviations from their historical norms and output growth, this paper uses macroeconomic data from the World Bank - WDI (2020) and IMF - IFS (2020) datasets and the Standardized Precipitation-Evapotranspiration Index (SPEI) from Vicente-Serrano et al. (2010) which measures droughts. The drought index is obtained as the opposite of the SPEI so that an increase in the index corresponds to drier climate conditions. Additional control variables are obtained from several other sources. The panel dataset has a yearly frequency, covers the period 1960–2018 and includes 21 Arab League member countries, Iran and Turkey. Bahrain is excluded from the sample due to missing climate variables. The empirical strategy uses the local projections method introduced in Jordà (2005) and builds upon de Bandt et al. (2021) to assess the effects of sustained drought index deviations from its historical norms on real GDP growth in the region. This strategy allows to make a step forward in assessing the effects of climate change instead of weather shocks.

The results show that droughts lead to a decline in the contemporaneous output growth rate in oil-importing countries and has a positive effect on output growth rate in oil-exporting countries, although the results for this group are only weakly significant and do not resist several robustness checks. The results also show that the effects do not strengthen as the horizon increases and vanish after one year. Since these effects do not revert afterwards, droughts do not have permanent effects on output growth, but lead to lasting losses in output level in oil-importing countries. Civil violence appears to be one of the transmission channels of the effects of droughts on growth. The agricultural sector is another channel through which droughts decrease real GDP growth, and irrigation has not proved to be an effective adaptation strategy at the macroeconomic level. These results shed light on the importance of economic diversification, and the risks associated.

The remainder of the article is organized as follows. Section 2 reviews the literature and Section 3 describes the data and introduces some stylized facts on droughts in the region. Section 4 details the empirical strategy, Section 5 presents the results of drought effects on output growth and Section 6 discusses robustness checks. Section 7 analyses transmission channels and Section 8 concludes.

## 2 Review of the Literature

The relation between the climate and the economy has long been studied. In the past millenia, Ibn Khaldun (1377) discussed how temperature deviations from a certain average, corrected by air humidity in the case of Hadhramaut and part of the Arabian Peninsula, affect human characteristics and production, while Montesquieu (1748) argued that high temperatures substantially diminish labour productivity.

Recently, a growing body of the literature has sought to shed light on the macroeconomic effects of climate change using panel data. These studies have mainly focused on the relation between temperatures and output (Dell et al., 2012; Burke et al., 2015; Acevedo et al., 2020) and usually found a negative relation. Kahn et al. (2021) consider instead temperatures deviation from their historical norms in order to focus on temperature *changes* instead of temperature *levels*. de Bandt et al. (2021) adopt this approach within an empirical strategy derived from the local projections method (Jordà, 2005) that allows to assess the effects of sustained temperature deviations from their historical norms on output growth in developing countries. These sustained temperature deviations from their historical norms correspond more closely to the notion of climate change than earlier studies in this strand of the literature, and this paper builds upon the empirical strategy introduced in de Bandt et al. (2021).

The previous papers usually control for precipitations, but their results mainly indicate an absence of relation with output level or output growth. While controling for the effects of precipitations is essential to assess the relation between temperatures and the macroeconomy, including these two variables separately does not allow to assess the combined effects of joint changes in these climate variables.

This joint effect of temperatures and precipitations has received little attention from macroeconomists, and this paper tries to fill this gap in the literature. Generoso et al. (2020) is an exeption: the authors assess the relation between the global climate cycle, and more specifically El Niño Southern Oscillation events, and economic growth. They take into account local weather conditions using the SPEI. This paper uses the opposite of this index (so that a positive value corresponds to a drought) to assess the macroeconomic effects of sustained drought deviations from their historical norms in Arab League members, Iran and Turkey.

The relation between the climate and the economy has recently received renewed attention in the Middle-East and North Africa (MENA) region. Cross-country analyses, such as Abou-Ali et al. (2021); Abdelfattah et al. (2021) and Abdel-Latif et al. (2021) have focused on the effects of temperature hikes while controling for precipitations, and the same is true for single-country studies (Karahasan and Pinar, 2021; Yüksel et al., 2021). Giovanis and Ozdamar (2021) is a notable exception as the authors assess the effects of self-declared droughts using microeconomic data from household surveys. This paper contributes to this literature by assessing the macroeconomic effects of droughts, measured by climate data, in one of the regions most affected by, and most vulnerable to, climate change.

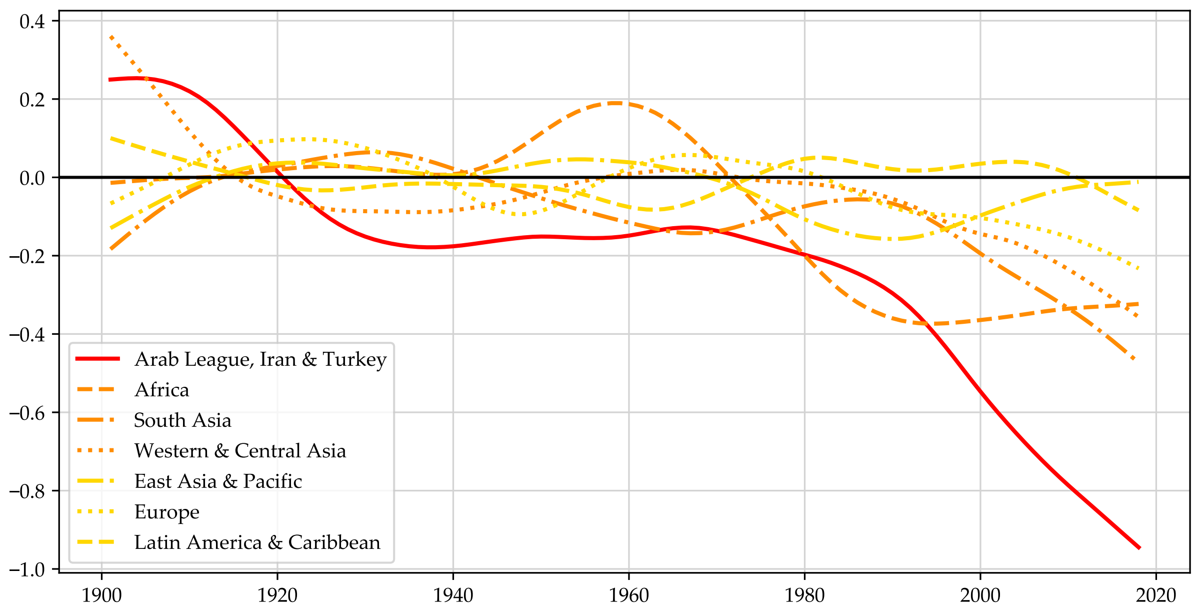
# 3 Data and Stylized Facts

This paper uses country-level annual data in order to assess the effects of droughts on real GDP growth. The data cover a total of 23 countries, corresponding to 21 Arab League members as well as Iran and Turkey, between 1960 and 2018. Bahrain is not included in the sample due to missing climate data. Appendix Table A.1 contains the list of the countries included in the sample, and Appendix Table A.2 lists all the data sources used in this paper.

The main variable of interest is constructed using the Standardized Precipitation-Evapotranspiration Index (SPEI) elaborated by Vicente-Serrano et al. (2010). The global dataset is gridded with a 0.5° latitude $\times$ 0.5° longitude resolution (approximately 55km near the equator) and covers the period 1901–2018 at a monthly frequency. It is standardized at the grid level and it denotes the difference between precipitations and evapotranspiration: for each grid cell, a positive value indicates therefore wetter climate conditions than its own average, and a negative value indicates dryer climate conditions than the average. Country-level data are obtained by computing the unweighted average of all the observations within the land boundaries of each country.

Following de Bandt et al. (2021), and contrary to the methodology used mostly for developed countries (Dell et al., 2012; Burke et al., 2015; Acevedo et al., 2020; Kahn et al., 2021, among others), climate observations are not weighted by local population density. Droughts can affect the economy by decreasing labour productivity. In many developing countries, the lack of access to drinkable water generates economic losses due to time, efforts and extra spending mobilized to obtain this critical resource. This happens both in large cities' informal neighbourhoods and in the countryside, where population density is much lower. Weighting the climate variable by population density would impede to capture properly the economic losses from declining labour productivity in the countryside. In addition, drought can also have macroeconomic effects through other channels, such as land productivity or crop yield. Since this channel occurs where population is relatively scarce, weighting by population density would once again impede to capture this mechanism through which drought affect economic activity. For these reasons, this paper uses an agnostic approach by taking the unweighted aggregation of climate data at the country level.

