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The Transboundary Effects of Climate Change and Global Adaptation: The Case of The Euphrates-Tigris Water Basin in Turkey and Iraq

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THE TRANSBOUNDARY EFFECTS OF CLIMATE CHANGE AND GLOBAL ADAPTATION: THE CASE OF THE EUPHRATES-TIGRIS WATER BASIN IN TURKEY AND IRAQ[1]

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Abstract

Drought has erupted across the Middle-East, as a result of climate change and global warming, leading to a considerable reduction in rainfall and snowfall, as well as a substantial drop in water resources. Climate change is, without a doubt, one of Iraq's most pressing issues, with considerable negative consequences for the environment, water resources, and the economy, particularly in the agricultural sector. With a growing global population and other factors, the effects of climate change, water ownership and distribution will certainly become more critical. The Euphrates-Tigris water basin is a major source of water supply for Turkey and Iraq, where the latter is a downstream riparian country and the former is an upstream country. Turkey is most vulnerable to climate change as the country will experience a substantial decline in the annual surface runoff. However, Turkey will suffer less than Iraq, which as a downstream country, relies primarily on the water released by Turkey as the upstream country. The empirical analysis relies on data from the Iraqi Household Socio-Economic Survey (IHSES) conducted in 2012 and the 2017 Rapid Welfare Monitoring Survey. We apply simultaneous unrelated regressions equations (SURE) with Probit models. We further extend the analysis by incorporating an instrument variables (IV) approach considering the population of the nearest Turkish city to where the dam is located, the water capacity, and the distance between this dam and the respondent's governorate in Iraq. Similarly, we construct other two instruments considering the distance between the dams in Iraq and in Syria and the nearest governorate along with the dams' water capacity and the population of the governorate in Iraq. The findings show a significant impact of climate change-related shocks on income, assets, food production and stock, and the overall economic situation of households in Iraq.

Keywords: Climate Change; Dam; Droughts; Euphrates-Tigris Water Basin; Food Security; Instrumental Variables; Iraq; Turkey; Water Supply and Quality.

JEL Classifications: D63, I31, Q21, Q25, Q54, Q58.

ملخص

اندلع الجفاف في جميع أنحاء الشرق الأوسط نتيجة لتغير المناخ والاحترار العالمي، مما أدى إلى انخفاض كبير في معدل هطول الأمطار وتساقط الثلوج، فضلاً عن انخفاض كبير في موارد المياه. ويعتبر تغير المناخ بلا شك أحد أكثر القضايا إلحاحًا في العراق، وله عواقب سلبية كبيرة على البيئة والموارد المائية والاقتصاد، لا سيما في القطاع الزراعي. ومع تزايد عدد سكان العالم وعوامل أخرى، تتزايد بالتأكيد أهمية تأثيرات تغير المناخ وملكية المياه وتوزيعها. ويعد حوض مياه الفرات ودجلة مصدرًا رئيسيًا لإمدادات المياه لكل من تركيا والعراق، حيث تعتبر الأخيرة دولةً تقع على ضفاف مجرى النهر والأولى دولة منبع. وتركيا هي الأكثر عرضة لتغير المناخ، حيث ستشهد انخفاضًا كبيرًا في معدل الجريان السطحي السنوي. ومع ذلك ستعاني تركيا بدرجة أقل من العراق، الذي يعتمد بشكل أساسي كدولة مصب على المياه التي تطلقها تركيا كدولة منبع. ويعتمد التحليل التجريبي على بيانات من المسح الاجتماعي والاقتصادي للأسرة في العراق (IHSES) الذي تم إجراؤه في عام 2012، ومسح رصد الرفاهية الاجتماعية السريع لعام 2017. وتطبق الدراسة معادلات الانحدار الآنية غير المرتبطة (SURE) مع نموذج "بروبيت". كما تقوم الدراسة بتوسيع التحليل من خلال دمج منهجية المتغيرات المساعدة (IV) ، مع الأخذ في الاعتبار عدد سكان أقرب مدينة تركية إلى موقع السد، والقدرة المائية، والمسافة بين هذا السد والمحافظة المتأثرة به في العراق. وبالمثل تم تصميم أداتين أخرتين مع مراعاة المسافة بين السدود في العراق وسوريا وأقرب محافظة متأثرة إلى جانب السعة المائية للسدود وعدد سكان المحافظة المتأثرة في العراق. وقد أظهرت النتائج تأثيرًا كبيرًا للصدمات المتعلقة بتغير المناخ على الدخل والأصول وإنتاج الغذاء والمخزون، والوضع الاقتصادي العام للأسر في العراق.

1. Introduction

The global climate is increasingly changing, and no region or country is resistant to its effects (Trenberth et al., 2007; UNFCCC, 2007a, 2007b). However, the degree of vulnerability varies widely, where this heterogeneity is explained by long-term transition and considerable variance in temperature, precipitation and wind patterns, which are involved in climate change (IPCC, 2007; Feleke et al., 2016; Yéo et al., 2016). Climate change contributes to the increase in frequency and intensity of floods and droughts, insect alteration, crop failure and low performance of lands, and livestock mortality (Harvey et al., 2014; Morton, 2007; Jamshidi et al., 2019). Because smallholder farmers' household income is strongly related and connected to agricultural production, climate change increases the vulnerability of farmers through its negative impact on crop yields. The reduction in crop increases prices and reduces food demand, which in turn result in a higher welfare loss for the stallholder farmers compared to the large landholders (e.g. Omiti et al., 2009; Karfakis et al., 2011).

Hence, climate change not only affects agricultural productivity but also jeopardizes global food security and well-being (Alam et al., 2016; Jamshidi et al., 2019). For the most vulnerable groups, climate change is a crisis aggravator and a threat multiplier. By 2080, its effect on food production, livelihoods, and health is expected to increase child malnutrition and push more than 600 million people into food insecurity (IPCC, 2007).

Adaptation is a major issue for climate negotiators and policymakers. Adaptation, in particular, is recognized as a "global challenge" in the Paris Agreement, but it does not receive the prominence it deserves in the international climate negotiations. Until recently, adaptation was almost exclusively framed as a national and local concern, with little attention has been paid to the wider international dimension of climate risk in negotiations and realistic adaptation planning. This problem stifles regional cooperation and global ambition on the subject. However, in several ways, climate danger is "borderless" in nature. Climate effects in one country can create opportunities, as well as threats in other countries in terms of trade, labour mobility and migration, finance and biophysical ecosystems, due to cross-border connectivity. Adaptation measures in one part of the world may have positive and/or negative consequences in other parts of the world by affecting cross-border relations and flows.

In 1990, Turkey cut off the Euphrates flow when Iraq invaded Kuwait, and the cooperation came in a deadlock (Gleick, 1994; Vajpeyi, 2012). Turkey's refusal to sign and ratify the 1997 United Nations Water Convention, as one of only three countries- along with China and Burundi- to vote against it in the United Nations General Assembly, exacerbated the impasse. The main argument of this rejection lies in the claim that the treaty will grant downstream countries excessive rights. As a result, Turkey, the upstream riparian, declared that it did not feel obligated to follow the principles codified in the agreement, particularly the obligations not to cause large-scale harm to co-riparian nations and sharing the river equally (Frenken, 2009). If countries cannot reach an international agreement, the problem of water sharing will continue to be a political bargaining issue, particularly in regions experiencing water famine, such as the Middle East and Africa.

Climate change resulted from global warming has had an effect on all weather-related factors, not only in Iraq but also in neighbouring countries. The temperature rises, air pressure fluctuations, rainfall intensities and their temporal and spatial distribution have all led to shifts in annual streamflow volumes of the Tigris and Euphrates rivers. Model studies show that these negative trends would persist at least until the end of the century and that they may become even more severe if greenhouse gas (GHG) and carbon dioxide (CO_2) emissions remain unchanged. These simulations show that storm activity in the Eastern Mediterranean is linked to the North Atlantic Oscillation (NAO) and that if global warming continues, storm activity will decrease in this century. This will lead to a decrease in rainfall by 15 to 25 per cent in parts of Turkey, Syria, northern Iraq, and north-eastern Iran, as well as the strategically important headwaters of the Euphrates and Tigris rivers (Adamo et al., 2018).

The stream flows of the Tigris and Euphrates Rivers are currently being affected by climate change. Natural streamflow has decreased because these rivers originate within Iraq's boundaries, and their watersheds are situated in areas affected by the same climate changes. Increased water withdrawals from other riparian countries, namely Turkey and Iran, and to a lesser degree Syria, have escalated the situation in recent decades and continue to be exacerbated today due to growing demand.

This study aims to examine the impact of climate change in Iraq through the mechanism of sharing common water basin resources. Iraq is experiencing the climate change effects in a way that is comparable to, if not worse than, many other countries around the world. Climate change manifests itself in the form of global warming, changes in weather-driving materials, and sea-level rise. Water stress is being caused in Iraq also by rising temperatures, declining precipitation rates, and changing distribution patterns, as well as increased evaporation. They do, however, set off a chain reaction that results in droughts, desertification, and sandstorms.

Reduced water availability for arable land has hit Iraq's agricultural sector hard so far, whether rain-fed lands in the north or irrigated lands in the south and middle parts, as a result of the Tigris and Euphrates Rivers' declining discharges. The unequal distribution practised by Turkey, which supplies the majority of the water supply for the two rivers, has put additional pressure on these discharges. The present negative climate change trends seem to be continuing in the future (USAID, 2017; Adamo et al., 2018; Al-Ansari et al., 2018a).

We aim to explore the impact of climate, such as droughts and agricultural and drinking water quality on various outcomes, including the change in income and assets of Iraqi households, food security measured from the changes in food production and stock, and subjective well-being, such as satisfaction with food and life. We found out that households located close to the Tigris River had experienced climate-related shocks in 2012. When we considered the 2017 Rapid Welfare Survey, we found that households located close to the Euphrates River were more likely to report an insufficiency in water availability, interruptions in water supply, and more likely to be forcibly displaced. This is due to the drop in annual rainfall in the Southern and Central parts of Iraq, where the Euphrates River is the principal source of water supply. Furthermore, due to Turkey's dams and irrigation projects, respondents in Iraq have witnessed a lack of water supply and a decline in water quality. Overall, we find a significant impact of climate change-related shocks on various outcomes, including the decrease in income, assets, food production and stock. Furthermore, using the data in 2012, we find a significant impact of drought and water quality on the quantity of agricultural products produced, such as cereals, fruits, vegetables and dates, ranging between 5 and 22 per cent. We should highlight our analysis focuses on the dams built in Syria, Turkey and Iraq and the impact of climate shocks on Iraqi households, even though, Euphrates-Tigris River Basin flows in Iran, Iraq, Turkey and Syria and a very small part of Saudi Arabia and Jordan. The rationale of exploring Iraq, lies in the data availability at the household level and the large number of dams built in Turkey followed by Iraq.

The structure of this study is the following: In section 2, we present the geographical and climatic characteristics of the Euphrates-Tigris River Basin, the water quality and resources, and the dams operated in the basin. In section 3, we briefly discuss the literature review of the climate change impact on agricultural yields, water supply and food security. We present the data and the main regression specifications applied in the empirical analysis in section 4. In section 5, we report the empirical results, and in section 6, we discuss the main concluding remarks.

2. Euphrates-Tigris River Basin

2.1 Geography, Climate and Water Resources

The Euphrates-Tigris River Basin, which spans 46 per cent of Iraq, 22 per cent of Turkey, 19 per cent of the Islamic Republic of Iran, 11 per cent of the Syrian Arab Republic, 1.9 per cent of Saudi Arabia, and 0.03 per cent of Jordan, is a transboundary basin with a total area of 879,790 km^2 (FAO, 2009). Both Euphrates and Tigris rivers have their origins in the mountains of eastern Turkey. The Euphrates-Tigris River Basin receives 335 mm of annual precipitation on average, and it varies by region (New et al., 2002). Summers can be extremely hot and dry, with midday temperatures approaching 50 degrees Celsius and relative humidity levels as low as 15 per cent. The annual average temperature in the Euphrates-Tigris River Basin is 18 degrees Celsius (Kibaroğlu, 2002; New et al., 2002; FAO, 2009).

The Euphrates River is 3,000 kilometres long, divided between Turkey with 1,230 kilometres, Iraq and Syria respectively at 1,060 and 710 kilometres. The 62 per cent of the catchment area that produces inputs into the river lies in Turkey and 38 per cent in the Syrian Arab Republic. Turkey contributes around 89 per cent of the annual flow, with the Syrian Arab Republic contributing 11 per cent, and only a small amount of water is contributed by the remaining riparian countries (FAO, 2009).

The Tigris River is 1,850 kilometres long, with 400 kilometres belonging to Turkey, 32 kilometres on the Turkish-Syrian Arab Republic border, and 1,418 kilometres in Iraq. Turkey receives 51 per cent of the Tigris' annual water volume, Iraq 39 per cent, and the Islamic Republic of Iran 10 per cent, but Iran is unable to use the Tigris' water for irrigation or hydropower due to unfavourable geographical and climatic conditions (FAO, 2009; Lashkaripour et al., 2011; Al-Ansari et al., 2018b).

Water quality in riparian countries downstream is a point of contention. The high rate of evaporation, sharp climatic changes, inadequate drainage, salt and sediment deposition, and poor soil quality in the lower reaches of Euphrates and Tigris rivers are all notable natural causes. The water quality in the Tigris near the Syrian border in Iraq, including water from Turkey and Iraq, is considered good. However, downstream, due to insufficient wastewater treatment facilities, water quality deteriorates, with substantial sewage and pollution inflows from urban areas such as Baghdad. The Euphrates River entering Iraq has a lower water quality than the Tigris, influenced by the return flows from irrigation projects in Turkey, and is predicted to deteriorate further as more land comes under irrigation (World Bank, 2006; FAO, 2009; Lashkaripour et al., 2011; Al-Ansari et al., 2018b).

Water quality is declining in the Euphrates-Tigris River Basin and heavy pollution from several sources pose serious threats. One major issue is the lack of an effective water monitoring network that makes it difficult to address water contamination and water quality because pollution sources are not easy to identify. Iraq insists on the international law doctrine of absolute territorial integrity, which states that no riparian can degrade the quality or quantity of water flowing through its territory. Turkey, on the other hand, vigorously uses the doctrine of unlimited territorial sovereignty, often known as the Harmon doctrine, which states that the water belongs to the upstream country, which has complete control over the water inside its borders (Michel, 2012; Warner et al., 2012). Neither theory has received much support from international tribunals or legal scholars, who prefer the principle of equitable utilization, which is grounded in the doctrine of limited territorial sovereignty and integrity within a given river basin. Iraq and Syria consider the Euphrates-Tigris basin as "international waters", implying that these should be shared among all riparian countries. In contrast, Turkey claims these are "transboundary waters" since water flows within its boundaries (El-Fadel et al., 2002; Al-Muqdadi, 2019). Another issue is that the

Law of Non-Navigational Uses of International Watercourses in 1997 was poorly developed and unenforceable (Priscoli and Wolf, 2009). Furthermore, while Syria and Turkey consider the Euphrates-Tigris Basin as a single water system, Iraq has asked to treat the rivers as two systems separately (Al-Muqdadi, 2019).

