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Windows of peace: the effect of ceasefires on economic recovery

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Abstract: While much of the literature studies causes and consequences of war, the reverberations of peace have rarely been studied. By focusing on the universe of ceasefire agreements since 1993, we study the causal effect of peace on economic recovery using a regression discontinuity in time approach. We estimate these impacts by temporally and spatially matching information on ceasefires with granular data about violence and economic recovery, allowing us to observe their dynamics at highly disaggregated levels and in temporal proximity to their entry into force. Overall, ceasefires have a marginal effect on violence, with their effectiveness in curbing hostilities being greater in areas where conflict is active closer in time to the agreement. These effects are driven by reductions in state-based conflicts, while other types of hostilities or civilian involvement remain unaffected. Using high-frequency data on night-time luminosity, we show that ceasefires have a positive impact on economic recovery, corresponding to an increase of 5.5 per cent when the agreement enters into place. Despite the effect being temporary, we find that it is not driven by external interventions, such as internationally funded new development projects or peace missions.

Key words: peace, conflict, agreement, ceasefire, development, recovery

JEL classification: D74, F5, O1, O20

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1 Introduction

The cost of conflict is estimated to be huge, not only in terms of loss of life and military spending, but in terms of the long-lasting consequences of destruction (De Groot et al. 2022; Stiglitz and Bilmes 2012). While much of the literature concentrates on the causes and consequences of conflicts (Blattman and Miguel 2010; Rohner and Thoenig 2021),[1] the economic consequences of peace have been rarely studied in the literature due to the endogeneity of the presence and timing of peace deals with respect to economic outcomes. However, the path to peace is very different from being the simple reversal of the path to conflict, and deserves a distinct analysis (Collier et al. 2008; Wolfsfeld 2004). Only recently, the literature turned its attention to these processes by focusing on the transition from war to peace, highlighting the importance of civilian cooperation (Berman et al. 2018, 2011), military disengagement (Fetzer et al. 2021), demobilization (Armand et al. 2020), and armed groups' response to peace agreements (Marending 2022). However, the overall effect of peace on recovery and economic development remains little understood.

This paper provides the first empirical evidence on the causal effect of ceasefires on economic recovery. During a conflict, ceasefires are agreements containing the commitment to suspend aggressive actions—that is, 'arrangements that include a statement in which at least one conflict party commits to stop violence temporarily or permanently from a specific point in time' (Clayton et al. 2022b: 5). Ceasefire agreements, together with declarations on disarmament, demobilization, and reintegration (DDR) of opposition parties, introduced as part of a more general peace agreement, represent a major factor for the success and stability of peace agreements (Berman et al. 2011). Despite having been used extensively in the history of war and conflict, until recently ceasefires have been neglected by the research community and examined only in the context of the role of different provisions in the success of a peace deal (Rohner 2018).

Using a global grid at $1^\circ \times 1^\circ$ resolution, we merge spatial and temporal information about ceasefires with temporally and geographically granular data about conflict and economic recovery. This methodology allows gathering disaggregated information about conflict in areas characterized by a ceasefire in temporal proximity to the date in which the agreement becomes effective. Areas characterized by ceasefires are defined as the geographical area where signatories of a ceasefire agreement have been active by perpetrating violence. Exploiting variation in the timing of ceasefires and using the high temporal and spatial resolution of our dataset, we identify the impact of peace through ceasefires using a regression discontinuity in time (RDiT) design. This allows estimating the impact of ceasefires at the time in which the agreement enters into place, taking into account the geographical dispersion of each conflict.

We measure the success of ceasefires focusing on its most directly related outcome: a reduction in violence.[2] Overall, ceasefires have limited effects on violence at the time of the agreement entering into effect. Ceasefires lead to a decrease of 0.4 percentage points in the presence of conflict in areas that are historically affected by violence perpetrated by signatories. This effect corresponds to a reduction of 4.6 per cent as compared to the average presence of violence in the six-month window around ceasefires. Ceasefires are instead more effective in areas where conflict is present in temporal proximity to the

[1] The literature highlights different reasons for the insurgence of a war, including commitment problems and asymmetric information about an opponent's military capabilities (Fearon 1995), the misalignment between the incentives of political leaders and those of citizens (Jackson and Morelli 2007), the balance between greed and grievance motives and the feasibility of conflict (Collier and Hoeffler 2004; Collier et al. 2009), and models based on rent-seeking (Esteban and Ray 2008; Skaperdas 1992; Van der Ploeg and Rohner 2012).

[2] An alternative approach looks at the duration of peace (DeRouen Jr et al. 2009; Hartzell and Hoddie 2003; Licklider 1995). Licklider (1995) finds that decisive military victories are more likely to bring long-lasting peace than a peaceful settlement of incompatibilities, while Joshi et al. (2015) find that the provisions related to the security sector incorporated into a peace agreement have an impact on its long-term success.

agreement. In these cases, ceasefires reduce the presence of violence by 3.4 percentage points, a reduction of 12.4 per cent as compared to the average presence of violence in the six-month window around ceasefires. These effects are driven by a decrease in violence perpetrated by signatories and associated with state-based conflicts. We do not observe any effect for violence associated with a non-state-based conflict, for violence against civilians, and for civilian response (i.e. protests and riots).

Focusing on night-time luminosity, we uncover how ceasefires affect the degree of economic recovery. In areas that are historically affected by violence perpetrated by signatories, ceasefires increase luminosity by 4.79 per cent over the mean luminosity in the six-month window around the ceasefire. This effect is not driven by larger decreases in violence, but rather by areas where conflict is not present in temporal proximity to the ceasefire. For these areas, the increase in night-time luminosity is equal to 5.50 per cent over the mean luminosity in the six-month window around the ceasefire. These results are not driven by external interventions. We do not find any effect of ceasefires on media coverage of the conflict, on the start of new internationally funded development projects, or on the presence of UN peace missions. In addition, determinants of conflict, such as weather and commodity prices, are not affected.

These results contribute to two important branches of the literature. First, they contribute to the existing literature on peace agreements by quantitatively examining the effects of ceasefires on violence. We complement this literature by providing evidence of the effect of ceasefires on economic recovery. While bottom-up initiatives proved to be able to provide longer peace duration (Fortna 2003; Joshi et al. 2017), and can result in higher social capital and level of trust (Cilliers et al. 2016), to our knowledge, there exists no causal evidence of the effect of peace on economic recovery.

The paper is organized as follows. Section 2 provides background on ceasefires, outlining the conceptual definition and success factors, while set in relation to the broader peace process. Section 3 describes data sources used in the analysis and general sample descriptive statistics. Section 4 highlights the empirical strategy exploited in the paper. In Section 5 we present the results, and Section 6 concludes.

2 Background

Ceasefires play an essential role in any peace process and represent a relatively common feature in civil conflict. While they might aim at transmitting a variety of signals to the stakeholders of a conflict, ceasefires are recognized as a tool to build trust, demonstrate peaceful intentions, and set conditions for participants of the conflict to pave the way from war to peace (Bara et al. 2021). All ceasefires relate to an immediate objective to terminate violence, either integrated into or independent of a broader peace agreement, but they differ in aiming to curb violence temporarily or permanently. Thereby, ceasefire agreements can be present in various contexts and answer to different purposes.

Highlighting further complexity of the phenomenon, there exists no universal definition of ceasefires. Alongside the initial term 'ceasefire', they are also labelled as 'truce', 'armistice', or 'cessation of hostilities'. Following Clayton et al. (2022b), ceasefires include the following features:

1. a written or verbal declaration in which at least one actor commits to stopping violence;
2. an exact point in time in which the agreement comes into force;
3. a commitment to stop violent activity.[3]

To measure ceasefires' success, a dominant criterion in the existing literature is to look at the duration of peace (e.g., Badran 2014; Hartzell and Hoddie 2003; Joshi and Quinn 2015; Licklider 1995). Its

[3] This feature distinguishes a ceasefire from measures de-escalating conflict.

measurement is non-trivial. While the onset of a ceasefire is identifiable based on dates of declaration and entry into force, it constitutes a challenge to identify its end: some ceasefires intend to curb violence during a specific period of time (e.g. a holiday period or to fulfil a humanitarian task), yet others may not indicate any end date. Furthermore, incidents violating the agreement do not necessarily imply that a ceasefire has ended in practice. At the same time, the agreement might be considered to have failed technically even before observed aggression restarts. Consequently, a ceasefire peace window is defined by its initiation and less so by its intended duration.