Figure 2 – Standardized Precipitation-Evapotranspiration Index

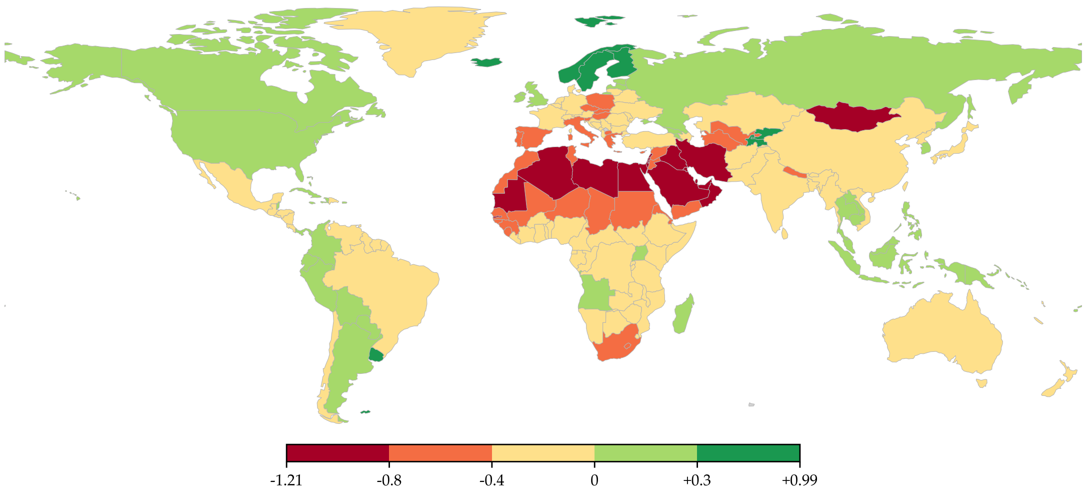



Note: The SPEI data are from Vicente-Serrano et al. (2010), country and regional level aggregation and elaboration are from the author. A decrease in the SPEI indicates a dryer climate.

Figure 2 shows the evolution of the SPEI accross regions. Arab League members, Iran and Turkey correspond to the region where climate conditions dries out the most with respect to historical levels, and this phenomenon seems to have accelerated since the 1990s. This graph suggests that freshwater resources renewal is unlikely to increase and that water stress is therefore likely to remain a distinct feature of the region, unless freshwater withdrawals decrease significantly.

Figure 3 shows for each country the average SPEI deviation from its historical norm over the period 2001–2018, where the historical norm corresponds to the period 1901–1950. The data presented in this figure confirm that the region is by far the one that has dried out the most during that period and that all its countries are affected to a high degree.

Figure 3 – Standardized Precipitation-Evapotranspiration Index Deviation from its Historical Norm




Note: The SPEI data are from Vicente-Serrano et al. (2010), country level aggregation and elaboration are from the author. A decrease in the SPEI indicates a dryer climate. The figure indicates the average SPEI deviation from the historical norm during the period 2001–2018. The historical norm corresponds to the period 1901–1950. This graph is better seen if printed in color.

Droughts correspond to negative values of the SPEI. In order to ease the interpretation of the results, the remainder of this paper uses a yearly drought index that corresponds to the opposite value of the yearly SPEI deviation from its historical norm[1]. As a consequence, an increase in the drought index corresponds to dryer climate conditions.

Other climate and weather data are used as control variables. Terrestrial mean annual temperatures and total annual precipitations are obtained from Matsuura and

[1] Therefore: $\widetilde{Drought}_t = -\widetilde{SPEI}_t$, with $\widetilde{SPEI}_t = SPEI_t - \overline{SPEI_{1901-1950}}$

Willmott (2019). The structure of this dataset is similar to the SPEI dataset and the data are aggregated at the country level using the same methodology. Climate-related natural disasters occurrences are obtained from CRED (2020) and correspond to floods, extreme temperature events, landslides, storms and wildfires.

Economic variables come from several sources. The main dependent variable is the real GDP growth rate. It is built using annual GDP data in constant local currency from the World Bank - WDI (2020) and the IMF - IFS (2020) datasets. Agricultural sector data, including output and total factor productivity as well as livestock, are obtained from USDA - ERS (2019), and irrigation data from the FAOSTAT database. Commodity terms of trade are used as a control variable and are obtained from Gruss and Kebhaj (2019). Civil violence intensity data are from the Major Episodes of Political Violence dataset from the Center for Systemic Peace. This variable is coded on a 0 to 10 scale, where 0 denotes the absence of conflict, and scores from 1 to 10 denote increasing intensity of conflicts, from "Sporadic or Expressive Political Violence" to "Extermination and Annihilation". This variable excludes civil wars from episodes of civil violence to focus on events which involve a lower degree of organization. Labour productivity data come from the ILOSTAT database and oil and natural gas liquids (NGL) production from the IEA Oil Information Statistics through OECD's statistics portal.

Table 1 – Summary Statistics

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| GDP growth rate | 1039 | 4.58 | 9.63 | -64.05 | 123.14 |
| Drought index deviation[a] | 1334 | 0.40 | 0.71 | -2.21 | 2.33 |
| Temperatures deviation[a] | 1368 | 0.38 | 0.67 | -1.62 | 2.95 |
| Precipitations deviation[a] | 1368 | -32.66 | 88.05 | -920.03 | 553.77 |
| Temperatures | 1368 | 22.72 | 4.54 | 9.34 | 29.03 |
| Precipitations | 1368 | 314.54 | 480.56 | 8.78 | 2946.00 |
| Floods occurrence (EMDAT) | 1392 | 0.29 | 0.72 | 0.00 | 6.00 |
| Extreme temperatures occurrence (EMDAT) | 1392 | 0.02 | 0.13 | 0.00 | 2.00 |
| Landslide occurrence (EMDAT) | 1392 | 0.02 | 0.14 | 0.00 | 2.00 |
| Storm occurrence (EMDAT) | 1392 | 0.07 | 0.29 | 0.00 | 3.00 |
| Wildfire occurrence (EMDAT) | 1392 | 0.01 | 0.10 | 0.00 | 2.00 |
| Commodity terms of trade | 1221 | 88.03 | 20.17 | 39.07 | 125.78 |
| Civil violence | 1112 | 0.06 | 0.28 | 0.00 | 3.00 |
| Agricultural output growth | 1287 | 0.04 | 0.13 | -0.85 | 1.31 |
| Agricultural TFP growth | 1287 | 0.02 | 0.13 | -0.78 | 1.21 |
| Livestock growth | 1287 | 0.02 | 0.08 | -0.57 | 0.85 |
| Share of irrigated land | 1382 | 11.79 | 21.17 | 0.05 | 100.00 |
| Labour productivity growth | 384 | 0.00 | 0.11 | -0.63 | 1.21 |
| Oil and NGL output growth | 773 | 0.05 | 0.46 | -1.00 | 7.55 |

Note: [a] Deviation from the historical norm, which corresponds to the period 1901–1950.

Table 1 reports the summary statistics for each variable used in this paper and for the entire sample. Appendix Table A.3 reports the summary statistics for oil exporters and Appendix Table A.4 does the same for oil importers.

# 4 Empirical Framework

Following de Bandt et al. (2021), this paper uses a variant of the local projections method (Jordà, 2005) introduced in Ramey and Zubairy (2018) to capture the effects of a cumulative drought index deviation from its historical norm on cumulative output growth over different horizons. Equation (1) is therefore separately estimated for horizons $h = 0, 1, ..., 5$:

$$y_{i,t:t+h} = \theta^h \sum_{p=t}^{t+h} \widetilde{Drought}_{i,p} + \mathbf{\Theta}^h \widetilde{\mathbf{X}'}_{i,t} + \delta_i^h + \gamma_t^h + \varepsilon_{i,t}^h \tag{1}$$

where $i$ denotes the country and $t$ the year. $y_{i,t:t+h}$ denotes total real GDP growth during years $t$ to $t+h$, $\widetilde{Drought}_{i,t}$ denotes the drought index deviation from its historical norm of country $i$ in year $t$. $\widetilde{\mathbf{X}'}_{i,t}$ is a vector of control variables that includes two lags of the dependent variable (the real GDP growth rate in $t-1$ and $t-2$) and two lags of the drought index deviation from its historical norm in the main specification. $\delta_i$ denotes country fixed effects and captures country-specific time-invariant factors that may affect real GDP growth, such as geography and history, and $\gamma_t$ denotes time fixed effects that capture common shocks, such as the international business cycle. Standard errors are clustered at the country level.

The specification of equation (1) remains parsimonious on purpose so that estimates are not affected by the issue of over-controlling, in line with the common practice when using the Local Projections Method and as discussed in Dell et al. (2014). Many of the traditional growth determinants are highly likely to response to weather shocks, including droughts, and adding them to the main specification would lead to bias in the estimates. Robustness checks include additional control variables in the vector $\widetilde{\mathbf{X}'}_{i,t}$.

Specification of equation (1) allows to assess whether the effects of lasting droughts strengthen over time. To test whether one-off droughts have immediate or lasting macroeconomic effects, this paper relies on the traditional local projections approach as specified in equation (2):

$$y_{i,t+h} = \theta^h \widetilde{Drought}_{i,t} + \mathbf{\Theta}^h \widetilde{\mathbf{X}'}_{i,t} + \delta_i^h + \gamma_t^h + \varepsilon_{i,t}^h \tag{2}$$

where $y_{i,t+h}$ is the real GDP growth rate at year $t+h$ and $\widetilde{Drought}_{i,t}$ is the drought index deviation from its historical norm at year $t$. All the remaining variables are as in equation (1). Equation (2) is also separately estimated for horizons $h = 0, 1, ..., 5$ and allows to build the impulse response function of the real GDP growth rate to a drought deviation from its historical norm.

# 5 Results

Table 2 presents the main estimates from equation (1) where each column corresponds to horizons $h = 0, 1, ..., 5$. panel A shows the results for the entire sample, panel B for oil exporters and Panel C for oil importers.[2] The results indicate that cumulative drought index deviations from its historical norm do not seem to affect output growth in the sample since estimates for all horizons are not significantly different from zero.