Figure 1 highlights the critical points of identification of the impact of water flows in Iraq. In particular, households located in governorates that receive water from Euphrates or Tigris based may experience different levels of droughts, water supply and quality. As we can see in figure 1, the water from the Tigris river flows directly from Turkey to Iraq, while the Euphrates flows from Turkey to Iraq through Syria. This implies that there is only one downstream country, Iraq, while in the case of Euphrates, Iraq is on the lower part of the stream since the water flows originate from Turkey and then crosses Syria before reaching Iraqi grounds. Based on figure 1, we will build the empirical strategy to investigate the differences in the economic and welfare outcomes of households receiving water from Tigris or Euphrates. As we discuss in the following sections, two main points are critical. The temperature and rainfall levels and the distance between the dams in the Tigris and Euphrates rivers and the household's governorate.

2.2 Dams in the Basin

Iraq was the basin's first riparian nation to embark on engineering ventures. The Al Hindiya and Ramadi-Habbaniya dams on the Euphrates were built for flood control and irrigation, respectively, in 1914 and 1951. In the late 1970s, as part of a flood-prevention campaign, Iraq built a canal to drain excess water from the Tigris into Lake Tharthar (FAO, 2009). Since then, Iraq has built more canals like this, linking Lake Tharthar to the Euphrates and then back to the Tigris. Iraq has also built hydropower dams on the Euphrates and Tigris, including the Haditha Dam, completed in 1985 (Allan, 1994; Shapland, 1997). In 1991, the North Al-Jazeera irrigation project was launched, aiming to serve approximately 60,000 hectares using water from the Mosul Dam. The East Al-Jazeera irrigation initiative is another project that has involved the development of irrigation networks on over 70,000 hectares of previously rainfed land near Mosul. These ventures were part of a wider scheme to irrigate 250,000 hectares of land in the Al-Jazeera plain.

Turkey began the construction of the Keban Dam, its first dam on the Euphrates River, near Keban Strait, in the mid-1960s and finished it in 1973. The Euphrates' second dam, the Karakaya Dam, was completed in 1988. The first dam built as part of the Southeastern Anatolia Project's implementation (GAP). Like the Keban Dam, the Karakaya Dam was designed to produce hydropower (FAO, 2009).

The GAP Project was intended as a series of land and water resource development initiatives on the Euphrates and Tigris Rivers, with the goal of improving one of Turkey's less developed regions. For the Euphrates, a single dam in the upper part of the catchment- the Atatürk Dam- is able to regulate a considerable portion of the river’s flow. The Atatürk Dam, which has been in operation since 1992, is commonly regarded as not only Turkey’s largest dam, but also one of the world’s largest. The dam produces 8,900 Gigawatt hours (GWh) of electricity each year, followed by the Karakaya and Keban dams, which generate 7,300 GWh and 6,000 GWh of electricity, respectively (Altinbilek and Tortajada, 2012). Table 1 shows the large dams in the Euphrates-Tigris River Basin in Iraq, Syria and Turkey, according to the definition of the International Commission on Large Dams (ICOLD)[4].

3. Literature Review

Water and food scarcity are the world’s greatest challenges as a result of climate change and have a significant negative impact on arid and semi-arid areas. Climate change has led to an increase in global average annual air temperature and regional rainfall variation, which is projected to continue and worsen in the future (Solomon et al., 2007; Misra, 2014). According to research studies, farm yields are likely to be severely impacted in the next century because of unprecedented climate system changes. A decrease of 20 per cent in precipitation or more is expected in arid and semi-arid areas over the next century (Jarvis et al., 2010, Thornton et al., 2011).

Since climate change is inevitable, many researchers have focused on the importance of adapting to new environments and mitigating the adverse effects of climate change. The need for adoption of those strategies is much greater in emerging countries, where vulnerability is greater (Deressa et al., 2009; Elum et al., 2017). In the literature, the climate change consequences on food production and protection in developing countries are well documented (Kurukulasuriya and Mendelsohn, 2008; Below et al., 2015; Nyuor et al., 2016; Richardson et al., 2018). Climate change, for instance, may reduce crop yield by up to 17 per cent, forage yield by 3-35 per cent, and livestock animal weights by 14-16 per cent, according to Butt et al. (2005).

The countries that are vulnerable to climate change are very uncertain of the potential water supply. Water stressed conditions found only in seven countries in 1955. This number grew to 20 countries in 1990, with an extending to 10-15 countries around the globe is expected for 2025. Water stress conditions are forecast at two-thirds of the world’s population by 2050 (Gosain et al., 2006). Most Arab countries rely for their water requirements on foreign water bodies, and there are no extensive water sources in those countries, and they have to rely on precipitation and water conservation techniques. About 190 million citizens of 10 nations live in the Nile Basin, and as most of the nations in the Nile Basin are among the ten poorest countries in the world, any water conservation techniques that require investment are utterly hard for them to follow (Misra, 2014).

[4] The definition refers to dams with a height of more than 15 metres or with a height of 5-15 metres and a reservoir capacity larger than 3 million m^3.

Droughts in Iraq have exacerbated food insecurity and poverty, particularly in rural areas where agriculture is the principal source of income for most of the people (Bazza, 2018). Between December 2007 and June 2009, 25,578 people from 4,263 families were displaced because of droughts. According to the Ministry of Health, the highest number of diseases spread by contaminated water and food occurred between 2007 and 2010, during the most severe droughts (UNESCO, 2014).

Droughts that hit the country for two years in a row, in 2008 and 2009, destroyed about 40 per cent of the country's farmland, particularly in the northern governorates. Between 2006 and 2007, barley production dropped from almost 423 thousand tons to roughly 238 thousand tons, while wheat production dropped from 486 thousand tons to 396 thousand tons (UNESCO, 2014). The total production for irrigated barley plummeted by 21 per cent in central and southern Iraq between 2007 and 2008, while wheat production dropped by 31 per cent (Ozguler and Yildiz, 2020).

Water scarcity also affects several industries in Iraq, including agriculture, causing problems in firm operations, capital losses, and layoffs, resulting in increased unemployment (World Bank, 2006; UNESCWA, 2013). In 2010, hydropower generation was Iraq's most important renewable energy source, accounting for over 10 per cent of the country's total electricity generation (IEA, 2012), which was peaked at 20 per cent in 2005 but declined to 7 per cent in 2009, indicating a possible effect of drought (UNESCO, 2014).

Water availability for irrigation, energy production, and residential and industrial use will be reduced, putting more stress on the ecosystems along the rivers. Water scarcity issues in the basin should be approached by several perspectives including legal, economic, environmental, technological and security aspects (El-Fadel et al., 2002). Yucel et al. (2014) discuss that the extreme drought that hit the region in 2008 conveyed crucial indications and messages about what could happen in the future. Such catastrophes, which are likely to become more frequent and intense in the future, could jeopardize water availability and food security, as well as spark regional conflict. The Southeastern Anatolia Project (GAP) project that was implemented to revitalize the southeastern Anatolia region is potentially the main cause of a considerable reduction in the water supply of the Euphrates and Tigris rivers, which consists of a massive number of 22 dams, 19 hydroelectric power plants, and a variety of other agricultural, industry, transportation, irrigation, and telecommunications facilities (Elaiwi, 2020).

An important issue is that the upper parts of the Euphrates-Tigris basin located in Turkey have a cold continental climate. Its lower parts in Iraq are classed as hot desert or hot semi-arid, which put further pressure on Iraq's reservoirs (Bozkurt and Sen, 2013). Summers are hot and dry that cause a lot of evaporation and low humidity during the day, and evaporation causes water salinization and loss in the two riparian countries' (Turkey and Iraq) largest reservoirs (Naff and

Matson, 1984; Kliot, 1994; Kibaroglu, 2019). Bozkurt and Sen (2013) show that by the end of the 21st century, the surface runoff for the Turkish portion will decrease by 23.5 per cent for Euphrates and 28.5 per cent for the Tigris basin. In the same simulation, by the end of the century, there will be little snow cover in the headwaters of these rivers caused by the increasing temperature that will cause further reduction in precipitation and drop in rainfall. Even though the decreases in the surface runoff are primarily caused by precipitation reduction, increased evapotranspiration rates as a result of rising temperatures also have a role, as they increase water loss into the atmosphere (Bozkurt and Sen, 2013).

Earlier studies have also raised concerns about the droughts and climate change impact in Turkey. According to the United Nations Environment Program (UNEP), Turkey will be one of the first countries in Europe to experience desertification, and the Konya closed basin in central Anatolia will face desertification by 2030 if nothing is done (Topcu et al., 2019). Simulations from previous studies show that the western and southern regions of Turkey may experience more frequent heatwaves in the future with a decrease in precipitation by 20-40 per cent (Gao and Giorgi, 2008; Önol and Semazzi, 2009; Sen et al., 2012). The Euphrates and Tigris rivers account for over a third of Turkey's total water potential, with snowfall being the primary source of discharge. As a result, increases in winter temperatures and decreases in precipitation will affect the snowmelt season, as well as river discharge and water availability in downstream countries. Rising temperatures and declining precipitation, increasing frequency, severity and duration of drought events and heatwaves will great water stress on water supply for drinking and agriculture purposes affecting displacement, food production and socio-economic conditions in Turkey (Sen et al., 2012; Kurnaz, 2014).

Apart from the impact of dams and droughts on economic and social welfare, severe droughts could also exacerbate the effect of other disturbances such as pollution and water abstraction for irrigation (Khelifa et al., 2021). Droughts can potentially affect air quality, such as increasing concentrations of tropospheric ozone (O3) and particulate matter (PM) (Jacob and Winner, 2009; Wang et al., 2017; Demetillo et al., 2019). For instance, Wang et al. (2017) found that the ground level O_3 will increase by 1-6 per cent in the US by 2100 compared to the 2000s and an increase in the PM2.5 at 1-16 per cent. Furthermore, another climatic shock variable explored in this study is the quality of agricultural and drinking water. Droughts not only reduce the water availability and air quality but have an impact on the water quality as well (Maestre-Valero and Martinez-Alvarez, 2010; Mosley, 2015; Peña-Guerrero et al., 2020). Droughts can extend water's residence time, reduce the flushing rate of water bodies with a little dilution of point source emissions, and disrupt organic matter and nutrient transport, among other things. Water quality issues such as an increase in total dissolved solids and their constituent ions, as well as a decrease in dissolved oxygen, could lead to agronomic issues in irrigated agriculture (Maestre-Valero and Martinez-Alvarez, 2010; Mosley, 2015). Therefore, the motivation of this study is to explore not only the droughts as the climatic shocks experienced by the households in Iraq but also affect water quality among other shocks related to climate change.

4. Methodology and Data

4.1 Simultaneous system of regression equations

The Euphrates River originates in the eastern highlands of Turkey, and it flows southward through southeastern Turkey around Adiyaman, Diyarbakir, Sanliurfa, and Gaziantep provinces. The river goes across the border into Syria and Iraq, passing from Mesopotamia, and empties into the Persian Gulf in Basra after joining with the Tigris River in Shatt al-Arab of Iran. Turkey finds itself in a strategically strong position as the only country in the Euphrates-Tigris River Basin to enjoy abundant surface water and groundwater resources, while Iraq is reliant upon these rivers. Furthermore, Iraq as a downstream riparian country complains about water quality, as Turkey mainly uses the water for irrigation purposes. The return flow from irrigation causes water pollution, which in turn affects potential downstream uses (FAO, 2009). Thus, the second proxy for the climate change shock, apart from droughts, will be the agricultural and drinking water quality. The first empirical set-up for our analysis involves a system of simultaneous unrelated regression equations (SURE) using full-information maximum likelihood (FIML), and it will be (Rivers and Vuong, 1988; van Wissen and Golob, 1990; Ronning and Kukuk, 1996; Roodman, 2011):

$$climate_{ihrt} = a_0 + a_1 T_{ihrt} + a'\mathbf{X}_{ihrt} + qh_d + \varepsilon_{ihrt} \quad (1)$$

$$y_{ihrt} = \beta_0 + \beta_1 climate_{ihrt} + \beta'\boldsymbol{Q}_{ihrt} + l_r + qh_d + u_{ihrt} \quad (2)$$

Where y_{ihrt} is the outcome of main interest (e.g. change in income, food production) for the individual i, in household h, in region-governorate r and year t, and *climate* denotes the climate change problems, such as droughts and water availability and quality. We should highlight that the governorates of Iraq are refereed as provinces in the classification of the administrative units in Europe. More precisely, these are equivalent to the Nomenclature of Territorial Units for Statistics-3 (NUTS-3) Level.

Variable T takes a value of 1 for the households located in governorates that receive the water from Euphrates and 0 for governorates where the water is supplied from Tigris, as Figures 1-2 show. In particular, in Figure 1 and Table 1, we illustrate the main dams in both rivers in Turkey, Syria and Iraq, while in Figure 2, we show the governorates' names close to the rivers. Thus, the governorates of Al-Anbar; Al-Najaf; Al-Qādisiyyah; Babylon; Karbala; Al-Muthanna; Al-Basrah and Thi-Qar take a value of 1 (Euphrates) and the governorates of Nineveh; Baghdad; Kirkuk; Salah Al-Din; Diyala; Duhok; Al-Sulaimaniya; Arbil; Misan, and Wasit take a value of 0 receiving water from Tigris (The Republic of Iraq and Japan International Cooperation Agency, 2016). We should highlight that Euphrates and Tigris provide 98 per cent of the water in Iraq (Barbooti et al., 2010).

Thus, the sustainable water management of the particular water basin from both upstream in Turkey and downstream in Iraq is considered of major importance. Furthermore, the climate change shocks are reported and recorded at the individual level and not a household since a household may consist of one person who is single or divorced and lives alone.

The estimated coefficient α_1 is the first coefficient of main interest showing whether households located in the governorates that receive water from Tigris or Euphrates are more likely to report issues related to droughts and water quality, while coefficient β_1 is the second coefficient of main interest, indicating the impact of climate change-related events on various outcomes y. Vector **X** includes climate characteristics, such as average temperature, the difference between the maximum and minimum temperature, precipitation, dew point and maximum wind speed. Vector **Q** includes individual and household characteristics, such as gender, age, employment status, education level, marital status, and household size. Sets qh_d is the *qhada*-fixed effects which translate to districts that include cities and their surrounding villages, while set l_r denotes the governorate-fixed effects. We should notice that we do not include the set l_r in regression (1), since the treat variable is defined based on the governorate the household is located into, while we do not include time-fixed effects, since we will perform the regressions separately for each survey, in the year 2012 and 2017.

