ERF Working Papers Series

# Measuring the Economic Cost of Conflict in Afflicted Arab Countries

Elif Semra Ceylan and Semih Tumen

ECONOMIC RESEARCH FORUM
منتدى البحوث الاقتصادية

Working Paper No. 1459
February 2021

# MEASURING THE ECONOMIC COST OF CONFLICT IN AFFLICTED ARAB COUNTRIES

Elif Semra Ceylan[1] and Semih Tumen[2]

**Working Paper No. 1459**

**February 2021**

We thank Khalid Abu-Ismail, Gunes Asik, Ibrahim Elbadawi, Belal Fallah, Samir Makdisi, Ramage Nada, and Raimundo Soto for very helpful comments and suggestions. We gratefully appreciate the support of the Economic Research Forum through the "Peace-Building and Post-Conflict Reconstruction in Conflict Affected Arab Countries" research theme. Various parts of this article re-use the material from the authors' previous research. The usual disclaimer holds.

Send correspondence to:
Elif Semra Ceylan
Ernst & Young
semra.ceylan@tr.ey.com

[1] Ernst & Young. Mahall Ankara B Blok, 06530 Cankaya, Ankara, Turkey.
[2] TED University, Department of Economics. Ziya Gokalp Cad., No.48, 06420 Kolej, Ankara, Turkey. ERF. semih.tumen@tedu.edu.tr

First published in 2021 by
The Economic Research Forum (ERF)
21 Al-Sad Al-Aaly Street
Dokki, Giza
Egypt
www.erf.org.eg

**Abstract**

The goal of this paper is to estimate the economic cost of conflict in selected Arab countries by using satellite images and geographical information systems (GIS) methods. Specifically, we employ image-processing techniques to generate data proxying intensity of economic activity at country and sub-region levels. The focus is on four countries: Iraq, Libya, Syria, and Yemen. These are the countries that have been most severely affected in various ways by the widespread wave of civil conflict occurred in the MENA region in the aftermath of the Arab Spring. Certain back-of-the-envelope calculations suggest that GDP and main factors of production are nearly halved in those countries. We use data provided by the National Geophysical Data Center of the United States to compare the night-light intensities before and after the conflict in those four countries. The night-light data serve as a proxy for regional economic activity and are widely used to generate credible economic data—mainly in circumstances where official data either do not exist or are not reliable. We construct indices combining the contrast and dispersion of night-lights within fine-grained geographical regions and then report the time series evolution of those indices both at country and sub-region levels. The estimates suggest that the scale and intensity of economic destruction in the region have been unprecedented in recent history and the extent of destruction is the largest in Syria and Yemen among those four conflict-afflicted countries. We also provide additional insights at sub-region level.



**Keywords:** Cost of conflict, Arab Spring, image processing, satellite data, night lights.
**JEL Classifications:** D74, E01, F51, O15.

# 1 Introduction

The Arab Spring has substantially shaken the political and economic foundations of many countries in the MENA region. Some countries have reacted positively by quickly restoring stability and implementing reforms to enhance resilience to shocks, while others—such as Syria, Yemen, Libya, and Iraq—have experienced devastating wars and terrorism entailing huge physical and human capital costs, large-scale institutional degradation, multi-dimensional conflict, and state failures. Millions of people have been forced to leave their homes. Cities, cultural heritage, and infrastructure have been utterly destroyed.

Recent research on the conflicts in the region has focused on the dynamics of democratic transition in the Arab world and the conditions for its success with a focus on select countries (Elbadawi and Makdisi, 2017) and on the post conflict economic and political agenda that would guide reconstruction and sustain national peace (Makdisi and Soto, 2020). Other work dealt specifically with the refugee issue and the potential impact of refugee waves on several key outcomes of natives in host countries—such as employment, wages, consumer prices, housing prices/rents, health status, crime rates, schooling, firm openings, and environmental outcomes.[1] Political economy consequences of refugee movements have been another major concern for host countries (Altindag and Kaushal, 2020; Doganay and Tumen, 2021).

Apart from a small number of studies, economists have not put much effort to investigate the consequences conflict in afflicted countries. This negligence is mostly due to a lack of systematic and healthy data on the state of those economies in the post-conflict era. With the objective of deepening our knowledge about what has happened in the conflict-afflicted countries, we employ a systematic approach to generate credible data with the ultimate purpose of measuring the economic cost of conflict by using satellite imagery and geographical information systems (GIS) methods. The focus is on four conflict-afflicted countries in the Arab world: Iraq, Libya, Syria, and Yemen. These are the countries that have experienced the most severe conflict-related eco-

[1]See, e.g., Del Carpio and Wagner (2015), Balkan and Tumen (2016), Tumen (2016), Ceritoglu, Gurcihan Yunculer, Torun, and Tumen (2017), Aksu, Erzan, and Kirdar (2018), Assaad, Ginn, and Saleh (2018), Balkan, Ozcan-Tok, Torun, and Tumen (2018), Fallah, Krafft, and Wahba (2019), Tumen (2018, 2019b,a), Boucher, Tumen, Vlassopoulos, Wahba, and Zenou (2020), and Aksoy and Tumen (2021). See Tumen (2021) for an up-to-date review of the literature.

nomic destruction in the region. Various studies show—mostly using model-based methods and/or back-of-the-envelope calculations—that GDP and physical capital stocks are nearly halved in those countries.[2]

Specifically, we use data provided by the National Geophysical Data Center of the United States to compare the night-light intensities before and after the conflict began in those four countries. Economists have recently started to use data collected by satellites to address various questions that requires gauging variation in economic activity at a more fine-grained geographical detail.[3] The night-light data serve as a proxy for changes in local economic activity and exhibit strong correlation with other major welfare indicators. We construct indices combining the contrast and dispersion of night-lights within fine-grained geographical regions and then report the time series evolution of those indices both at country and province levels. It should be noted that satellite data are used in two different ways to construct indicators proxying economic activity: night-lights and day-light imagery. This paper focuses on the former, while the latter approach generally requires the use of machine learning techniques to analyze rooftop images and other landscape information for the purpose of examining changes in economic activity over time, which is out of the scope of the current paper.[4]

Technically, measuring economic activity using satellite data has two major advantages. First, night light intensity is a valuable source of information that can be used to measure income growth at aggregate level. It is well known that classical national income accounting is prone to measurement errors due to various reasons. Any potential measurement issues related to night-light-based satellite imagery will most likely be uncorrelated with measurement errors associated with classical GDP calculation methods (Henderson, Storeygard, and Weil, 2012). Thus, night light data can be a complementary source of information improving the accuracy of national income accounting. Second, economic analysis of regional growth is scant due to a lack of availability of appropriate measures of local economic activity. Night light imagery offers a far more detailed

[2]See, for example, ESCWA (2018), WorldBank (2017), and Devadas, Elbadawi, and Loayza (2019). See also Tumen (2019c) for an overview.