Table 2 – Cumulative Response of GDP Growth to Cumulative Drought

| Dependent Variable: | Real GDP Growth | | | | | |
|---|---|---|---|---|---|---|
| | $h = 0$ | $h = 1$ | $h = 2$ | $h = 3$ | $h = 4$ | $h = 5$ |
| *Panel A: Sample includes Arab League Members, Iran and Turkey* | | | | | | |
| $\widetilde{Drought}_h$ | -0.007 | 0.004 | 0.004 | 0.007 | 0.007 | 0.008 |
| | (0.006) | (0.008) | (0.008) | (0.009) | (0.010) | (0.010) |
| Observations | 912 | 888 | 864 | 840 | 818 | 796 |
| $R^2$ | 0.10 | 0.13 | 0.15 | 0.16 | 0.18 | 0.18 |
| *Panel B: Sample includes oil exporters* | | | | | | |
| $\widetilde{Drought}_h$ | 0.027* | 0.043** | 0.030* | 0.033* | 0.032 | 0.030 |
| | (0.013) | (0.016) | (0.014) | (0.016) | (0.018) | (0.016) |
| Observations | 383 | 373 | 363 | 353 | 343 | 333 |
| $R^2$ | 0.22 | 0.27 | 0.29 | 0.31 | 0.34 | 0.34 |
| *Panel C: Sample includes oil importers* | | | | | | |
| $\widetilde{Drought}_h$ | -0.020*** | -0.016*** | -0.013*** | -0.014*** | -0.013** | -0.012** |
| | (0.006) | (0.003) | (0.003) | (0.004) | (0.004) | (0.005) |
| Observations | 529 | 515 | 501 | 487 | 475 | 463 |
| $R^2$ | 0.18 | 0.24 | 0.24 | 0.24 | 0.24 | 0.26 |

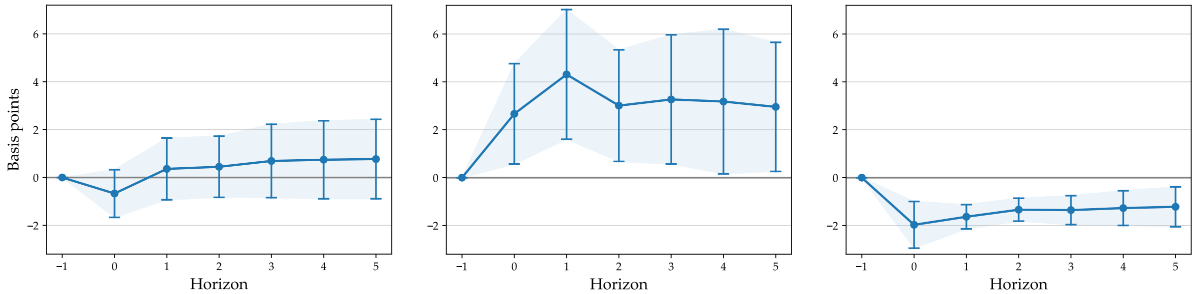
Note: The estimates are in percentage points. Standard errors in parentheses are clustered at the country level. * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Taking into account heterogeneity within the MENA region by splitting the sample between oil exporters and importers leads to different results however. Estimates reported in panel B show that droughts seem to lead to higher growth in oil-exporting

[2]The division of the sample between oil exporters and oil importers follows that of the IMF and is indicated in Appendix Table A.1.

Figure 4 – Cumulative Response of GDP Growth to Cumulative Drought

(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers

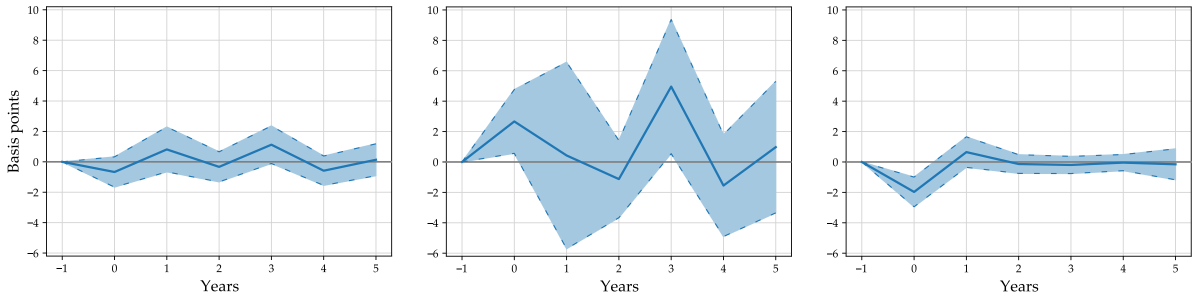



Note: The estimates are in basis points and show the effects of cumulative drought index deviations from its historical norm on total GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

countries, but the estimates are only weakly significant, at the 10 % level. On the contrary, estimates in panel C show that droughts lead to lower GDP growth rates in oil-importing countries, and this effect is statistically significant at the 1 % or the 5 % levels for all horizons $0 \leq h \leq 5$. Figure 4 represents graphically these results and evidences the heterogeneity of output response to droughts within the region.

Figure 5 – Impulse Response of GDP Growth to Drought

(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Droughts can lead to lower output growth in oil-importing countries of the MENA region through several channels. First, these events can increase the cost of access to drinkable water and decrease labour productivity. Second, droughts can damage physical capital and public infrastructure, and can lower the value of services provided by biodeversity, which are increasingly recognised by economists (Heal, 2020; Svartzman et al., 2021). Third, drought can decrease land productivity and crop yields, and increase cattle mortality. This channel is particularly important since food security relies to a large extent on water availability and several oil-importing countries of the region remain commodity exporters to a large extent, relying partially on fruits that require relatively high quantities of freshwater to grow. Finally, droughts can affect output growth through increased social unrest.

The increase in output growth in oil-exporting countries could result from endogenous policy response to counter the destabilizing effects of droughts on economic activity, although the effect appears to be weakly significant. Increased oil production and exports might compensate for losses in other sectors, and increased social transfers might reduce social unrest and increase consumption in the short term.

The output growth response to droughts in both oil-exporting and oil-importing countries does not seem to build upon the immediate effect over time, although the effects remain sizable in the medium-term. These results contrast with the findings in de Bandt et al. (2021) for temperatures hikes in developing countries.

Table 3 – Impulse Response of GDP Growth to Drought

| Dependent Variable: | Real GDP Growth | | | | | |
|---|---|---|---|---|---|---|
| Year | $t$ | $t+1$ | $t+2$ | $t+3$ | $t+4$ | $t+5$ |
| *Panel A: Sample includes Arab League Members, Iran and Turkey* | | | | | | |
| $\widetilde{Drought}_t$ | -0.007 | 0.008 | -0.003 | 0.011 | -0.006 | 0.001 |
| | (0.006) | (0.009) | (0.006) | (0.008) | (0.006) | (0.006) |
| Observations | 912 | 909 | 903 | 879 | 855 | 831 |
| $R^2$ | 0.10 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 |
| *Panel B: Sample includes oil exporters* | | | | | | |
| $\widetilde{Drought}_t$ | 0.027* | 0.004 | -0.011 | 0.050* | -0.016 | 0.010 |
| | (0.013) | (0.037) | (0.015) | (0.027) | (0.020) | (0.026) |
| Observations | 383 | 382 | 378 | 368 | 358 | 348 |
| $R^2$ | 0.22 | 0.19 | 0.20 | 0.20 | 0.18 | 0.18 |
| *Panel C: Sample includes oil importers* | | | | | | |
| $\widetilde{Drought}_t$ | -0.020*** | 0.006 | -0.001 | -0.002 | -0.000 | -0.002 |
| | (0.006) | (0.006) | (0.004) | (0.003) | (0.003) | (0.006) |
| Observations | 529 | 527 | 525 | 511 | 497 | 483 |
| $R^2$ | 0.18 | 0.18 | 0.21 | 0.21 | 0.22 | 0.22 |

Note: The estimates are in percentage points. Standard errors in parentheses are clustered at the country level. * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

The local projection method allows to assess whether one-off droughts have lasting effects on output growth. The impulse response functions in Figure 5 report the estimates obtained from equation (2) and show that droughts affect GDP growth contemporaneously. This effect vanishes the following year however, although a weakly significant positive effect seem to remain after three years in oil-exporting countries. Table 3 reports the estimates from equation (2) for the entire sample (panel A), oil-exporting (panel B) and oil-importing countries (panel C).

The results reported in Figure 5 and Table 3 confirm that droughts have an immediate but temporary effect on output growth which does not strengthen over time. However, the result also indicate that such episodes lead to permanent output losses in oil-importing countries, since output growth does not appear to compensate for the contemporary loss in subsequent years: while droughts do not appear to lead to permanent changes in output growth, they lead to lasting losses in the level of output in oil-importing countries from the region.

# 6 Robustness Tests

This section presents a series of tests to show that the main results resist several robustness checks.