We should highlight that set-up of the variable T relies on whether the household receives water from Euphrates or Tigris based on the governorate location. This implies a limitation as the households located closer to the river may have a clear advantage in terms of water supply, as becomes obvious in Figures 1-2. However, the identification of the regressions system (1)-(2) using instrumental variables, as we describe in the next section, relies on the centroid of the governorate the household is located. To reduce this limitation, we control for the *qhada* districts which map a higher level of geographic disaggregation to capture the distance between the household's location and the river or the dam, as we discuss later in the identification strategy. However, the surveys do not record the exact name of the district, but they record only a random number. Nevertheless, the best we can do is to control the *qhada* districts in the first stage regression. Furthermore, the climate change shocks reported by the respondents depend on variable T, indicating whether the household is located in a governorate receiving water from Tigris or Euphrates. As we can see in figure 1, the water from the Tigris river flows directly from Turkey to Iraq, while the Euphrates flows from Turkey to Iraq through Syria. Based on the discussion in the following sections, and the number of dams built across both rivers determine the water supply and thus, droughts, and also the water quality. Moreover, households in the southeastern governorates have experienced higher levels of temperature and low precipitation and rainfall levels that affect the water flows and supply from the Euphrates river. Since it mainly crosses those governorates, climate change shocks further exacerbate the droughts and water quality. However, another issue is that Baghdad and Al-Basrah receive water from both rivers but the surveys do not record the information on whether the household receives water from a network connected to a particular river. To alleviate this issue, we will perform IVs and we will also repeat the estimates in the appendix, excluding the households located in Baghdad and Al-Basrah or assigning them in a different group.

The benchmark estimates involve the SURE (1)-(2), while for robustness check we will apply an instrumental variables (IV) approach using Probit and ordered Probit and the maximum likelihood method. More specially, as we discuss in the data section, the main outcomes in regression (1) are binary and thus, we will apply the Probit model, while in most of the cases, the outcomes in regression (2) are ordered, that includes satisfaction and ranking such as decrease, increase or no change in income, assets and food production. For this reason, we will apply the ordered Probit model. Therefore, the SURE will also involve an IV approach, where the variable *T,* along with weather conditions are used as instruments for the climate shocks experienced from the households.

We should notice that even though we apply the ordered Probit SUR, the estimated coefficients using the simultaneous order Probit regressions with the Generalized Methods of Moments (GMM) remain almost identical, especially for the principal variables of interest, which are the climate change shocks, such as droughts, water quality and availability of grazing areas. While GMM account for the presence of heteroscedasticity, we implement Huber-White robust standard errors us in the benchmark ordered Probit models. For robustness check we will report a part of the estimates using the simultaneous ordered Probit regressions with GMM. Furthermore, we highlight that the estimates derived from the Logit and ordered Logit models are very similar to the marginal effects found in the Probit models, and hence, we do not report the results.

4.2 Weather and climate

In this section, we discuss the evidence from the literature about the relationship among the climate change shocks we explore, such as droughts and water quality, and various weather conditions. The main underlying reasons for providing this discussion is to justify the inclusion of certain weather conditions in regression (1).

While it is already well documented that the average temperature reduces the water quality, which leads to droughts (Booij, 2002; Frei et al., 2006, Trenberth et al., 2014) and poor water quality (Van Vliet and Zwolsman, 2008; Mosley, 2015). Climate variability, hydrological, biogeochemical, and anthropogenic impacts control the water quality of freshwater systems. These effects operate at various spatial and temporal scales, for example, at a river basin or local catchment. Droughts disrupt the natural meteorological and hydrologic system having a variety of effects on the determinants of water quality. For instance, low flows and water levels, increase the residency time and reduce the flushing rate of water bodies during hydrological droughts and the reduced water flows/levels. High temperatures may alter the rates of processes of respiration and reaeration, which is the exchange of gases between the atmosphere and water. The water quality during droughts may deteriorate in terms of eutrophication and water temperature caused by a reduction of the dilution capacity of point source effluents and the development of algae blooms that produce toxins that could be harmful to people, pets, and wildlife (Van Vliet and Zwolsman, 2008; Mosley, 2015).

The temperature difference between daily maximum and minimum temperatures is known as the diurnal temperature range (DTR) and it is found to be related to climate change. While global mean surface temperature variations are a useful indicator of climate change, maximum and minimum temperatures provide more information than the average, because trends in mean surface temperature can be caused by changes in either the maximum or minimum temperature, or by relative changes in both (Braganza et al., 2004; Yang et al., 2013). Thus, we additionally use the DTR to capture the potential effects of intraday variation temperature, which can also be a suitable index of climate change and variability (Braganza et al., 2003, 2004; Qu et al., 2014). The observed reduction in DTR since 1960 is associated with a relatively higher increase in the minimum temperature rather than in maximum temperatures (Braganza et al., 2004; Wild, 2009). Nevertheless, higher values of DTR lead to droughts, as the average temperature, since the difference between the maximum and minimum temperature is combined from both values. DTR and average temperature are negatively related to precipitation and precipitation deficits, which are the primary cause of drought (Trenberth, 2011; Viste et al., 2013; Hoerling et al., 2014). Increased temperature and reduction in precipitation cause surface drying, lengthening the drought's intensity and duration.

The other meteorological conditions used as proxies to climate change are the dew point and the maximum wind speed. Dew point is the temperature the air needs to be cooled to attain a relative humidity of 100 per cent. The air can no longer hold any more water in the gaseous state, and the amount of moisture in the air increases as the dew point rises. Evidence shows that climate change and increase in temperature are related to the reduction in high cloud covers and dew point that in turn increase the lack of atmospheric moisture that reduce rainfall and precipitation and thus, increasing droughts and deteriorate water quality (Hardwick et al., 2010; Lenderink and Van Meijgaard, 2010; Wasko et al., 2015). However, as the dew point temperature rises by 1°C, the water holding capacity of air increases by around 7 per cent, resulting in increased water vapour in the atmosphere. As a result, storms containing more moisture create more severe precipitation episodes including thunderstorms, extratropical rain or snowstorms, or tropical cyclones. Even when overall precipitation is decreasing, such occasions are observed to be common (Trenberth, 2011).

Maximum wind speed is the last meteorological variable included in regression (1). Severe winds, unlike other weather and climate factors like temperature, precipitation and rainfall, are frequently examined in conjunction with the extreme occurrences they are linked with, such as tropical and extratropical cyclones, thunderstorm downbursts, and tornadoes. Nevertheless, an increase in wind speed at high air temperatures enhances evapotranspiration that accelerates the process of drying the soil (McVicar et al., 2008; McInnes et al. 2011). Thus, trends in average wind speed can influence potential evaporation and in turn water availability and droughts. We expect that a higher wind speed will be associated with droughts and poor water quality.

For each weather condition, we have included the yearly averages of the last three years before each survey, considering the monthly variations, implying that we take the annual averages using monthly data. Hence, for the first survey used in the empirical work and which was conducted in 2012, we will consider the period 2009-2011. While climate change can be measured by taking the average temperature of the last 100-150 years, we consider a short period to account for the potential volatility observed in recent years and to account for the possible impact of dams. Furthermore, we have tested the estimates using 10 years, as well as using the one year lagged weather conditions, giving very similar estimates.

We should highlight that earlier studies have employed the Standard Precipitation Index (SPI) (e.g. Yeo et al., 2016) or the Standard Temperature Index (SRI). Nevertheless, while we could have calculated those indices, we should notice that they are associated with certain disadvantages (Angelidis et al., 2012). Although one advantage is their standardization, assuring the frequency of extreme occurrences is consistent across all locations and time scales, a drawback is an assumption that a suitable theoretical probability distribution can be identified to simulate the actual temperature and precipitation data. In particular, various distributions have different feedbacks and can provide different results. The second drawback is that when these indices are used to places with low seasonal precipitation over short time frames, such as 1-3 months, we might obtain misleadingly large positive or negative index readings. The third limitation is coming from the standardized nature of those indices, which are not capable of distinguishing locations that are more prone to drought than others. Therefore, a similar standardization index at two distinct places does not always reflect a similar water shortage at these two locations (Angelidis et al., 2012). New variations of the SPI and STI - the Standardized Precipitation and Evapotranspiration Index (SPEI) - has been developed (Vicente-Serrano et al., 2010), which also includes the temperature, or the Palmer Drought Severity Index (PDSI) developed by Palmer (1965) that accounts for temperature, soil moisture and evapotranspiration. However, the main core of the identification strategy is the instrumental variables discussed in the next section and not the weather conditions. Moreover, we use not only droughts as the climate change shock but we also explore the agricultural and drinking air quality, and availability of grazing areas and displacement which are determined from other weather conditions as well.

4.3 Instrumental variables

A potentially principal threat to our identification strategy is that people and households may decide to locate in areas close to the water basin and engage in agriculture activities. Thus, the allocation of people is likely not random. For this reason, the second specification model includes an instrumental variables (IV) approach and the full information maximum likelihood (FIML) method. The instrument used for the endogenous variable of *climate* in regression (1), and which replaces the variable *T*, is:

$$IVT_{st-1} = \sum_{s} \frac{1}{D_{sd}} P_s WC_d \tag{3}$$

The instrumental variable (3) taken in the period *t-1*- one year before the interview- is the sum of the ratio of the product of two components. The first is the share of the population in the dam's province *s* in Turkey over the total population denoted by P_s. The second is the water capacity (WC_d) of the dam *d* belonging to province *s*. Then we take this product over the distance between the dam and the centroid of each Iraqi governorate.

Thus, the first step involves the estimation of the product P_s and WC_d. The water capacity of dam *d* (WC_d) is reported in Table 1, while we obtain the population of each province by the Turkish Statistical Institute (TURKSTAT). The population refers to one year before the survey, and P_s is the share of the population of a province over the total population of Turkey. In the second step, we take the distance (D) between the dam *d* and the centroid of the respondent's Iraqi governorate *s*, expressed by D_{sd}. In the third step, we take the average values of relation (3) by each governorate in Iraq. In particular, for each governorate in Iraq, we have estimated relation (3) for each dam.

Since there are 33 dams then we will take the average of those 33 values across 18 governorates in Iraq. We should notice that the GAP started with 22 dams, some of which are still under construction, and very few others not operated. However, we have also included other large dams in Turkey, as we discussed in the previous section, given their potentially substantial impact on water flow and supply in the downstream country of Iraq. Excluding these dams will probably underestimate the climate shocks on the economic situation of households in Iraq.

We should highlight that while the dams explored in this study were constructed as part of the Southeastern Anatolia Project (Güneydoğu Anadolu Projesi GAP) in Turkey, their principal purpose, as we have discussed earlier, is for irrigation and hydropower generation. However, one drawback of the instrument could be that we consider the total population and not the population of the provinces in Southeastern Anatolia since the irrigation could be focused on this area. However, the dams are used for irrigation and hydropower generation in other provinces as well (Kankal et al., 2016). Nevertheless, considering the P_s as a share of the total population of

Southeastern Anatolia leads to trivial changes in our estimates. Similarly, we will construct an instrument for the climate-related shocks using the dams in Iraq as:

$$IVR_{rt-1} = \sum_r \frac{1}{D_{rw}} P_r WC_w \quad (4)$$

Where P_r and WC_w denote respectively the population of each Iraqi governorate r and the water capacity of each dam w reported in Table 1. The steps followed for the construction of the instrumental variable are the same as those described for relation (3). In particular, Pr is the share of the population of governorate r over the total population of Iraq, and D_{rw} is the distance between dam w and governorate r. The third instrument is employed to consider the role of the dams in the Syrian Arab republic. Following a similar procedure with the instrumental variables (3)-(4), we have:

$$IVS_{gt-1} = \sum_r \frac{1}{D_{gd}} P_r WC_d \quad (5)$$

As in (3), P_g and WC_d denote respectively the population of each Syrian governorate g and the water capacity of dam d reported in panel C of Table 1. The steps to calculate the instrumental variable (5) are the same with those described in the procedure of calculating variable (3).

A potential threat to our identification strategy is whether these instrumental variables meet the exogeneity conditions. We argue that the first set of instruments employed refer to various meteorological conditions discussed in the previous section. In particular, the causal effect of the climate change shocks is obtained by conditioning on the weather-climatic conditions or an association between the meteorological variables and the outcomes explored in this study is only detected when we condition on the climate change shocks. While previous studies have employed temperature and precipitation as an instrument for income (e.g. Miguel et al., 2004; Feng et al., 2012) we argue that we do not have a direct effect on the outcomes explored in this study but only through climate change shocks experienced from the households.

The second set of variables that includes the distance of dams to the respondents' location may also affect the outcomes explored but we argue that the effect is indirect through the climate change shocks like drought quality of drinking and agriculture water. Nevertheless, still, we may not account for the endogeneity issue coming from the fact that the respondents' location is not randomized. Thus, given the temporal ordering we argue that weather conditions and the construction and operation of dams initially cause the climate change shocks experienced by the respondents, which in turn have an impact on the economic and well-being outcomes explored in the study. As we show in the estimates in the next section we check the suitability of the IVs using the weak instrument and endogeneity tests. Furthermore, we should notice that we do not consider the height in the construction of the IVs since height is not associated with the dams' water capacity as we see in Table 1. Another critical piece of information could be the water consumption, but unfortunately, this is not available. Overall, we argue that the exclusion restriction assumption would be valid if the dams and weather conditions in the first place affect the water supply, droughts, and water quality and then these climate change shocks have an impact on the outcomes explored.

Therefore, while the aim of the paper is to estimate the causal impact of climate change-related shocks on income and food security, the motivation is to consider the transboundary effects of climate change and the need for adaptation and mitigation strategies that focus on the global, and not only at the national-local level. Hence, the study explores the water basin and common water resources, while the analysis can be expanded to investigate the impact of air pollution, nuclear waste on soil and water resources, solid and hazardous waste generation and waste management.

Dam construction is one of the key factors affecting river ecosystems' environmental conditions and, as a result, water quality and water self-purification. Dams disrupt the river's continuum, disrupting the transfer of organic materials and metals in a fluvial system, and ultimately influencing the chemical and biological properties of the ecosystem, which deteriorates the water quality (Ligon, 1995; Jansson et al., 2000; Szarek-Gwiazda and Mazurkiewicz-Boroń, 2002). The underlying reason for using this instrument is that a higher water capacity implies higher consumption in Turkey and thus, less water availability to the downstream country of Iraq. This, in combination with rising average temperatures and a drop in precipitation and snowfall, may cause an increase in droughts in Iraq. The instrument will have a higher value if the nominator is quite large given the water capacity and the share of the population, but we expect to have a higher impact if the distance of the dam d to Iraqi governorate r is longer, since the water supply reduces with the distance.

