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RESEARCH ARTICLE

Armed conflict and household water sources

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Abstract
Access to safe drinking water is among the most important determinants of public health outcomes. We pair household-level data from Iraq together with data on armed conflict and adopt a generalized difference-in-differences approach to study the relationship between household drinking water sources and armed conflict intensity. We find that households located in conflict-affected areas are more likely to use piped water accessed at their homes or bottled water as their primary source of drinking water, but are less likely to use public water sources or tanked water delivered on trucks and carts. We explore the temporal dynamics of these adjustments as well as heterogeneity by household characteristics. We further present direct evidence that conflict-exposed households are less likely to travel to obtain water.

Keywords: Armed conflict; Iraq war; Middle East; water

JEL Classification: F51; I15; J13; N45

Introduction

The most visible consequences of armed conflict are the destruction of life and property. More difficult to see are its impacts on public services like water, waste management, and electricity. The relatively new, but growing, literature on the effects of armed conflict is increasingly focused on household-level outcomes and, in developing countries, one of the most important infrastructure issues for households is access to safe drinking water. This paper examines the relationship between the intensity of armed conflict in Iraq and households' drinking water sources.

The World Health Organization defines an improved drinking water source as one that is protected from contamination by construction or active intervention (World Bank, 2023). Ideally, households obtain drinking water through a piped system that gives them access to clean water. Other sources of drinking water include public wells and springs, bottled water, and tanker-truck deliveries. Armed conflict creates an array of consequences that can lead households to reconfigure their water sourcing. Among these effects, household members might be reluctant to travel to obtain water, and economic repercussions could constrain household budgets. Furthermore, conflict and its aftermath can degrade the quality of water available through piped systems, e.g., through direct damage to systems, brain drain among staff, or difficulty obtaining parts.

There is an abundance of literature documenting the wide variety of health consequences from lack of access to clean water, especially among children (Centers for Disease Control, 2022). The quality of drinking water is linked to its source, and other authors have observed that there can be substantial variation in the quality of water among "improved" systems (Shaheed et al., 2014). In turn, there are numerous examples of war as a causative factor for deterioration of the quality of drinking water available to households, many from the Middle East (Diep et al., 2017).

The primary contribution of our paper is to dovetail various aspects of the existing literature and provide empirical support for one piece of the complex relationship between war and health. Violent conflict is known to impose large, multifaceted, and long-lasting damage on the health of affected populations (Kadir et al., 2018), and the link between clean drinking water and health is well-substantiated. Thus, clean water is a natural intermediating factor in the relationship between conflict and health. While there is a lot of descriptive evidence linking conflict and water quality, our paper adds additional empirical support using a large sample and difference-in-differences techniques. It is ultimately water *quality* that is important for health, but understanding how households reconfigure water *sourcing* decisions during conflict periods is a key piece of this puzzle, given the wide array of plausible household responses and the way in which war can alter the normal links between water's source and its quality.

Water is, of course, a perennial problem in the Middle East, and a major source of conflict there (Gleick, 2014). Iraq is a country with high baseline water stress, and there is direct evidence of conflict-related drinking water disruptions that have affected several million of its residents (Hofste et al., 2019; Reliefweb, 2022a; Diep et al., 2017). Furthermore, critical to our identification strategy, there are large geographic variations in conflict intensity, and these variations are not uniform across time. In other words, the locus of conflict shifted continually over our study period. Finally, Iraq has a young population and so, to the extent that the impacts of conflict fall disproportionately on children, the context there is doubly important (Naufal, 2011; Ghobarah et al., 2003). Overall, Iraq offers a unique opportunity to study the relationship between conflict and water given its history of armed conflict, periods of extensive damage to its infrastructure, the struggles of successive Iraqi governments in managing the country's water resources, and the availability of good data (Human Rights Watch, 2019).

While the world has recently seen a surge in armed conflict, many of these conflicts in the Middle East, there remains a paucity of the microlevel data needed to study its effects on civilians (Gates et al., 2012), which has made rigorous study of the association between armed conflict and household behavior challenging. We circumvent this problem by merging household-level data from the Iraq Multiple Indicator Cluster Survey (MICS) together with geolocational data on conflict-related deaths from the Iraq Body Count (IBC) project, which allows us to construct a governorate-year specific measure of conflict exposure for each household. MICS-Iraq is a nationally representative survey of Iraqi households, collected by a joint effort of the Iraqi government and the United Nations International Children's Emergency Fund (UNICEF). We use three waves of data that are publicly available: 2006, 2011, and the recently added 2018 wave. Concurrently, the IBC project has recorded conflict-related civilian deaths since 2003 and consists of verified death records that are substantiated by a variety of sources (media reports, hospital and morgue records, and NGOs and official public records). The main empirical innovation in our paper is to merge the two, allowing us to study the association between conflict intensity and a household's primary source of drinking water.

Using a generalized difference-in-differences approach, our main result is that increases in conflict-related fatalities are associated with a higher probability that a household uses piped water or bottled water as its primary source of drinking water, but a lower probability that it uses public water sources or water carried on a tanker-truck or cart. A variety of robustness checks provide insight into the interpretation of these results. First, an obvious piece of the dynamic underlying the main result, at least in part, is that households are less likely to travel to obtain water under conflict conditions, and we present direct evidence of this assertion. Second, short-run and long-run responses may vary, with some evidence that substitution to bottled water is more likely to be a short-term response, while substitution to piped water is more sustainable in the long term. Third, the effect size is heterogeneous and appears strongest for wealthier urban households.

Briefly, our identification strategy relies on contrasting variations in conflict exposure (i.e., treatment) by governorates and over time. Generalized difference-in-differences is required because several governorates switch between treatment (conflict-exposed) and control (non conflict-exposed) status irregularly over the study period; in other words, the treatment and control groups change continuously. The structure of our data limits the degree to which we can ascribe a causal interpretation to our results, and we discuss some of the most important challenges after presenting these results in detail.

The next section summarizes the relevant literature, with a particular focus on how our study fits in with what is currently known. We then proceed to present the data and methodology, followed by the results and conclusion.