[3]See, for example, Henderson, Storeygard, and Weil (2012), Michalopoulos and Papaioannou (2013, 2014), Rohner, Thoenig, and Zilibotti (2013), Hodler and Raschky (2014), Alesina, Michalopoulos, and Papaioannou (2016), Storeygard (2016), and Engstrom, Hersh, and Newhouse (2017).

[4]See Groger, Hersh, Matranga, Mueller, and Serrat (2019) for an example of the latter approach.

degree of geographic fineness than is attainable by any standard NIPA item. GDP numbers are not systematically available at a regional level in most countries. In terms of both policy design and academic research, variation in economic growth within countries is at least as interesting as the cross-country variation in economic performance. Therefore, image-processing methods provide a robust basis for measurement of economic activity at regional level.

Existing evidence and experience suggest that economic reconstruction in conflict-affected regions cannot be successfully achieved without a feasible and sustainable road map. Estimating the economic cost of conflict in Iraq, Libya, Syria, and Yemen—the four most severely destroyed countries in the MENA region—would serve as a robust and technical starting point and a basis for policy debate on post-conflict reconstruction and economic growth. This paper aims to provide an example for such a basis. By presenting the magnitude of economic destruction in Iraq, Libya, Syria, and Yemen, the paper also motivates further research on data-scientific methods of regional economic activity measurement especially in afflicted regions. Although economic growth indicators exist for some those countries, they may be highly unreliable and, therefore, can be misleading due to the lack of a stable/trusted national statistical infrastructure. Satellite-based estimates can, thus, be used to complement and sometimes even replace the existing statistical figures for those countries.

The plan of the paper is as follows. Section 2 discusses the refugee issue from a perspective of human capital depreciation in the afflicted countries. Section 3 introduces the data and methods used in our analysis. Section 4 presents the results at both national and sub-region levels. Section 5 concludes.

## 2 Human capital depreciation in afflicted countries

Although the goal of this paper is to estimate the extent of economic and physical destruction in the afflicted Arab countries using satellite-based data, the total destruction cannot be fully understood only by focusing on the visible and tangible aspects of economic activity, as human capital is inarguably among the most important factors of production that a country could possess. The purpose of this section is to discuss the extent of human capital depreciation in afflicted countries, which have suffered from massive refugee outflows. Repatriation is widely discussed among policy circles as the only option to restore the human capital stock in source countries in the short-run, but political and economic stability needs to be restored before repatriation is discussed as a viable solution.

Understanding the socio-economic conditions of refugees in the host countries is an important first step for developing policies to restore the human capital stock in afflicted countries. The magnitude of refugee outflows—measured in terms of mover-to-stayer ratio—is very different across the four afflicted countries and, among those countries, the extent of human capital loss due to refugee outflows is the largest in Syria. Therefore, the focus of this section will be on the socio-economic conditions of Syrian refugees in the major hosting countries in the region. The UNHCR data as of December 2020 suggest that among approximately 5.6 million total persons of concern seeking refuge in the region, 3.6 million (65 percent) live in Turkey, 880,000 (16 percent) live in Lebanon, 660,000 (12 percent) live in Jordan, and the remaining 400,000 (7 percent) live in Iraq, Egypt, and other countries in North Africa. These numbers clearly suggest that Turkey is the major hosting country and understanding the socio-economic conditions of Syrian refugees in Turkey would be a huge step toward understanding the overall socio-economic situation of Syrian refugees in the hosting economies. The developments in Lebanon and Jordan are also important to comprehend the big picture. Figure (1) displays the time series evolution of the total number of Syrian refugees in the region.

Labor market outcomes and employment conditions in host countries are among the key topics as a point of departure. There is an emerging literature investigating this issue. The main findings in this literature can be summarized as follows. For Turkey, refugees are, on average, less skilled than natives [see Table (1)] and they do not have easy access to work permit; so, they penetrate the labor market through informal manual jobs and they displace natives informally employed in those jobs (Del Carpio and Wagner, 2015; Tumen, 2016; Ceritoglu, Gurcihan Yunculer, Torun, and Tumen, 2017; Aksu, Erzan, and Kirdar, 2018). Informally employed refugee workers provide important labor cost advantages and, accordingly, potential wages decline in the low-skill market (Balkan and

Tumen, 2016; Akgunduz, Bagir, Cilasun, and Kirdar, 2020). Informal refugee workers employed in manual tasks are complementary to formal native workers employed in more complex tasks (Akgunduz, Hassink, and Van den Berg, 2018; Akgunduz and Torun, 2018). These results suggest that competition between refugees and natives for low-skill jobs imposes a downward pressure on employment probabilities and potential wages in the low-skill labor market. At the same time, increased availability of formal jobs with higher skill requirements encourages skill acquisition. As a result, the decline in the expected returns to staying low-skilled and low-educated may increase school attainment and academic success among native youth. Indeed, Tumen (2018) documents that the high school enrollment rates increased by 2.7-3.6 percentage points among native youth in refugee-receiving regions in Turkey. Moreover, Tumen (2019a) finds that Syrian refugee influx generated an increase in the PISA scores of native adolescents. Finally, anecdotal evidence suggests that firms demanding low-skilled labor becoming increasingly dependent on Syrian workers and they are lobbying against repatriation of refugees at least in the short term.

The Jordanian and Lebanese cases are also very interesting in the sense that when the magnitude of refugee influx is measured in terms of the ratio to the native population rather than absolute numbers, Jordan and Lebanon become larger host countries than Turkey. Fallah, Krafft, and Wahba (2019) find that the Syrian refugees in Jordan are mostly children and women and their labor market participation rates are low, which suggests that they are less likely to compete with natives in the labor market. In addition, the refugees increase the demand for goods and services, which potentially generates additional jobs and mitigate any potential negative impact of refugees on labor market outcomes of natives in Jordan. The findings for the Lebanese economy are rather similar to the findings for Turkey. In particular, David, Marouani, Nahas, and Nilsson (2020) document that Syrian refugees did not affect high-skilled natives negatively in Lebanon, but their negative impact was more heavily felt by low-skilled Lebanese workers. So, a competition story for jobs with low-skill requirements also holds for Lebanon. Finally, Malaeb and Wahba (2018) argue that the refugee influx negatively affected the labor market outcomes of incumbent immigrants in Jordan.

Integration of Syrian children into the education systems in host countries is another important topic. Syrian children are vulnerable for two main reasons. First, Syrian children are over-represented among refugees and they need urgent support to minimize the impact of war and conflict on their future outcomes. The support is needed along several dimensions ranging from removal of language barriers to psychological support/counseling and from educational attainment to the quality of education provided. Second, their parents are on average less-skilled than native parents, which means that parental investment in human capital will highly likely be less intensive for Syrian children relative to native children. If necessary steps are not taken, the education gaps will persist into future generations, which is a significant socio-economic threat for the society as a whole.