Thus, we expect to find a negative relationship between the instrument and the probability of drought in governorates closer to the dams. This can be justified by two reasons. First, if the numerator is higher and thus, a larger proportion of the population has access to the water capacity of the dam, the impact will be lower on the Iraqi governorates closer to the dam compared to the governorates located farther. As we mentioned before, while dam may have a negative impact on the water supply for the downstream countries, this will deteriorate with distance, as less water will be available to the governorates located farther. Second, if the denominator is lower, implying a shorter distance between the dam and the governorate, and thus, a higher value of the instrumental variable, then governorates located farther, as before, will experience a higher likelihood of droughts. Similarly, for the second and third instrument, we expect that people located close to the dams may experience droughts, potentially because they could be more populated areas, but the impact will increase with the distance (López-Moreno et al., 2009).

The impact of the distance on water quality is ambiguous. On the one hand, water quality can be positively correlated with distance, implying that the farther the dam is located from the governorate less the impact of the dam on the water quality and water self-purification capacity of the downstream flowing segment will be (Wei et al., 2009). Dams, and especially those used for hydropower generation, degrade water quality along rivers. Many aquatic animals suffer because of the oxygen depletion in the water flowing downstream from the dams. Reservoirs atop dams are prone to dangerous algal blooms, which can leach dangerous metals like mercury from submerged soil (Roulet et al., 1999; Szarek-Gwiazda, 1999; Ozdilek et al., 2007; Ong et al., 2013; Varol, 2013). Overall, there might be a negative relationship between water quality and the distance from the dam, implying that the water quality deteriorates in the governorates or places located closer to the dam (Varol, 2013; Ling et al., 2017). On the other hand, as we have highlighted earlier, droughts may cause poor water quality, and thus, governorates far away from dams are more likely to experience lower water quality (Van Vliet and Zwolsman, 2008; Mosley, 2015). For instance, the study by Varol (2013) shows that the highest concentrations of water pollution were identified at sites very near the entrance of streams that feed into reservoirs in Kralkizi, Dolce and Batman dams in Turkey. However, the average concentrations of dissolved metals in the reservoirs never exceeded the maximum allowable concentrations proposed by the World Health Organization (WHO) and the European Community (EC). Therefore, the estimated coefficients of the instruments in the water quality regression will depend on two opposite forces; the water pollution in the entrance of streams feeding reservoirs, and the water pollution caused by droughts.

Finally, another climate change-related shock explored is the availability of grazing areas. While this can be the result of the droughts caused by the dams, their reduction is also due to rising temperature and drop in precipitation, as well as human action and poor agricultural management, resulting in overgrazing. This further leads to desertification where no vegetation or trees are available, and the soil becomes very dry. Desertification also leads to increasing soil temperature and evaporation rates that reduce the soil moisture levels, causing soil particles to become hydrophobic. This prevents water infiltration and diminished water soil water reduces further the available forage and causing more droughts.

4.4 Data

The empirical analysis relies on data from the Iraq Household Socio-Economic Survey (IHSES) and is part of the Living Standards Measurement Study (LSMS). The first round conducted in 2006-2007, the second nationwide IHSES took place in 2012, while in 2017, the Rapid Welfare Monitoring Survey was conducted, which contains questions related to water sufficiency. While the surveys are repeated cross-sectional, in the first part of the analysis, we consider only the second round of the IHSES since it includes specific questions on shocks households have experienced, such as droughts, agricultural and drinking water quality. Furthermore, the second round includes questions related to the financial situation of the household and the respondent's satisfaction with food and life that will be used as additional outcomes. These questions unfortunately are not recorded in the first round of the IHSES, and thus, we do not consider this round. For the second part of the analysis, we derived the data from the Rapid Welfare Monitoring Survey in 2017.

The surveys are available for academic and research purposes from the MicroData Library of the World Bank available at https://microdata.worldbank.org/. We derived the climate and weather conditions from the US National Oceanic and Atmospheric Administration (NOAA) at https://library.noaa.gov/ and https://www.worldweatheronline.com. In Table 2, we report the outcomes and main variables of interest that indicate the effects of climate change and are derived from the IHSES in 2012, while in Table 3 we report the outcomes of the 2017 Rapid Welfare Monitoring Survey since the outcomes explored are different.

In Table 2, we report the proportions of the main outcomes explored when we consider the IHSES in 2012. Since the outcomes differ when we use the Rapid Welfare Monitoring Survey in 2017, we report the outcomes and their proportions in Table 3. We should notice that in Table 2, the first four variables refer to only those who have experienced the shocks. The main reason is that if we consider only those who have not experienced any type of shock, then the possible answer for a change in income and assets is only "Did not change". Furthermore, we should highlight that the shocks refer to different types which are not related to the climate, such as unexpected loss of job, protests and riots, loss of government payment support and others that are not directly linked to climate. Moreover, we should clarify that for those variables we consider those who have experienced the related climate change shocks as a proportion of the households having experienced any type of shock.

Therefore, the outcomes explored are categorical and ordered variables. In particular, the first set of variables answer to the question whether the climate change shocks affect the income, assets, food production and food stock, as well as the satisfaction with food and life. The first four outcomes are ordered variables measures in a scale taking values between 1 and 3, where 1 indicates decrease, 2 shows no change and 3 indicates increase. Similarly, the satisfaction with food and life are 4-scale ordered variables taking values between *very satisfied* and *not at all satisfied*. The last outcome explored is the assessment of the overall household's situation, which takes 4 values; 1 for good, 2 for satisfactory-middle; 3 for poor, and 4 for very poor.

In most of the cases, we observe that households saw a decrease in their income, assets, food production and stock as a result of the climate-related shocks explored in this study, and in particular, droughts, water quality and available grazing area that we present in Table 4. Almost 88 per cent have experienced a decrease in income followed by a reduction in food production and stock ranging between 71 and 74 per cent, and 58 per cent have reported a decrease in assets. On the contrary, almost one-third of the respondents have reported that the climate-related shocks have not changed the assets, food production and stock, while only 8.18 per cent have reported no change in income. Finally, almost 3-4 per cent of the population has seen an increase in the outcomes.

Then we report the proportions of three satisfaction variables: satisfaction with food, such as consumption and availability; satisfaction with life and assessment about the households' overall situation, in terms of poverty, deprivation and well-being. In this case, we compare those who have not experienced shocks (both climate-related and non-related) to those who have experienced only a climate change-related shock. Based on the Kruskal-Wallis test, used to test the mean differences for categorical and ordered variables, we find no difference in life satisfaction, as we can see from the *p-value*=0.1100. About food satisfaction and the evaluation of the overall household situation, we find that the differences are significant at the 5 and 10 per cent level. This preliminary finding shows that households who have experienced a climate-related shock, report lower levels of satisfaction compared to those who have not experienced any type of shock.

Similarly, in Table 3, we report the proportions of the main outcomes used in 2017. We should recall that in Table 2, we have presented four variables referring only to those who have experienced a shock, such as a decrease or increase in income, assets and food production. In Table 3, we report two variables related to shocks; whether the household has recovered economically from the shocks experienced in January 2014 and if these shocks have negatively affected the wealth of the household. As in the case of Table 2, we report the proportions only to those who have reported a problem related to climate change. However, these two variables are binary, and therefore, in this case, we will estimate a Probit model, while an ordered Probit model is applied when we have ordered outcomes as those in Table 2. In particular, the respondents reply whether the climate change-related shocks affect negatively the income and wealth of the households, or whether in the past four weeks any household member had to eat fewer meals in a day. The remaining variables are ordered answering to the overall economic situation of the household. For instance, the present economic situation compared to the past situation takes five values; 1 for much better, 2; for better; 3 for same; 4 for slightly worse, and 5 for much worse. Similar values are defined for the economic situation in the next year with an additional value-answer of uncertainty. The rest of the variables are also ordered, taking values between very good and very bad and not recovered and fully recovered on whether the household in 2017 has recovered economically since 2014. In all cases, these variables are self-reported.

In Table 4, we report the proportions of the availability of water supply, used as a proxy for droughts, and the frequency of interruptions in the water supply. We also include those who were forcibly displaced. However, other factors not related to climate can cause forced displacement and migration, such as economic reasons, riots and the invasion of the Islamic State of Iraq and Syria in certain areas. While we control for the governorates in regression (2), we still have to consider this variable with caution.

In Panel A we report the climate change shocks using the survey in 2012 and the questions available in the survey of 2017 are presented in panel B. We observe that all the variables are binary taking a value of yes or no. Thus, the first stage regression will be estimated using a binary Probit model. An exception is the question about interruptions in supply of water which measures frequency and therefore, is an ordered variable. The question takes five possible answers, from no interruption in the water supply at all to daily interruptions. It becomes clear that these shocks had a considerable impact on the households' income and wealth, where 96.21 per cent have reported a negative influence. We should highlight that if we consider only those who have reported a poor water supply and exclude those who were displaced by force, the percentage remains very close at 97.83. Only 3.52 of the households have managed to recover fully economically, 35.36 partially recovered, while 61.12 have not recovered at all. As the outcomes in Tables 2-3, the climate change shocks explored are self-reported variables.

As pointed in Table 2, we compare the households' economic situation between those who have experienced a climate-related shock and those who have not experienced any type of shock. We observe that in all cases, the current, past and future households' overall situations of those who have experienced a climate-related shock is lower or are more likely to report that it is worse and less likely to be good. Furthermore, 25.11 of the households having experienced a climate-related shock report that they have to eat fewer meals in a day because there was not enough food compared to the 10.38 per cent of the household with no shock experience. We should mention other variables are related to food consumption but they are very similar such as whether anybody in the household had to eat fewer meals because there were not enough resources or having to go to sleep at night hungry because there was not enough food. Thus, since the results are relatively similar, we include only this variable in the empirical analysis.

5. Empirical Results and Discussion

In Table 5 we report the SURE and SURE-IV Probit estimates using the IHSES of 2012 and the outcome of "change in income". To recall, we estimate regression (1) the Probit analysis since all three outcomes are binary, as we have shown in Table 4. The outcomes in regression (2) are ordered variables taking three values; increase in income, no change and decrease in income. Thus, in this case, we use the ordered Probit analysis.

In the first column, we report the estimates of regression (1) of the SURE. Those located in governorates close to the Euphrates River show no difference in the probability of experiencing a drought compared to those living close to the Tigris River. However, those located close to the Euphrates River are less likely to experience a deterioration in drinking and agricultural water quality and a reduction in the availability of grazing areas. This finding can be due to the higher capacity of the Euphrates River and the limitations of the Tigris. The weather conditions present the expected estimated coefficients based on the discussion in the methodology section. In particular, average temperature, DTR and average wind speed are positively correlated with the probability of the household experiencing the climate change-related shocks explored in the study for the reasons we have discussed earlier.

In the third and last column, we report the SURE and SURE-IV estimates, respectively, for regression (2). We should highlight that we do not present the SURE-IV estimates of regression (1), as we obtain the same concluding remarks. Nevertheless, this study aims to explore the impact of the three climate change shocks of Table 5 on the probability the households will experience a decrease in their income. Both SURE and SURE-IV estimates show a significant impact of drought on the probability that the income will decrease. Similarly, households experiencing a drop in water quality and a reduction in the availability of grazing areas are more likely to report a decline in their income compared to those who have not experienced the particular shocks. The estimated coefficients derived from SURE and SURE-IV are relatively close, with those estimated by the IV being slightly higher. For robustness check, we report the simultaneous Ordered Probit V-GMM estimates in Table 6 only for the outcome of "*Change in Income*", and we conclude that the estimates remain very similar.

As we have discussed, endogeneity in our case occurs because of simultaneity, selection bias and measurement errors, given the self-reported answers on climate change shocks. A possible explanation for the higher estimated IV coefficient is the measurement error on the endogenous climate change shocks, or because there is no significant change in the probability of reporting a drought or low water quality incidence from one period to another. This is particularly an issue when we employ cross-sectional instead of panel data, as we do in our empirical analysis. The correlation between our endogenous variables and residuals is positive, and thus, measurement error may bias the estimates towards zero since the OLS bias is downward.

Households based on their previous experience may form expectations about the climatic conditions in their area. Hence, they may use practices that are suited to these conditions. For instance, farmers may adopt a drought-resistant variety of maize or product, or households may decide to preserve water for their needs. However, the resulting bias could be positive or negative depending on the correlation between climate change shocks and the omitted variables absorbed in the error term. Thus, on the one hand, they may adopt more resistant agricultural products, but this does not imply are more profitable. Furthermore, even though households and farmers may form expectations about the climatic conditions, they cannot predict either the quantity and quality of the water provided by the upstream country (Turkey) or the role of dams in Turkey, Iraq and Syria.

While we do not report the results using the variable *T* and the remaining outcomes, we prefer to present the estimates using the instruments discussed in the methodology section. In Table 7, we report the SURE-IV estimates, when the outcomes are the change in income and change in assets. In Table 8, we present the estimates for the remaining five outcomes; decrease in food production and stock, satisfaction with food consumption and life, and overall household economic situation.

In all cases, we find a negative impact of the three climate change-related shocks on the outcome explored, implying a higher probability the household will experience a decrease in food production and stock. The respondents who have experienced those shocks are more likely to report a poor economic situation of the household and are very dissatisfied with the food consumption and production.

Overall, using the *F-statistic* to test the instrument used in regression (1) we conclude that we reject the null hypothesis and we reject the presence of weak instruments. This finding holds when we employ both variable *T* in regression (1) in the methodology section and the instruments (3)-(4) in Tables 7 and 8, including also the weather conditions. Furthermore, based on the *Atanh ρ* endogeneity test (Lokshin and Sajaia, 2004; Roodman, 2011), we accept the null hypothesis of no endogeneity, implying no correlation between the error terms of the two regressions. Thus, no unobservable factors are affecting simultaneously the climate shocks and the various outcomes of regression (2).

Also, the estimated coefficients of the instrumental variables in the droughts regression in Table 7 present a negative sign indicating that if the distance is shorter, then respondents are less likely to report issues about droughts compared to those living in areas far away from the dam, as we have discussed in the previous section. The same holds for the availability of grazing areas. The expected coefficients in the water quality regression are ambiguous, as we discussed earlier, as this may depend on the distance between the residents and the dam. In particular, this is related to droughts, where increasing temperature, fall in precipitation in combination with less quantity of water lead to lower water quality. On the other hand, areas closer to dams may present higher levels of water pollution. Our results are consistent with previous studies, and we find that respondents living in the governorates far away from dams are more likely to experience a lower water quality. This finding is also justified by the intensity of the dams built mainly in Mosul and Kirkuk in Northwestern Iraq and Lake Tharthar and governorates in Southwestern Iraq, as we can see in Figure 2. Thus, governorates in South Iraq may face shocks related to droughts and water quality. This finding is also supported in a report by the United Nations International Organization for Migration (IOM), as we highlight below.