The first series of tests corresponds to the choice of the variable that captures droughts. The main independent variable is the opposite of the 6-month SPEI. This index is built taking into account a 6-month period over which water deficits and surpluses can accumulate. It is therefore able to capture seasonal trend in weather conditions (Generoso et al., 2020). The results do not depend on the choice of this specific indicator however. Appendix Figure B.1 shows that the negative effect of droughts on oil-importing countries output growth and the positive but weakly significant effect of droughts on oil-exporting countries output growth are confirmed when using the opposite of the 3-month SPEI, and Appendix Figure B.2 shows that the same is true when using the 12-month SPEI.

Robustness tests for the results obtained from the impulse response functions are reported in Table 4 for horizon $h = 0$. The main results are also confirmed when using alternative drought indexes. Appendix Figure B.3 shows the impulse response functions obtained when estimating equation (2) using the opposite of the 3-month SPEI, and Appendix Figure B.4 reports the same functions when using the 12-month SPEI. Table 4 columns (1) and (2) report the estimate for $h = 0$. These robustness checks confirm that droughts negatively affect GDP growth contemporaneously and that this effect vanishes the following year in oil-importing countries. The positive but weakly significant effect on output growth in oil-exporting countries becomes statistically not significant when using the 3- and 12-month SPEI, confirming the weakness of the rela-

Table 4 – Impulse Response of GDP Growth to Drought (Robustness Checks)

| Dependent Variable: | Real GDP Growth Rate at year $t$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Full IRF: | Fig. B.3 | Fig. B.4 | Fig. B.5 | Fig. B.6 | Fig. B.7 | Fig. B.8 | Fig. B.9 | Fig. B.10 | Fig. B.11 | Fig. B.12 |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| *Panel A: Sample includes Arab League Members, Iran and Turkey* | | | | | | | | | | |
| $\widetilde{Drought}_t$ | -0.002 | -0.008 | -0.004 | -0.013* | -0.007 | -0.004 | -0.004 | -0.007 | -0.005 | -0.008 |
| | (0.008) | (0.006) | (0.006) | (0.007) | (0.005) | (0.007) | (0.007) | (0.006) | (0.006) | (0.006) |
| Observations | 912 | 912 | 936 | 912 | 912 | 890 | 890 | 912 | 859 | 806 |
| $R^2$ | 0.10 | 0.11 | 0.11 | 0.11 | - | 0.10 | 0.10 | 0.11 | 0.12 | 0.12 |
| *Panel B: Sample includes oil exporters* | | | | | | | | | | |
| $\widetilde{Drought}_t$ | 0.045* | 0.013 | 0.027 | -0.007 | 0.027 | 0.028 | 0.028 | 0.026* | 0.026* | 0.026 |
| | (0.023) | (0.013) | (0.015) | (0.014) | (0.016) | (0.018) | (0.018) | (0.012) | (0.013) | (0.016) |
| Observations | 383 | 383 | 393 | 383 | 383 | 373 | 373 | 383 | 383 | 359 |
| $R^2$ | 0.23 | 0.22 | 0.24 | 0.10 | - | 0.23 | 0.23 | 0.22 | 0.22 | 0.21 |
| *Panel C: Sample includes oil importers* | | | | | | | | | | |
| $\widetilde{Drought}_t$ | -0.020** | -0.016** | -0.018** | -0.017** | -0.020*** | -0.016** | -0.016** | -0.020*** | -0.019** | -0.020*** |
| | (0.007) | (0.005) | (0.006) | (0.008) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Observations | 529 | 529 | 543 | 529 | 529 | 517 | 517 | 529 | 476 | 447 |
| $R^2$ | 0.17 | 0.18 | 0.18 | 0.15 | - | 0.19 | 0.19 | 0.19 | 0.23 | 0.21 |

Note: Each column presents the contemporary effect of droughts on GDP growth. The robustness check to which it corresponds is indicated in the main text and in Appendix B, which contains the figures of the full impulse response functions for each test. The estimates are in percentage points. Standard errors in parentheses are clustered at the country level (except for column (5) which reports Driscoll and Kraay (1998) standard errors). * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

tion between drought and growth in oil-exporting countries.

The second series of tests confirms that the main results of this paper are robust to alternative specifications. Appendix Figure B.5 shows the impulse response functions when only one lag of both the GDP growth rate and the drought index are included in the set of control variables, as opposed to two lags in the baseline specification, and Table 4 column (3) resports the estimate for $h = 0$. Results for both oil-exporting and oil-importing countries remain unchanged. Excluding entirely the lags of the dependent and independent variables from the specification does not change the results either.[3]

Following Burke et al. (2015), an alternative specification of equation (2) includes country-specific linear and quadratic time trends in order to capture within-country changes over the sample period, including convergence dynamics. The results shown in Table 4 column (4) and Appendix Figure B.6 are again robust to this robustness check, despite the fact that time trends capture a share of the drought index variation.

Table 4 column (5) and Appendix Figure B.7 report the estimated coefficients of the baseline specification with Driscoll and Kraay (1998) standard errors, which are robust to cross-sectional dependence in addition to autocorrelation and heteroskedasticity. The main results remain unchanged.

The third series of robustness checks tests whether the results resist to including additional control variables that might explain output growth in countries included in the sample. Table 4 column (6) and Appendix Figure B.8 report the results when mean annual temperatures and total annual precipitations deviations from their historical norms are included as control variables. These results confirm the negative contemporary effect of droughts on output growth in oil-importing countries.Table 4 column (7) and Appendix Figure B.9 show the results obtained when temperature and precipitations deviations from their historical norms are reimplaced by temperature and precipitations levels, in order to control for the separate effects of these variables. These results lead to the same conclusion.

Table 4 column (8) and Appendix Figure B.10 report the results obtained when climate-related natural disasters occurrences are included as additional control variables and shows that the main results of this paper are robust to this alternative specification. Table 4 column (9) and Appendix Figure B.11 report the results adding commodity terms of trade as a control variable. Commodity terms of trade are know to be a major determinant of the business cycle in developing countries, and including this control variable does not affect the results of this paper.

Civil conflicts have been highly prevalent in the region and have had strong

[3] These results are not reported but are available from the author upon request.

macroeconomic effects in affected countries, both on the real and the monetary sectors (see Devadas et al., 2021; Lemaire, 2021, for examples in the MENA region). Furthermore, droughts usually represent a negative shock on food supply and can therefore lead to civil conflicts. Table 4 column (10) and Appendix Figure B.12 report the results controlling for civil conflict intensity and shows that the main results of this paper are robust to this additional test.

The last robustness test assesses whether any single country affects the results decisively. Appendix Table B.1 reports the baseline results when countries are excluded from the sample one by one. In the case of oil importers, the negative effect of drought on growth remain significant at the 1% or the 5% level, and the estimates value remain close to the baseline level of $-0.02$. The estimate value decreases in absolute terms to $-0.015$ when Syria is removed from the sample, but it remains negative and statistically significant at the 1% level. In the case of oil exporters, the range of estimates value is greater and their statistical significance remains low, at the 10% level, or even disappears when some countries are separately removed from the sample. This indicates that the positive and weakly significant effect of drought on growth in oil-exporting countries is not robust.

To sum up, the series of robustness tests presented in this section confirm that droughts have a negative effect on output growth in oil-importing countries. They also confirm that the positive effect of droughts on growth in oil-exporting countries is only weakly significant and not robust, and must therefore be interpreted with caution.

# 7 Transmission Channel

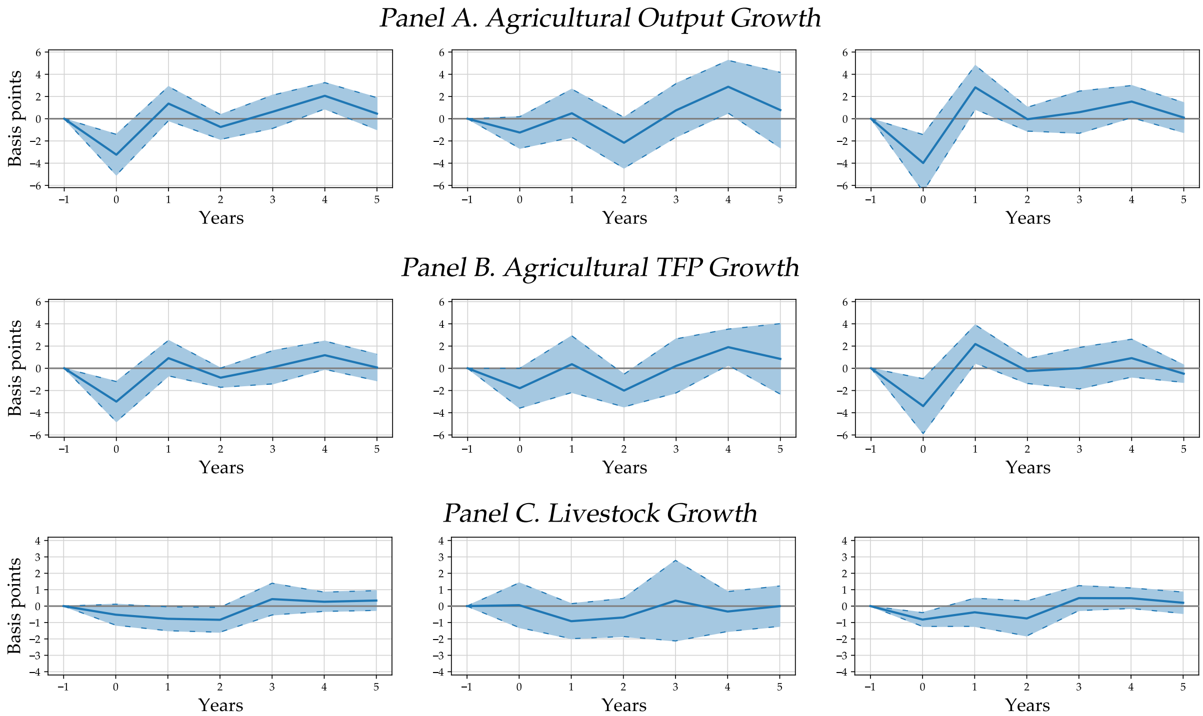
This section presents additional results showing that the agricultural sector and civil conflicts are two of the transmission mechanisms through which droughts lead to lower economic growth in oil-importing countries in the region.