Beyond the criterion of temporal duration of peace, a ceasefire incurs a spatial extent. The difficulty here lies in defining where exactly a ceasefire applies. While a ceasefire might be declared by actors present on a specific territory, violence committed by signatory groups can relocate to other locations ex post given armed actors' mobility (Marending 2022). As to humanitarian criteria, curbing human fatalities (i.e. decreasing the intensity of fighting) is another means to measure success.

In terms of economic recovery induced by peace, there remains an important lacuna in the literature, not least due to important identification challenges (Collier 2007; Rohner 2018). The universe of ceasefires implies varying windows of peace and as such offers a unique possibility to understand their impact on economic outcomes.

Turning to the factors that contribute to the success or failure of a ceasefire in terms of peace duration, it is highlighted in the literature that the context in which ceasefires are declared (political will, features of the opposition, etc.), as well as provisions included in ceasefires (monitoring, demobilization, etc.), matter for their success (Clayton et al. 2022a).

Relating ceasefires and general conflict dynamics, ceasefires are not understood as an end to a conflict settling opposing parties' differences, but rather as a window of peace in the wider peace process.[4] Most conflicts observe more than one ceasefire: as ceasefires do not require a long preparation process and might occur due to multiple motivations (that are largely unobservable), they do not necessarily relate to a specific moment in the broader peace process and might happen at the beginning, in the middle, or at the end of it. It is the transitory nature of ceasefires that we will exploit in our empirical analysis.

3 Data

We collect data from different sources, which we summarize in this section. Appendix A provides further details of the variables and data sources used.

3.1 Ceasefires

The data on ceasefires comes from the comprehensive ETH/PRIO Civil Conflict CeaseFire dataset and contains information on agreements globally between 1989 and 2020 (see Clayton et al. 2022b for a detailed description). The data covers the universe of ceasefires ranging from unilateral to multilateral arrangements, of verbal to highly detailed text formats, as well as including agreements independent of whether they successfully terminate violence for some period. This broad definition allows us to study 1,547 ceasefires across 62 countries and their impact on peace processes over the course of 25 years

[4] In a minority of cases, ceasefires manage to curb violence for a long period of time, either as part of a broader peace agreement, such as Burundi in 2008, or as a separate deal, such as Cyprus in 1974 (Clayton et al. 2022b).

(1993–2017). The data describes dates (declaration and entry into force), location, type, or the parties to the ceasefire, mapped onto the UCDP/PRIO conflict data (Sundberg and Melander 2013).[5]

The CeaseFire database defines ceasefire agreements as 'arrangements that include a statement in which at least one conflict party commits to stop violence temporarily or permanently from a specific point in time' (Clayton et al. 2022b: 5). The ceasefires are further categorized by the nature of the intended violence suspension, whereas the sample is characterized as follows: (1) cessation of hostilities without meaningful compliance mechanism (74 per cent); (2) cessation of hostilities with monitoring, often written and linked to a peace process (18 per cent); and (3) definitive ceasefires with an objective to terminate conflict rather than suspend hostilities (8 per cent). The stated purpose of a ceasefire at the point of declaration varies, such as relating to a peace process, holidays, or humanitarian task, with a majority (69 per cent) referring to the first of these.

Panel A in Table 1 further describes the ceasefires studied. Ceasefires at large are bilaterally or unilaterally declared (49 and 43 per cent, respectively) with one-third being in written format. The government is a co-signatory in 74 per cent of the ceasefires. The timing of agreements is in a majority of cases not directly linked to peace negotiations (61 per cent), with a very small share making reference to DDR provisions (9 per cent).

Figure 1 illustrates the temporal distribution of ceasefires across five geographical regions covering the full available time span from 1998 until 2020. The Americas observe most agreements between 1989 and the mid-1990s, driven by conflicts in El Salvador, Guatemala, and Nicaragua. In the early 1990s most identified ceasefires are declared in Europe, relating to the conflicts in former Yugoslavia, with an increased activity since 2014 primarily due to the conflict in Ukraine. Africa and Asia together show dynamic ceasefire activity throughout the sample period, driven by conflicts in the Democratic Republic of Congo, Sudan, and South Sudan in the former, and India and Myanmar in the latter. Ceasefires in the Middle East have been increasing from relatively few events in the 1990s and early 2000s relating largely to Lebanon and the Israeli–Palestinian conflict, to holding the largest share in the last decade due to conflicts in Syria and Yemen.

3.2 Conflict

We measure conflict at high temporal and spatial granularity using the Uppsala Conflict Data Program (UCDP). The dataset provides event-based information, supplying precise dates and geocoded locations of events across the study area. Information draws on reports from news agencies, NGOs, and governments. The UCDP qualifies an event as an incident characterized by 'armed force by an organized actor against another organized actor, or against civilians, resulting in at least 1 direct death' (Sundberg and Melander 2013: 524) .

We supplement information from the UCDP database with information about attacks against civilians and about protests and riots from the Armed Conflict Location & Event Data Project (ACLED) database (Raleigh et al. 2010). ACLED codes political violence events and demonstrations, and selects politically relevant non-violent events. Because of the temporal and geographical coverage of the ACLED database, we use this information as a complement to the information provided by the UCDP or conditional on available information.

[5] The CeaseFire dataset relies primarily on the Factiva global news database to source information. The search is limited by geographical extent of civil conflicts coded in UCDP/PRIO, allowing for a temporal window spanning three years before and after the said conflict periods. However, some ceasefires relate to actors not related to a UCDP conflict. Due to the lower likelihood of reporting on brief, localized agreements in less accessible areas, the results are not necessarily representative of their dynamics.

Table 1: Descriptive statistics

	Mean	Std dev.	Percentiles			*N*
			1st	Median	99th	
	(1)	(2)	(3)	(4)	(5)	(6)
A. Ceasefires						
Year of ceasefire	2,004.01	7.56	1,993.00	2,004.00	2,017.00	1,543
Location: Europe/Middle East	0.33	0.47	0.00	0.00	1.00	1,543
Location: Asia	0.33	0.47	0.00	0.00	1.00	1,543
Location: Africa	0.31	0.46	0.00	0.00	1.00	1,543
Location: Americas	0.03	0.17	0.00	0.00	1.00	1,543
Unilateral ceasefire	0.44	0.50	0.00	0.00	1.00	1,543
Written agreement	0.28	0.45	0.00	0.00	1.00	1,464
No link to or before peace negotiations	0.62	0.49	0.00	1.00	1.00	1,543
Reference to DDR	0.09	0.28	0.00	0.00	1.00	1,541
Ceasefire has a state signatory	0.74	0.44	0.00	1.00	1.00	1,543
B. Conflict and violence						
Any event	0.08	0.28	0.00	0.00	1.00	3,173,040
Any event (signatory)	0.07	0.25	0.00	0.00	1.00	3,173,040
Any violent event (other actors)	0.02	0.14	0.00	0.00	1.00	3,173,040
Any state-based violence	0.07	0.25	0.00	0.00	1.00	3,173,040
Any non-state violence	0.01	0.11	0.00	0.00	1.00	3,173,040
Any one-sided violence	0.02	0.15	0.00	0.00	1.00	3,173,040
Any event (signatory, unilateral)	0.04	0.19	0.00	0.00	1.00	3,173,040
Any event (signatory, confrontation)	0.04	0.20	0.00	0.00	1.00	3,173,040
Violence against civilians	0.04	0.20	0.00	0.00	1.00	3,173,040
Any protest/riot	0.04	0.18	0.00	0.00	1.00	1,212,943
C. Other outcomes						
Night-time luminosity	7.56	8.51	0.00	4.96	63.00	3,101,714
Peace troops	52.06	646.85	0.00	0.00	18,695.00	3,046,353
Presence of peace missions	0.04	0.19	0.00	0.00	1.00	3,046,353
International financing	0.01	0.09	0.00	0.00	1.00	2,920,010
Average temperature	22.21	9.21	–44.74	24.92	42.27	3,173,040
Average precipitations	3.26	4.98	0.00	1.17	125.35	3,173,040
Value of commodities	1,326.47	3,962.88	0.00	0.00	38,044.75	3,173,040
News index	0.07	0.17	0.00	0.01	2.89	55,548

Note: descriptive statistics for selected ceasefires (Panel A) and for outcomes related to violence in the study area and in temporal proximity to a ceasefire (±6 months) (Panel B). In Panel B, the spatial unit of observation is the grid cell at the 1° × 1° resolution.

Source: authors' compilation, based on data sources outlined in Section 3.