The Turkish government reacted to this increase by heavily investing in integrating Syrian refugees into daily life in Turkey. Integrating Syrian children to the public education system in Turkey has been a major component of those efforts. The number of Syrian children of school age (5-17) has increased from 833,039 in the 2016-17 academic year to 1,047,536 in the 2018-19 academic year based on the Ministry of Interior figures. As of the 2018-19 academic year, 643,058 Syrian children of school age have been provided school education at various levels. Considering the total number of school-age Syrian children, which is 1,047,536, this corresponds to approximately 61.4 percent access to schooling ratio. This ratio varies across grades: 95.5 percent at primary-school level, 57.7 percent at lower secondary-school level, and 26.8 percent at upper secondary-school level. Table (2) visualizes these figures.

To facilitate the integration of Syrian refugees into the public education system in Turkey, the Turkish government implements various programs, which can be listed as follows: Turkish language training provided to Syrian children of various ages and grades; back-up training program implemented to under-performing Syrian children who are already enrolled in school; catch-up training program implemented to facilitate the transition of out-of-school children into school; pre-school integration programs (Boucher, Tumen, Vlassopoulos, Wahba, and Zenou, 2020); and teacher and administrative staff training programs aiming to create an environment in schools to resolve the issues and remove the obstacles in front of successful integration of Syrian children into the education system in Turkey.

Recent data shows that the fertility rate of Syrian refugees in Turkey is above 5 (around 2.5 times that of Turkish natives), which suggests that the number of Syrian children in the Turkish education system will keep increasing sharply in the near future. Moreover, the integration efforts will likely to expanded to cover pre-school education and upper-secondary vocational education. These figures and concerns also imply that the efforts to integrate Syrian children into the education system and the socio-economic life in Turkey will gain utmost importance. The sharp increase in the number of Turkey-born Syrian children requires the continuation of existing efforts, which may generate additional challenges.

Assaad, Ginn, and Saleh (2018) document that the public education system in Jordan absorbs the majority of Syrian kids. They find that, with the efforts of Jordanian government, the existence of Syrian kids in the Jordanian education system did not negatively affect the educational choices and outcomes of Jordanian students. A similar picture also holds for Lebanon except that Lebanon also hosts a large group of "twice displaced" people—namely, the Palestinian refugees who were in Syria and have later been displaced into Lebanon. The common issue in all host countries is that Syrian people experience post-conflict trauma and they are also trying to adjust into the cultures of the host countries, which are mostly new for them.

The overall picture suggests that the socio-economic conditions of natives are mixed in the post-influx era, i.e., there are both "winners" and "losers" in host countries, while the sign of the net gain is still unknown. The refugees on the other hand getting more and more integrated into the cultures of the host countries over time. Some of their outcomes are much better than those in the pre-conflict Syria. For example, the primary school enrollment rates were around 85 percent in Syria before 2011, while the primary school enrollment rate increased to approximately 95 percent for the Syrian children in Turkey. They have also brought their capital, businesses, firms, occupations, and skills into the host economies, which suggests that they tend to develop longer-term goals. At the end, it is clear that Syrian refugees are becoming better integrated into the host communities over time and repatriation will be a viable option for them only if a permanent economic and political solution takes place.

## 3 Data and method

This section develops a systematic approach to generating credible data using data science techniques with the ultimate purpose of measuring the economic cost of conflict in the afflicted Arab countries. The main data source is the satellite imagery processed by means of the geographical information systems methods. The focus will be on four afflicted countries: Iraq, Libya, Syria, and Yemen. These are the countries that have experienced the most severe physical and economic destruction in the region.

Specifically, the data provided by the National Geophysical Data Center of the United States are used to compare the night-light intensities before and after the conflict in those four countries. Economists have recently started to utilize night-light data measured by satellites—see, e.g., Henderson, Storeygard, and Weil (2012) for an early example. The night-light data serve as a proxy for local economic activity and exhibit a strong correlation with other major welfare indicators. Indices are constructed combining the contrast and dispersion of night-lights within fine-grained geographical regions and then the time series evolution of those indices are reported. It should be noted that there are two possible components of night-light-based estimates: decline in economic activity as a consequence of conflict and physical destruction. Night lights proxy a combination of both, since the two are possibly highly correlated. This may be relevant for a sector-level analysis. For example, services sector does not rely heavily on physical assets. So, the services component likely proxies mostly the economic activity effect. For manufacturing, on the other hand, both physical destruction and economic activity components kick in. Although a detailed sectoral breakdown is out of the scope of this paper, this distinction should be made to elucidate the interpretation of the estimates.

In a recent companion work, Ceylan and Tumen (2018) use satellite data provided by the National Geophysical Data Center of the United States to compare the night-light intensity in Syria before and after the conflict began. Using the Geographic Information System (GIS) methods adopted in related research, they construct indices combining the contrast and dispersion of the night-lights and report the time series evolution of those indices both for the entire country and at regional level. This paper extends Ceylan and Tumen (2018) by including Iraq, Libya, and Yemen into the analysis and providing sub-region level estimates for the afflicted countries.

To perform this task, satellite data have been collected to construct economic activity indices using the night light data for Iraq, Libya, Syria, and Yemen. The indices are constructed both in aggregate and for sub-regions in the afflicted countries. The data period is 1994-2018, with some breaks in 2014 and 2018 for some regions. It should be noted that the timing and duration of conflict differ across those four countries; so, a detailed examination of the existing data horizon is required to understand the impact of the conflict. Technical details on the methodology are provided in the next section.

### 3.1 Methodology

In this part, the measurement methodology is described in detail. The United States Air Force satellites—the Defense Meteorological Satellite Program (DMSP)—orbit the earth 14 times a day. The satellites have used their sensors to record the Earth-based lights since 1970s—there has been a digital archive open to public use and available for research since 1992. Although the satellites were originally manufactured to collect meteorological information, i.e., the cloud images, mostly for forecast purposes, the night lights from human settlements are also collected in the course of orbiting. Images from every location on earth are recorded by each satellite every night between (local time) 8.30pm-10.00pm. The observations are processed by the National Geophysical Data Center (NGDC), where certain data cleaning activities are carried out. First, the observations from locations experiencing the bright half of the lunar cycle are removed. Second, summer observations with late sunsets are dropped. Third, the polar lights (i.e., the auroral lights) are removed. Fourth, observations obscured by clouds are dropped. And, finally, observations from the locations where there are forest fires are also eliminated.

The purpose of this data cleaning/processing is to end up with a data set consisting solely of lights produced by human activity. This data set reflects man-made outdoor and also some indoor activity, which proxy aggregate economic activity for each observation. The main idea is that consumption of goods in the evening requires lights Henderson, Storeygard, and Weil (2012). At the end, valid observations are averaged over nights for each satellite in a given year and a large data set with satellite-year variation for each location on earth is constructed. Those locations are classified as "pixels" (around 0.86 square kilometers at the equator). The reported pixels are placed between 65 degrees south and 75 degrees north latitude. The excluded pixels fall into the Arctic regions, where a very tiny and negligible fraction of human activity is recorded. For each pixel, observations are averaged across satellites to obtain pixel-year data, which is also used in the analysis in this section.