Figure 6 shows the response of agricultural sector growth to droughts based on equation (2), where the dependent variable $y_{i,t+h}$ is reimplaced by agricultural output growth (Panel A), agricultural total factor productivity growth (Panel B), and livestock growth (Panel C). The vector of control variables $\widetilde{\mathbf{X}}'_{i,t}$ is modified accordingly to include two lags of the dependent variable.

The results for the agricultural sector show that agricultural output growth, agricultural total factor productivity growth and livestock growth all significantly decrease when droughts occur in oil-importing countries. Contrary to the aggregate results, the negative contemporary effect appears to be partially compensated the following year. In the case of agricultural output growth, droughts lead to a 3.98 basis points decline in

Figure 6 – Impulse Responses of Agricultural Sector Growth to Drought

(a) Arab League members, Iran and Turkey | (b) Oil exporters | (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual agricultural sector growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

the contemporary growth rate, followed by a 2.82 basis points increase in the growth rate the year after, denoting a partial recovery. Results for oil exporters are not statistically different from zero, showing an absence of reaction of the agricultural sector to droughts in these countries, potentially explained by a more capital-intensive structure in the Gulf.

The decline in the agricultural sector output and total factor productivity growth as well as the decline in livestock growth can partially explain the observed decline in real GDP growth. Adaptation policies such as developing the irrigation system have long been considered and implemented to increase the region's resilience to droughts.

Table 5 – Agricultural Sector Contemporary Response to Drought

| Dependent variable | *Agricultural Output Growth* (1) | *Agricultural TFP Growth* (2) | *Livestock Growth* (3) |
|---|---|---|---|
| $\widetilde{Drought}_t$ | -0.045** | -0.038** | -0.008** |
| | (0.017) | (0.016) | (0.003) |
| $Irrigation_t$ | -0.002 | -0.002 | 0.000 |
| | (0.001) | (0.001) | (0.001) |
| $\widetilde{Drought}_t \times Irrigation_t$ | 0.000 | 0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) |
| $\widetilde{Drought}_{t-1}$ | 0.022** | 0.015* | -0.001 |
| | (0.010) | (0.007) | (0.006) |
| $\widetilde{Drought}_{t-2}$ | 0.009 | 0.005 | -0.004 |
| | (0.011) | (0.011) | (0.006) |
| *Agricultural Output Growth*$_{t-1}$ | -0.402*** | - | - |
| | (0.065) | - | - |
| *Agricultural Output Growth*$_{t-2}$ | -0.071* | - | - |
| | (0.038) | - | - |
| *Agricultural TFP Growth*$_{t-1}$ | - | -0.426*** | - |
| | - | (0.071) | - |
| *Agricultural TFP Growth*$_{t-2}$ | | -0.079 | - |
| | - | (0.048) | - |
| *Livestock Growth*$_{t-1}$ | - | - | 0.127 |
| | - | - | (0.091) |
| *Livestock Growth*$_{t-2}$ | - | - | -0.032 |
| | - | - | (0.040) |
| Country Fixed Effects | Y | Y | Y |
| Year Fixed Effects | Y | Y | Y |
| Observations | 633 | 633 | 633 |
| $R^2$ | 0.33 | 0.32 | 0.11 |

Note: The estimates are in percentage points. Standard errors in parentheses are clustered at the country level. * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

To test whether irrigation is an adaptation policy that is effective at eliminating the negative effects of droughts on agricultural sector growth in oil-importing countries of the region, equation (3) is separately estimated for horizons $h = 0, 1, ..., 5$:

$$
\begin{aligned}
y_{i,t+h} =& \theta^h Drought_{i,t} + \alpha^h Irrigation_{i,t} + \beta^h Drought_{i,t} \times Irrigation_{i,t} \\
&+ \boldsymbol{\Theta}^h \widetilde{\mathbf{X}}'_{i,t} + \delta_i^h + \gamma_t^h + \varepsilon_{i,t}^h
\end{aligned}
\tag{3}
$$

where the variables are as in equation (2) and $Irrigation_{i,t}$ denotes the share of agricultural land area dedicated that is irrigated. This specification allows to recover the coefficient $\beta^h$ which indicates whether irrigation affects the impact of droughts on output growth.

Table 5 presents the estimates from equation equation (3) for horizon $h = 0$. Droughts do affect agricultural sector growth, and irrigation alone does not. The interaction term between droughts and irrigation is small and not statistically different from zero. This result indicates that, at the macroeconomic level, irrigation does not fully protect oil-importing economies of the region from the effects of droughts on the agricultural sector.

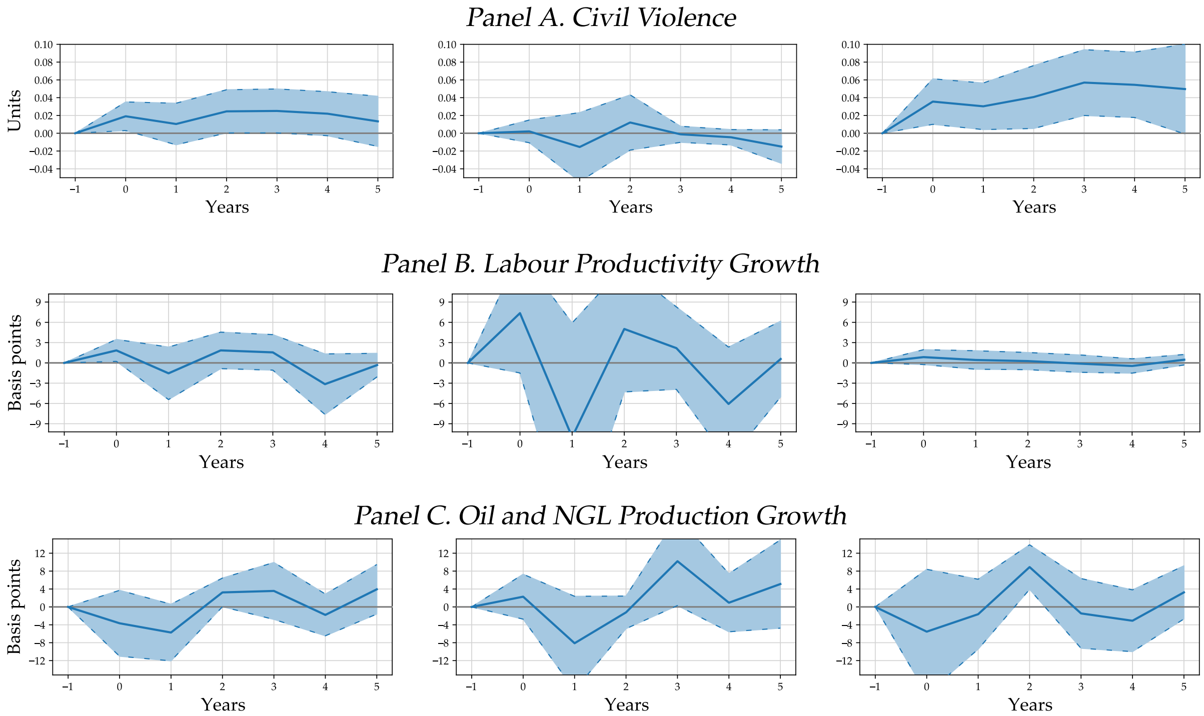
Equation (2) allows to test alternative potential transmission channels by reimplacing the dependent variable $y_{i,t+h}$ by the prevalence of civil violence (Panel A), labour productivity growth (Panel B), and oil and NGL output growth (Panel C). The vector of control variables $\widetilde{\mathbf{X}}'_{i,t}$ is again modified to include two lags of the dependent variable. Figure 7 shows the impulse response function of these three variables to droughts.

The results presented in Figure 7 panel A show that droughts lead to an increase in civil violence in oil-importing countries in the region, while oil-exporting countries remain unaffected. Part of the decline in real GDP growth due to droughts in oil-importing countries might therefore be attributed to this increase in civil violence. Contrary to the aggregate results, which indicate in temporary decline in the real GDP growth rate, and the results for the agricultural sector, which indicate a partial recovery after an initial decline, the effect of droughts on civil violence appear to be persistent. The intrinsic dynamics of civil violence might explain this persistent effect: droughts can trigger civil violence, which will have a tendency to be self-sustaining afterwards.

Other potential transmission mecanisms include labour productivity growth, which might be affected differently in oil-importing and oil-exporting countries, as well as oil and NGL output growth. Oil-exporting countries could increase oil (and gas where available) production when droughts occur to prevent their income from falling and cover higher food imports needs.