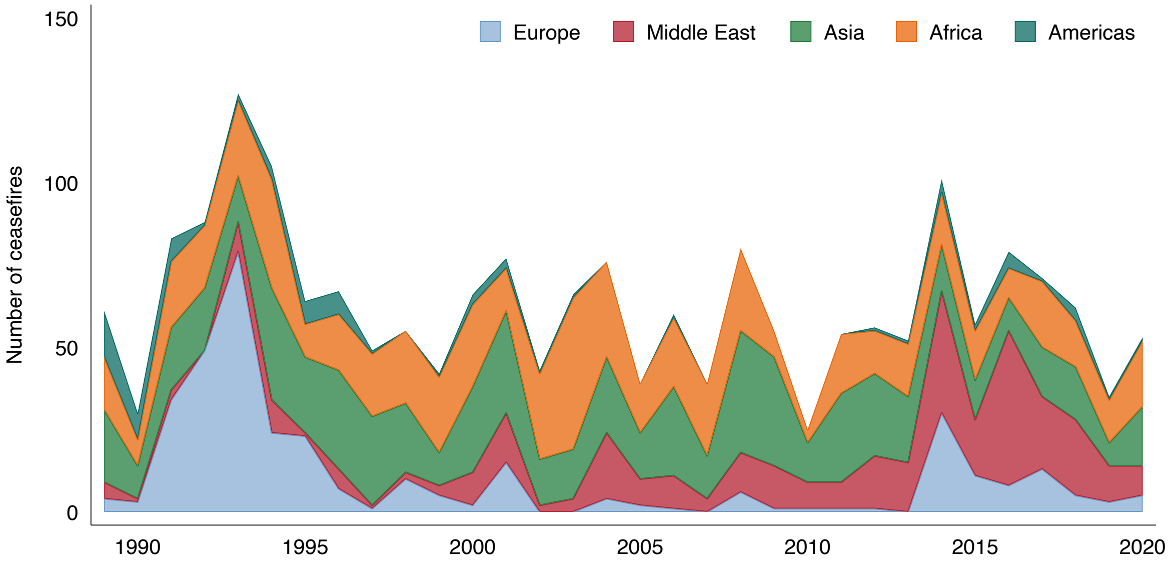
Figure 2 shows the geographical distribution of violent events in the UCDP and ACLED datasets spanning the period 1989–2020 for the UCDP dataset and with varying coverage for the ACLED dataset.[6] Restricting to the UCDP dataset, the Middle East accounts for the majority of violent conflict events (53 per cent), followed by Asia (30 per cent) and Africa (12 per cent). The Americas and Europe account for 2 and 3 per cent, respectively.

Because our interest is not only on areas affected by conflict, but also those influenced by a ceasefire, we need to restrict the area of interest spatially. This approach requires some reasoning about the nature of ceasefires. First, most ceasefires do not have a specific geographical area. We therefore do not have a clearly defined area that is treated by the ceasefire. In addition, when ceasefires have a well-defined geographical area, not necessarily the full area is treated because conflict is not equally spaced. Second, ceasefires can have cross-border and international actors; therefore, relying uniquely on the state or region of conflict is an imperfect approach. Given these constraints, we first build a global grid at a 1° ×

[6] Countries in Africa have the longest temporal coverage, spanning from 1997 to today, while the rest of the world has varying coverage. Detailed information is provided by ACLED (2019).

1° resolution, which will be the base of our analysis. Focusing on a gridded dataset rather than a dataset based on administrative boundaries reduces concerns about potential endogeneity between conflict and administrative bounds.

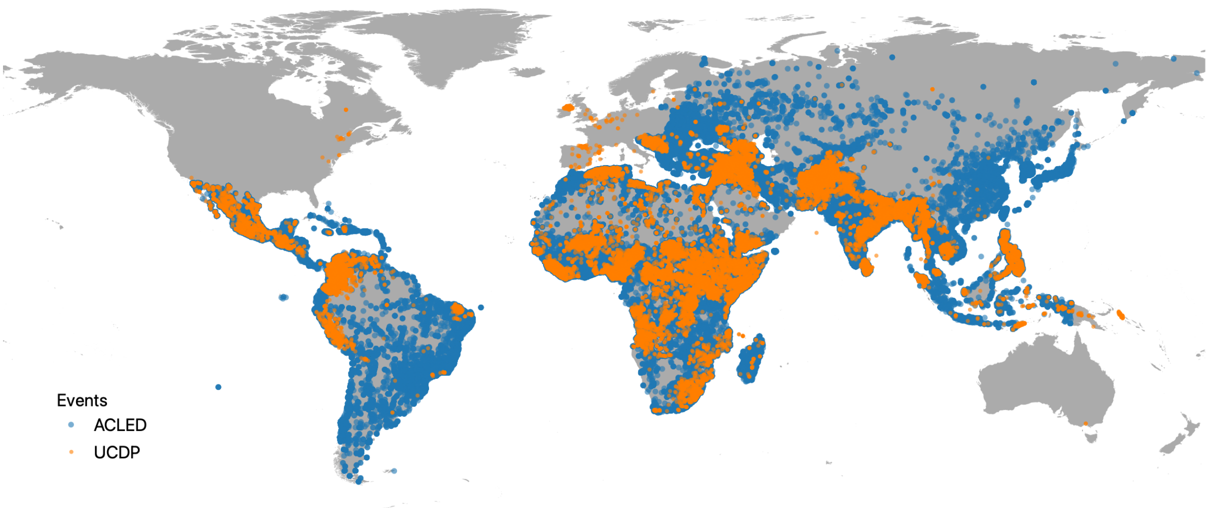
Figure 1: Frequency of ceasefire declarations



Note: number of ceasefires declared, disaggregated by geographical regions in the ETH-PRIO database. We include all ceasefires available in the entire sample period from 1989 until 2020.

Source: authors' compilation, based on the ETH-PRIO database.

Figure 2: Distribution of conflict



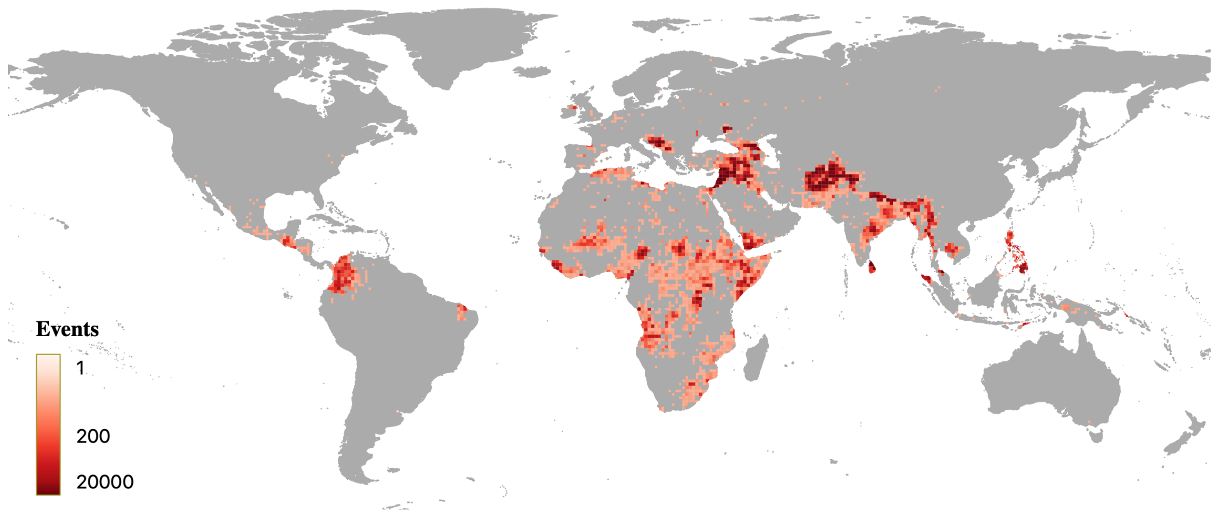
Note: each dot represents an event in the UCDP database. We include all events in the full period available.

Source: authors' compilation, based on the UCDP database.