The pixel-year data is described by an integer number ranging between 1 to 63. A tiny fraction of data from very densely populated and rich locations are top-coded to take the value of 63. As Henderson, Storeygard, and Weil (2012) clearly indicate, the quality of observations decline with the age of the satellite. So, year fixed effects are used to control for the satellite age effect in statistical analysis. Figure (2) provides an example of a satellite image for Syria, Lebanon, Iraq, Northern Jordan, and Southeastern Turkey. The pink color represents the locations for which the light intensity in 2012 declined as of 2016, while the blue color represents the locations for which the light intensity in 2012 increased as of 2016. Clearly, the picture is consistent with the movement patterns of forcibly displaced Syrians. In the next section, the results of the satellite data analysis are presented for Iraq, Libya, Syria, and Yemen—both in aggregate and at sub-region level.

# 4 Results and discussion

## 4.1 Aggregate results

The conflict in Iraq has been one of the most profound, complicated, and long-lasting ones in the MENA region. The 1980-1988 Iran-Iraq War and the invasion Kuwait by Iraq in 1990 are not covered in our data set. So, the main focus is on the most recent major conflict in Iraq, which started in 2003 and continued until the withdrawal of U.S. troops in 2011. After the emergence of terrorism in the northern region of the country at the end of 2014, a local conflict has re-emerged especially in Northern Iraq, which still continues locally and intermittently.

The upper left panel of Figure (3) plots the nigh-light index constructed to characterize the trends in the level of overall economic activity in Iraq between 1994 and 2018. Two main episodes are observed during this time period: 1994-2008 and 2008-2018. The first period is characterized by political instability, civil conflict, international disputes, wars, and heavy economic sanctions. The economic activity is nearly stagnant, averaging approximately 3 percent annual growth over 15 years despite booming oil prices—which is low in developing country standards. The second period is an episode of gradual resolution of disputes and selective lifting of economic sanctions. The annual rate of economic growth—measured by the evolution of satellite-based night lights—is above 10 percent. With the increase in the intensity of local conflict after 2016, the economic activity has again become stagnant. The Iraqi case suggests that there is a strong positive correlation between conflict, economic sanctions and economic growth.

Libya has constantly experienced international dispute and conflict in the past three decades, which resulted in the ouster and death of the former leader Muammar Al-Qaddafi in October 2011. The post-Qaddafi era did not bring peace either; the civil conflict has continued and risks for further blazing of violence are still alive.

The upper right panel of Figure (3) demonstrates the trends in satellite-based night-light intensity in Libya between 1994 and 2018. The period between 2002 and 2008 has exhibited the strongest economic growth in the near history of the country. It was the period in which the Qaddafi regime built good relationships with the Western world—for example, the United States Secretary of State made the highest-level official US visit to Libya in 2008 since 1953; Qaddafi paid the first official visit to Italy the year after. As part of the uprisings in the Arab world, an anti-Qaddafi uprising emerged in 2011 in Libya and the regime was ousted. The country has been experiencing a civil conflict since then and it has struggled to reconstruct state institutions in the post-Qaddafi era. As a result, the economic activity is stagnant and there are substantial political and economic uncertainties. The Libyan experience also shows that conflict undermines long-term economic growth.

The civil conflict in Yemen started in 2011 and the main inspiration was again the Arab spring. The Houthi expansion during the 2011-2015 period transitioned into violent armed conflict after

2015. Yemen has been among the least developed countries in the region and the heavy conflict has generated a dramatic humanitarian crisis. Millions of Yemenis have needed humanitarian assistance and the risks of famine and epidemic disease are still alive.

The lower left panel of Figure (3) depicts the trends in the aggregate index constructed using the night-light series. There are two episodes. The first is until the end of 2011; the second one begins in 2012 and still continues. During the first period, the Yemeni economy expanded rapidly and benefited the favorable economic conditions in the region due to booming oil prices. In the second period, however, the economy experienced a rapid decline and the economic environment returned to its conditions in late 1990s, which basically means that the extent of economic destruction has been huge. The country is still struggling to overcome the sources of internal and international disputes. There is also a lack of domestic and international coordination in terms of improving the general institutional structure and the key institutions in the country.

The Syrian Conflict, which started to escalate in the Spring of 2011, has displaced millions of Syrians. Based on the most recent United Nations figures, around 5.6 million Syrian refugees have fled to the neighboring countries, which has had important socio-economic impacts on the entire MENA region and most of the Europe. The conflict in Syria is different from Iraqi, Yemeni, and Libyan conflicts in that it generated one of the largest refugee waves in the past century. This suggests that the Syrian conflict entails large human capital destruction, which may have irreversible consequences on the country's economic growth potential in the long term.

The lower right panel of Figure (3) plots the trends in economic activity in Syria based on satellite data covering the period between 1994 and 2018. The figure suggests that the Syrian conflict has had devastating economic consequences. The level of night-light intensity is way below its level in mid 1990s. In comparison to Iraq, Libya, and Yemen, the Syrian economy is in a much worse situation in terms of physical destruction along with vanished human capital and destroyed institutions. Any reconstruction efforts for the Syrian economy should entail serious repatriation efforts in addition to investments in physical infrastructure and institutions. Figure (4) presents a clear comparative picture.

The estimates presented in this section suggest that the scale and intensity of the violence and destruction in the region have been unprecedented in the recent history and the extent of economic destruction is the largest in Syria and Yemen. The death toll in Syria, as of the first half of 2019, has reached to 570,000 according to the calculations of the Syrian Observatory for Human Rights (SOHR). The United Nations Economic and Social Commission for Western Asia (ESCWA) performed a very detailed study to estimate the economic costs of the Syrian civil war and conflict. According to their estimates the destruction of the physical capital stock by the end of 2017 reached to almost 120 billion USD (ESCWA, 2018). Another detailed study calculating the cost of the Syrian conflict is the one conducted by the World Bank. Their estimates suggest that the cumulative loss in GDP reached to 226 billion USD—approximately four times the Syrian GDP in 2010—between 2011 and 2016 (WorldBank, 2017). Finally, Devadas, Elbadawi, and Loayza (2019) use a version of the World Bank's long-term growth model (augmenting public capital and infrastructure investments) and show that the real GDP in Syria contracted 12 percent per year on average over the 2011-18 period. These estimates are largely in agreement with the satellite-based estimates presented in this section.

### 4.2 Regional results

Next we present the results for sub-regions in the afflicted countries. It should be noted in advance that the sub-region-level results may not be directly comparable to the aggregate results as the normalizations are performed for each sub-region separately; so, the sub-region-level results may not consistently sum up to the aggregate estimates for each country. It should also be noted that the sub-region results for Iraq do not yield convincing estimates, since some parts of the images (in multiple sub-regions) might be masked by authorities due to the existence of international military bases and other sensitive landmarks. Therefore, the sub-region-level results are presented for Libya, Syria, and Yemen.