Figure 7 – Impulse Responses of Civil Violence, Labour Productivity Growth and Oil/NGL Production Growth to Drought

(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on civil violence, labour productivity growth and oil and natural gas liquids production growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

The results presented in Figure 7 panel B and panel C show that none of these potential transmission mecanisms are active in the region. Labour productivity growth does not respond to droughts, and oil output growth does not increase in oil-exporting countries in response such events.

# 8 Conclusion

This paper assesses the effects of droughts on real GDP growth in Arab League members, Iran and Turkey, the region where water stress is the most accute in the world. It adds to the empirical literature on the macroeconomic effects of climate change by focusing on changes in drought patterns with respect to their historical norms, which capture the joint effect of temperatures and precipitations, instead of changes in temperatures and precipitations taken separately. The empirical strategy relies on two specifications of the local projections method that allow to assess the effects of drought deviations and sustained drought deviations from their historical norms over several horizons.

This paper finds that droughts lead to a decline in the contemporaneous output growth rate in oil-importing countries. The evidence in oil-exporting countries is mixed due to weak statistical significance but suggests at most a mild positive contemporary effect. In both cases, the effect does not strengthen as the horizon increases and vanishes after one year. Since this effect does not revert afterwards, drought do not have a permanent effect on output growth, but lead to a lasting loss in output level in oil-importing countries. This result resists a series of robustness checks on the drought index construction, the empirical specification and additional control variables.

The analysis of the transmission mechanisms indicate that the observed temporary decline in real GDP growth in oil-importing countries of the region in response to an increase in the drought index can be partially explained by an temporary adverse effect on the agricultural sector growth and a more lasting increase in civil violence. Labour productivity growth and oil and natural gas liquids output growth, two alternative potential transmission channels, do not appear to respond to droughts in the region.

This paper's results strongly advocate for economic diversification in oil-importing countries of the region. Output growth still depends substantially on the climate-dependent agricultural sector in several of these countries. Further diversification of their productive sectors would increase their business cycles' resilience to weather shock and climate change. Such a development strategy should therefore be incorporated in their set of adaptation policies and efforts, and be considered as such since it would allow to better cope with the effects of climate change. This global challenge, attributed mainly to past and current carbon emissions in countries outside of the region, makes economic diversification an even more pressing condition to foster resilient economies and lay the foundations for inclusive growth and sustainable development.

Several oil-exporting countries of the region have attempted to difersify their economies away from oil production and reduce their dependence on this sector, with heterogenous but limited success so far. This is partly due to changing regulations and increasing mitigation efforts in the EU and the US, among other countries. These efforts are essential to ensure future economic growth and sustainable development in oil-exporting countries, but this paper's results illustrate the fact that currently, the oil sector largely insulates their business cycles from weather shocks. The tourism sector is an important component in many of the current diversification strategies, in part due to its capacity to attract foreign currencies, but Covid-19 has shown that it is even more dependent on the international business cycle than the oil sector, and its resilience to droughts and climate change is far from certain. Economic diversification in these countries must therefore be carefully planned and carried out in order not to increase further their business cycle's dependence to exogenous shocks.

Future empirical research could assess the macroeconomic effects of droughts using higher frequency data. A growing strand of the literature has shown that income distribution matters for the business cycle, and droughts does not affect all individuals and social groups equally. Assessing the effects of droughts on income and wealth inequality could also provide valuable insight for the conduct and elaboration of both stabilization and structural economic policy in the region.

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# Appendix

## A Data, Sources and Descriptive Statistics

Table A.1 – List of Countries Included in the Sample

| | |
|---|---|
| Arab League members, Iran and Turkey | United Arab Emirates, Comoros, Djibouti, Algeria, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libyan, Morocco, Mauritania, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Somalia, Syrian, Tunisia, Turkey, Yemen |
| Oil exporters | United Arab Emirates, Algeria, Iran, Iraq, Kuwait, Libyan, Oman, Qatar, Saudi Arabia, Yemen |
| Oil importers | Comoros, Djibouti, Egypt, Jordan, Lebanon, Morocco, Mauritania, Palestine, Sudan, Somalia, Syrian, Tunisia, Turkey |

Note: Bahrain is not included in the sample due to missing data for the Standardized Precipitations Evapotranspiration Index.

Table A.2 – Data Sources

| Variable: | Source: |
|---|---|
| *Socio-Economic Variables:* | |
| Real GDP growth rate | World Bank - WDI (2020); IMF - IFS (2020) |
| Commodity terms of trade | Gruss and Kebhaj (2019) |
| Agricultural sector | USDA - ERS (2019) |
| Irrigation | FAOSTAT |
| Civil violence | Major Episodes of Political Violence (Center for Systemic Peace) |
| Labour productivity growth | ILOSTAT |
| Oil and NGL output growth | IEA Oil Information Statistics |
| *Climate Variables:* | |
| Standardized Precipitations-Evapotranspiration Index | Vicente-Serrano et al. (2010) |
| Terrestrial temperature and precipitation | Matsuura and Willmott (2019) |
| Climate-related natural disasters | CRED (2020) |

Table A.3 – Summary Statistics (Oil Exporters)

| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| GDP growth rate | 458 | 5.03 | 12.76 | -64.05 | 123.14 |
| Drought index deviation[a] | 580 | 0.58 | 0.72 | -2.21 | 2.33 |
| Temperatures deviation[a] | 627 | 0.45 | 0.66 | -1.17 | 2.68 |
| Precipitations deviation[a] | 627 | -20.80 | 44.73 | -171.49 | 538.44 |
| Temperatures | 627 | 24.39 | 2.86 | 15.98 | 28.64 |
| Precipitations | 627 | 124.42 | 71.55 | 11.58 | 729.67 |
| Floods occurrence (EMDAT) | 638 | 0.30 | 0.79 | 0.00 | 6.00 |
| Extreme temperatures occurrence (EMDAT) | 638 | 0.00 | 0.06 | 0.00 | 1.00 |
| Landslide occurrence (EMDAT) | 638 | 0.01 | 0.11 | 0.00 | 1.00 |
| Storm occurrence (EMDAT) | 638 | 0.06 | 0.26 | 0.00 | 2.00 |
| Wildfire occurrence (EMDAT) | 638 | 0.00 | 0.07 | 0.00 | 1.00 |
| Commodity terms of trade | 594 | 73.01 | 17.92 | 39.07 | 104.73 |
| Civil violence | 536 | 0.03 | 0.17 | 0.00 | 1.00 |
| Agricultural output growth | 605 | 0.05 | 0.15 | -0.85 | 1.31 |
| Agricultural TFP growth | 605 | 0.02 | 0.14 | -0.78 | 1.21 |
| Livestock growth | 605 | 0.03 | 0.09 | -0.57 | 0.85 |
| Share of irrigated land | 641 | 11.28 | 13.04 | 0.40 | 55.56 |
| Labour productivity growth | 176 | -0.00 | 0.15 | -0.63 | 1.21 |
| Oil and NGL output growth | 524 | 0.05 | 0.44 | -0.83 | 7.55 |

Note: [a] Deviation from the historical norm, which corresponds to the period 1901–1950.

Table A.4 – Summary Statistics (Oil Importers)

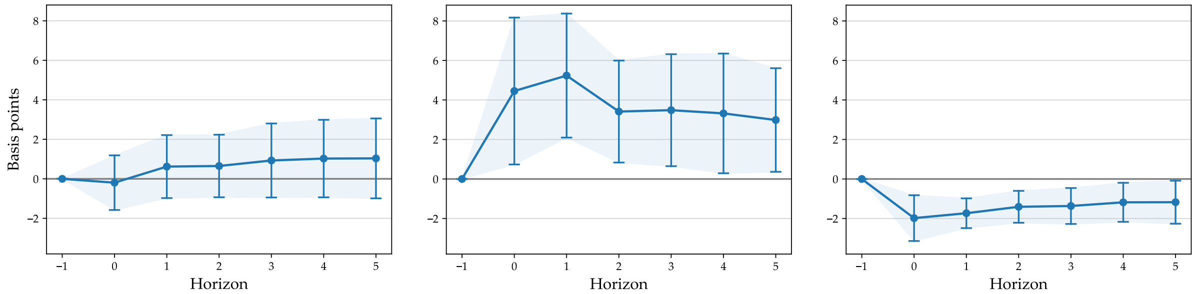
| Variable | Obs. | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| GDP growth rate | 581 | 4.23 | 6.10 | -42.45 | 49.45 |
| Drought index deviation[a] | 754 | 0.26 | 0.67 | -1.93 | 2.20 |
| Temperatures deviation[a] | 741 | 0.32 | 0.67 | -1.62 | 2.95 |
| Precipitations deviation[a] | 741 | -42.70 | 111.40 | -920.03 | 553.77 |
| Temperatures | 741 | 21.31 | 5.18 | 9.34 | 29.03 |
| Precipitations | 741 | 475.42 | 604.76 | 8.78 | 2946.00 |
| Floods occurrence (EMDAT) | 754 | 0.29 | 0.65 | 0.00 | 5.00 |
| Extreme temperatures occurrence (EMDAT) | 754 | 0.03 | 0.17 | 0.00 | 2.00 |
| Landslide occurrence (EMDAT) | 754 | 0.02 | 0.16 | 0.00 | 2.00 |
| Storm occurrence (EMDAT) | 754 | 0.07 | 0.31 | 0.00 | 3.00 |
| Wildfire occurrence (EMDAT) | 754 | 0.01 | 0.11 | 0.00 | 2.00 |
| Commodity terms of trade | 627 | 102.26 | 8.47 | 81.10 | 125.78 |
| Civil violence | 576 | 0.08 | 0.36 | 0.00 | 3.00 |
| Agricultural output growth | 682 | 0.03 | 0.11 | -0.47 | 0.73 |
| Agricultural TFP growth | 682 | 0.02 | 0.11 | -0.48 | 0.66 |
| Livestock growth | 682 | 0.02 | 0.07 | -0.39 | 0.64 |
| Share of irrigated land | 741 | 12.24 | 26.25 | 0.05 | 100.00 |
| Labour productivity growth | 208 | 0.01 | 0.05 | -0.24 | 0.19 |
| Oil and NGL output growth | 249 | 0.05 | 0.49 | -1.00 | 5.79 |

Note: [a] Deviation from the historical norm, which corresponds to the period 1901–1950.