Next, in Table 9 we report the estimates of regressions (1)-(2) using the variable T and the 2017 Rapid Welfare Survey. We find a negative impact of the water supply sufficiency, interruptions in the water supply and forced displacement on the current economic situation of the household. One remarkable difference in our estimates is that in 2017 households located close to the Euphrates are more likely to report a higher probability of experiencing a climate change shock, compared to those located close to Tigris. This finding contradicts the results in Table 5 when we use the IHSES of 2012. Turkey's water management and control over the Euphrates-Tigris Basin could be one explanation. According to Iraq's minister of water resources, the country may suffer serious water shortages if no deals are reached with Turkey over the dam projects and irrigation that have substantially reduced the river inflows. The inflows from the border with Turkey in northern Iraq were 50 per cent below the average in 2020. The reduction in water flows combined with an equivalent drop in annual rainfall compared to the previous year has put additional stress on the water supply. [5]

Furthermore, a report by the United Nations International Organization for Migration (IOM) identified a large number of around 21,300 internally displaced persons (IDPs) from the southern and central governorates near the Euphrates River. The main reason for displacement was the lack of water associated with high salinity content and waterborne disease outbreaks, implying a low drinking water quality (International Organization for Migration, 2020).

In Tables 10-11, we report the SURE-IV estimates using the instrumental variables (3)-(4). Based on Table 3, the current economic situation of the household is an ordered variable measured on a scale from very good to very bad. Similarly, the evaluation of the economic situation in the past, and the perception about the future economic situation of the household are ordered variables measured from "much better" to "much worse". However, the future perception includes also the category of "uncertain". While an ordered Probit model may not capture that precisely, we assume that increasing uncertainty is a negative aspect because it may postpone spending or show higher insecurity about incomes and jobs (Giavazzi and McMahon, 2012; Christiano et al., 2014). Nevertheless, removing this category, the concluding remarks and estimates remain similar. Based on the results in Tables 9-11 the positive coefficient of the climate change-related shocks implies that respondents will report a worse past, current and future economic situation of their households.

On the other hand, the outcome "Has the household recovered economically from the shocks of January 2014" is an ordered variable measured from not recovered at all to fully recovered. In this

[5] https://thearabweekly.com/iraq-complains-turkey-causing-water-shortages

case, we find a significant and negative coefficient, except for the forced displacement, implying that the water supply decreases the probability of the households recover from those shocks. The last outcome explored is a binary indicating whether the climate-related shocks harmed households' wealth and income. We find a positive and significant coefficient, showing all the climate change-related shocks, especially forced displacement, have negatively affected the wealth of households. As in Tables 5-8, we conclude that our instruments are not weak, while based on the endogeneity test, we accept that the error terms in regressions (1)-(2) are not correlated.

However, we reject the null hypothesis in most of the displacement regressions, except for the perception of the future household economic situation and whether these shocks have adversely affected the household's wealth. Thus, the exclusion restriction assumption is not met, indicating that they were displaced, because of the poor economic conditions caused by the weather conditions combined with the low water quantity and quality coming from the dams.

In Table 12, we briefly present the estimates using the IHSES in 2012 and the impact of drought, water quality and availability of grazing areas on five major categories of agricultural products in Iraq. Furthermore, we limit the analysis to farmers. The outcome is the logarithm of the production expressed as quantity in kilograms (kg). In all cases, we find a significant negative impact on the production of cereals, fruits, vegetables, and industrial products, such as cotton and tobacco. The major agricultural products in Iraq include dates, and cereals like maize, barley and wheat. Main vegetable products include potatoes, egg-plant, cabbage, lettuce, cucumber, tomatoes, cauliflower, pepper, onion, melon and watermelon, among others, while the main fruit plants are: pears, apples, figs, pomegranates, oranges, lemons, peppers, grapes and olives (FAO, 2007; Jongerden et al., 2018). As we found earlier, governorates close to the Euphrates River in 2012 report a lower probability of incident of poor water quality or reduction in the availability of grazing area compared to those located close to the Tigris River. However, we found no difference in drought, but when we use the 2017 Rapid Welfare Survey, we found higher levels of water stress in the governorates close to the Euphrates River. This result is because most of the country's irrigated agriculture is in the central and southern governorates, mainly depend on the Euphrates river, while rainfed agriculture is practised more in the northern governorates (Moyel and Hussain, 2015).

Overall, while the products produced in Iraq require less water, we observe a significant drop in the quantity produced by the farmers who have experienced one of the three climate-related shocks compared to those who have experienced shocks not related to climate. We find an insignificant impact of droughts on date palms, showing that these are water-resistant. On the other hand, we find that water quality has a significant adverse effect on the number of dates produced. Droughts caused by rising temperature and drop in precipitation, rainfall and snowfall, and the water management practices ranging from irrigation projects, water consumption and dams in Turkey and Iraq; are some of the potential causes of poor water quality.

Thus, in the case of drought, we find a reduction in the production of cereals by around 15 per cent, an 18 per cent reduction in the production of vegetables, a reduction in the production of fruits and industrial products at 22 and 16 per cent respectively. Regarding the agricultural and drinking water quality, the reduction in fruits, cereals and industrial production, between 5 and 10 per cent, and the reduction in vegetables production reaches roughly 13.5 per cent. We find a lower impact on the production of date palms at 3.5 per cent. Regarding the remaining agricultural products, we find a 4-5 per cent decline in the quantity produced because of a reduction in the availability of grazing areas, except for the date palms where we find no impact (George et al., 2013; Willer et al., 2018).

While the number of date palms is reduced significantly since the war in 2003, water quality has also harmed the production growth, which is related to a reduction in water inflows and increased salinity, because of the increasing impact of climate change and the construction of dams in neighbouring countries (Tripler, 2011; Zabar and Borowy, 2012; Khierallah et al., 2015; Asrey et al., 2018; FAO and WHO, 2019).

The analysis could also focus on livestock production, as water quality and grazing areas can affect the production in terms of quantity or weight and quality. More specifically, droughts and availability of water resources and grazing areas may have a detrimental impact on crop and livestock farming systems, including the production and availability of fodder and feed, animal productivity and farmer well-being.

However, the study has various drawbacks. The first major drawback is the structure of the dataset and surveys employed in the empirical work. In particular, we used the IHSES in 2012 and the 2017 Rapid Welfare Monitoring Survey, both cross-sectional datasets, implying that we cannot apply panel data models, such as fixed effects to control for heterogeneity and unobservable characteristics. Moreover, we cannot examine the potential dynamics of the climate change shocks and their impact on various outcomes. In line with this, we have used the surveys separately, and thus, we have not pooled the data since both climate change-related shocks and outcome variables were different. Nevertheless, climate change is a long-term process implying that we do not investigate the short variation, such as a daily variation on temperature or rainfall but we consider yearly averages since climate change is measured in this way.

The second drawback refers to the invasion by the Islamic State of Iraq and Syria (ISIS) in Iraq in 2014, and this issue is related to the 2017 analysis. This invasion started with the attack in Mosul and Tikrit of Kirkuk. In particular, the invasion of ISIS probably has created problems in the water supply system by controlling the dam in Tigris River in Mosul of Kirkuk (Strategic Foresight Group, 2014). However, even though ISIS had control of the water supply of the Tigris River, the findings show that respondents located in Southeastern Iraq, in governorates far away from the dams in Kirkuk or the dams in Syria and Turkey, are more likely to experience droughts and climate change-related shocks.

The third drawback is that the analysis considers the role of Syria as an upstream country related to Iraq since the Euphrates River, which originated from Turkey, flows in Iraq through Syria. However, the civil war in Syria could have potentially created additional stress on the water supply. We should recall that we determine our instrument using the population. However, many Syrians were displaced within the country and migrated to Turkey, Lebanon, Iraq, Jordan and Egypt after 2012. Also, Syria has built only two large dams in the Euphrates River, while Turkey and Iraq operate a significantly larger number of dams. Nevertheless, the results remain robust, excluding the instrumental variables in Syria since there are only two dams in the country, while the dams in Turkey and Iraq have a more significant role in the climate change shocks. Another drawback refers to the inclusion of meteorological and climatic conditions. In particular, while we employed temperature and precipitation among others, we could have used the SPEI or the PDSI, discussed in the methodology section.

6. Conclusions

In this study, we investigated the impact of climate change-related shocks, such as water quality and availability, droughts, availability of grazing areas and forced displacement on various outcomes, including income, assets, food stock and production and satisfaction with the overall household's economic situation. Using the capacity of dams and the population of provinces in Turkey and governorates in Iraq, we have attempted to establish a causal inference and highlight the importance of the climate change shocks on income, assets, agricultural production and the overall household economic situation.

The findings show that two components are critical for the impact of climate change shocks on the households' economic situation. The first finding highlights the role of whether the households in Iraq are located in governorates receiving water from Tigris or Euphrates. More specifically, Tigris flows from Turkey to Iraq, while the Euphrates flows from Turkey to Iraq through Syria placing Iraq as a country in a lower part of the stream. Thus, the findings show the importance of the number of riparian countries sharing a water basin area since 54 per cent of the Tigris basin lies in Iraq, while the respective percentage of the Euphrates basin is 40 per cent in Iraq and 17 per cent in the Syrian Arab Republic (FAO, 2009). The second component is the role of dams in the climatic shocks as we have investigated, which is related to the river those dams are built. As we mentioned above, Euphrates flows from Turkey to Iraq through Syria where a larger number of dams is built in those three countries. Thus, this indicates that the climatic shocks and their impact on the economic situation of households in Iraq depend on whether they receive water from Tigris or Euphrates whose water availability and quality is further determined by the number of riparian countries, which countries are upstream or downstream and the number and capacity of the dams built.

In 1926, Iraq, Syria, and Turkey signed their first agreement, however, Turkey did not follow through on its promises at the time. As we mentioned earlier, the United Nations General Assembly ratified the convention on the Law of Non-Navigational Uses of International Watercourses in 1997, which came into force on August 17, 2014. The convention urged countries to work together and create mutually beneficial agreements. However, certain nations, like Turkey, one of the major countries in our analysis, continue to oppose the convention, even though Iraq and the Syrian Arab Republic have ratified it (Al-Muqdadi et al., 2016). As a result, one of the most critical steps in international coordination and cooperation required to solve the water supply and quality issues, droughts, and climate change is for all countries affected by the Euphrates-Tigris Basin, both upstream and downstream, to sign and join the agreement.

In the existing state of affairs in the region, the main task is to coordinate water resource management and promote transboundary water cooperation. Overarching political issues, such as the Syrian civil war and the degradation of bilateral political relations between any pair of riparian countries, create an unfavourable political backdrop for the implementation of an effective and equitable water policy in the Euphrates-Tigris river basin. The basin has long struggled with a lack of coordination in transboundary water management. That is, an examination of national water policy and management reveals that riparian countries have created complex national water management systems, with institutional and legal inconsistencies. As a result, the institutional ability of riparian countries and the adequate water policy coordination will be critical to the successful implementation of water protocols and treaties.

Furthermore, with the long-standing internal upheaval in Syria and Iraq's recovery from two decades of sanctions and war, the water resource management skills are significantly diminished in both countries (Michel et al. 2012). The water policy in Turkey, on the other hand, has been evolving since the early 1990s, resulting in a more complicated legislative and organizational structure and only partial success in the preservation of water resources and public engagement in the water policy-making process (Kibaroglu, 2019).

Overall, while both Turkey and Syria are very likely to experience a significant decrease in the annual surface runoff due to climate change, such as rising temperature, drop in rainfall and snowfall, Iraq is likely to suffer considerably more, given the fact that it is a downstream country, and the water supply relies mainly on Turkey. Significant changes in the hydro-climate of the basin are likely to increase the challenges associated with the management of multiple dam reservoirs and hydroelectric plants, as well as the physical and biological components of the ecosystems along these rivers. These challenges will further adversely affect agriculture, water supply, economy and increase deprivation and poverty.

The lack of a trilateral agreement makes it difficult to address the ET basin's significant environmental concerns collectively. Scholars have pointed out that the environmental repercussions of irrigation plan that have resulted in salinity and pollution through chemicals and are likely to have, larger and more direct effects on the basin's population than a reduction in water quantity (Kibaroglu, 2019; Topcu et al., 2019). Given the importance of agriculture in Iraq, Turkey, and Syria, the degradation of water and soil would put further strain on local populations (Lorenz and Erikson, 2013). In addition to these environmental consequences, the UN anticipates significant temperature increases in these countries by the end of the century, ranging between 2 to 3 degrees Celsius, reducing by then the Euphrates flow by 30 per cent and the Tigris flow by 60 per cent (Lorenz and Erikson, 2013). This will have even more significant adverse effects on the agriculture and water supply and quality in Iraq as a downstream country. The results and the location of those countries highlight the policy implications for the economy and welfare of Iraq.

The research has focused on the impact of dams through climatic shocks on the economic situation of Iraqi households but not on the social and economic welfare of households in other riparian countries. In particular, Syria is a downstream riparian country with a significant share of the Tigris river, while Iran is the country at the lowest part of the stream of both rivers. More specifically, the two rivers are crossing in the eastern part of Iraq, and then the water flows in the Persian Gulf. Moreover, as we have discussed in a previous section, the Euphrates-Tigris basin spans less than 2 per cent of the area in Saudi Arabia and only 0.03 per cent in Jordan. Nevertheless, future studies may explore the impact of climate shocks and dams on the economic situation of households in Syria and Iran. However, there are no surveys available recording detailed household information in Iran and Syria as the IHSES employed in this study.