Tables (3), (4), and (5) present the estimated cumulative growth rates from the start of the conflict to the end of 2018. The estimates suggest that there is substantial sub-regional heterogeneity in terms of the impact of conflict on local economic activity. The post-conflict degradation is particularly large in Syria and Yemen, relative to Libya—consistent with the aggregate figures. Another observation is that the economic cost of conflict exhibit substantial regional heterogeneity in Syria and Yemen, while the cost of conflict is more homogeneous across regions of Libya. For Syria and Yemen, violence intensity seems to be an important determinant both in terms of the magnitude of destruction and volume of refugee outflows. A more careful look at the case of Libya suggests that the economic cost of conflict is larger in more populated areas—see Figure (5). Finally, relatively lower degree of economic destruction in certain sub-regions of afflicted countries does not mean that those regions suffer less. Pre-conflict poverty was already higher in some of those regions (for example, Hadhramaut in Yemen); hence, urgent need for humanitarian aid is equally high in those regions.

## 5 Concluding remarks

The purpose of this paper is to discuss the economic cost of conflict and the post-conflict growth in conflict-afflicted countries. To achieve this goal, the level of economic destruction in the four main conflict-afflicted countries—Iraq, Libya, Syria, and Yemen—is quantified using satellite data and GIS-based estimates both at aggregate and sub-region levels. The economic conditions in conflict-afflicted countries do not look promising. Satellite-based estimates suggest that conflict has severely destroyed economic activity and the size of economic destruction is very large in Syria and Yemen.

It should be noted that the satellite-based method likely measures the sacrificed component of economic activity in conflict-afflicted areas in the sense that it makes a comparison relative to the point in time at which the conflict started—for example, mid-2011 in Syria. The direct calculations ignores the foregone component of economic activity—i.e., what would happen to national income had the conflict had not happened. In practice, some simulation exercises should be performed manually to incorporate the forgone opportunities. On a related issue, the method incorporates the effect of displacement only partially and does not capture the potential contribution of human capital growth to foregone economic opportunities in the absence of conflict. These issues should be considered in calculations and projections relying on all kinds of GIS-based estimates.

Analysis of satellite imagery based on night-light data has some limitations. The most important limitation is that there might be power outages in some regions of afflicted countries especially during periods of high conflict/violence intensity. This may lead to an overestimation of the cost of conflict. To overcome this potential bias, night-light data might be combined/supplemented with daylight imagery. Another potential limitation is that the share of agriculture-related economic activity in GDP is not low in the afflicted countries and agriculture-related activities are not necessarily correlated with high nigh-light intensity—in fact, the opposite might be true as large agricultural lands may appear as dark areas in night-light imagery. One potential solution is to incorporate satellite imagery showing agricultural lands into the analysis, which is also included into the NASA's Public Access to Remote Sensing Data program. These two extensions are out of the scope of the current paper and are potential avenues for future research.

## References

Akgunduz, Y. E., Y. K. Bagir, S. M. Cilasun, and M. Kirdar (2020): "Consequences of a Massive Refugee Influx on Firm Performance and Market Structure," IZA Discussion Paper #13953.

Akgunduz, Y. E., W. Hassink, and M. Van den Berg (2018): "The Impact of the Syrian Refugee Crisis on Firm Entry and Performance in Turkey," *World Bank Economic Review*, 32, 19–40.

Akgunduz, Y. E. and H. Torun (2018): "Two and a Half Million Syrian Refugees, Skill Mix, and Capital Intensity," GLO Discussion Paper #186.

Aksoy, C. G. and S. Tumen (2021): "Local Governance Quality and the Environmental Cost of Forced Migration," *Journal of Development Economics*, forthcoming.

Aksu, E., R. Erzan, and M. Kirdar (2018): "The Impact of Mass Migration of Syrians on the Turkish Labor Market," IZA Discussion Paper #12050.

Alesina, A., S. Michalopoulos, and E. Papaioannou (2016): "Ethnic Inequality," *Journal of Political Economy.*

Altindag, O. and N. Kaushal (2020): "Do Refugees Impact Voting Behavior in the Host Country? Evidence from Syrian Refugee Inflows in Turkey," *Public Choice*, forthcoming.

Assaad, R., T. Ginn, and M. Saleh (2018): "Impact of Syrian Refugees in Jordan on Education Outcomes for Jordanian Youth," ERF Working Paper #1214.

Balkan, B., E. Ozcan-Tok, H. Torun, and S. Tumen (2018): "Immigration, Housing Rents, and Residential Segregation: Evidence from Syrian Refugees in Turkey," IZA Discussion Paper #11611.

Balkan, B. and S. Tumen (2016): "Immigration and Prices: Quasi-Experimental Evidence from Syrian Refugees in Turkey," *Journal of Population Economics*, 29, 657–686.

Boucher, V., S. Tumen, M. Vlassopoulos, J. Wahba, and Y. Zenou (2020): "Ethnic Mixing in Early Childhood," CEPR Discussion Paper #15528.

Ceritoglu, E., H. B. Gurcihan Yunculer, H. Torun, and S. Tumen (2017): "The Impact of Syrian Refugees on Natives' Labor Market Outcomes in Turkey: Evidence from a Quasi-Experimental Design," *IZA Journal of Labor Policy*, 6, 1–28.

Ceylan, E. S. and S. Tumen (2018): "Measuring Economic Destruction in Syria from Outer Space," The Forum: ERF Policy Portal, Blog article, 19 June 2018, https://theforum.erf.org.eg/2018/06/19/measuring-economic-destruction-syria-outer-space/.

David, A., M. A. Marouani, C. Nahas, and B. Nilsson (2020): "The Economics of the Syrian Refugee Crisis in Neighboring Countries: The Case of Lebanon," *Economics of Transition and Institutional Change*, 28, 89–109.

Del Carpio, X. and M. Wagner (2015): "The Impact of Syrian Refugees on the Turkish Labor Market," Unpublished manuscript, World Bank.

Devadas, S., I. A. Elbadawi, and N. V. Loayza (2019): "Growth after War in Syria," World Bank Policy Research Working Paper #8967.

Doganay, H. and S. Tumen (2021): "The Impact of Syrian Refugees on Political Preferences in Turkey: Do Regional Differences in Refugees' Skills Matter?" Unpublished manuscript, TED University.

Elbadawi, I. and S. Makdisi (2017): *Democratic Transitions in the Arab World*, Cambridge, UK: Cambridge University Press.

Engstrom, R., J. S. Hersh, and D. L. Newhouse (2017): "Poverty from Space: Using High-resolution Satellite Imagery for Estimating Economic Well-being," World Bank Policy Research Working Paper #8284.