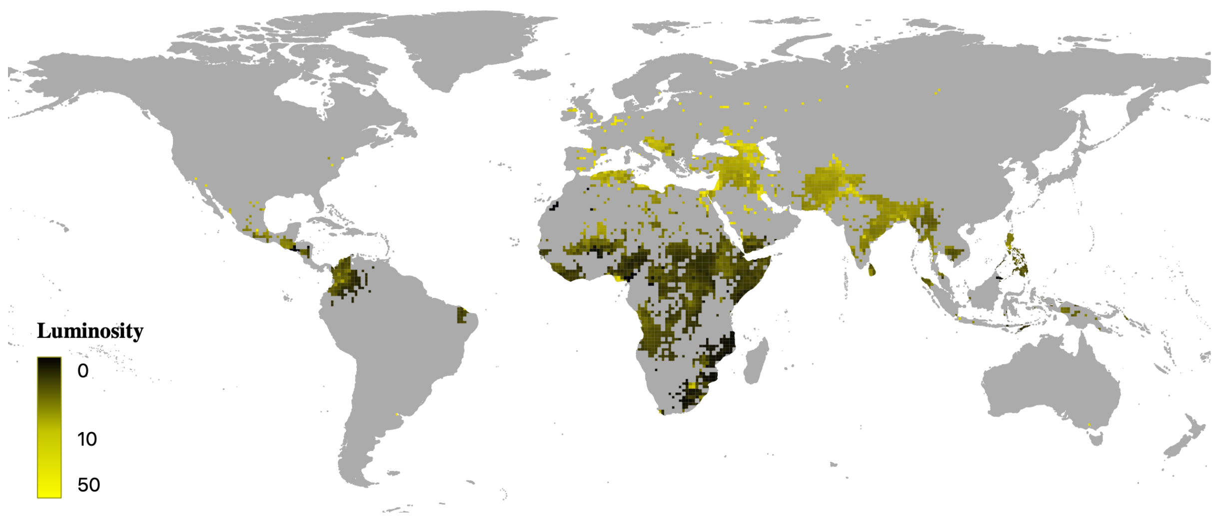
For a specific ceasefire, we select treated cells based on the violent activity of actors declaring a ceasefire (i.e. signatories). We select one grid cell if at least one of the signatory has been active by perpetrating or participating in violence at any point in time. We refer to this approach as *selection based on signatories' activity*. This approach allows selecting our sample area considering in the analysis not only the temporal dimension of violence, but also its spatial dispersion. Figure 3 shows the geographical distribution of grid cells selected under this criteria and the historical intensity of conflict in these grid cells, defined as the cell-level number of events present in the UCDP dataset that are perpetrated by signatories of ceasefires at any point in time.

Figure 3: Historical intensity of conflict by signatories and night-time luminosity

A. Historical intensity of conflict



B. Average night-time luminosity



Note: in Panel A the figure shows the total number of events recorded in the UCDP dataset in which at least one actor is a signatory of a ceasefire. The area is restricted to the grid cells selected according to the procedure described in Section 3. The global grid is at the 1 ° × 1 ° resolution. Colours indicate the intensity of conflict, defined as the cell-level number of historical events present in the UCDP that are perpetrated by signatories of ceasefires. In Panel B the figure shows the average night-time luminosity at the grid level, across the sample period 1993–2017.

Source: authors' compilation, based on data sources outlined in Section 3.

Panel B in Table 1 provides descriptive statistics about violence in the study area and in temporal proximity to a ceasefire (±6 months; see Section 4 for further details on the panel structure). Conflict events are relatively rare events across the spatial and temporal extent considered, with 8 per cent of the panel observations reporting any event. In total we consider 158,448 events, of which a large majority belongs to state-based violence (80 per cent) and, to a minor extent to one-sided violence (14 per cent) and to non-state violence (6 per cent). The direct cost of human lives amounts to 1,254,975 reported conflict deaths.

3.3 Economic recovery

We proxy recovery with a consistent measurement of night-time light emissions from Earth using satellite-based imagery from the DMSP-OLS sensor. Satellite-based night-time luminosity captures aspects of human economic activity and is widely used to proxy for economic productivity, growth, and human development in rural and urban areas (Bruederle and Hodler 2018; Henderson et al. 2012).

Because ceasefires happen at daily granularity, we obtain daily night-time luminosity data from the World Bank's Light Every Night (LEN) project for the 1993–2017 sample period.[7] The spatial resolution translates to about 4.9 km at the equator, where pixel values range from no light at 0 to full light at 63. The entire time series is based on the same sensor technology (DMSP-OLS), yet satellites used change over time and lack respective onboard calibration.[8] We account for any differences in overall level of nightlight intensity across years using a moving average adjustment (Henderson et al. 2012). A known challenge of the DMSP-OLS sensor is top-coding, typically in major cities, and general challenges of cloud cover. We average luminosity in a gridded dataset at the $1° \times 1°$ resolution.[9] Panel B in Figure 3 illustrates the measured luminosity average at the grid cell level. Given the spatial extent considered and variation over time, only a few cells reach high digital number levels beyond 30 (<1 per cent).

3.4 External intervention

We supplement information with data on external interventions in conflict zones. Panel C in Table 1 provides descriptive statistics for these outcomes.

First, we gather information on media coverage of ceasefires in international news, to measure whether the level of public interest is raised after the ceasefire. Given the time frame of the study, we report on coverage of ceasefires in international news using www.newspapers.com, a database of digitized historical newspapers that allows computing the number of pages in which a word or a set of words appear on a specific day. We select newspapers from Canada, the United States, and the United Kingdom, not only to focus on searches using English language and a larger collection of newspapers, but also to highlight international media attention, rather than local media attention. For each ceasefire, we build a query composed by the word *ceasefire* and the location of the ceasefire (as reported in the ETH/PRIO database). For each day in the sample, we can therefore compute the number of pages in which both words appear. Following Beach and Hanlon (2022), we then define the *news index* as the number of pages returned by the search query for a specific ceasefire in a day, normalized by the total number of pages available in the www.newspapers.com dataset in the corresponding day (multiplied by 100). Higher values indicate that the composition of news in newspapers shifted towards articles covering ceasefires in a specific conflict, thus indicating media attention. We merge information about media coverage with the one on ceasefires and conflict using the location of the ceasefire. Figure 4 superimposes the time series of the news index for each ceasefire location in the sample.

Second, because the reconstruction of damaged infrastructure or reinstating the provision of public goods in conflict-affected areas can support the recovery of economic activity, likely visible by night-time light, we focus on whether formal development projects financed by (inter)national institutions coincide with ceasefire declarations. We overlap their date (signing, entry into force) and geospatial coverage with our daily grid-level panel. The projects are sourced from World Bank lending projects 1947–2017 and AidData's Global Chinese Development Finance Dataset covering 2000–17 (Dreher et al. 2022).

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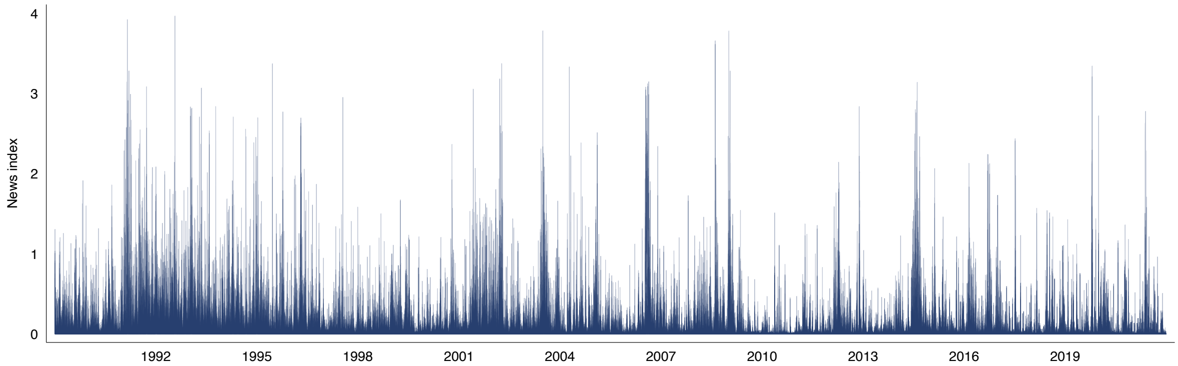
[7] The data are sourced from the NOAA National Centers for Environmental Information (NCEI) archive, and we use the VIS processed imagery band where non-human light emissions are removed and non-light values are set to zero.

[8] Following the recommendation of NOAA/World Bank for highest data quality, we select satellites: F10 (1993–94), F12 (1995–97), F14 (1998–2003), F16 (2004–08), F18 (2009–10), F15 (2011–17).

[9] Across all luminosity observations, 6 per cent of values are not available due to having tiles of bad quality (78 per cent) or missing tiles altogether (22 per cent) for the respective day and spatial extent.

Figure 4: Coverage of sampled ceasefires in international news



Note: the figure shows the time series of the news index for each ceasefire location in the sample. The *news index* is defined as the number of pages returned by the search query for a specific ceasefire in a day over the total number of pages available in the www.newspaper.com dataset in the corresponding day (multiplied by 100).

Source: authors' compilation, based on data in the www.newspaper.com dataset.

Third, to understand whether night-time light emissions correspond to the deployment of peace corps, we supplement information with the Geo-PKO Dataset, which provides information on UN peacekeeping deployments at the local level in the period 1994-–2020 (Cil et al. 2020). Using information about the location of deployment, the time of deployment, and the characteristics of each mission, we merge temporal and geographical variation in the presence of peace missions and the number of troops deployed with our main sources of information.