# B Additional Robustness Checks

Figure B.1 – Cumulative Response of GDP Growth to Cumulative Drought (3-Month SPEI)

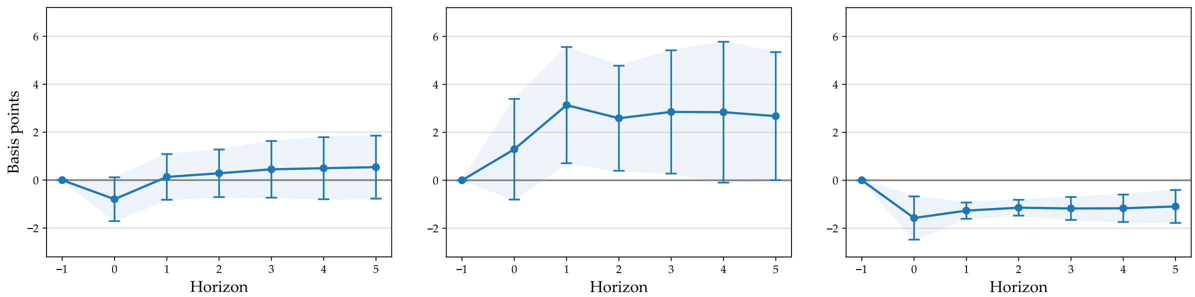
(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in percentage points. Standard errors in parentheses are clustered at the country level. * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Figure B.2 – Cumulative Response of GDP Growth to Cumulative Drought (12-Month SPEI)

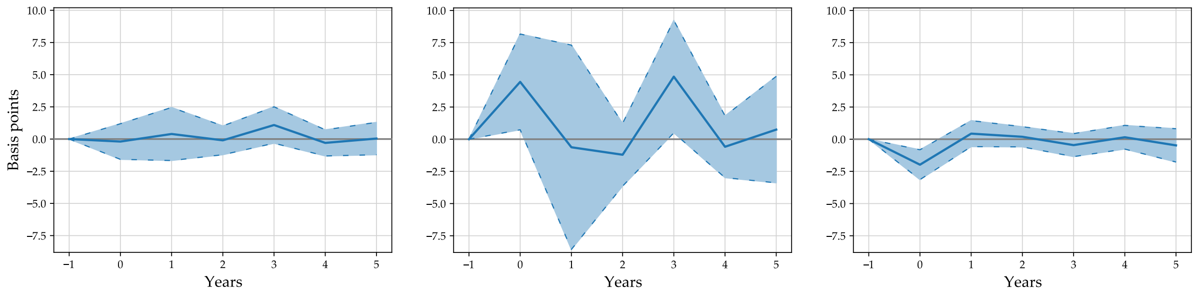
(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in percentage points. Standard errors in parentheses are clustered at the country level. * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

Figure B.3 – Impulse Response of GDP Growth to Drought (3-Month SPEI)

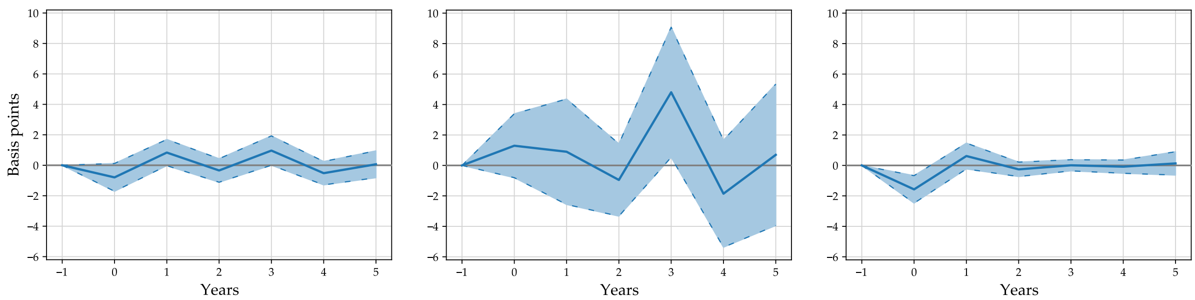
(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.4 – Impulse Response of GDP Growth to Drought (12-Month SPEI)

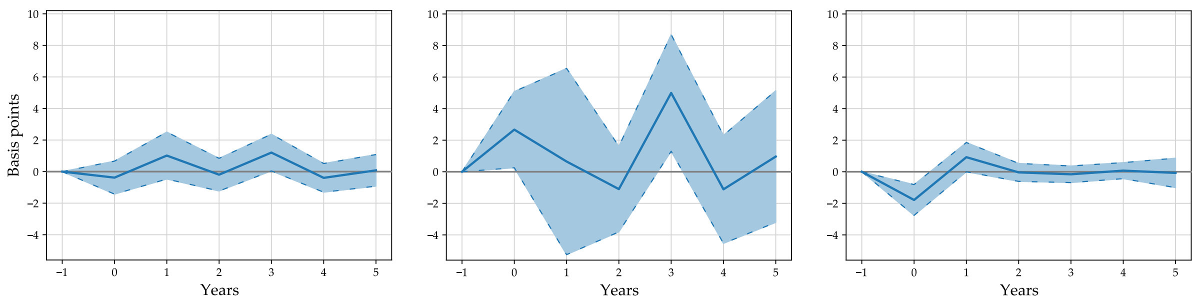
(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.5 – Impulse Response of GDP Growth to Drought (Controls Include One Lag)

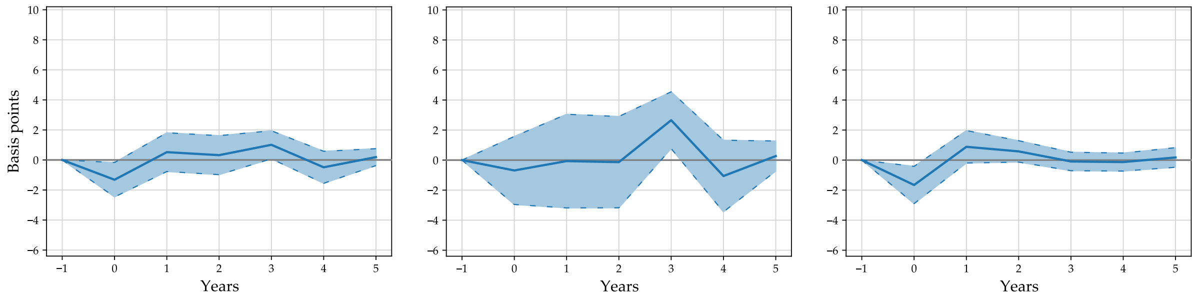
(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.6 – Impulse Response of GDP Growth to Drought (Controls Include Country-Specific Linear and Quadratic Time Trend)

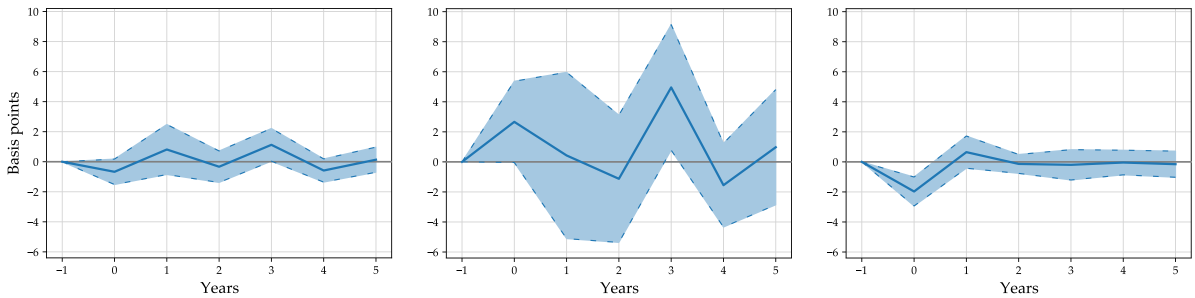
(a) Arab League members, Iran and Turkey | (b) Oil exporters | (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.7 – Impulse Response of GDP Growth to Drought (Driscoll and Kraay Standard Errors)

(a) Arab League members, Iran and Turkey | (b) Oil exporters | (c) Oil importers



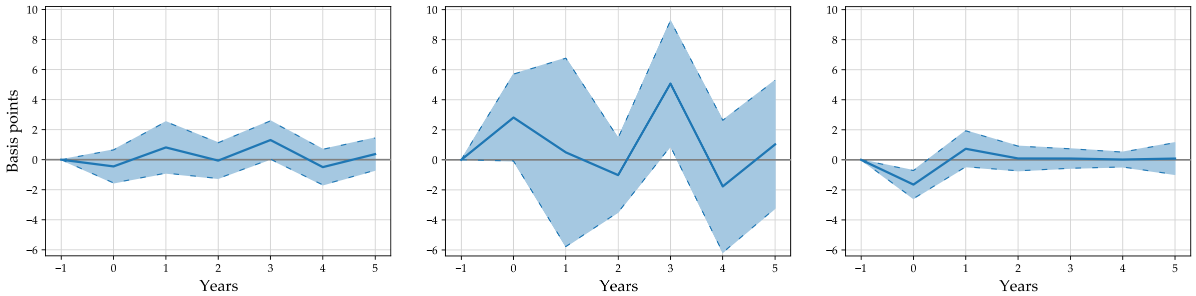

Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level using Driscoll and Kraay standard errors (Driscoll and Kraay, 1998).