ESCWA (2018): "Syria at War – Seven Years On (The Economic Implications of the Conflict in Syria)," Presentation at Consultation Meeting on Policy Alternatives for Post-Conflict Reconstruction and Economic Recovery. National Agenda for the Future of Syria. August. United Nations Economic and Social Commission for Western Asia.

Fallah, B., C. Krafft, and J. Wahba (2019): "The Impact of Refugees on Employment and Wages in Jordan," *Journal of Development Economics*, 139, 203–216.

Groger, A., J. Hersh, A. Matranga, H. Mueller, and J. Serrat (2019): "Monitoring War Destruction from Space: A Machine Learning Approach," Unpublished manuscript, Universitat Autonoma de Barcelona.

Henderson, J. V., A. Storeygard, and D. N. Weil (2012): "Measuring Economic Growth from Outer Space," *American Economic Review*, 102, 994–1028.

Hodler, R. and P. A. Raschky (2014): "Regional Favoritism," *Quarterly Journal of Economics*, 129, 995–1033.

Makdisi, S. and R. Soto (2020): "Economic Agenda for Post-conflict Reconstruction," Forthcoming.

Malaeb, B. and J. Wahba (2018): "Impact of Refugees on Immigrants' Labor Market Outcomes," Economic Research Forum Working Paper #1194.

Michalopoulos, S. and E. Papaioannou (2013): "Pre-Colonial Ethnic Institutions and Contemporary African Development," *Econometrica*, 81, 113–152.

——— (2014): "National Institutions and Subnational Development in Africa," *Quarterly Journal of Economics*, 129.

Rohner, D., M. Thoenig, and F. Zilibotti (2013): "Seeds of Distrust: Conflict in Uganda," *Journal of Economic Growth*, 18, 217–252.

Storeygard, A. (2016): "Farther on Down the Road: Transport Costs, Trade, and Urban Growth," *Review of Economic Studies*, 83, 1263–1295.

Tumen, S. (2016): "The Economic Impact of Syrian Refugees on Host Countries: Quasi-Experimental Evidence from Turkey," *American Economic Review*, 106, 456–460.

——— (2018): "The Impact of Low-Skill Refugees on Youth Education," IZA Discussion Paper #11869.

——— (2019a): "The Effect of Refugees on Native Adolescents' Test Scores: Quasi-experimental Evidence from PISA," ERF Working Paper #1356.

——— (2019b): "Refugees and 'Native Flight' from Public to Private Schools," *Economics Letters*, 181, 154–159.

——— (2019c): "Repatriation: Potential Contributions to Post-conflict Economic Development," in *Repatriation of Refugees from Arab Conflicts: Conditions, Costs and Scenarios for Reconstruction*, ed. by I. Elbadawi and S. Makdisi, FEMISE, EuroMed Report, chap. 4.

——— (2021): "Refugees and Forced Migration: The Impact on Natives," *Handbook of Labor, Human Resources, and Population Economics*, forthcoming.

WorldBank (2017): "The Toll of War – The Economic and Social Consequences of the Conflict in Syria," Washington DC: World Bank.

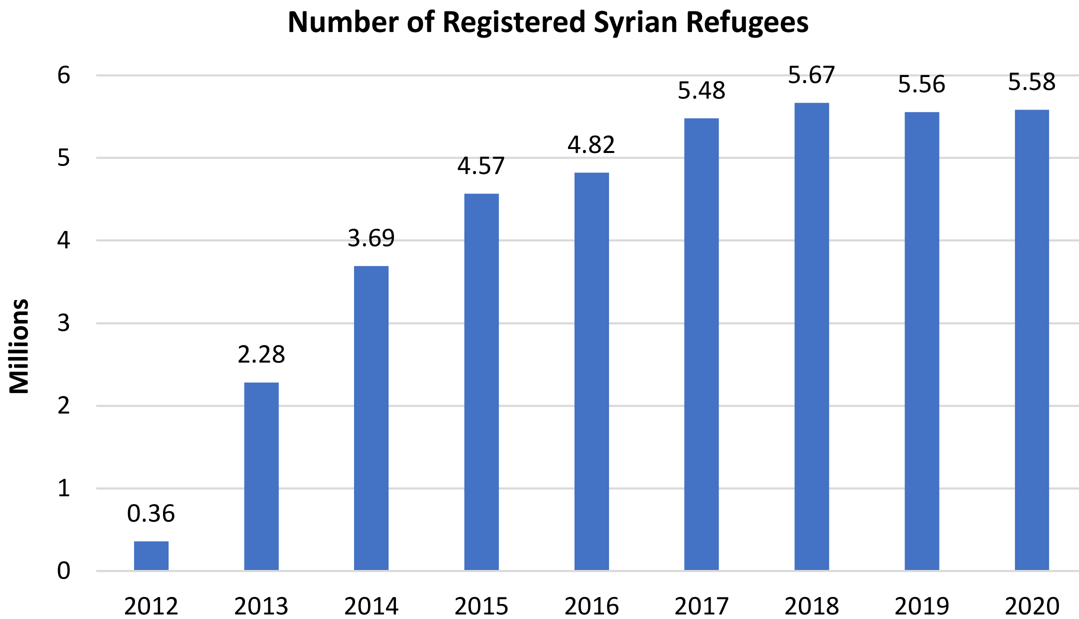


**Figure 1:** The data source is the UNHCR (https://data2.unhcr.org/en/situations/syria). The 2020 data point reflects the refugee numbers reported as of Dec 23, 2020.