3.5 Other indicators

We use climatic information from the ERA5-Land daily reanalysis dataset aggregated to our sample grid from an original spatial resolution of $0.1° \times 0.1°$ (Sabater 2019). Measures of gridded precipitation and temperature account for climatic frictions that impact local production directly. To proxy natural resource wealth at the grid cell level we combine data on observed commodity presence with their respective global market prices. Geospatial information on resources (mines, deposits, occurrences) globally is retrieved from the US Geological Survey (USGS), which distinguished more than 100 different types in 2011, and extended to include deposits of diamonds and petrol administered by PRIO (Gilmore et al. 2005; Lujala et al. 2007). Commodities and prices are matched individually or by grouped resources. We use monthly prices from the IMF's Primary Commodity Prices dataset measured in US dollars. The resource wealth of a sample grid cell is defined as the average price value across all commodities present.

4 Empirical strategy

This section describes the empirical approach followed for the estimation of the effect of ceasefires. For identification, we exploit the high temporal and spatial resolution of the data discussed in Section 3, available for a long time horizon, and we identify the impact of the ceasefire using a RDiT design. Hausman and Rapson (2018) provide a review on the use of this approach in the economics literature.

Our unit of observation is a set of grid cells, selected according to the procedure detailed in Section 3, and expanded by ceasefire agreement. Each cell can therefore be selected multiple times depending on the signatories of a specific ceasefire and the activity of signatories. The outcome of interest is $y_{ic,t}$, which represents the value y in grid cell i selected as part of ceasefire c at time t. By exploiting the temporal discontinuity at the time of the ceasefire, which we assume to be $t = 0$, our approach assumes that at all dates $t > 0$, the grid cell is treated, and for all $t < 0$, the grid cell is not treated. Additional confounders change smoothly across the date of the ceasefire.

We estimate the impact of the ceasefire using the following equation:

$$y_{ic,t} = \alpha + \beta c_{ic,t} + f(date_{ic,t}) + \varepsilon_{ic,t} \tag{1}$$

where $c_{ic,t}$ is an indicator variable equal to unity if the ceasefire is in place, and zero otherwise, and $date_{ic,t}$ is measured as the number of periods from the date of the ceasefire. Notice that $date_{ic,t}$ is ceasefire-dependent and is built considering periods of 10 days each. For example, $t = 1$ groups the first 10 days following a ceasefire. We exclude the day of the ceasefire's entry into force from the analysis. In this approach, identification is achieved by eliminating the potentially endogenous relationship between the date of the ceasefire and the unobserved determinants of the outcome variable by including a flexible functional form in the date, $f(date_{ic,t})$. When estimating the impact of the ceasefire on violence, the design is a sharp RDiT, since $date_{ic,t}$ determines fully whether the ceasefire is in place, independently from whether it is respected or not.

Following Imbens and Lemieux (2008) and Anderson (2014), we estimate equation (1) using local regressions of the following form:

$$y_{ic,t} = \alpha + \beta c_{ic,t} + \delta_1 date_{ic,t} + \delta_2 c_{ic,t} \cdot date_{ic,t} + \delta_3 c_{ic,t} \cdot date^2_{ic,t} + \gamma \mathbf{X_{ic,t}} + \varepsilon_{ic,t} \tag{2}$$

where $X_{ic,t}$ is a set of cell-level controls. While adding control variables is not required to achieve identification when $\varepsilon_{ic,t}$ does not change discontinuously at the time of the ceasefire, we control for country and year fixed effects in the estimating equation. Equation (2) identifies the effect of the ceasefire at the time the ceasefire becomes effective. We assume a uniform kernel and use a bandwidth of six months on each side. For statistical inference, we follow Anderson (2014) and we assume that $\varepsilon_{ic,t}$ is clustered at the period–ceasefire level, guaranteeing robustness of standard errors to both within-month and within-ceasefire serial correlation. Results are robust to selecting alternative bandwidths or estimating effects using local polynomial RD point estimators with robust bias-corrected confidence intervals and inference as developed in Calonico et al. (2020).

5 Results

5.1 Violence

We begin by studying the overall effect of a ceasefire on violence. Table 2 reports the estimates using equation (2). Columns (1)–(3) focus on whether violent events from any actor are recorded in the grid cell, while columns (4)–(9) distinguish between events perpetrated by signatories and by other (non-signatory) actors. We distinguish between three geographical areas. First, we provide estimates considering the area selected under the procedure described in Section 3. Second, we select only cells in which any of the signatory is active in the six months before the ceasefire. We label this area as *salient*. Third, we focus on the remaining cells, in which signatories are active, but not in the six months before the ceasefire. Figure 5 presents the RDiT plots for the estimates corresponding to column (1) in Panel A and column (2) in Panel B.

Overall, ceasefires have a marginal effect on violence, corresponding to a reduction of 0.4 percentage points in the share of cells characterized by violence at the temporal discontinuity (column 1). Notice, however, that prior to ceasefire, violence is much more localized as compared to the historical presence of signatories. In fact, when we select all cells, only 8.7 per cent are characterized by violence. Restricting the sample to salient areas (column 2) leads instead to a reduction in violence of 3.4 percentage points at the temporal discontinuity (column 2). In this sub-sample, 27.4 per cent of cells are characterized by violence. Focusing instead on the remaining cells, we observe a slight increase in violence at the temporal discontinuity, corresponding to 0.7 percentage points. The overall level of violence in these cells is relatively small, equal to 2.1 per cent.

Table 2: The effect on violence

	Any violent event by ...								
	any actor			signatories			other actors		
Area:	All (1)	Salient (2)	Other (3)	All (4)	Salient (5)	Other (6)	All (7)	Salient (8)	Other (9)
Ceasefire in place	–0.004 (0.002) [0.028]	–0.034 (0.003) [0.000]	0.007 (0.001) [0.000]	–0.003 (0.002) [0.061]	-0.033 (0.003) [0.000]	0.008 (0.000) [0.000]	–0.001 (0.001) [0.236]	–0.002 (0.001) [0.061]	–0.001 (0.001) [0.438]
Mean (dep.var.)	0.087	0.274	0.021	0.069	0.250	0.005	0.021	0.036	0.016
Observations	3,911,940	1,021,932	2,890,008	3,911,940	1,021,932	2,890,008	3,911,940	1,021,932	2,890,008
Ceasefires	2,004	1,846	1,909	2,004	1,846	1,909	2,004	1,846	1,909
Countries	119	92	119	119	92	119	119	92	119

Note: violence is based on UCDP data. Estimates are based on local linear regressions—equation (2). Standard errors (in parentheses) are clustered at the period–ceasefire level. *P*-values are presented in brackets. The spatial unit of observation is the grid cell at the $1° \times 1°$ resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ± 6 months. *Any violent event* is an indicator variable equal to 1 if at least one violent event is recorded, and 0 otherwise.

Source: authors' compilation, based on data sources outlined in Section 3.

Figure 5: Violence in temporal proximity to a ceasefire

Note: violence and fatalities are based on UCDP data. Estimates are based on local linear regressions—equation (2). The spatial unit of observation is the grid cell at the $1° \times 1°$ resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ± 6 months. Dots represent the average of the dependent variable in the corresponding period.

Source: authors' compilation, based on data sources outlined in Section 3.

These results are driven primarily by changes in violence perpetrated by signatories, which are the main actors active in the areas. Overall, in the temporal bandwidth surrounding a ceasefire, 6.9 per cent of cells are characterized by violence perpetrated by signatories and only 2.1 per cent by violence perpetrated by other actors. The reduction in violence perpetrated by signatories is equal to 3.3 percentage points at the temporal discontinuity as compared to 0.2 percentage points for violence perpetrated by other actors. Figure 5 shows that the pre-ceasefire pattern in conflict is an increasing one, while in the post-ceasefire period the pattern is either stagnating or decreasing in salient areas.

We turn our attention to the effect of ceasefires distinguishing by type of conflict characterizing the area. Table 3 shows estimates of the effect of ceasefires on the presence of state-based conflict, non-state-based conflict, attacks against civilians, and civilian response. Attacks against civilians combine information from both the UCDP and ACLED datasets (conditional on the information being available in ACLED in the corresponding geographical and temporal frame). We code the presence of attacks against civilians in a grid cell if at least one event is recorded in the ACLED dataset as 'violence against civilians' or at least one event is recorded as 'one-sided violence' in the UCDP dataset.[10] Civilian response measures the presence of at least one protest or riot, as recorded by the ACLED dataset, again conditional on the information being available. Figure 6 provides RDiT plots for these variables.