Literature review

Our study dovetails several aspects of the existing literature on conflict and health. Here, we briefly review this literature and the context in which our research question arises.

Access to safe drinking water and waste disposal have large and well-documented effects on health. In fact, Magana-Arachchi and Wanigatunge (2020) argue that waterborne pathogens are *the* most common vector for disease globally. Dirty water is associated with the transmission of cholera, typhoid, hepatitis, dysentery, Guineaworm disease and polio, and also with diarrhea, which is a leading cause of childhood wasting and mortality (Centers for Disease Control, 2022; World Bank, 2023; Troeger et al., 2018). With respect to childhood diarrhea, a majority of documented cases in Cameroon and Chad were directly attributable to dirty water (Ntouda et al., 2013; Yongsi, 2010). Reconstitution of infant formula with unsafe water is a particular problem (Diwakar et al., 2019). Bisung and Elliot (2017) argue that the health consequences of dirty water go beyond physical health, and include psychosocial harm, with a disproportionate impact on women. In sum, the World Bank links access to clean drinking water with higher levels of education, a reduction in health expenditures, and more robust economic growth (World Bank, 2023).

The quality of drinking water is directly related to its source. The World Health Organization and UNICEF define an improved drinking-water source as a source that "by nature of its construction or through active intervention is protected from outside contamination" (World Bank, 2023). Shaheed et al. (2014) note that, while "improved" drinking water systems do reduce health risks, the moniker can mask considerable variation in the safety and accessibility of water among improved systems.

The analysis in Shaheed et al. (2014) suggests that, even for civilians who ordinarily have access to an improved public water system, conflict can disrupt the availability and safety of their drinking water. Gates et al. (2012) find from a study of 146 countries that an increase in conflict fatalities is associated with a statistically significant decline in access to potable water; specifically, a conflict with 2500 battle deaths deprives about 1.8% of the surrounding population of access.

The Middle East is replete with examples. Conflict in Gaza has damaged wells, pipelines and water treatment plants there, and the ongoing embargo often renders timely repairs impossible. As a result, wastewater contamination and overuse have led to irreversible damage to Gaza's single aquifer and, by 2015, less than 5 percent of water from that aquifer "was deemed fit for human consumption" (Diep et al., 2017; Lazarou, 2016; UNEP, 2009; Gostoli 2016; World Bank 2016). Repercussions can extend beyond conflict zones. In Jordan, an influx of refugees has led to excess stress on water systems there, leading to physical damage to the piped water infrastructure (Diep et al., 2017). Households can respond to these stresses in a variety of ways, although the solutions may be costly. One study in southern Syria found that, between 2016 and 2017, the use of piped water as the main drinking water source for households declined from 22.0% to 15.3% over the survey rounds. This forced households to access water from private trucking networks, spending on average a fifth of their income on water (Sikder et al., 2018).

Turning specifically to Iraq, the World Resources Institute classifies Iraq as a country with high baseline water stress (Hofste et al., 2019). Water levels from the Tigris and Euphrates, Iraq's main sources of water, risk continuing decline from prolonged drought and from damning of upstream water sources (Gavlak, 2022; Reliefweb, 2022b). We should note here that there is considerable subnational variation, and a drinking water crisis in rural areas of Basra in 2018 led to violent protests and to at least 118,000 hospitalizations (Baker, 2019). Overall, it has been estimated that 1.6 million internally displaced persons and returning refugees will require emergency water, sanitation and hygiene (WASH) services (Reliefweb, 2022a).

Unsurprisingly, persistent conflict in Iraq has only aggravated this problem. A study drawing on a meta-analysis of unpublished literature on Basra explored the impact of armed conflict on drinking water service from 1978 to 2013. The authors observed a steep decline in service quality of water, which they attributed to a lack of water treatment chemicals and spare parts, in addition to a brain drain among water service staff (Zeitoun et al., 2017). Also with respect to Iraq, Dowdeswell and Hania (2014) discuss the limited access to potable drinking water and adequate sewage systems that many communities in Iraq face because of the ongoing war there, and note in particular that many public water sources are contaminated. Combatants specifically targeted water pipelines during battle for Mosul in 2016, which left 650,000 people without access to piped water; the authors specifically noted that continuing unrest following the battle made it impossible for staff to assess and repair damage (Diep et al., 2017).

Violent conflict is known to have severe consequences for the health of affected populations, spanning physical and mental health, and increased risk of death and disability from a host of causes. Furthermore, these effects are potentially persistent for a decade or more after the conflict's end, with the costs for women and children especially large (Kadir et al., 2018; Ghobarah et al., 2003). Given the extensive documentation of the damage that conflict can do to WASH infrastructure, coupled with primacy of access to clean drinking water for health, it seems obvious that water is a natural linking construct for the relationship between conflict and health. Nevertheless, Gates et al. (2012) claimed that the literature on this point is "at best scarce". One study finds that, in 16 conflict-affected countries, including Iraq, almost three times as many children under the age of 15 died from inadequate WASH facilities than from violence that was directly linked to conflict (UNICEF, 2019). Certainly, understanding the relationship between armed conflict and WASH resources is an important element of understanding the long-term development consequences of war.

We should briefly discuss the broader context for this study. While our paper focuses on how conflict can affect access to water, the converse has become a major focal point for the Middle East. The United Nations has called the Middle East the “most water-scarce region” in the world (Food and Agriculture Organization of the United Nations,2018), and it contains 17 countries that fall below the “water poverty line” (Scott, 2019). Gleick (2014) has notably emphasized the role of water in Syria’s ongoing civil war. Haddadin (2001) and Salameh et al. (2021) engage in an extensive analysis of the multifaceted array of political, economic, and social consequences of water stress in the Middle East, including the security implications and the potential for future violent water-related conflicts. Sullivan and Jemmali (2014) discuss the economic dimensions of this problem, particularly for oil-wealthy countries that suffer from water scarcity. Note that this analysis introduces the possibility of two-way effects: increasing water scarcity at the national and subnational level can increase the prevalence of water-related conflict, and this conflict in turn affects the condition and availability of water-related infrastructure.