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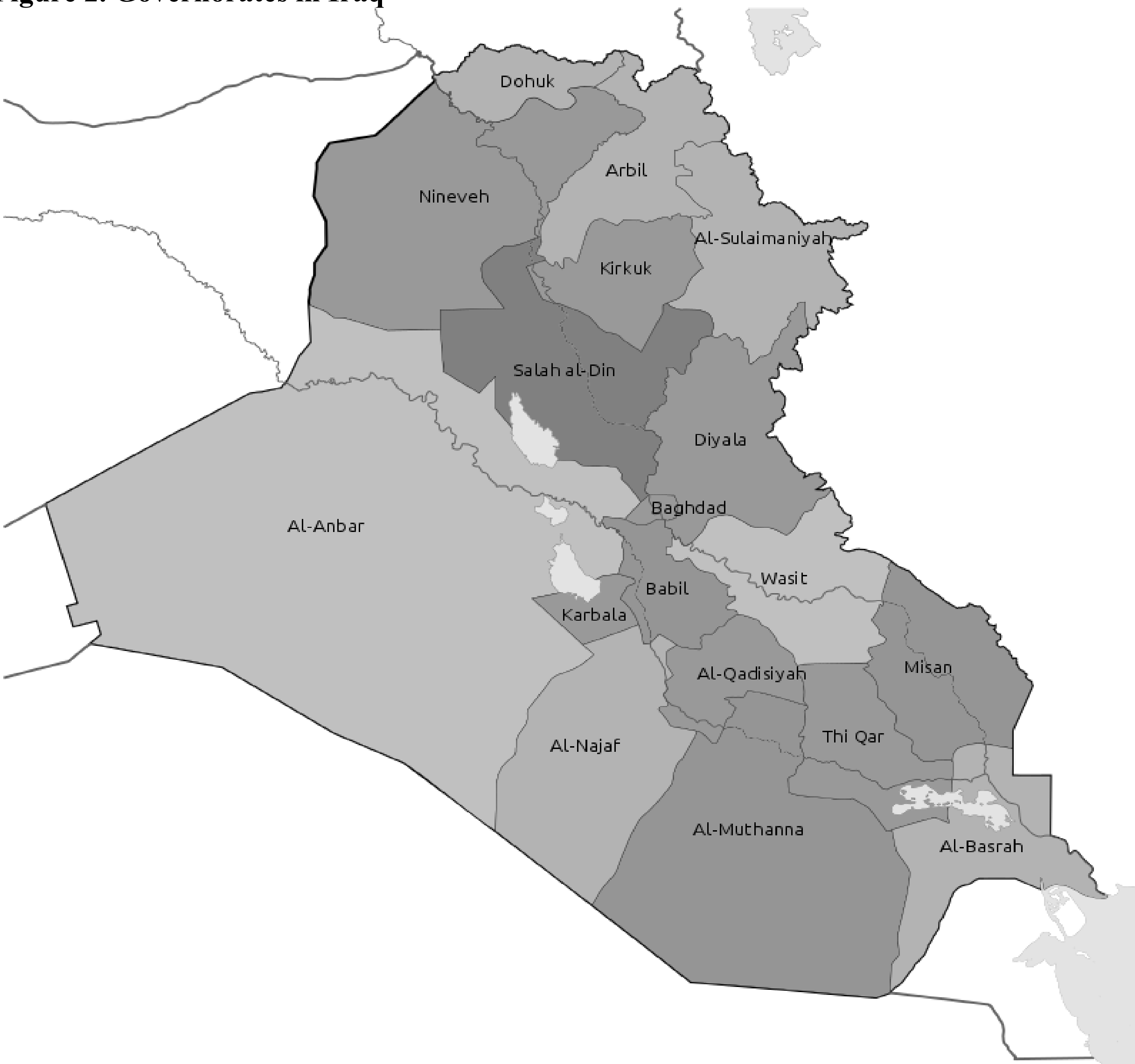
Figure 1. The Euphrates-Tigris Water Basin

Source: https://www.savethetigris.org/water-and-its-infrastructure-are-not-weapons-of-war-protect-civilians-right-to-water-in-iraq/

Figure 2. Governorates in Iraq



Source: https://ethnicgeography.wordpress.com/tag/iraqi-kurdistan

Table 1. Large dams in the Euphrates-Tigris river basin

Name of Dam	Nearest City	Year	Height (m)	Capacity (million in m^3)	Main Use
Panel A: Turkey					
Keban	Elazig	1975	210	31,000	H, F
Karakaya	Diyarbakir	1987	173	9,580	H
Atatürk	Sanliurfa	1992	169	48,700	I, H
Ozluce	Bingol	2000	144	1,075	H
Kralkizi	Diyarbakir	1997	126	1,919	H
Kuzgun	Erzurum	1996	110	312	I, H
Dicle	Diyarbakir	1997	87	595	I, H, W
Batman	Batman	1999	85	1,175	I, H, F
Erzincan	Erzincan	1997	81	8	I
Zernek	Van	1988	80	104	I, H
Kockopru	Van	1992	74	86	I, H, F
Kayalikoy	Kirklareli	1986	72	150	I
Demirdoven	Erzurum	1996	67	34	I
Tercan	Erzincan	1988	65	178	I, H
Birecik	Sanliurfa	2000	63	1,220	I, H
Sarimehmet	Van	1991	62	134	I
Sultansuyu	Malatya	1992	60	53	I
Mursal	Sivas	1992	59	15	I, H
Surgu	Malatya	1969	55	71	I
Polat	Malatya	1990	54	12	I
Goksu	Diyarbakir	1991	52	62	I
Kayacik	Gaziantep	2002	50	117	I
Hancagiz	Gaziantep	1989	45	100	I
Camgazi	Adiyaman	1999	45	56	I
Medik	Malatya	1975	43	22	I
Hacihidir	Sanliurfa	1989	42	68	I
K. Kalecik	Elazig	1974	39	13	I
Gayt	Bingol	1998	36	23	I
Devegecidi	Diyarbakir	1972	33	202	I
Dumluca	Mardin	1991	30	22	I
Karkamis	Gaziantep	2000	29	157	H
Cip	Elazig	1965	23	7	I
Palandoken	Erzurum	1997	19	1,558	I
Porsuk	Eskişehir	1994	17	770	I
Panel B: Iraq					
Name of Dam	**Nearest City**	**Year**	**Height (m)**	**Capacity (million in m^3)**	**Main Use**
Mosul	Mosul	1983	131	12,500	F, I, H
Darbandikhan Dam	Baqubah	1962	128	3,000	F, I, H
Dokan	Sulaimani	1961	116	6,800	I, H
Al Qadisiyah	Haditha	1984	57	8,200	I, H
Hamrin	Baqubah	1980	40	4,000	F, I, H
Dibbis	Dibbis	1965	15	3,000	I
Samarra - Tharthar	Samarra	1954	65	72,800	F
Panel C: Syrian Arab Republic					
Al Tabka	At Thawrah	1973	60	11,200	I, H
Tishrin	Aleppo	1999	40	1,300	F, I, H

Source: FAO (2009). http://www.fao.org/3/ca2132en/CA2132EN.pdf and Abdullah and Al-Ansari (2021)
Notes: I = irrigation; H = Hydropower, W = water supply; F = Flood protection

Table 2. Proportions of Outcomes by Climate Change Shock Status in 2012

	Did the shock increase or decrease income?	Did the shock increase or decrease assets?	Did the shock increase or decrease food production?	Did the shock increase or decrease food stock?	
Increase	4.09	2.90	2.77	2.51	
Did not change	8.18	39.18	23.48	26.25	
Decrease	87.73	57.92	73.75	71.24	
Satisfaction with Food	**No- Shock**	**Shock**	**Life Satisfaction**	**No- Shock**	**Shock**
Very Satisfied	35.36	44.73	Very Satisfied	20.99	25.48
Fairly Satisfied	45.86	41.16	Fairly Satisfied	53.59	58.03
Not Very Satisfied	12.15	10.86	Not Very Satisfied	21.00	16.17
Not at all Satisfied	6.63	3.25	Not at all Satisfied	4.42	0.32
Kruskal-Wallis Test	6.351 [0.0117]		Kruskal-Wallis Test	2.555 [0.1100]	
How would you assess the household situation	**No- Shock**	**Shock**			
Good	13.56	11.05			
Satisfactory/Middle	59.68	51.93			
Poor	21.96	29.84			
Very Poor	4.80	7.18			
Kruskal-Wallis Test	6.379 [0.0115]				

P-values within brackets

Table 3. Proportions of Outcomes by Climate Change Shock Status in 2017

What is your household's overall situation now?	**No- Shock**	**Shock**	**What is the overall economic situation of your household now compared to before**	**No- Shock**	**Shock**
Very Good	0.92	0.84	Much Better	1.36	1.87
Good	11.16	10.10	Better	14.37	7.43
Regular	54.28	51.50	Same	38.71	14.29
Bad	26.86	28.39	Slightly Worse	30.38	31.19
Very Bad	6.78	9.17	Much Worse	15.18	45.22
Kruskal-Wallis Test	1,457.662 [0.000]		Kruskal-Wallis Test	1,847.629 [0.000]	
What do you think will be the economic situation of the household in the next year	**No- Shock**	**Shock**	**In the past 4 weeks (30 days), did you or any household member have to eat fewer meals in a day because there was not enough food?**	**No- Shock**	**Shock**
Much Better	2.07	2.43	Yes	10.38	25.11
Better	14.77	13.48	No	89.62	74.89
Same	33.42	30.95			
Slightly Worse	13.14	17.03			
Much Worse	4.17	6.15			
Uncertain	32.43	29.96			
Kruskal-Wallis Test	60.642 [0.000]		Kruskal-Wallis Test	272.979 [0.000]	
Has the household recovered economically from the shocks experienced since January 2014		**Did these shocks negatively affect the income or wealth of households?**			
Not recovered at all	61.12	Yes	96.21		
Partially recovered	35.36	No	3.79		
Fully recovered	3.52				

P-values within brackets

Table 4. Summary Statistics for Climate Change Shocks

Panel A: Year 2012			
Climate Change Shocks	**Droughts**	**Agricultural and drinking water quality**	**Reduced availability of grazing areas**
Yes	13.05	10.10	2.92
No	86.95	89.90	97.08
Panel B: Year 2017			
Climate Change Shocks	**Is the water supply sufficient?**	**Forced displacement**	**Interruptions in supply of water**
Yes	31.83	19.75	
No	68.17	80.25	
No interruptions			12.64
Interruption once or less monthly			13.61
Interruption once or less weekly			16.05
Interruption more than once a week			16.79
Daily interruption			40.91

Table 5. Ordered Probit SURE and SURE-IV Estimates for 2012 and Change in Income

SURE	DV: Droughts	DV: Did the shock decrease income?	SURE-IV	DV: Did the shock decrease income?
Drought		4.4818*** (0.4245)	**Drought**	4.8785*** (0.4248)
Treat (1 for Euphrates)	0.0199 (0.0746)		**Weak Instrument Test**	81.45 [0.000]
Average Temperature	0.0343*** (0.0098)		***Atanh ρ* Endogeneity Test**	-0.0517 (0.477)
DTR	0.0564*** (0.0182)		**No. Observations**	173,570
Precipitation	-0.3424*** (0.0851)		**Maximum Likelihood**	-2,816.998
Dew Point	-0.0336*** (0.0132)			
Maximum Wind Speed	0.0103* (0.0059)			
No. Observations	173,570			
Maximum Likelihood	-2,839.904			
SURE	**DV: Water quality**	**DV: Did the shock decrease income?**	**SURE-IV**	**DV: Did the shock decrease income?**
Agricultural and drinking water quality		3.6606*** (0.2945)	**Agricultural and drinking water quality**	4.0097*** (0.3196)
Treat (1 for Euphrates)	0.0993* (0.0582)		**Weak Instrument Test**	34.18 [0.000]
Average Temperature	0.0036 (0.00102)		***Atanh ρ* Endogeneity Test**	0.0272 (0.0418)
DTR	0.0241** (0.0115)		**No. Observations**	173,494
Precipitation	-0.1899*** (0.0601)		**Maximum Likelihood**	-2,620.859
Dew Point	-0.0287** (0.0121)			
Maximum Wind Speed	0.0037 (0.0082)			
No. Observations	173,494			
Maximum Likelihood	-2,638.609			
SURE	**DV: Reduced availability of grazing areas**	**DV: Did the shock decrease income?**	**SURE-IV**	**DV: Did the shock decrease income?**
Reduced availability of grazing areas		2.8779*** (0.1797)	**Reduced availability of grazing areas**	3.2749*** (0.5757)
Treat (1 for Euphrates)	0.2036* (0.1170)		**Weak Instrument Test**	21.17 [0.000]
Average Temperature	0.0230 (0.0173)		***Atanh ρ* Endogeneity Test**	0.0247 (0.0574)
DTR	0.1051** (0.0408)		**No. Observations**	173,279
Precipitation	0.1207 (0.1275)		**Maximum Likelihood**	-1,864.106
Dew Point	0.0185 (0.0218)			
Maximum Wind Speed	-0.0140 (0.0121)			
No. Observations	173,279			
Maximum Likelihood	-1,879.114			

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Table 6. Simultaneous Ordered Probit IV-GMM Estimates for 2012 and Change in Income

Variables	DV: Drought	DV: Did the shock decrease income?	Variables	DV: Water quality	DV: Did the shock decrease income?	Variables	DV: Reduced availability of grazing areas	DV: Did the shock decrease income?
Drought		4.7980*** (0.4178)	**Agricultural and drinking water quality**		4.0011*** (0.2942)	**Reduced availability of grazing areas**		3.2078*** (0.5266)
Treat (1 for Euphrates)	0.0197 (0.0668)		**Treat (1 for Euphrates)**	0.0951* (0.0512)		**Treat (1 for Euphrates)**	0.2043* (0.1158)	
Average Temperature	0.0347*** (0.0065)		**Average Temperature**	0.0038 (0.0077)		**Average Temperature**	0.0225 (0.0147)	
DTR	0.0568*** (0.0125)		**DTR**	0.0245** (0.0121)		**DTR**	0.1049** (0.0408)	
Precipitation	-0.3431*** (0.0606)		**Precipitation**	-0.1902*** (0.0663)		**Precipitation**	0.1207 (0.1531)	
Dew Point	-0.0332*** (0.0099)		**Dew Point**	-0.0279*** (0.0086)		**Dew Point**	0.0188 (0.0220)	
Maximum Wind Speed	0.0104** (0.0051)		**Maximum Wind Speed**	0.0035 (0.0053)		**Maximum Wind Speed**	-0.0134 (0.0097)	
Weak Instrument Test	72.71 [0.000]		**Weak Instrument Test**	38.56 [0.000]		**Weak Instrument Test**	21.45 [0.000]	
Sargan Endogeneity Test	19.163 [0.2064]		**Sargan Endogeneity Test**	7.895 [0.1179]		**Sargan Endogeneity Test**	13.579 [0.5576]	
No. Observations	173,570		**No. Observations**	173,494		**No. Observations**	173,279	
Maximum Likelihood	-2,559.241		**Maximum Likelihood**	-2,264.591		**Maximum Likelihood**	-1,696.535	

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Table 7. Ordered Probit SURE-IV Estimates for 2012 and Change in Income and Assets using the Weighted Distance Instrument