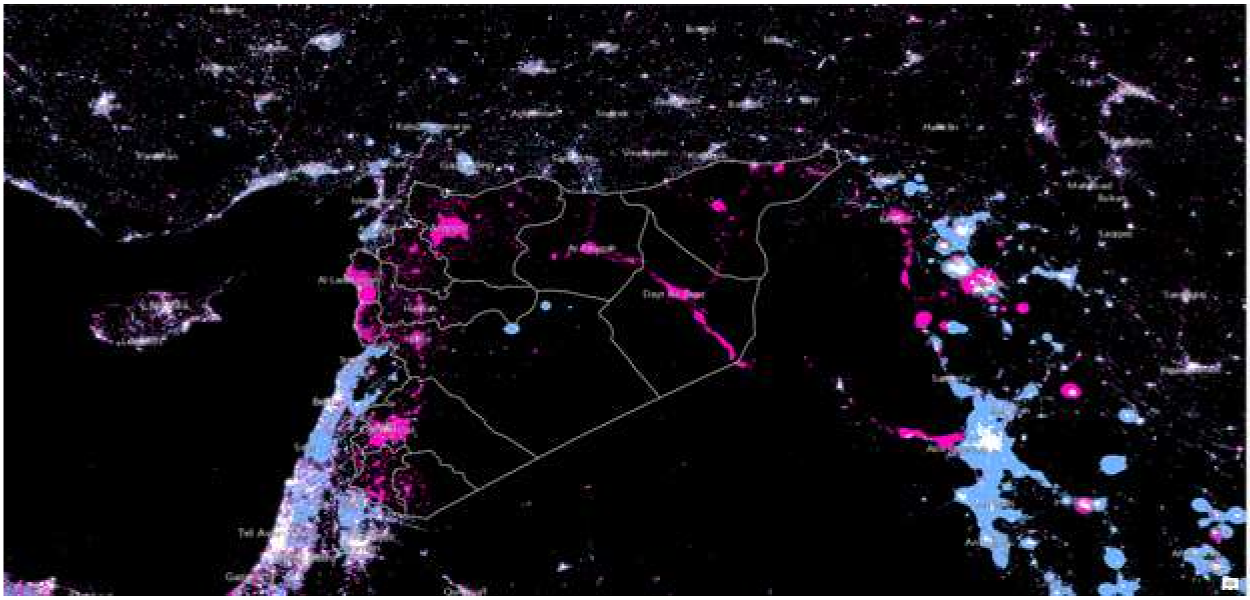

**Figure 2:** Satellite image documenting the movement patterns of forcibly displaced Syrians between 2012 and 2016. *Source:* Ceylan and Tumen (2018) and the National Geophysical Data Center of the United States.

**Refugee vs native characteristics in Turkey (2016)**

| | Natives | Refugees |
|---|---|---|
| **Age** | | |
| 0-14 | 23.7 | 41.7 |
| 15-64 | 68.0 | 56.5 |
| 65+ | 8.3 | 1.8 |
| **Gender** | | |
| Male | 50.2 | 53.1 |
| Female | 49.8 | 46.9 |
| **Education** | | |
| Unknown | 0.7 | 27.8 |
| No degree | 14.9 | 44.4 |
| Less than high school | 51.6 | 22.3 |
| High school | 19.2 | 3.5 |
| College & above | 13.7 | 2.0 |

**Table 1:** Comparison between refugee versus native characteristics in Turkey as of 2016. Source: Tumen (2018).

**Enrollment figures for Syrian students (2018-19)**

| Education level | Total number of students | Total population | Percentage |
|---|---|---|---|
| Pre-school (age 5) | 32,198 | 95,094 | 33.86% |
| Primary (age 6-9) | 365,535 | 382,748 | 95.50% |
| Secondary (age 10-13) | 173,252 | 300,458 | 57.66% |
| High-school (age 14-17) | 72,073 | 269,236 | 26.77% |
| **Total** | **643,058** | **1,047,536** | **61.39%** |

**Table 2:** Enrollment figures for Syrian students in Turkey as of the 2018-2019 academic year. *Source:* The Ministry of National Education of the Republic of Turkey.

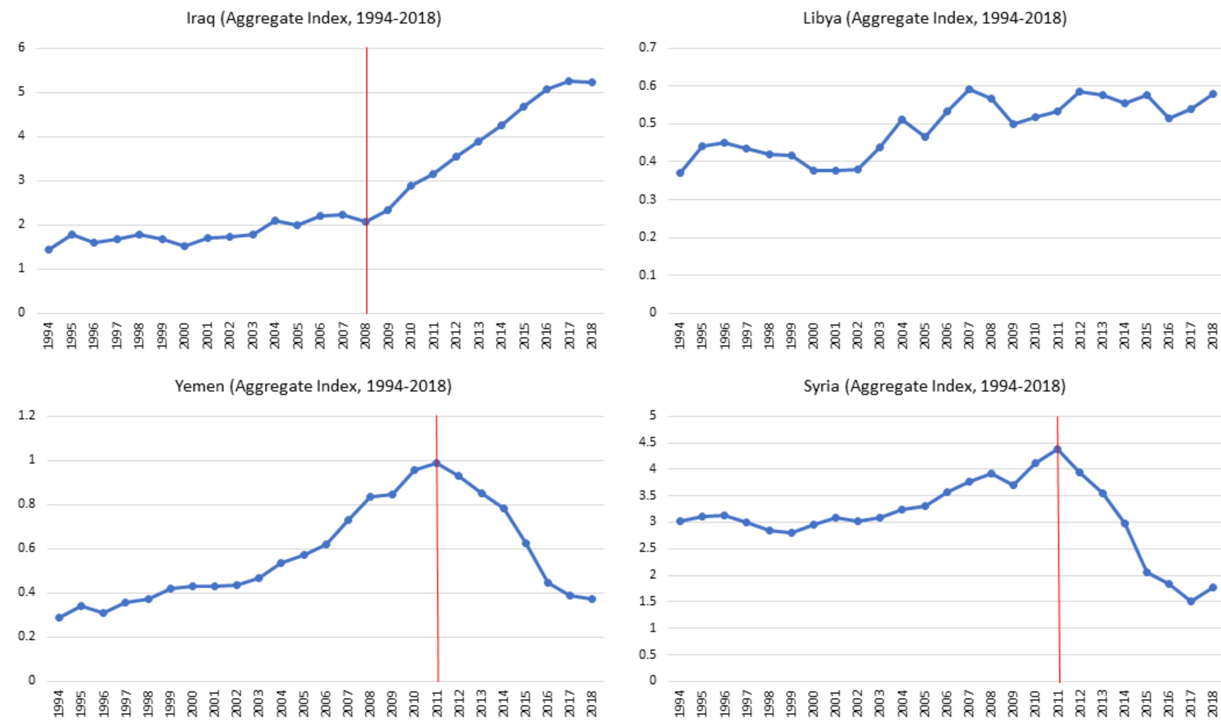


**Figure 3:** Aggregate economic activity in Syria between 1994-2018 measured in terms of satellite-based night-light data.