Table 3: The effect on conflict type

	State-based conflict	Non-state-based conflict	Violence against civilians	Civilian response
	(1)	(2)	(3)	(4)
Ceasefire in place	–0.004	–0.000	–0.001	–0.002
	(0.002)	(0.001)	(0.001)	(0.001)
	[0.008]	[0.919]	[0.193]	[0.200]
Mean (dep.var.)	0.067	0.012	0.041	0.035
Observations	3,173,040	3,173,040	3,173,040	1,212,943
Ceasefires	1,543	1,543	1,543	674
Countries	116	116	116	70

Note: violence is based on UCDP data in columns (1)–(3) and on ACLED data in columns (3)–(4). Estimates are based on local linear regressions—equation (2). Standard errors (in parentheses) are clustered at the period–ceasefire level. *P*-values are presented in brackets. The spatial unit of observation is the grid cell at the $1° \times 1°$ resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ± 6 months. Outcome variables are indicator variables equal to 1 if at least one event of the type reported in the header is recorded, and 0 otherwise. *Civilian response* is available only for the spatial and temporal subset available in the ACLED dataset.

Source: authors' compilation based on the UCDP and ACLED databases.

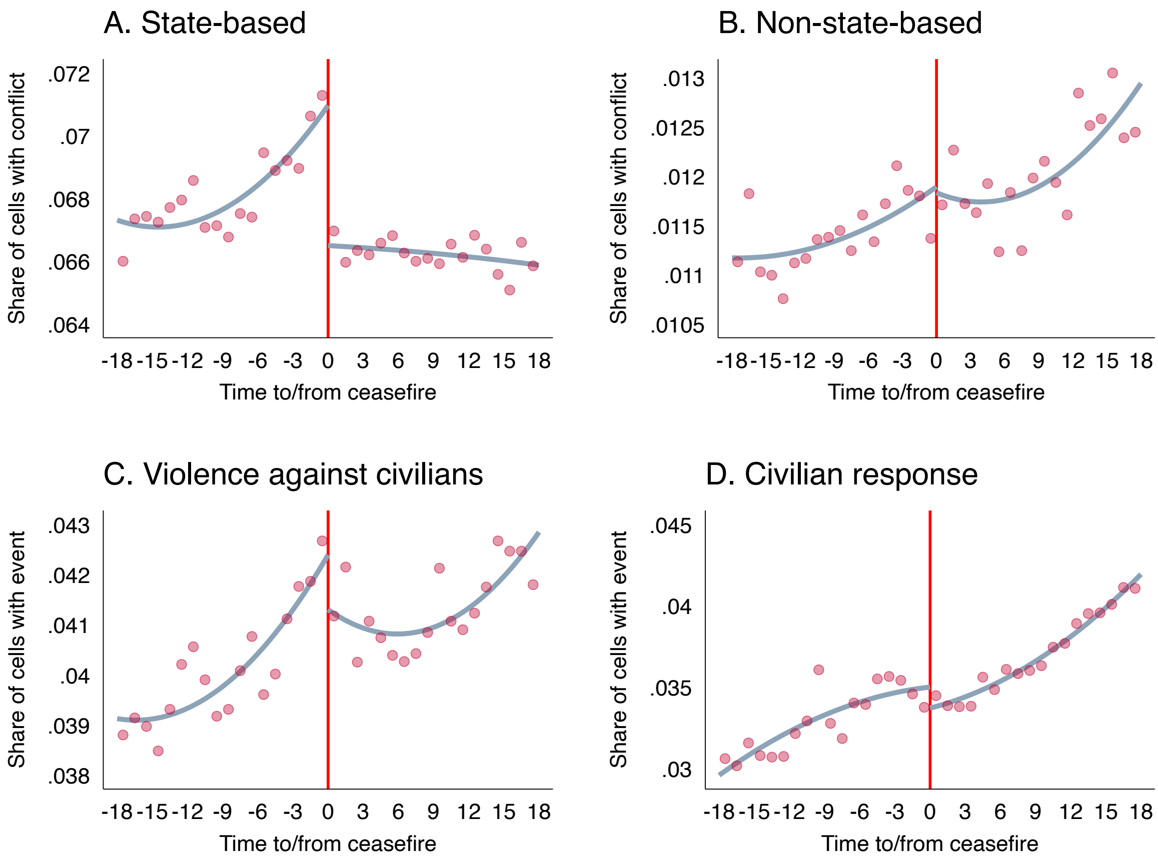
Areas characterized by ceasefires are primarily areas afflicted by state-based conflict—that is, areas in which at least one of the armed forces is the government of a state. Violent events associated with this type of conflict characterize 6.7 per cent of the study area, as compared to just 1.2 per cent of violent events associated with non-state-based conflicts. In these areas, we also have prevalence of violence against civilians, which is present in 4.1 per cent of grid cells, and of civilian response, which is present in 3.5 per cent of cells.

Ceasefires have a significant effect on reducing violence in state-based conflict only. We observe a reduction of 0.4 percentage points in this type of violence at the temporal discontinuity. On the contrary, we do not observe any significant effect not only on non-state-based violence, but also on violence against civilians and on civilian response. This result highlights the importance of the presence of a state to enforce the ceasefire, while for smaller conflicts ceasefires tend not to generate significant reductions in violence.[11]

[10] *One-sided violence* includes events in which a formally organized group perpetrates violence against civilians, resulting in the death of at least 25 people. See Sundberg and Melander (2013).

[11] We find a significant effect of ceasefires for both direct confrontation between signatories and events in which a signatory perpetrates unilateral violence or is targeted by a non-signatory actor. As expected, the magnitude of the effect for direct confrontations is larger compared to unilateral violence.

Figure 6: Conflict type in temporal proximity to a ceasefire



Note: violence is based on UCDP data in panels (A)–(C) and on ACLED data in panels (C)–(D). Estimates are based on local linear regressions—equation (2). The spatial unit of observation is the grid cell at the $1° \times 1°$ resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ± 6 months. Outcome variables are indicator variables equal to 1 if at least one event of the type reported in the header is recorded, and 0 otherwise. *Civilian response* is available only for the spatial and temporal subset available in the ACLED dataset. Dots represent the average of the dependent variable in the corresponding period.

Source: authors' compilation based on the UCDP and ACLED databases.

5.2 Economic recovery

This section focuses on the effect of ceasefires on economic recovery and on potential external inputs to such a dimension. As discussed in Section 3, we proxy economic recovery using night-time luminosity, as measured from satellites. Table 4 reports the estimates using equation (2). Column (1) focuses on the effect for all cells selected under the procedure described in Section 3. Column (2) selects only *salient* cells—that is, cells in which any of the signatories is active in the six months before the ceasefire. Column (3) provides the estimate for the remaining cells. Figure 7 presents the RDiT plots for the estimate corresponding to column (1). In the overall area, the ceasefire increases night-time luminosity by 0.362 at the temporal discontinuity. This corresponds to an increase by 4.79 per cent over the mean luminosity in the period surrounding the ceasefire. However, while the largest effects in violence are driven by salient areas, we observe no significant increase in luminosity in these areas, which tend to also present a higher luminosity (8.02 versus 7.56). Instead, the increase in luminosity at the temporal discontinuity is driven by other cells, for which we observe an increase in night-time luminosity of 0.407, equivalent to an increase by 5.50% over the mean luminosity in the period surrounding the ceasefire.

Beyond highlighting important returns of a ceasefire in terms of economic recovery, these results also indicate that the main economic gains from a ceasefire are not observed where the conflict is happening in temporal proximity to the ceasefire, but in areas where conflict is instead not present before the ceasefire.