Variables	DV: Droughts	DV: Did the shock decrease income?	Variables	DV: Did the shock decrease assets?
Drought		4.6843*** (0.3574)	**Drought**	4.2367*** (0.3373)
Distance-Dams Iraq	-0.0222** (0.0098)		**Weak Instrument Test**	133.90 [0.000]
Distance-Dams Syria	-0.0354*** (0.0078)		***Atanh ρ* Endogeneity Test**	0.0363 (0.0512)
Distance-Dams Turkey	-0.1945** (0.0853)		**No. Observations**	173,570
Weak Instrument Test	132.34 [0.000]		**Maximum Likelihood**	-2,731.126
***Atanh ρ* Endogeneity Test**	-0.0071 (0.0489)			
No. Observations	173,570			
Maximum Likelihood	-2,796.670			
Variables	**DV: Agricultural and drinking water quality**	**DV: Did the shock decrease income?**	**Variables**	**DV: Did the shock decrease assets?**
Agricultural and drinking water quality		4.0101*** (0.3202)	**Agricultural and drinking water quality**	3.2234*** (0.2995)
Distance-Dams Iraq	-0.0223** (0.0107)		**Weak Instrument Test**	39.71 [0.000]
Distance-Dams Syria	-0.0191*** (0.0078)		***Atanh ρ* Endogeneity Test**	0.0071 (0.0089)
Distance-Dams Turkey	-0.2023** (0.0864)		**No. Observations**	173,494
Weak Instrument Test	38.98 [0.000]		**Maximum Likelihood**	-2,544.173
***Atanh ρ* Endogeneity Test**	0.0011 (0.0246)			
No. Observations	173,494			
Maximum Likelihood	-2,614.079			
Variables	**DV: Reduced availability of grazing areas**	**DV: Did the shock decrease income?**	**Variables**	**DV: Did the shock decrease assets?**
Reduced availability of grazing areas		3.1779*** (0.2780)	**Reduced availability of grazing areas**	2.8681*** (0.2988)
Distance-Dams Iraq	-0.0405** (0.0192)		**Weak Instrument Test**	29.23 [0.000]
Distance-Dams Syria	-0.0383** (0.0188)		***Atanh ρ* Endogeneity Test**	0.0189 (0.0319)
Distance-Dams Turkey	-0.1768** (0.0816)		**No. Observations**	173,279
Weak Instrument Test	28.16 [0.000]		**Maximum Likelihood**	-1,776.821
***Atanh ρ* Endogeneity Test**	0.0220 (0.0292)			
No. Observations	173,279			
Maximum Likelihood	-1,860.281			

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. *** and ** indicate significance at the 1% and 5% level

Table 8. Ordered Probit SURE-IV Estimates for 2012 and the Remaining outcomes using the Weighted Distance Instrument

Variables	DV: Did the shock decrease food production?	DV: Did the shock decrease food stock?	DV: Life Satisfaction	DV: Food Satisfaction	DV: Household Situation
Drought	4.6521***	4.4901***	1.6914**	0.0938*	1.1844***
	(0.5520)	(0.5299)	(0.7835)	(0.0548)	(0.4196)
Weak Instrument Test	140.55	133.28	150.10	143.85	181.19
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	-0.0201	0.0026	0.0475	0.0269	0.5209
	(0.0304)	(0.0314)	(0.1199)	(0.0698)	(0.4423)
No. Observations	173,570	173,570	168,657	168,657	168,657
Maximum Likelihood	-2,722.375	-2,736.288	-55,358.492	-53,590.446	-52,852.975
Variables	**DV: Did the shock decrease food production?**	**DV: Did the shock decrease food stock?**	**DV: Life Satisfaction**	**DV: Food Satisfaction**	**DV: Household Situation**
Agricultural and drinking water quality	3.9003***	3.7819***	0.2786	1.1704*	1.0562*
	(0.3273)	(0.3337)	(0.1822)	(0.6491)	(0.6226)
Weak Instrument Test	38.15	39.29	39.11	38.17	39.27
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	-0.0069	-0.0165	0.0409	0.0887	0.3636
	(0.0172)	(0.0306)	(0.2844)	(0.2765)	(0.2822)
No. Observations	173,494	173,494	166,533	166,533	166,533
Maximum Likelihood	-2,510.101	-2,487.702	-55,004.521	-53,219.34	-52,492.600
Variables	**DV: Did the shock decrease food production?**	**DV: Did the shock decrease food stock?**	**DV: Life Satisfaction**	**DV: Food Satisfaction**	**DV: Household Situation**
Reduced availability of grazing areas	4.3078***	4.6513***	1.8877**	1.3427***	0.6808
	(0.3406)	(0.5351)	(0.9147)	(0.4732)	(1.2671)
Weak Instrument Test	33.16	29.17	32.89	33.13	31.72
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	-0.0092	-0.0142	-0.6354	0.4188	0.2244
	(0.0353)	(0.0458)	(0.5492)	(0.3761)	(0.4179)
No. Observations	173,279	173,279	162,373	162,373	162,373
Maximum Likelihood	-1,810.607	-1,740.580	-53,573.562	-51,789.261	-51,066.231

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Table 9. Ordered Probit SURE and SURE-IV Estimates for 2017 and Current Household Overall Situation

SURE	DV: Water Supply sufficiency	DV: Current household overall situation	SURE-IV	DV: Current household overall situation
Water Supply Sufficiency		0.1824*** (0.0125)	**Water Supply Sufficiency**	0.3457*** (0.0578)
Treat (1 for Euphrates)	0.7085*** (0.0185)		**Weak Instrument Test**	1,476.38 [0.000]
Average Temperature	0.0342*** (0.0038)		***Atanh ρ* Endogeneity Test**	-0.0352 (0.1008)
DTR	0.0269** (0.0127)		**No. Observations**	48,389
Precipitation	-0.2098** (0.0819)		**Maximum Likelihood**	-80,370.425
Dew Point	-0.0642*** (0.0133)			
Maximum Wind Speed	0.0485*** (0.0012)			
No. Observations	48,389			
Maximum Likelihood	-80,374.562			
SURE	**DV: Interruptions in supply of water**	**DV: Current household overall situation**	**SURE-IV**	**DV: Current household overall situation**
Interruptions in supply of water		0.1092*** (0.0053)	**Interruptions in supply of water**	0.2662*** (0.0174)
Treat (1 for Euphrates)	0.9485*** (0.0151)		**Weak Instrument Test**	1,328.40 [0.000]
Average Temperature	0.2984*** (0.0032)		***Atanh ρ* Endogeneity Test**	-0.2286 (0.2054)
DTR	0.1171*** (0.0021)		**No. Observations**	48,389
Precipitation	-0.7392*** (0.0665)		**Maximum Likelihood**	-114,658.612
Dew Point	-0.0032* (0.0018)			
Maximum Wind Speed	0.0228*** (0.0009)			
No. Observations	48,389			
Maximum Likelihood	-114,696.434			
SURE	**DV: Forced displacement**	**DV: Current household overall situation**	**SURE-IV**	**DV: Current household overall situation**
Forced displacement		0.5711*** (0.0166)	**Forced displacement**	0.1944*** (0.0508)
Treat (1 for Euphrates)	0.8993*** (0.0207)		**Weak Instrument Test**	1,935.60 [0.000]
Average Temperature	0.1902*** (0.0034)		***Atanh ρ* Endogeneity Test**	0.3298*** (0.0287)
DTR	0.0123*** (0.0025)		**No. Observations**	52,597
Precipitation	-0.6646*** (0.0726)		**Maximum Likelihood**	-80,701.745
Dew Point	-0.0642*** (0.0133)			
Maximum Wind Speed	0.0678*** (0.0016)			
No. Observations	52,597			
Maximum Likelihood	-80,758.218			

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Table 10. Ordered Probit SURE-IV Estimates for 2017 and Current Household Overall Situation using the Weighted Distance Instrument

Variables	DV: Water Supply sufficiency	DV: Current household overall situation	Variables	DV: Household overall situation compared to before
Water Supply Sufficiency		0.2014** (0.0966)	Water Supply Sufficiency	0.4741*** (0.0436)
Distance-Dams Iraq	-0.0249*** (0.0051)		Weak Instrument Test	1,773.19 [0.000]
Distance-Dams Syria	-0.3072*** (0.0382)		*Atanh ρ* Endogeneity Test	-0.3231 (0.2352)
Distance-Dams Turkey	-1.4829*** (0.2128)		No. Observations	48,389
Weak Instrument Test	1,551.18 [0.000]		Maximum Likelihood	-89041.313
Atanh ρ Endogeneity Test	0.0504 (0.1727)			
No. Observations	48,389			
Maximum Likelihood	-81,895.139			
Variables	**DV: Interruptions in supply of water**	**DV: Current household overall situation**	**Variables**	**DV: Household overall situation compared to before**
Interruptions in supply of water		0.2507*** (0.0520)	Interruptions in supply of water	0.3140*** (0.0231)
Distance-Dams Iraq	-0.0061* (0.0035)		Weak Instrument Test	8,114.60 [0.000]
Distance-Dams Syria	-0.1605*** (0.0319)		*Atanh ρ* Endogeneity Test	0.4238 (0.3742)
Distance-Dams Turkey	-0.2778*** (0.0208)		No. Observations	48,389
Weak Instrument Test	7,840.48 [0.000]		Maximum Likelihood	-120363.476
Atanh ρ Endogeneity Test	-0.2009 (0.1651)			
No. Observations	48,389			
Maximum Likelihood	-113,045.330			
Variables	**DV: Forced displacement**	**DV: Current household overall situation**	**Variables**	**DV: Household overall situation compared to before**
Forced displacement		0.1421*** (0.0524)	Forced displacement	0.1036* (0.0573)
Distance-Dams Iraq	-0.1497*** (0.0057)		Weak Instrument Test	8,497.06 [0.000]
Distance-Dams Syria	-0.4641*** (0.0530)		*Atanh ρ* Endogeneity Test	-0.1426*** (0.0191)
Distance-Dams Turkey	-0.6572*** (0.0351)		No. Observations	52,597
Weak Instrument Test	8,902.35 [0.000]		Maximum Likelihood	-84,653.714
Atanh ρ Endogeneity Test	0.3556*** (0.1214)			
No. Observations	52,597			
Maximum Likelihood	-76,038.471			

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Table 11. Ordered Probit SURE-IV Estimates for 2017 and the Remaining outcomes using the Weighted Distance Instrument

Variables	DV: Future household overall situation	DV: Not enough food (Yes)	DV: Has the household recovered economically	DV: Did these shocks negatively affect the income or wealth of households (Yes)
Water Supply sufficiency	0.5078***	0.3590***	-0.6607***	0.2975**
	(0.0582)	(0.1161)	(0.1038)	(0.1282)
Weak Instrument Test	1,552.39	1,747.08	1,540.81	1,259.29
	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	0.3888	-0.0151	-0.6436	0.0149
	(0.4814)	(0.0349)	(0.5664)	(0.0683)
No. Observations	48,389	48,389	48,389	48,389
Maximum Likelihood	-96,671.877	-37,426.466	-47,814.46	-38,400.556
Variables	**DV: Future household overall situation**	**DV: Not enough food**	**DV: Has the household recovered economically**	**DV: Did these shocks negatively affect the income or wealth of households**
Interruptions in supply of water	0.0412**	0.1980***	-0.3430***	0.0937***
	(0.0202)	(0.0571)	(0.0343)	(0.0362)
Weak Instrument Test	8,456.65	7,810.67	8,154.15	6,648.13
	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	0.0181	-0.3534	0.4565	0.0686
	(0.0458)	(0.3918)	(0.3805)	(0.0491)
No. Observations	48,389	48,389	48,389	48,389
Maximum Likelihood	-128,099.01	-71,437.472	-79,133.075	-69,650.298
Variables	**DV: Future household overall situation**	**DV: Not enough food**	**DV: Has the household recovered economically**	**DV: Did these shocks negatively affect the income or wealth of households**
Forced displacement	0.1864*	0.1798*	-0.0528	0.6212***
	(0.1094)	(0.0934)	(0.0699)	(0.1526)
Weak Instrument Test	9,321.49	8,824.82	8,815.27	8,249.32
	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	-0.0619	0.5905***	-0.2435*	0.0939
	(0.1922)	(0.1314)	(0.1360)	(0.0650)
No. Observations	52,597	52,597	52,597	52,597
Maximum Likelihood	-92,969.084	-36,038.471	-39,469.081	-30,236.713

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Table 12. SURE-IV Estimates for 2012 and Agricultural Production using the Weighted Distance Instrument

Variables	Cereals	Fruits	Vegetables	Dates	Industrial Products
Drought	-0.1621***	-0.3352***	-0.1992**	0.0268	-0.1823**
	(0.0219)	(0.0262)	(0.0852)	(0.0202)	(0.0828)
Weak Instrument Test	115.55	113.32	115.44	115.48	113.65
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	0.2800	0.3449	-0.0864	-0.2403	0.6834
	(0.2472)	(0.2772)	(0.1905)	(0.2756)	(0.5791)
No. Observations	18,766	7,742	12,136	3,269	753
Maximum Likelihood	-1,666.437	-1,133.476	-1,4037.727	-798.079	-331.499
Variables	**Cereals**	**Fruits**	**Vegetables**	**Dates**	**Industrial Products**
Agricultural and drinking water quality	-0.0796***	-0.0659**	-0.1509***	-0.0483*	-0.0976**
	(0.0247)	(0.0318)	(0.0362)	(0.0251)	(0.0419)
Weak Instrument Test	36.90	36.84	36.88	36.11	35.74
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	0.2221	-0.1432	-0.0457	0.2159	-0.5845
	(0.3163)	(0.2195)	(0.2093)	(0.7367)	(0.6237)
No. Observations	18,762	7,853	12,285	3,303	751
Maximum Likelihood	-1,514.887	-1,356.863	-1,346.608	-896.919	-362.804
Variables	**Cereals**	**Fruits**	**Vegetables**	**Dates**	**Industrial Products**
Reduced availability of grazing areas	-0.3997	-0.0524**	-0.0525***	0.1927	-0.0487***
	(0.3138)	(0.0248)	(0.0041)	(0.1636)	(0.0125)
Weak Instrument Test	28.25	27.63	27.69	27.70	27.72
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
***Atanh ρ* Endogeneity Test**	-0.2325	0.3355	0.2156	-0.1700	0.1018
	(0.2052)	(0.2823)	(0.3923)	(0.6164)	(0.3357)
No. Observations	18,637	7,790	12,137	3,275	749
Maximum Likelihood	-1,324.343	-1,065.024	-1,294.318	-828.155	-354.522

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

Appendix: Additional Estimates

In Table A1, we report the estimates for the control variables derived from the ordered Probit SURE-IV in Tables 7-8. We explore only the LSMS of 2012 as the concluding remarks using the 2017 survey remain similar. Furthermore, we consider only the droughts since we get the same estimates when we consider the water quality and the availability of grazing areas. Since the main scope of the study is to explore the impact of climate change-related shocks on various welfare outcomes, we report the findings for the control variables in Table A1. Based on the estimates, there is no difference in the self-reported outcomes between males and females except for the food production and household situation, where we find females are more likely to report higher levels of food satisfaction and a better household economic situation. To recall, a negative sign in all regressions implies a better economic welfare status. More specifically, in the first four outcomes, which are change in income, assets, food production and food stock, a negative sign implies a higher probability of an increase in those outcomes.