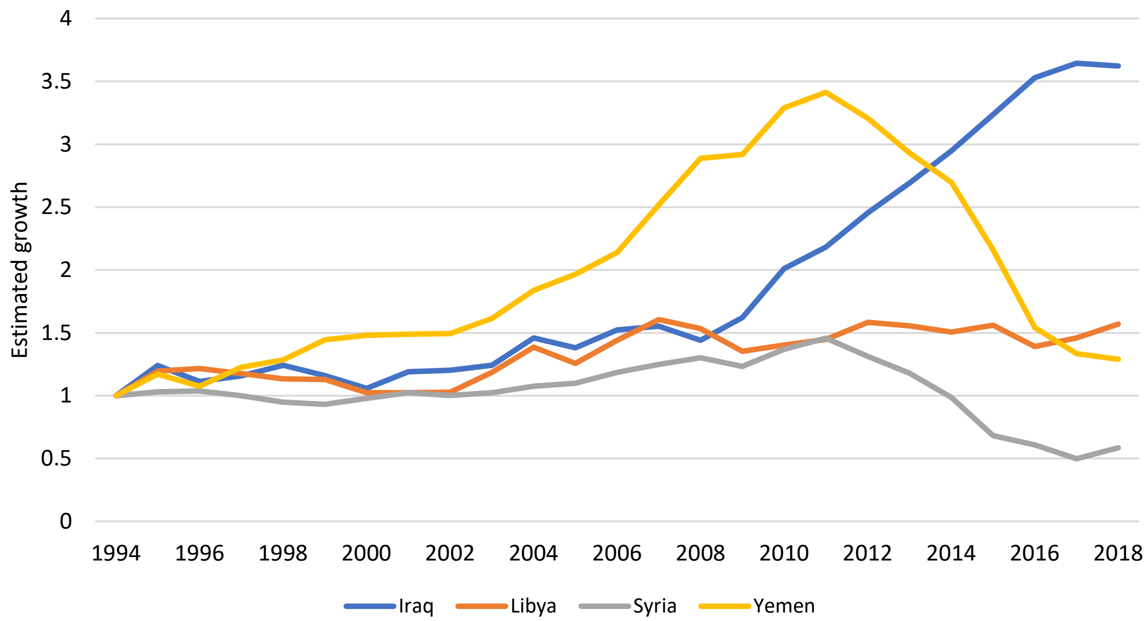


**Figure 4:** Relative growth performance of the four afflicted countries between 1994-2018 measured in terms of satellite-based night-light data. The initial period is normalized to 1.

**Sub-regional estimates for Libya**

| State | District | Estimated growth |
|---|---|---|
| Cyrenaica | Al Butnan | 1.03 |
| | Al Jabal al Akhdar | 1.11 |
| | Al Kufrah | 0.95 |
| | Al Marj | 1.01 |
| | Al Wahat | 0.99 |
| | Banghazi | 0.96 |
| | Darnah | 0.95 |
| Tripolitania | Al Jabal al Gharbi | 0.94 |
| | Al Jafarah | 1.02 |
| | An Nuqat al Khams | 1.03 |
| | Az Zawiyah | 1.14 |
| | Marqab | 0.97 |
| | Misratah | 0.94 |
| | Nalut | 1.02 |
| | Surt | 1.08 |
| | Tarabulus | 0.93 |
| Fezzan | Al Jufrah | 1.02 |
| | Ghat | 1.15 |
| | Murzuq | 1.14 |
| | Sabha | 1.11 |
| | Wadi al Hayat | 1.04 |
| | Wadi ash Shati' | 1.03 |

**Table 3: Sub-regional economic growth estimates for Libya.** The "estimated growth" coefficient defines the cumulative growth from the beginning of conflict to 2018. For example, if the coefficient is 1.05, then the cumulative sub-regional growth in the period of analysis is 5 percent.

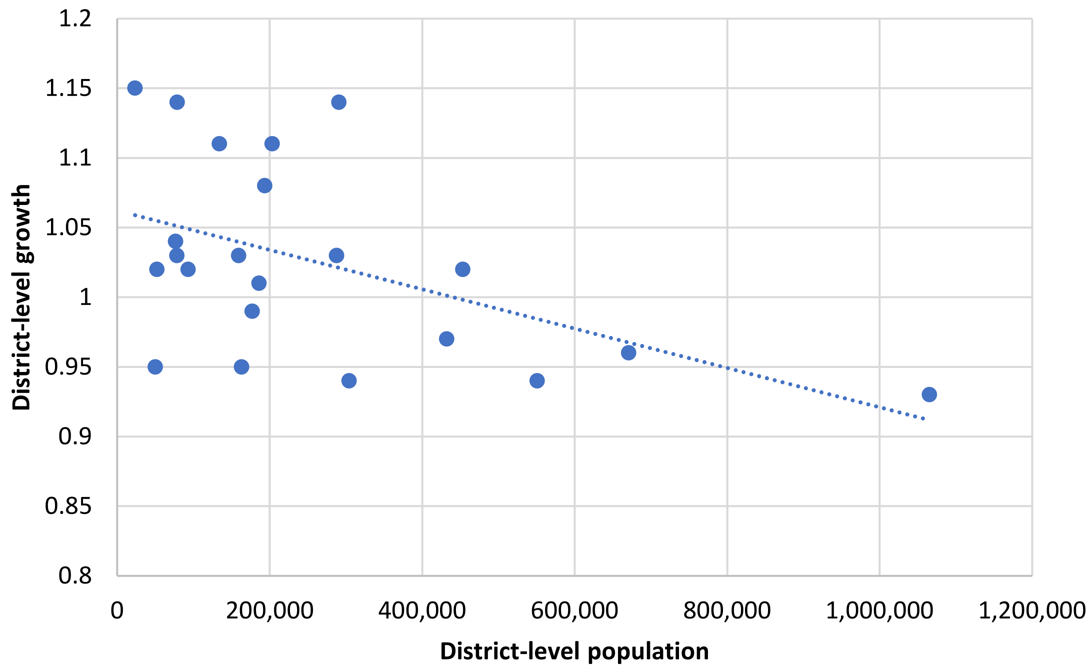


**Figure 5:** Relationship between sub-regional economic growth and population in Libya.

**Sub-regional estimates for Syria**

| **Governorate** | **Estimated growth** |
|---|---|
| Al-Hasakah | 0.65 |
| Aleppo | 0.42 |
| As-Suwayda | 0.74 |
| Damascus | 0.85 |
| Daraa | 0.51 |
| Deir ez-Zor | 0.65 |
| Hama | 0.79 |
| Homs | 0.76 |
| Idlib | 0.09 |
| Latakia | 0.69 |
| Quneitra | 0.82 |
| Raqqa | 0.62 |
| Rif Dimashq | 0.75 |
| Tartus | 0.76 |

**Table 4: Sub-regional economic growth estimates for Syria.** The "estimated growth" coefficient defines the cumulative growth from the beginning of conflict to 2018. For example, if the coefficient is 0.80, then the cumulative sub-regional growth in the period of analysis is -20 percent.

**Sub-regional estimates for Yemen**

| **Governorate** | **Estimated growth** |
|---|---|
| Abyan | 0.52 |
| Ad Dali' | 0.56 |
| Aden | 0.48 |
| Al Bayda' | 0.48 |
| Al Hudaydah | 0.29 |
| Al Jawf | 0.22 |
| Al Mahrah | 0.66 |
| Al Mahwit | 0.52 |
| Amanat Al Asimah | 0.43 |
| Amran | 0.41 |
| Dhamar | 0.46 |
| Hadhramaut | 0.61 |
| Hajjah | 0.27 |
| Ibb | 0.49 |
| Lahij | 0.40 |
| Ma'rib | 0.31 |
| Raymah | 0.58 |
| Sa'dah | 0.18 |
| Sana'a | 0.36 |
| Shabwah | 0.52 |
| Ta'izz | 0.39 |

**Table 5: Sub-regional economic growth estimates for Yemen.** The "estimated growth" coefficient defines the cumulative growth from the beginning of conflict to 2018. For example, if the coefficient is 0.80, then the cumulative sub-regional growth in the period of analysis is -20 percent.