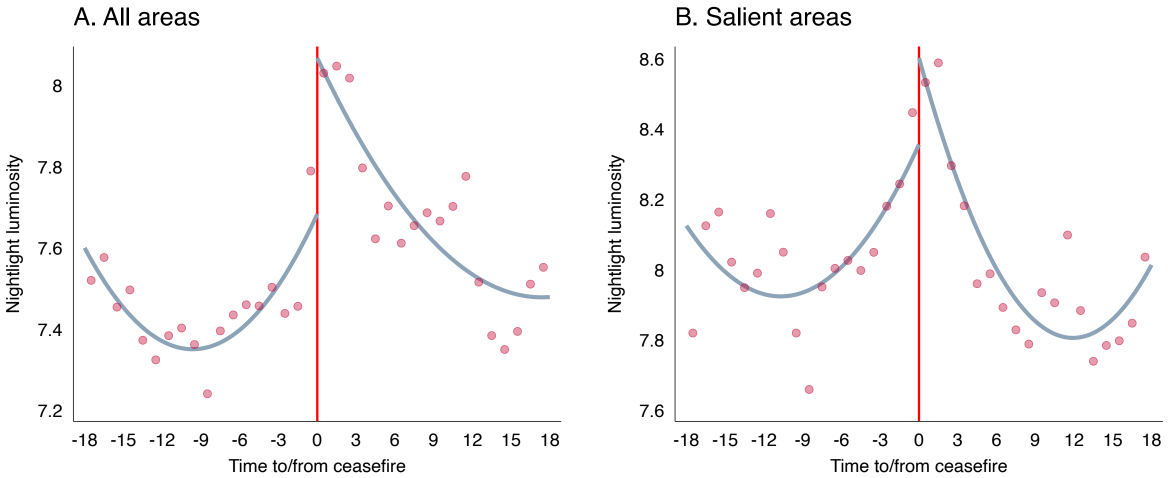
Table 4: The effect on night-time luminosity

	Area		
	All	Salient	Other
	(1)	(2)	(3)
Ceasefire in place	0.362	0.237	0.407
	(0.191)	(0.233)	(0.201)
	[0.059]	[0.309]	[0.043]
Mean (dep.var.)	7.558	8.020	7.400
Observations	3,101,714	787,165	2,314,549
Ceasefires	1,543	1,433	1,477
Countries	116	81	116

Note: estimates are based on local linear regressions—equation (2). Standard errors (in parentheses) are clustered at the period–ceasefire level. *P*-values are presented in brackets. The spatial unit of observation is the grid cell at the 1°× 1° resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ±6 months. The outcome variable is the average night-time luminosity in the grid cell in the corresponding time relative to the date of the ceasefire.

Source: authors' compilation, based on data sources outlined in Section 3.

Figure 7: Night-time luminosity in temporal proximity to a ceasefire



Note: the outcome variable is the average night-time luminosity in the grid cell in the corresponding time relative to the date of the ceasefire. The spatial unit of observation is the grid cell at the 1° × 1° resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ±6 months.

Source: authors' compilation, based on data sources outlined in Section 3.

To further understand what drives the effect on night-time luminosity, we look at whether any external intervention related to the ceasefire could induce increases in luminosity. As discussed in Section 3, we focus on variables related to the coverage of the ceasefire in international news, on international financing, and on peace missions.

Table 5 reports estimates of the effect of a ceasefire on these indicators. In column (1), the dependent variable is a news index, defined as the number of newspaper pages reporting news about the ceasefire on a specific day over the total number of pages on the same day (multiplied by 100). In column (2), the dependent variable is an indicator variable equal to 1 if a new development project is started in the grid cell in the corresponding day, and 0 otherwise. In column (3), the dependent variable is a dummy variable equal to 1 if a UN peace mission is active in the grid cell in the corresponding period, and 0 otherwise. Finally, column (4) focuses on the number of troops active as part of a UN peace mission. Figure 8 shows the RDiT plots for these outcomes.

Table 5: The effect on external intervention

	Coverage in international news (1)	International financing (2)	Presence of peace missions (3)	Peace troops (4)
Ceasefire in place	0.017	–0.001	–0.000	–0.614
	(0.016)	(0.001)	(0.002)	(1.779)
	[0.305]	[0.352]	[0.952]	[0.730]
Mean (dep.var.)	0.073	0.009	0.035	51.299
Observations	55,548	2,920,010	3,055,068	3,055,068
Ceasefires	1,543	1,343	1,416	1,416
Countries	114	113	115	115

Note: estimates are based on local linear regressions—equation (2). Standard errors (in parentheses) are clustered at the period–ceasefire level. *P*-values are presented in brackets. The spatial unit of observation is the grid cell at the 1° × 1° resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ±6 months. The outcome variables are reported in the column header.
Source: authors' compilation, based on data sources outlined in Section 3.

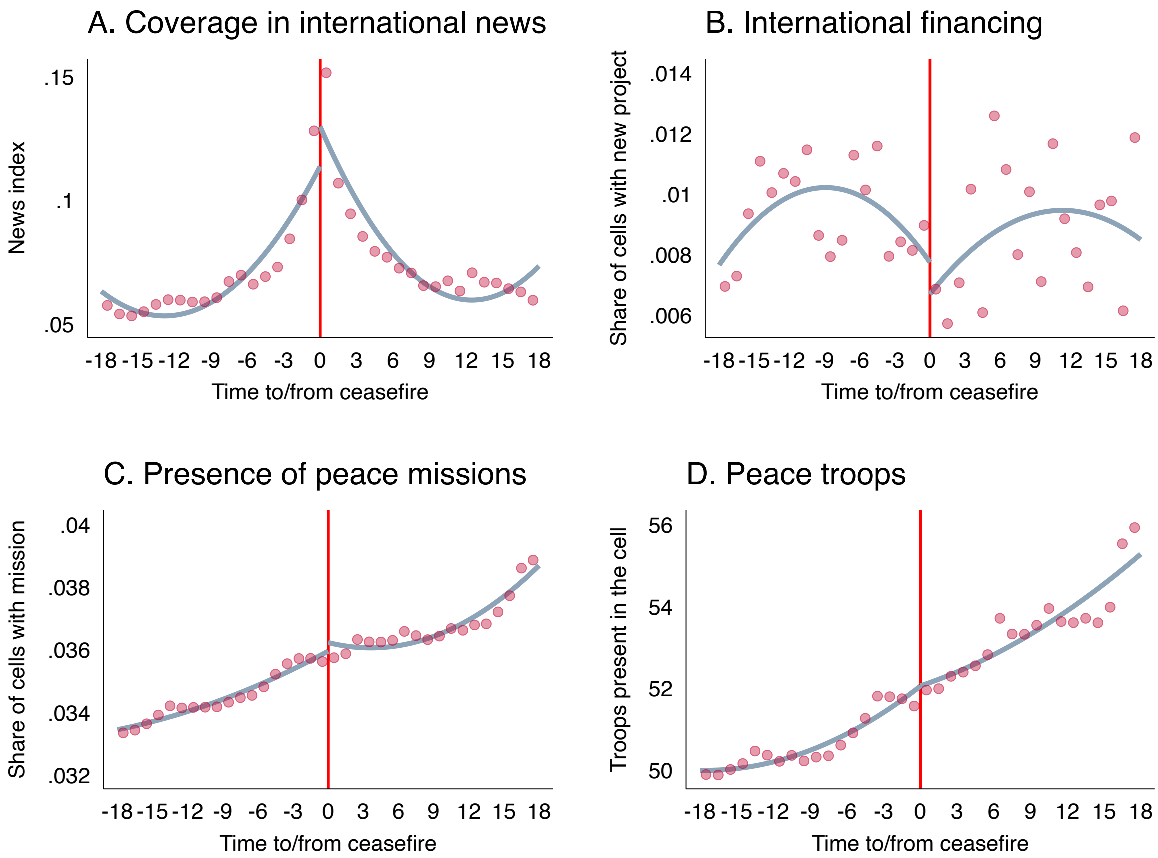
We do not highlight any significant effect on any of these variables. First, the share of pages covering the ceasefire in international news is equal to 0.073 per cent, and it increases rapidly in the month prior to the ceasefire and dissipates over time. This result highlights that international news, on average, covers news about the ceasefire already before the date in which the ceasefire enters into effect. However, while the ceasefire entering into effect increases its coverage in international news, the increase is small and not statistically significant. We therefore exclude that increases in night-time luminosity are driven by events that are large enough to justify attention in international media.

Second, the share of starting new projects from international financing in proximity to a ceasefire is highly limited. Only 0.01 of cells start a new project in this period. In addition, we do not highlight any effect of the ceasefire. This highlights that changes in night-time luminosity are not driven by reconstruction projects financed by international donors. In fact, the probability to start new projects is relatively constant on both (temporal) sides of the ceasefire.

Third, we do not highlight any significant change in UN peace missions following the ceasefire. Similar to the case of international financing, active peace missions characterize only a small fraction of cells in temporal proximity to ceasefires. This area equals 3.5 per cent of the overall study area. On average, cells have 51.3 troops active during this period. In both cases, we do not highlight any significant effect at the temporal discontinuity.

As a placebo check, we verify whether variables that should not be affected by the ceasefire, but that could be influencing income, are in fact not presenting any discontinuity at the time of the ceasefire. First, we focus on an important determinant of agricultural income, weather, which is also found to be an important determinant of conflict (Dell et al. 2014). Second, we focus on the value of commodities in the cell as determined by international prices. Price shocks in these commodities have been found to influence conflict in different directions (Bazzi and Blattman 2014; Berman et al. 2017; Dube and Vargas 2013; McGuirk and Burke 2020). Figure 9 shows RDiT plots for these variables, defined in Section 3. Figure 9 shows balance on observable characteristics on both sides of the temporal discontinuity, highlighting that any change discussed in the previous sections can be attributed to the ceasefire and not to changes in weather or economic prices driven by international markets.