As we have shown in Table 2, the outcomes are ordered variables taking three values; increase, the same and decrease. The same applies to life and food satisfaction, where a negative sign shows that the respondents are more satisfied with the life or food. Based on the household economic situation regression, we observe that women are more likely to report a better economic situation. While the differences are unclear, and since it is out of the study's main scope, we could assume those female respondents are household heads or earn more. However, this is a strong assumption, which cannot be supported by our estimates. Similarly, we find that age is positively related to food and life satisfaction, and with the perception about the household situation. We should notice that a quadratic relationship between age and the outcomes explored may be present, such as the relationship between life satisfaction and age (Giovanis and Ozdamar, 2016), but we do not further examine this. Moreover, the inclusion of age in higher polynomial terms does not changes our results and main concluding remarks.

Regarding the education level, we find those with higher educational attainment are less likely to report a decrease in income or assets, while there is no difference among the other educational attainment levels. Interestingly, we find a non-monotonic relationship between education and satisfaction outcomes, as well as with the household economic situation. In particular, we find that those with no education qualification certificate and primary school education report lower levels of life and food satisfaction and lower levels of the household economic situation shown by the positive sign. The sign becomes negative for those who have completed secondary school, but the coefficient is significant, while it becomes significant for the high school and the higher reduction graduates showing a positive relationship between satisfaction, economic situation and the particular education qualifications. In most of the cases, there is no difference between the respondents with different marital statuses. On the other hand, we find that divorced and widowed are less satisfied with the food and life, while there is no difference between singles and married. The same holds when we explore the household economic situation. However, in this case, single respondents report a better household economic situation. This finding is also supported by the estimated positive coefficient of the household size, indicating that households with a large number of family members are less satisfied with food and life, report lower levels of the economic situation, and are more likely to experience a decline in income, assets, food production and stock.

Those who work report higher levels of life and food satisfaction and economic situation. We should notice that the reference category are the non-employed respondents, but this does not imply are unemployed. More specifically, this category includes those who do not participate in the labour market or labour force, such as students, housekeepers, disabled and retired. We find no differences across the type of household unit, except for the satisfaction with life and food and the economic situation, where those living in a house report higher levels of well-being compared to those living in clay houses and flats. Finally, we include the area, and we observe that those living in urban areas report higher levels of satisfaction and economic situation, highlighting the potential inequalities between rural and urban regions. Overall the results confirm the findings from previous studies, especially regarding food and life satisfaction (Alesina et al., 2004; Blanchflower and Oswald, 2004; Deaton, 2008; Giovanis and Ozdamar, 2016).

Table A1. Ordered Probit SURE Second Stage Regressions for 2012 and Droughts

	DV: Did the shock decrease income?	DV: Did the shock decrease assets?	DV: Did the shock decrease food production?	DV: Did the shock decrease food stock?	DV: Life Satisfaction	DV: Food Satisfaction	DV: Household Situation
Gender (Female)	0.0780 (0.1342)	0.0524 (0.1401)	-0.0370 (0.1424)	0.0721 (0.1282)	0.0065 (0.0179)	-0.1232*** (0.0186)	-0.1528*** (0.0180)
Age	0.0035 (0.0058)	0.0049 (0.0063)	0.0040 (0.0062)	0.0046 (0.0055)	-0.0030*** (0.0005)	-0.0029*** (0.0005)	-0.0067*** (0.0005)
Education Level (Reference Category-Illiterate)							
No illiterate but no certificate	-0.3570 (0.2586)	-0.3604 (0.2527)	-0.4130 (0.2687)	-0.2853 (0.2484)	0.1657*** (0.0434)	0.1575*** (0.0451)	0.4224*** (0.0437)
Primary School	-0.2238 (0.1862)	-0.3110 (0.2618)	-0.2813 (0.2778)	-0.2028 (0.2574)	0.0744* (0.0434)	0.0914** (0.0449)	0.2411*** (0.0436)
Secondary School	-0.2634 (0.2455)	-0.3101 (0.3585)	-0.5819 (0.3659)	-0.3540 (0.3294)	-0.0107 (0.0464)	-0.0019 (0.0048)	-0.0269 (0.0467)
High School	-0.1790 (0.1281)	-0.3841 (0.2903)	-0.6221* (0.3221)	-0.2090 (0.4006)	-0.1180** (0.0491)	-0.1405*** (0.0508)	-0.1229** (0.0493)
Higher Education	-0.2378** (0.1060)	-0.2998** (0.1277)	-0.4604** (0.2215)	-0.0646 (0.3293)	-0.1802*** (0.0455)	-0.2763*** (0.0473)	-0.4710*** (0.0459)
Marital Status (Reference Category-Married)							
Single	0.1451 (0.1790)	0.2888 (0.1880)	0.2602 (0.1882)	0.1267 (0.1715)	0.0041 (0.0178)	0.0156 (0.0183)	-0.0585*** (0.0179)
Divorced-Separated	0.0940 (0.1193)	0.1368 (0.2921)	0.2058 (0.7981)	0.0581 (0.7142)	0.2882*** (0.0561)	0.2905*** (0.0567)	0.3313*** (0.0569)
Widowed	0.1633 (0.4495)	-0.0382 (0.1271)	0.4252 (0.4623)	0.2462 (0.3998)	0.0841** (0.0359)	0.0998*** (0.0365)	0.2597*** (0.0361)
Employed (Yes)	-1.0755*** (0.3025)	-0.9419** (0.4471)	-1.3188*** (0.3076)	-1.3188*** (0.3076)	-0.2828*** (0.0563)	-0.1930*** (0.0472)	-0.4270*** (0.0556)
Household Size	0.0240** (0.0113)	0.0127 (0.0133)	0.0192* (0.0108)	0.0192* (0.0108)	0.0089** (0.0015)	0.0089** (0.0042)	0.0263*** (0.0015)
Type of Household Unit (Reference Category-House)							
Flat	0.0795 (0.5412)	0.1006 (0.4117)	0.0465 (0.1015)	0.0827 (0.5117)	0.0401 (0.0380)	0.1929*** (0.0487)	0.1929*** (0.0487)
Clay House	0.0137 (0.1826)	0.1835 (0.1754)	0.0909 (0.1780)	0.2020 (0.1578)	0.2045*** (0.0232)	0.3620*** (0.0231)	0.3620*** (0.0231)
Area (Urban)	0.1395 (0.1234)	0.0791 (0.1342)	-0.0676 (0.1327)	0.0108 (0.0119)	-0.0294** (0.0126)	-0.1169*** (0.0129)	-0.0591*** (0.0127)
No. Observations	173,570	173,570	173,570	173,570	168,657	168,657	168,657
Maximum Likelihood	-2,796.670	-2,731.126	-2,722.375	-2,736.288	-55,358.492	-53,590.446	-52,852.975

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

In Table A2 we report the ordered Probit regression (2) including the treat variable. More specifically, as a robustness check we estimate only regression (2) using ordered Probit aiming to explore the potential differences in the economic and well-being outcomes explored between those located in governorates receiving water from Euphrates and those from Tigris. Hence, we repeat the estimates of the regression (2) in Table 5. The results show that there is no difference in income and food stock between those two groups but we find a positive and significant coefficient in the assets and food production regressions. This finding shows that households receiving water from Euphrates are more likely to report a decrease in assets and food production. Furthermore, we find a large and significant negative relationship between the households supplied with water from Euphrates and their life and food satisfaction, and the overall household economic situation. Therefore, based on the discussion in the methodology section, we conclude that Euphrates water supply is potentially reduced since in flows from Turkey to Iraq through Syria and a large number of dams is built in all three countries. On the other hand, a lower number of dams is present in the Tigris river, while it flows directly from Turkey to Iraq. We should notice that we report only the estimates for the drought to check the results when we use the treat in the second regression.

Table A2. Ordered Probit SURE for 2012 and Droughts using Variable Treat

	DV: Did the shock decrease income?	DV: Did the shock decrease assets?	DV: Did the shock decrease food production?	DV: Did the shock decrease food stock?	DV: Life Satisfaction	DV: Food Satisfaction	DV: Household Situation
Drought	4.5437***	4.1398***	4.4254***	4.3601***	1.4076**	0.1050*	0.5278**
	(0.4244)	(0.3015)	(0.3835)	(0.3852)	(0.6737)	(0.0579)	(0.2162)
Treat (1 for Euphrates)	0.0587	0.6747**	0.2749*	0.2066	1.3797***	1.2797***	1.0253**
	(0.0590)	(0.2851)	(0.1467)	(0.1692)	(0.1387)	(0.2085)	(0.4110)
No. Observations	173,570	173,570	173,570	173,570	168,657	168,657	168,657
Maximum Likelihood	-1,247.194	-1,426.947	-1,410.692	-1,417.739	-51,968.144	-50,649.548	-50,752.702

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level

The second set of robustness checks involves the setting of the treat variable. In particular, as we have discussed in the man text, households in two governorates Baghdad and Al-Basrah receive water from both rivers. In our initial setting and the estimates in Tables 5-6 and 9 we have assigned the households in the governorate of Baghdad in Tigris group and those located in Al-Basrah in the Euphrates river. In panel A of Table A3, we replicate the SURE-IV estimates of Table 5 by assigning the households in Baghdad in the treat group of Euphrates that was before assigned to Tigris river. Similarly, we assign the governorate Al-Basrah to Tigris which before was assigned to Euphrates. In panel B, we report the estimates by excluding the households in governorates of Al-Basrah and Baghdad. The estimates in Table A3 confirm the robustness checks and in particular, the estimated coefficient of climate change-related shocks. We should notice that we have repeated also the regressions in Table 5 by assigning the households in both governorates Al-

Basrah and Baghdad in the group of the Euphrates river and another set of estimates that assign the governorates of Al-Basrah and Baghdad in the Tigris river.

Table A3. Ordered Probit SURE-IV Estimates for 2012 and Change in Income

Panel A: Assigning Baghdad to Euphrates and Al-Basrah to Tigris		
	DV: Droughts	**DV: Did the shock decrease income?**
Drought		4.7811*** (0.4274)
Treat (1 for Euphrates)	0.0204 (0.0273)	
Average Temperature	0.0312*** (0.0071)	
DTR	0.0534*** (0.0139)	
Precipitation	0.3929*** (0.1465)	
Dew Point	-0.0396** (0.0182)	
Maximum Wind Speed	0.0107* (0.0058)	
Weak Instrument Test	220.94 [0.000]	
***Atanh ρ* Endogeneity Test**	-0.0060 (0.0149)	
No. Observations	173,570	
Maximum Likelihood	-2,814.260	
	DV: Water quality	**DV: Did the shock decrease income?**
Agricultural and drinking water quality		4.0095*** (0.3219)
Treat (1 for Euphrates)	0.1081* (0.0579)	
Average Temperature	0.0054 (0.0177)	
DTR	0.0252** (0.0118)	
Precipitation	-0.1880*** (0.0637)	
Dew Point	-0.0269** (0.0123)	
Maximum Wind Speed	0.0035 (0.0087)	
***Atanh ρ* Endogeneity Test**	31.84 [0.000]	
No. Observations	0.0035 (0.0140)	
No. Observations	173,494	
Maximum Likelihood	-2,620.366	
SURE	**DV: Reduced availability of grazing areas**	**DV: Did the shock decrease income?**
Reduced availability of grazing areas		3.2321*** (0.5747)
Treat (1 for Euphrates)	0.2944** (0.1362)	
Average Temperature	0.0346* (0.0183)	
DTR	0.0969** (0.0381)	
Precipitation	0.1384 (0.1341)	
Dew Point	0.0162 (0.0201)	
Maximum Wind Speed	-0.0165 (0.0154)	
Weak Instrument Test	19.07 [0.000]	
***Atanh ρ* Endogeneity Test**	0.0257 (0.0368)	
No. Observations	173,279	
Maximum Likelihood	-1,862.004	

Table A3 (Cont.) Ordered Probit SURE-IV Estimates for 2012 and Change in Income

Panel B: Excluding households in Baghdad and Al-Basrah

	DV: Droughts	DV: Did the shock decrease income?
Drought		4.7120*** (0.4100)
Treat (1 for Euphrates)	0.0142 (0.0197)	
Average Temperature	0.0306*** (0.0043)	
DTR	0.0596*** (0.0187)	
Precipitation	0.3350*** (0.1205)	
Dew Point	-0.0445** (0.0186)	
Maximum Wind Speed	0.0233* (0.0124)	
Weak Instrument Test	130.49 [0.000]	
***Atanh ρ* Endogeneity Test**	-0.0174 (0.0215)	
No. Observations	148,544	
Maximum Likelihood	-2,702.527	
	DV: Water quality	**DV: Did the shock decrease income?**
Agricultural and drinking water quality		3.9140*** (0.3197)
Treat (1 for Euphrates)	0.0859* (0.0483)	
Average Temperature	0.0179 (0.0218)	
DTR	0.0280** (0.0129)	
Precipitation	-0.1837*** (0.0554)	
Dew Point	-0.0259** (0.0121)	
Maximum Wind Speed	0.0171 (0.0282)	
***Atanh ρ* Endogeneity Test**	28.51 [0.000]	
No. Observations	0.0340 (0.0352)	
No. Observations	148,347	
Maximum Likelihood	-2,702.527	
	DV: Reduced availability of grazing areas	**DV: Did the shock decrease income?**
Reduced availability of grazing areas		3.3436*** (0.5673)
Treat (1 for Euphrates)	0.1827* (0.1041)	
Average Temperature	0.0432* (0.0235)	
DTR	0.0778** (0.0360)	
Precipitation	0.0755 (0.1494)	
Dew Point	0.0063 (0.0282)	
Maximum Wind Speed	-0.0052 (0.0117)	
Weak Instrument Test	22.35 [0.000]	
***Atanh ρ* Endogeneity Test**	-0.0298 (0.0362)	
No. Observations	148,151	
Maximum Likelihood	-1,805.4780	

Clustered standard errors at the qhada-district level within the parentheses, p-values within the brackets. ***, ** and * indicate significance at the 1%, 5% and 10% level