Data and methods

Our paper uses microlevel data from the MICS, which is a nationally representative data set of Iraqi households collected by a joint effort between the Iraqi government and the United Nations International Children’s Emergency Fund (UNICEF). We use the three waves of data that are publicly available: 2006, 2011 and the recently added 2018 wave. Households are selected using stratified random sampling, in order to be representative of the governorates that make up Iraq.[1] The response rate to the survey is quite high, 98% for the 2006 wave and 99% for the other two years, and the sample size is large. Our unit of observation is the household, and the survey includes 17,739 households in 2006, 35,662 households in 2011 and 20,206 households in 2018, for a total sample size of 73,608 households. MICS undertakes these surveys approximately every five years. In 2018, certain districts in two provinces were excluded because of insecurity; we discuss the potential bias and implications for our findings in the next section. Because MICS uses stratified random sampling, it could be possible for a household to be surveyed in more than one round. However, survey administrators assign a unique household ID each year, and so there is no way to use the data to create a panel.

We derive our primary dependent variables from the response to the following question: “What is the main source of drinking water used by members of your household?”.[2] The survey offers 14 options for the participant (mainly the head of household) to select. Table 1 lists the full set of choices available to respondents, along with their overall frequencies in the data. Each respondent is prompted to select one option from among the 14 given. We group these responses into five categories:

1. Piped water, which includes water piped directly into the dwelling or into the household’s yard or plot

[1]A new Halabja Governorate was carved out of the Sulaymaniyah Governorate in 2014, comprising a 19th governorate. However, both MICS and the IBC continued to use the original 18 governorates and their respective boundaries across the sample period considered in our study.

[2]The next question in the survey asks about where members of the household obtain water for other purposes like cooking and handwashing. However, there is no question that differentiates water *use* and water *access*.

Table 1. Main source of drinking water used

Source	Proportion	Classification
Piped into dwelling	0.5485	Piped
Piped into yard or plot	0.0655	Piped
Public tap/standpipe	0.0213	Public
Tubewell/borehole	0.0067	Public
Protected well	0.0249	Public
Unprotected well	0.0014	Public
Protected spring	0.0046	Public
Unprotected spring	0.0025	Public
Tanker-truck	0.0534	Tank on truck/cart
Cart with small tank/drum	0.0338	Tank on truck/cart
Bottled water	0.1140	Bottled water
Surface water	0.0330	Other
Rainwater collection	0.0009	Other
Other	0.0894	Other

Note: Averages over all survey years.

2. Public water, which includes public taps, wells of all types, and springs of all types
3. Tank on truck/cart water, which includes water carried in tanker trucks or on carts
4. Bottled water, which includes packaged water and bottled water
5. Other water sources, including surface water and any other source not listed

The survey data do not provide any additional detail about the fifth category (about 12% of the responses), and so we treat these observations as missing data since we lack information about how the household obtains drinking water. In the next section, we do explore the robustness of our results to the inclusion or non-inclusion of these observations.

To supplement our main findings, we also consider the determination of whether a family travels to obtain water. Specifically, the survey asks: "How long does it take for members of your household to (go there) get water and come back?". One option provided to respondents is that members of the household do not travel to acquire drinking water. For households that do travel, the survey records the number of minutes required for the trip. We operationalize this as a dummy variable equal to 1 if the household travels to obtain drinking water and equal to 0 otherwise.

To better understand the implications of our findings, we should discuss the dynamics of these various water sources for households. Piped water is generally thought to be the safest and most convenient option, as it does not require leaving the home to acquire drinking water. However, crucially, as we discussed in the previous section, piped water may not necessarily be the highest in quality, especially during times of conflict. Public water sources, by contrast, require household members to travel in order to obtain water, potentially to crowded areas. Tankers carrying water travel to households using the road network and pump water into water tanks. Bottled water can either be purchased or delivered to the dwelling, implying that households may or may not have to travel in order to acquire it.

Conceptually, the effect of conflict on the relative merits of these various means of obtaining water is uncertain. On one hand, one would expect higher conflict intensity to hinder traveling and thus reduce the likelihood that a household member would travel to obtain water from a public source or a store or that tanker-delivered water would be easily accessible. On the other hand, infrastructure damage could reduce the quality of piped water. Finally, if conflict disrupts the economy and stresses household budgets, bottled water may become unaffordable. The ambiguity of these effects motivates an empirical analysis of the question.

Our primary explanatory variable of interest is the intensity of armed conflict, which we derive from the number of conflict-related civilian deaths per 1000 population in the governorate in which the household is located. The source of these data is the IBC, a comprehensive source of conflict data in Iraq, and the curators of this database have maintained these records continuously since 2003 (Carpenter et al., 2013). Specifically, our main measure of conflict intensity is the conflict-related death rate in the household's governorate one year prior to survey administration. As a check on the robustness of our results, we alternatively consider death rates two years prior to survey administration and the contemporaneous death rate in the survey administration year. We then use these death rates to construct a treatment variable that is equal to one if a governorate experienced high conflict during the respective period and equal to zero if the governorate did not experience high conflict.[3] Following Diwakar et al. (2019), Malcolm et al. (2020) and Naufal et al. (2019), we define high conflict as the 75th percentile of conflict-related civilian death rates within the distribution of death rates across all governorates for that specific year. In other words, the treatment variable is one for a household residing in a governorate where the number of conflict-related civilian deaths per 1000 residents is higher than the death rate for the 75th percentile of *all* governorates for that year. We also employ standard household-level controls: the head of household's age, the head of household's gender (1 for male), the head of household's level of education, the number of bedrooms in the primary dwelling per household member, the total number of household members and whether the household lives in an urban area (1 for urban). Number of bedrooms per household member is our proxy for household wealth, as there is no direct measure of household wealth or income available for all three survey rounds.[4]

Table 2 presents full summary statistics on all variables, aggregated across the full sample. Table 3 presents means for all variables, but separated by year and by treatment status. Household characteristics are roughly comparable across treatment and control groups and across the three survey waves.