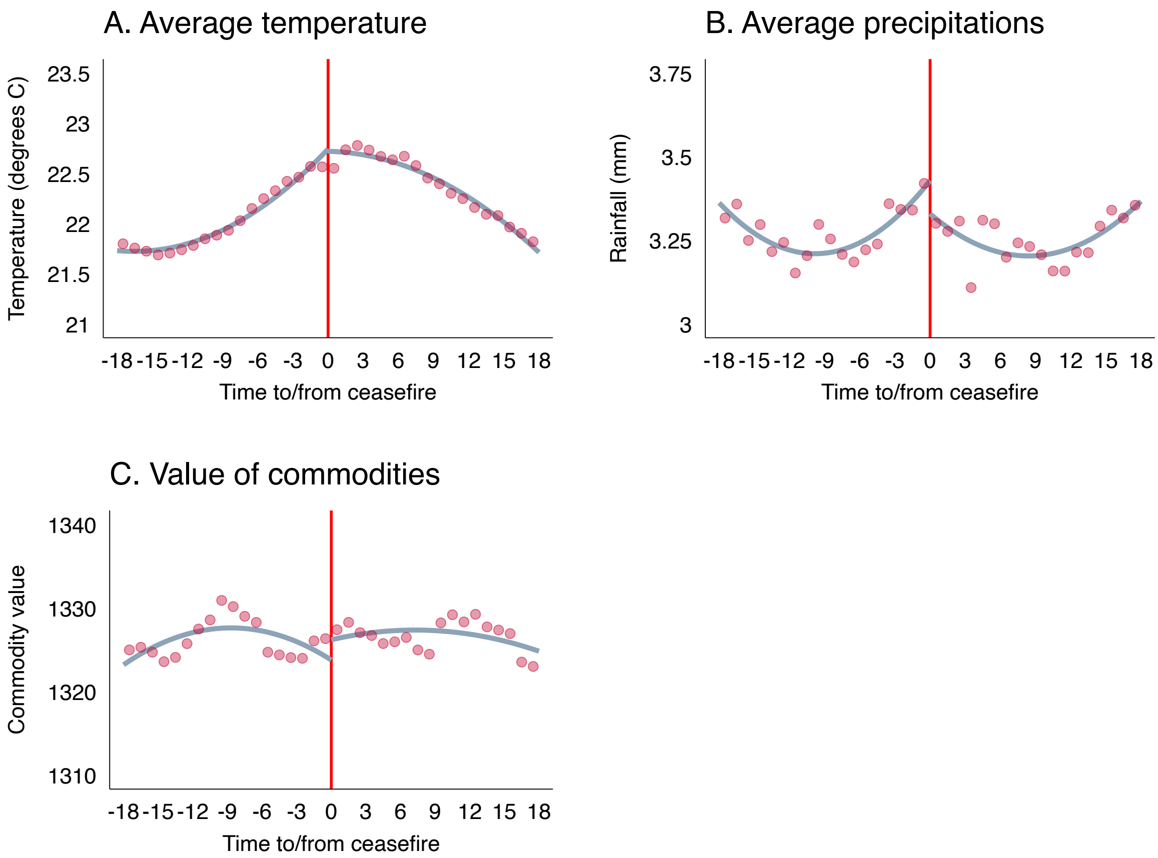
Figure 8: External intervention in temporal proximity to a ceasefire



Note: estimates are based on local linear regressions–equation (2). The spatial unit of observation is the grid cell at the 1° × 1° resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ±6 months.

Source: authors' compilation, based on data sources outlined in Section 3.

Figure 9: Balance



Note: estimates are based on local linear regressions—equation (2). The spatial unit of observation is the grid cell at the 1° × 1° resolution. The temporal unit is a ten-day period preceding or following the day of the ceasefire. We exclude the day of the ceasefire from the estimation. The bandwidth is ±6 months. Dots represent the average of the dependent variable in the corresponding period.

Source: authors' compilation, based on data sources outlined in Section 3.

6 Conclusions

Ceasefires are a widely used instrument to end violent confrontations and wars. However, there exists limited evidence about their effectiveness. In this paper, we study the universe of ceasefires in the period 1993–2017 to produce estimates of their causal effect. We show that ceasefires do not end conflicts, but induce significant reductions in the presence and the intensity of conflict, and that they can lead to significant economic recovery.

While the United Nations highlight as an important Sustainable Development Goal the promotion of peaceful societies at national and international levels, there remains limited knowledge on the role of ceasefires in ending conflict. Our results provide not only important insights for the use of ceasefires as an instrument to end wars, but also open different avenues for future research. First, because ceasefires do not provide persistent effects, there is a demand for further research to understand in which settings and under which mechanisms ceasefires can serve as an effective instrument for reinforcing peace. Second, we highlight that ceasefires are generally not effective for non-state conflicts. This finding requires further research to understand why ceasefires are not stable in these conflicts and in which conditions peacemakers can increase the effectiveness of the agreements.

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Appendix A

Table A1 presents a description of the variables and their sources used in the paper.

Table A1: Variables and data sources

Variable (source)	Description
Commodity prices (IMF)	Monthly market prices measured in US dollars as reported by the IMF's Primary Commodity Price System (PCPS) from 1990 to present. The monthly price for the six resource groups (see *Mineral Resources* (USGS)) is calculated as the average across several commodities representative of these classes. It can be accessed at https://www.imf.org/en/Research/commodity-prices.
Diamonds (PRIO)	Measured as the binary occurrence of any known diamond deposits in each grid cell. Occurrence is defined as any 'activity, meaning production (either commercial or artisan) or confirmed discovery'. Data are from Diamond Resources, PRIO (Gilmore et al. 2005).
Reconstruction (WB, AidData)	Both datasets report geolocations for a subset of their projects. The World Bank data is available for download from https://datacatalog.worldbank.org/search/dataset/0037800. The Global Chinese Development Finance Dataset is a uniquely granular dataset that captures 13,427 development projects worth US$843 billion financed by government and state-owned entities globally from 2000 until 2017 (Dreher et al. 2022). It is available for download from https://www.aiddata.org/data/aiddatas-global-chinese-development-finance-dataset-version-2-0.
Mineral resources (USGS)	Measures presence of any gold, silver, copper, iron, lead, cobalt, and zinc in each grid cell separately. The data, from the USGS Mineral Resources Data System (USGS MRDS), includes location and deposit description globally until 2011. Among these we have direct price matches for the following resources: aluminium, coal, cobalt, copper, gold, iron, lead, molybdenum, natural gas, nickel, oil, palladium, platinum, silver, tin, uranium, zinc; and grouped matches for the following six classes: metal (31 types, including cadmium, mercury, titanium), precious metal (11 types, including rhodium, tantalum), mineral (48 types, including clay, magnesite, sulphur), precious mineral (4 types, including diamond, gemstone), chemicals (4 types, including sulphuric acid, iodine), and industrial (2 types, pigment and rock asphalt). The dataset can be accessed at https://mrdata.usgs.gov/mrds/.
Peacekeeping operations (PRIO)	The Geocoded Peacekeeping Operations Dataset (Geo-PKO) provides details on global UN peacekeeping deployments from 1994 until 2020 (Geo-PKO 2.1). It describes attributes of peacekeeping presence at the local level, including location, size, troop type, and headquarters (Cil et al. 2020). It can be accessed at https://www.pcr.uu.se/data/geo-pko/
Petroleum (PRIO)	The presence of all known *oil* and *gas* deposits (active mines and discoveries) are measured separately and conjoined in each grid cell. The analysis considers on-shore and off-shore deposits that intersect with the sample grid cells. The data is from Petroleum Dataset, PRIO, version 1.2 (Lujala et al. 2007).
Precipitation (ERA5-Land)	Total precipitation is measured as accumulated depth in metres over a grid box of 0.1° $\times$ 0.1° latitude–longitude over the model time step of a month, which we average at the sample grid cell level. The data is from the ERA5-Land monthly reanalysis dataset covering 1981 to present, provided by the Copernicus Climate Change Service (C3S) (Sabater 2019).
Temperature (ERA5-Land)	Temperature of air measured at 2 metres above surface (land, in-land waters). Gridded data at 0.1° $\times$ 0.1° latitude–longitude averaged at the sample grid cell level. The data is from the ERA5-Land monthly reanalysis dataset covering 1981 to present, provided by the Copernicus Climate Change Service (C3S) (Sabater 2019). Values are converted from kelvin to degrees Celsius by subtracting 273.15.

Source: authors' compilation.