Figure B.8 – Impulse Response of GDP Growth to Drought (Controls Include Temperature and Precipitations Deviations from their Historical Norms)

(a) Arab League members, Iran and Turkey

(b) Oil exporters

(c) Oil importers



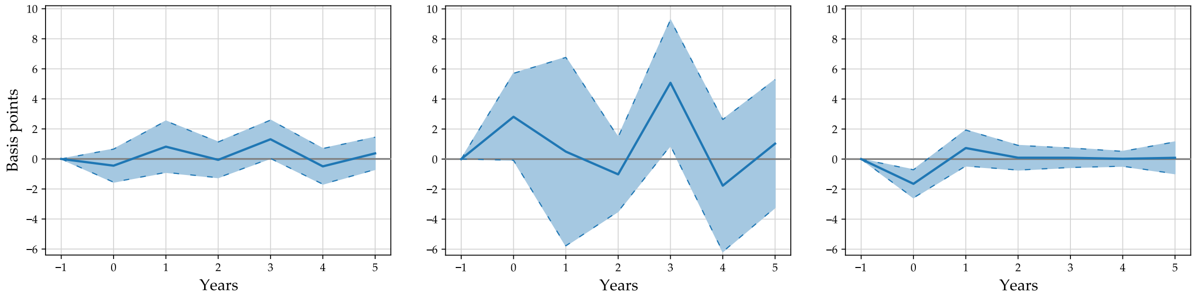

Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.9 – Impulse Response of GDP Growth to Drought (Controls Include Temperature and Precipitations Levels)

(a) Arab League members, Iran and Turkey

(b) Oil exporters

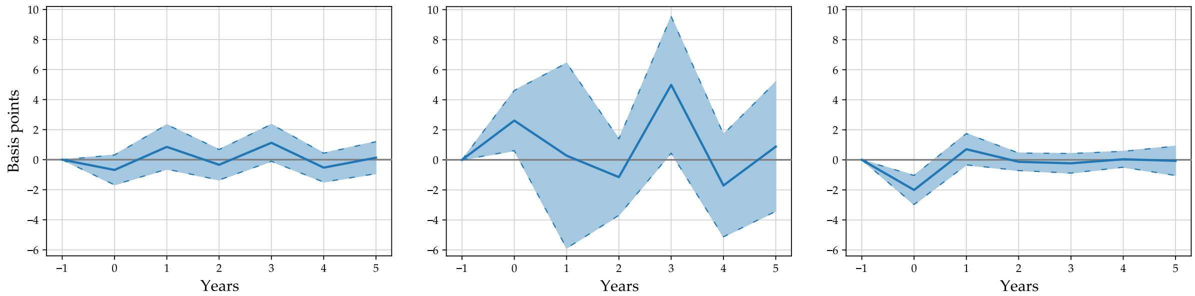
(c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.10 – Impulse Response of GDP Growth to Drought (Controls Include Climate-Related Natural Disasters Occurrences)

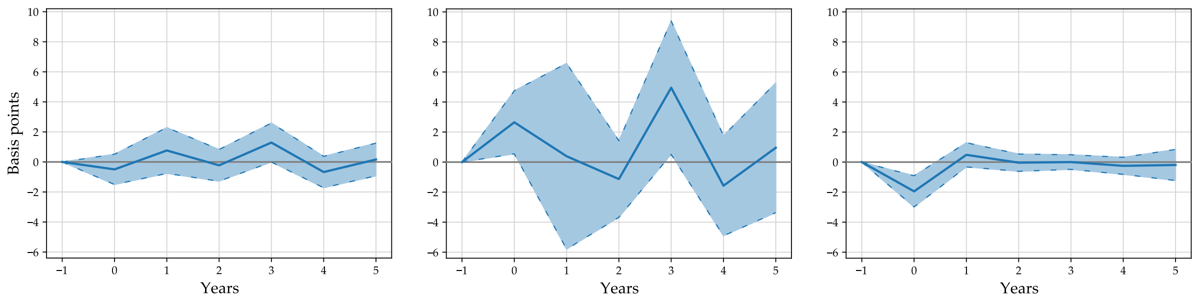
(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.11 – Impulse Response of GDP Growth to Drought (Controls Include Commodity Terms of Trade)

(a) Arab League members, Iran and Turkey (b) Oil exporters (c) Oil importers



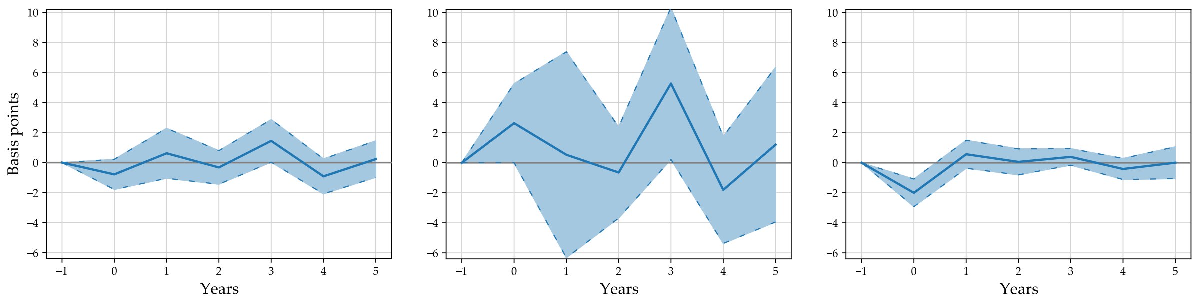

Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Figure B.12 – Impulse Response of GDP Growth to Drought (Controls Include Civil Conflict Intensity)

(a) Arab League members, Iran and Turkey

(b) Oil exporters

(c) Oil importers




Note: The estimates are in basis points and show the effects of a drought index deviations from its historical norm on annual GDP growth for each horizon $h = 0, 1, ..., 5$. Confidence intervals correspond to the 10 % level.

Table B.1 – Contemporary Response of GDP Growth to Drought, Excluding Countries One by One

| Country Excluded | Coefficient | Standard Error | Observations | $R^2$ |
|---|---|---|---|---|
| | *Panel A: Sample includes oil importers* | | | |
| *Baseline* | *-0.020****** | *(0.006)* | *529* | *0.18* |
| Comoros | -0.022*** | (0.007) | 493 | 0.20 |
| Djibouti | -0.020*** | (0.006) | 526 | 0.18 |
| Egypt | -0.022*** | (0.006) | 473 | 0.20 |
| Jordan | -0.020** | (0.006) | 489 | 0.18 |
| Lebanon | -0.019*** | (0.006) | 501 | 0.19 |
| Morocco | -0.018** | (0.007) | 479 | 0.20 |
| Mauritania | -0.019** | (0.006) | 474 | 0.21 |
| Palestine | -0.021*** | (0.006) | 507 | 0.19 |
| Somalia | -0.019** | (0.006) | 498 | 0.22 |
| Sudan | -0.021** | (0.007) | 473 | 0.19 |
| Syria | -0.015*** | (0.004) | 484 | 0.17 |
| Tunisia | -0.021*** | (0.006) | 478 | 0.19 |
| Turkey | -0.020** | (0.007) | 473 | 0.20 |
| | *Panel B: Sample includes oil exporters* | | | |
| *Baseline* | *0.027** | *(0.013)* | *383* | *0.22* |
| Algeria | 0.037** | (0.013) | 327 | 0.26 |
| Iraq | 0.035** | (0.012) | 335 | 0.25 |
| Iran | 0.021 | (0.013) | 327 | 0.27 |
| Kuwait | 0.028* | (0.014) | 359 | 0.23 |
| Libya | 0.023* | (0.012) | 366 | 0.28 |
| Oman | 0.027 | (0.016) | 332 | 0.25 |
| Qatar | 0.027* | (0.014) | 367 | 0.23 |
| Saudi Arabia | 0.020 | (0.012) | 335 | 0.25 |
| United Arab Emirates | 0.026* | (0.014) | 342 | 0.23 |
| Yemen | 0.026 | (0.015) | 357 | 0.22 |

Note: The table reports the contemporary effect of droughts on output growth (*i.e.* for $h = 0$) when countries are excluded from their respective sample one by one. The estimates are in percentage points. Standard errors in parentheses are clustered at the country level. * Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.