Regarding statistical methodology, an important piece of context surrounding our choice of model is that the nature of armed conflict in Iraq changed dramatically from the first data wave in 2006 to the most recent wave in 2018. In 2006, most of the conflict in Iraq was related to the 2003 US invasion and to the removal of Saddam Hussein's regime. By

[3]To the general point of using deaths as a proxy for conflict intensity, this approach is common in quantitative work on international conflict (e.g., Looney 2006 and Berman et al. 2011, both dealing with Iraq). Fox and Sandler (2006) argue that civilian deaths are a good proxy for the level of violence, which is the best way to measure the effects of conflict on civilian populations.

[4]We also tried total number of bedrooms (rather than bedrooms per household member) as our proxy for household wealth and the results did not change.

Table 2. Descriptive statistics

Variable	Mean	S.D.	Min	Max
HOUSEHOLD DEMOGRAPHICS				
Head of household age	45.86	13.92	12.00	96.00
Head of household gender	0.91	0.29	0.00	1.00
Head of household primary education	0.33	0.47	0.00	1.00
Head of household secondary+ education	0.45	0.50	0.00	1.00
Number of bedrooms per member	0.38	0.28	0.04	25.00
Number of members in household	6.58	3.23	1.00	39.00
Urban	0.64	0.48	0.00	1.00
MAIN DRINKING WATER SOURCE USED				
Piped	0.61	0.49	0.00	1.00
Public	0.09	0.29	0.00	1.00
Tank on truck/cart	0.09	0.28	0.00	1.00
Bottled water	0.11	0.32	0.00	1.00
Other	0.09	0.29	0.00	1.00
Travel to obtain water	0.11	0.32	0.00	1.00
CONFLICT-RELATED DEATHS PER 1000 POPULATION				
Current year	0.33	0.59	0.00	2.68
Lagged 1 year	0.24	0.40	0.00	2.26
Lagged 2 years	0.23	0.35	0.00	1.91

Note: Summary statistics calculated over all survey years. Age is measured in years. Gender = 1 for male. Primary education = 1 if head of household completed primary education but does not hold a secondary credential. Secondary+ education = 1 if head of household completed secondary education. Number of bedrooms and number of members in household are counts. Urban = 1 if residence is in an urban area. Main drinking water sources are given as a proportion. Conflict-related deaths are the number of civilian conflict-related deaths in the governorate in which the respondent lives, per 1000 persons in the governorate, lagged the respective number of years from survey administration.

contrast, the main source of violent conflict in 2018 was the aftermath of the fall of the Islamic State of Iraq and the Levant (ISIL). These various conflicts affected different geographical areas in different ways. For example, the Kurdish-dominated region in northern Iraq was relatively conflict-free during the first survey wave but was heavily affected by ISIL-related conflict. What this means for us is that certain governorates are high-conflict governorates in some years, but not in others, which necessitates an extension of the standard difference-in-differences approach. The generalized difference-in-differences estimator described by Hansen (2022) allows for more than two periods and also allows for governorates to switch between the treatment and control groups across periods, which gives us the opportunity to better exploit the evolution in the nature of the Iraqi conflict over time as an explanatory variable. Note that our model expands on existing work on armed conflict in Iraq, which uses simple difference-in-differences (Cetorelli, 2015; Malcolm et al., 2020; Naufal et al., 2019). Explicitly, the baseline model is:

Table 3. Means by group and year

Variable	Control			Treatment		
	2006	2011	2018	2006	2011	2018
HOUSEHOLD DEMOGRAPHICS						
Head of household age	45.40	45.19	46.97	46.47	45.59	47.81
Head of household gender	0.90	0.91	0.91	0.88	0.92	0.90
Head of household primary education	0.31	0.34	0.33	0.27	0.33	0.32
Head of household secondary+ education	0.43	0.40	0.50	0.53	0.47	0.55
Number of bedrooms per member	0.36	0.37	0.42	0.40	0.35	0.43
Number of members in household	6.50	6.61	6.54	6.46	6.99	6.36
Urban	0.67	0.61	0.69	0.73	0.54	0.67
MAIN DRINKING WATER SOURCE USED						
Piped	0.75	0.58	0.42	0.89	0.64	0.82
Public	0.12	0.10	0.09	0.04	0.11	0.04
Tank on truck/cart	0.05	0.04	0.21	0.04	0.16	0.02
Bottled water	0.01	0.10	0.27	0.01	0.08	0.12
Other	0.07	0.19	0.00	0.02	0.01	0.00
Travel to obtain water	0.21	0.07	0.13	0.08	0.13	0.01
CONFLICT-RELATED DEATHS PER 1000 POPULATION						
Current year	0.44	0.08	0.11	1.79	0.30	1.36
Lagged 1 year	0.21	0.06	0.11	1.19	0.29	1.19
Lagged 2 years	0.19	0.07	0.12	0.99	0.35	1.03

Note: Arithmetic means by group and year. See Table 2 notes for variable definitions.

$$Y_{i,t} = \beta_0 + \beta_1 T_{i,t} + \beta_2 HH_{i,t} + \alpha_g + \delta_t + \varepsilon_{i,t} \quad (1)$$

Here, $Y_{i,t}$ is the outcome (type of water source) for household i in period t. The dummy variable $T_{i,t}$ is the treatment status of the governorate in which household i resides in period t. Importantly, this treatment status can vary within groups (governorates) across time. A governorate might be part of the high-conflict treated group in one period, but a part of the low-conflict control group in another. The vector $HH_{i,t}$ constitutes our household-level control variables. The dummies α_g are a set of governorate indicators and δ_t are a set of period indicators. These are just the general versions of the treatment and post-year indicators in the conventional difference-in-differences setup. If the model is properly specified, then β_1 is the effect of treatment (conflict) on the household's respective source of drinking water.

Given the binary nature of the outcome variable (main drinking water source), we adapt the generalized difference-in-differences estimator in Equation (1) by incorporating a probit linking function:

$$\Pr\left(Y_{i,t} = 1\right) = \Phi\left(\hat{\beta}_0 + \hat{\beta}_1 T_{i,t} + \hat{\beta}_2 HH_{i,t} + \alpha_i + \delta_t\right) \tag{2}$$

where $Y_{i,t}$ is a binary variable reflecting whether a household primarily uses the respective source of drinking water, and $T_{i,t}$ is treatment status as described above.

As a robustness check on our main results, we also adopt a multinominal logistic approach, which examines the choice across all categories simultaneously.

Results

Main results

Table 4 presents our main results, with treatment defined as the governorate's total of conflict-related civilian deaths per 1000 population being above the 75th percentile of the number of deaths per 1000 population lagged one year across all governorates for the respective year. Our unit of observation is a household, and thus the results indicate that residing in a high conflict area is associated with a higher probability that the household uses piped water or bottled water as its primary drinking water source, but a lower probability that the household uses public water or tank-on-truck water as its primary drinking water source. All of these coefficients are significant at the 5% level.

Table 4 gives an indication of the direction and statistical significance of our results. Estimating the magnitude of treatment effects in nonlinear difference-in-differences models is an active area in the literature (Greene, 2010; Botosaru and Muris, 2022). A common approach is to calculate marginal effects evaluated at the mean values of the regressors, and we report these marginal effects in Table 5, which correspond to our main results in Table 4. Exposure to high conflict is associated with a 0.023 increase in the probability that a household uses piped water and a 0.047 increase in the probability that it uses bottled water. Conversely, there is a decline of 0.008 and 0.012 in the probability that a household uses public or tanked water, respectively. Qualitatively, the most substantial impact for this specification seems to be an increase in the reliance on bottled water as a primary drinking water source.

One straightforward interpretation of our main findings is that households in areas with more severe conflict are more likely to find ways to obtain drinking water as close to their homes as possible and are less likely to travel to public water sources or to rely on trucked water, both of which are riskier when there is intense conflict. However, the positive association between armed conflict and bottled water highlights the importance of *quality* of drinking water, and we are implicitly assuming here that bottled water assures the highest quality. This is especially important if the quality of piped water falls during conflict periods, and we previously provided quite a bit of descriptive evidence that this was the case; increases in the use of bottled water indicate that households are aware of these quality issues and are responding to it. Put together, these forces can create competing effects, especially if a household has to travel to obtain bottled water. The data do give us the ability to directly tackle one piece of this dynamic, on the relationship between conflict and travel to obtain water, and we do so below.

Importantly, difference-in-differences estimators reduce concerns about biased coefficients resulting from selection problems since the estimates are based on *changes* in conflict status and water source within the groups across years, rather than on comparing the groups directly.

As for other household controls, education of the head of the household (both primary and secondary) is positively associated with use of piped and bottled water and negatively associated with use of public water and tanker-truck water; this is perhaps due to the exclusion of a direct measure of income as a control. Unsurprisingly, households in urban

Table 4. Determinants of water source – generalized difference-in-differences estimates

	(1)	(2)	(3)	(4)
VARIABLES	Piped	Public	Tank on truck/ cart	Bottled water
High conflict	0.090*** (0.029)	−0.062** (0.029)	−0.095** (0.039)	0.314*** (0.079)
Head of household age	0.004*** (0.000)	−0.004*** (0.001)	−0.007*** (0.001)	0.003*** (0.001)
Head of household gender	−0.096*** (0.021)	0.122*** (0.028)	0.026 (0.028)	0.021 (0.028)
Head of household primary education	0.179*** (0.017)	−0.167*** (0.021)	−0.246*** (0.022)	0.093*** (0.023)
Head of household secondary+ education	0.289*** (0.017)	−0.304*** (0.021)	−0.458*** (0.022)	0.221*** (0.023)
Number of bedrooms per member	0.015 (0.020)	−0.123** (0.060)	−0.028 (0.029)	−0.018 (0.027)
Number of members in household	−0.007*** (0.002)	0.009*** (0.003)	0.016*** (0.002)	−0.020*** (0.003)
Urban	0.816*** (0.012)	−1.114*** (0.016)	−0.512*** (0.015)	0.085*** (0.016)
Constant	1.570*** (0.050)	−1.082*** (0.067)	−2.378*** (0.107)	−3.550*** (0.070)
Governorate FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	73,608	73,608	73,608	73,608

Note: Probit regression. Table shows coefficient estimates, followed by Huber Sandwich standard errors in parentheses. High conflict = 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate, lagged by one year, is above the 75th percentile of the number of deaths per 1000 population across all governates, also lagged by one year. All other variables are as defined in Table 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

areas are also more likely to use piped water and bottled water, as are households with an older head of household. Relative to female-headed households, male-headed households are less likely to use piped drinking water; note that most Iraqi households are headed by a male (about 90%). Finally, households with a larger number of members are more likely to use public water and tanked water, while households with a larger number of bedrooms per member (our proxy for wealthier households) are less likely to use public water. These results are consistent with our findings on urban and rural areas.

Robustness checks

We present several robustness checks to examine the sensitivity of our result to variations in specification and to extend our main analysis in some important ways. These results are given in the appendices.

First, we consider alternative measures of conflict intensity to determine the treatment status of each governorate. While our main specification uses the conflict-related

Table 5. Marginal effects evaluated at the mean

Variables	(1) Piped	(2) Public	(3) Tank on truck/cart	(4) Bottled water
High conflict	0.023*** (0.007)	−0.008** (0.004)	−0.012** (0.005)	0.047*** (0.013)
Head of household age	0.001*** (0.000)	−0.001*** (0.000)	−0.001*** (0.000)	0.000*** (0.000)
Head of household gender	−0.025*** (0.005)	0.016*** (0.004)	0.003 (0.004)	0.003 (0.004)
Head of household primary education	0.046*** (0.004)	−0.022*** (0.003)	−0.031*** (0.003)	0.013*** (0.003)
Head of household secondary+ education	0.075*** (0.004)	−0.041*** (0.003)	−0.057*** (0.003)	0.031*** (0.003)
Number of bedrooms per member	0.004 (0.005)	−0.017** (0.008)	−0.003 (0.004)	−0.003 (0.004)
Number of members in household	−0.002*** (0.001)	0.001*** (0.000)	0.002*** (0.000)	−0.003*** (0.000)
Urban	0.211*** (0.003)	−0.149*** (0.002)	−0.064*** (0.002)	0.012*** (0.002)
Governorate FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	73,608	73,608	73,608	73,608

Note: Table shows the estimated marginal effect of a 1-unit increase in the respective variable, evaluated at the mean values of the regressors, corresponding to the regressions in Table 4. Standard errors appear below, in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

death rate lagged by one year, Appendix A reports results from regressions that use contemporaneous death rates and death rates lagged by two years. All these regressions use the same controls as the baseline model, although we show only the coefficients on the treatment dummy. Marginal effects at the mean are reported in brackets. In both cases, conflict is associated with a higher probability that the household will use piped water. For the regression that uses conflict lagged by two years to determine treatment status, all the coefficients are consistent with our main specification, except for the regression dealing with use of bottled water – conflict is positively associated with use of bottled water in our main specification, but the association is negative here. This perhaps sheds light on temporal dynamics relating to household behavioral adjustments to armed conflict. Households in high conflict areas may respond initially with a short-term solution to obtain safe water (i.e., bottled water), but eventually adjust to more sustainable long-term solutions as information improves and other opportunities become more easily available. War is also associated with economic disruptions, and bottled water may become unaffordable if primary earners are forced to relocate or if they lose access to their main sources of income. We will explore this relationship in more detail later.

Second, the sample is large enough to conduct heterogeneity analysis, contrasting the treatment effects by demographic characteristics. While the main results give average treatment effects across the sample, it is interesting to understand whether these

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associations arise uniformly, or disproportionately in certain demographic groups. To explore this possibility, we interact the treatment dummy (high conflict) with both the urban dummy (1 for households living in urban areas) and with the number of bedrooms per household member (our proxy for wealth). The results are given in Appendix B, and again these regressions use the same controls as the baseline specification. The coefficients on the interaction terms indicate that the effect of conflict is stronger (i.e., more positive for piped and bottled water and more negative for public and tanker-truck water) for urban households than for rural households, and for households with a larger number of bedrooms per member, with the exception of bottled water, where the interaction with the number of bedrooms is not significant.

Third, among the plausible reasons for the directional effects in the main results is that households are less likely to travel for water in high-conflict situations, and the survey gives us the data to tackle that question directly. Using a dependent variable equal to 1 for a household that travels to obtain water and equal to 0 otherwise, we find that households exposed to high conflict are indeed less likely to travel to obtain water; the coefficient is significant at the 10% level. The full results for this analysis are given in Appendix C, where again the regression uses the same controls as the baseline model.

Fourth, given that the data offer independent information on water source and whether travel is required to obtain water, we examine combinations of these factors. Specifically, we sort each observation into one of eight categories: piped water (no travel required by definition), public water with travel required, public water with no travel required, tanked water with travel required, tanked water with no travel required, bottled water with travel required, bottled water with no travel required, and other water sources.[5] These results, given in Appendix D, reveal that conflict is associated with a significant decline in the use of public water sources that require travel but an increase in the use of public water sources that do not require travel. There is also an increase in the use of piped water and bottled water, the latter irrespective of whether travel is required. This result perhaps speaks to the quality issue that we alluded to earlier; even if travel is required to obtain bottled water, this may still be the best option to obtain safe drinking water in a conflict situation if other sources are compromised.

Fifth, we consider more explicitly the possibility of varying short-run and long-run responses, as suggested by the analysis in Appendix A. Specifically, we sort each governorate year into one of four categories: High conflict in both 1-year and 2-years lagged, high conflict in 1-year lagged only, high conflict in 2-year lagged only and high conflict in neither of the previous two years. We then implement regressions analogous to our main specifications using these dummy variables. The results are given in Appendix E (the omitted category is that neither of the previous two years had high conflict), and they are consistent with the hypothesis we outlined previously. The increase in use of piped water (relative to a situation with no conflict in the previous two years) is significant only when high conflict existed two years prior, or both one and two years prior, but not when high conflict existed *only* one year prior, suggesting that this substitution to piped water is more of a long-term response. By contrast, increases in the use of bottled water are significant over the baseline only for short-term conflict lagged one or two years prior, but *not* when there was persistent high conflict in both previous years.

Finally, we consider an alternative statistical model. A somewhat different approach to our series of probit regressions is a single multinominal logistic regression that examines the choice among all five water source options jointly (we are including the "other" category in this analysis for completeness). These results are given in Appendix F and are consistent with our

[5]The sample size is too small (i.e., there is not sufficient variation within governorates) to decompose this last category.

main findings. Using piped water as the baseline category, high conflict is associated with a decline in the use of public water and tanker-truck water and an increase in the use of bottled water and other unspecified sources of water, relative to piped water.

Limitations of identification strategy

We should caution that limitations of our data prevent us from fully ascribing our results to causation. In particular, migration is a major challenge for conflict-related studies. Millions of Iraqis have left the country or migrated internally as a result of conflict there (Reliefweb, 2022a). As the MICS survey identifies only residence at the time of survey administration, if households that remain in conflict areas are systematically different from households that left, this could bias our results. However, it would seem to work against our main results, as wealthier households with the means to flee should be households that are *more* likely to purchase bottled water and to have piped water systems.

A second issue is that MICS excluded a few districts from two governorates from their 2018 survey (representing 22% and 5% of the urban populations of these two governorates) because of security issues. This omission could distort our estimate of mean treatment effects by removing households affected by some of the most extreme levels of conflict from the sample, although the omission would presumably dampen the magnitude of the effects.

A third limitation is that MICS data does not geo-code households at any level lower than the governorate, leading to potential measurement error if a household in a large governorate is recorded as conflict-exposed, even if it is located far from the occurrence of the violence (or vice versa if a household near substantial violence is recorded as non-exposed because the overall rate in the governorate is low). Generally, measurement error in a regressor biases the coefficient estimate toward zero, but it is worth noting that the measurement error is potentially endogenous here because it is less likely to occur in smaller, but more densely populated governorates.[6]

Conclusion

Existing literature studying the effects of armed conflict on households residing in afflicted areas is small but growing. There is, however, a strong interest in these effects because they go beyond the direct and immediately obvious effects of war (e.g., loss of life and property) and often involve long-term consequences for the local population. Among these effects, household access to clean drinking water may be at the center stage. The public health literature on the relationship between clean water and the psychological and physical health of the population is clear. Populations without stable access to drinking water are at increased risk for a host of diseases, with concurrent psychosocial impacts. There are already concerns about disparities in access to drinking water, so any relationship between armed conflict and water would only exacerbate these inequalities, given that poorer families generally lack the means to mitigate the effects of conflict.

[6]One reviewer was concerned that Baghdad, the smallest and most densely populated governorate in Iraq, might exert an outsized influence on the results. While Baghdad is highly developed it was, for several years, the most violence-prone governorate in the sample. To investigate this possibility, we ran our main regressions from Table 4 while excluding observations from Baghdad (reducing the sample size to 66,844), and the main results hold. Namely, high conflict, as defined in our main model, is associated with statistically significant increases in the use of piped and bottled water.

This problem is especially pronounced in the Middle East, which is among the most conflict-prone areas in the world, and which the United Nations describes as "the most water-scarce region" on earth (Food and Agriculture Organization of the United Nations, 2018). Conflict and climate change are seemingly creating a "polycrisis" in the region as it relates to clean water, and our analysis contributes to a more holistic conceptualization of well-being, which includes access to basic services. Recent literature focuses on interventions to mitigate the effect of conflict on civilian populations, but addressing human development in the context of armed conflict must occur in an environment with access to basic services that support people's health and welfare. The international context unfortunately provides us with a multitude of examples that illustrate how clean water is situated in this milieu, and our study provides empirical support for a piece of the picture. By pairing household data with geolocational data on armed conflict and utilizing a generalized differences-in-differences approach, we examine the relationship between conflict intensity and households' sources of drinking water. Our data show that high conflict is associated with increases in the use of piped water and bottled water, but with declines in the use of public water sources and tanked water carried on trucks and carts.

Households can adjust their behavior in response to conflict in their environments in a variety of ways, and so these findings are not surprising. Households presumably avoid traveling to public areas to collect water during periods of intense conflict, and travel on roads to deliver tanked water may not be safe. Consequently, households residing in conflict areas are more likely to rely on piped drinking water available at their own homes; indeed, our supplementary findings provide direct evidence that conflict reduces the likelihood that household members travel to obtain water. However, other authors have cautioned against equating piped water from improved systems with safe water, and we have cited numerous examples of disruptions to Iraq's public water infrastructure resulting from armed conflict there. Thus, it is certainly possible that households may be trading off water safety for accessibility. Households in conflict areas are also more likely to use bottled water, although bottled water is expensive, and the temporal association here is more complex; our findings suggest that the substitution to bottled water is more short-term, whereas substitution to piped water is more sustainable. Furthermore, we find evidence that the magnitude of this reconfiguration is strongest for households in urban areas and with more robust financial means, who presumably have the easiest access to safe water sources at or close to their homes.

An important extension of this work that would inform its policy relevance is a more careful examination of the potential trade-off between easy accessibility of water and the quality of the water. Our ultimate object of interest for public health is water quality. Thus, it would be interesting to know in more detail how water quality and water source are related, and how households perceive this relationship, in order to better understand their behavioral adjustments to armed conflict. After all, the household's choice is presumably the product of a constrained optimization problem, where the choices that it makes about its water use are subject to external constraints that it faces with respect to accessibility of these sources, and war can alter these constraints. Questions like this are critical as local governments, paired with international organizations, seek to restore access to safe drinking water in conflict-affected areas.

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Ethical standards. We have no conflicts of interest related to this research, and the data are publicly available.

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Appendix A. Alternative measures of conflict

VARIABLES	(1) Piped	(2) Public	(3) Tank on truck/cart	(4) Bottled water
Current Year	0.059** (0.026) [0.015]	0.072** (0.028) [0.010]	0.286*** (0.031) [0.036]	−0.210*** (0.062) [−0.029]
Lagged 2 Years	0.259*** (0.025) [0.067]	−0.099*** (0.027) [−0.013]	−0.120*** (0.035) [−0.015]	−0.118** (0.054) [−0.016]
Governorate FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	73,608	73,608	73,608	73,608

Note: Probit regression. All regressions use the same controls as the regressions in Table 4. Table shows coefficient estimates, Huber Sandwich standard errors in parentheses, and estimated marginal effects at mean values in brackets. The coefficient shown is the coefficient on a treatment variable, equal to 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate, lagged as described, is above the 75[th] percentile of the number of deaths per 1000 population across all governates, also lagged as described. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix B. Heterogeneity analysis

Variables	(1) Piped	(2) Public	(3) Tank on truck/ cart	(4) Bottled water
High conflict * Urban	0.471*** (0.037)	−0.881*** (0.096)	−1.197*** (0.108)	0.183*** (0.042)
High conflict * Number of bedrooms per member	0.278** (0.113)	−1.288*** (0.128)	−2.994*** (0.283)	0.030 (0.059)
High conflict	−0.107*** (0.035)	0.242*** (0.041)	0.470*** (0.060)	0.176** (0.070)
Number of bedrooms per member	−0.062** (0.028)	0.005 (0.035)	0.193*** (0.045)	−0.027 (0.028)
Urban	0.712*** (0.014)	−0.974*** (0.020)	−0.309*** (0.022)	0.052*** (0.018)
Governorate FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	73,608	73,608	73,608	73,608

Note: Probit regression. All regressions use the same controls as the regressions in Table 4. Table shows coefficient estimates, followed by Huber Sandwich standard errors in parentheses. High conflict = 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate, lagged by one year, is above the 75[th] percentile of the number of deaths per 1000 population across all governates, also lagged by one year. All other variables are as defined in Table 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix C. Travel to access water

Variables	Travel to access water
High conflict	−0.043* (0.026)
Head of household age	−0.006*** (0.001)
Head of household gender	0.149*** (0.027)
Head of household primary education	−0.242*** (0.020)
Head of household secondary+ education	−0.393*** (0.021)
Number of bedrooms per member	−0.086** (0.041)
Number of members in household	0.008*** (0.002)
Urban	−0.904*** (0.015)
Constant	−1.468*** (0.085)
Governorate FE	Yes
Year FE	Yes
Observations	73,608

Note: Probit regression. Table shows coefficient estimates, followed by Huber Sandwich standard errors in parentheses. Dependent variable = 1 if household members travel to obtain drinking water. High conflict = 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate, lagged by one year, is above the 75th percentile of the number of deaths per 1000 population across all governates, also lagged by one year. All other variables are as defined in Table 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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Appendix D. Travel to access water by source

Variables	(1) Piped	(2) Public + Travel	(2) Public + No travel	(3) Tank on truck/cart + Travel	(3) Tank on truck/cart + No travel	(4) Bottled water + Travel	(4) Bottled water + No travel	(5) Other
High conflict	0.090*** (0.029)	−0.481*** (0.035)	0.399*** (0.048)	0.120*** (0.044)	−0.225 (0.141)	1.795*** (0.293)	0.294*** (0.090)	0.204*** (0.072)
Head of household age	0.004*** (0.000)	−0.003*** (0.001)	−0.004*** (0.001)	−0.007*** (0.001)	−0.006*** (0.001)	−0.005* (0.003)	0.004*** (0.001)	−0.005*** (0.001)
Head of household gender	−0.096*** (0.021)	0.149*** (0.036)	0.057 (0.036)	0.067* (0.038)	0.028 (0.038)	0.105 (0.122)	−0.009 (0.028)	0.097* (0.057)
Head of household primary education	0.179*** (0.017)	−0.177*** (0.026)	−0.109*** (0.026)	−0.262*** (0.028)	−0.151*** (0.031)	−0.179** (0.088)	0.130*** (0.024)	0.039 (0.045)
Head of household secondary+ education	0.289*** (0.017)	−0.281*** (0.026)	−0.239*** (0.028)	−0.435*** (0.029)	−0.338*** (0.031)	−0.291*** (0.091)	0.270*** (0.023)	−0.025 (0.044)
Number of bedrooms per member	0.015 (0.020)	−0.189** (0.094)	−0.012 (0.040)	−0.094* (0.056)	0.000 (0.030)	−0.344 (0.263)	−0.012 (0.026)	0.172*** (0.033)
Number of members in household	−0.007*** (0.002)	0.004 (0.004)	0.013*** (0.003)	0.007** (0.003)	0.019*** (0.003)	0.001 (0.012)	−0.021*** (0.003)	0.010** (0.005)
Urban	0.816*** (0.012)	−1.014*** (0.019)	−0.906*** (0.021)	−0.585*** (0.020)	−0.280*** (0.020)	−0.047 (0.059)	0.151*** (0.016)	−0.398*** (0.031)
Constant	1.570*** (0.050)	−1.684*** (0.104)	−1.696*** (0.081)	−2.589*** (0.218)	−1.436*** (0.084)	−3.595*** (0.369)	−3.627*** (0.072)	−2.347*** (0.191)
Governorate FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	73,608	73,608	73,608	73,608	73,608	73,608	73,608	73,608

Note: Probit regression. Table shows coefficient estimates, followed by Huber Sandwich standard errors in parentheses. High conflict = 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate, lagged by one year, is above the 75th percentile of the number of deaths per 1000 population across all governates, also lagged by one year. All other variables are as defined in Table 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix E. Short-run and long-run responses

VARIABLES	(1) Piped	(2) Public	(3) Tank on truck/ cart	(4) Bottled water
High conflict lagged both 1 year and 2 years	0.132*** (0.026)	−0.367*** (0.036)	−1.307*** (0.040)	0.041 (0.034)
High conflict lagged 1 year only	−0.048 (0.035)	−0.479*** (0.048)	−1.475*** (0.043)	1.198*** (0.128)
High conflict lagged 2 years only	0.433*** (0.038)	−0.306*** (0.045)	−0.783*** (0.048)	1.000*** (0.075)
Governorate FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	73,608	73,608	73,608	73,608

Note: Probit regression. All regressions use the same controls as the regressions in Table 4. Table shows coefficient estimates, followed by Huber Sandwich standard errors in parentheses. High conflict variables are equal to 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate in the two years prior to survey administration satisfy our criteria (above or below the 75th percentile of the number of deaths per 1000 population across all governates in the respective year) for the given lags. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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Appendix F. Multinomial logistic regression

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Piped	Public	Tank on truck/ cart	Bottled water	Other
High conflict		−0.121** (0.058)	−0.419*** (0.114)	0.980*** (0.186)	3.258*** (0.505)
Head of household age		−0.011*** (0.001)	−0.017*** (0.001)	−0.000 (0.001)	−0.009*** (0.002)
Head of household gender		0.261*** (0.056)	0.128** (0.058)	0.091* (0.052)	0.097 (0.082)
Head of household primary education		−0.427*** (0.041)	−0.562*** (0.046)	−0.029 (0.045)	0.031 (0.065)
Head of household secondary+ education		−0.758*** (0.042)	−1.050*** (0.046)	0.039 (0.044)	−0.091 (0.066)
Number of bedrooms per member		−0.226** (0.110)	−0.034 (0.053)	−0.042 (0.051)	0.350*** (0.047)
Number of members in household		0.025*** (0.006)	0.033*** (0.005)	−0.022*** (0.005)	0.025*** (0.007)
Urban		−2.386*** (0.032)	−1.392*** (0.032)	−0.449*** (0.031)	−0.762*** (0.049)
Constant		−2.078*** (0.137)	−5.225*** (0.274)	−6.465*** (0.147)	−8.912*** (0.420)
Governorate FE		Yes	Yes	Yes	Yes
Year FE		Yes	Yes	Yes	Yes
Observations		73,608	73,608	73,608	73,608

Note: Multinomial logit regression, with piped water as the omitted category. Table shows coefficient estimates, followed by Huber Sandwich standard errors in parentheses. High conflict = 1 if the number of civilian deaths due to armed conflict per 1000 population in the respondent's governorate, lagged by one year, is above the 75^{th} percentile of the number of deaths per 1000 population across all governates, also lagged by one year. All other variables are as defined in Table 2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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