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Climate change, rice crops, and violence: Evidence from Indonesia

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Abstract

This article contributes to the literature on the nexus between climate change and violence by focusing on Indonesia over the period 1993–2003. Rice is the staple food in Indonesia and we investigate whether its scarcity can be blamed for fueling violence. Following insights from the natural science literature, which claims that increases in minimum temperature reduce rice yields, we maintain that increases in minimum temperature reduce food availability in many provinces, which in turn raises the emergence of actual violence. We adopt an instrumental variable approach and select the instruments taking into account the rice growing calendar. Results show that an increase of the minimum temperature during the core month of the rice growing season, that is, December, determines an increase in violence stimulated by the reduction in future rice production per capita. Results are robust across a number of different functional specifications and estimation methods. From a methodological point of view, we claim that the inconclusive results obtained in this literature may be caused by an overlook of the correct bundle crop/temperature. Studies concentrating on several countries with different crops and using variations of average temperature as a measure of climate change missed the biological mechanism behind the relationship between climate change and violence.

Keywords

climate change, food availability, Indonesia, minimum temperature, paddy rice, rainfall, rice crops, routine violence

Introduction

The impact of climate change on emergence and recrudescence of violent conflicts has become one of the more lively debates in recent years. However, despite the substantial number of studies, results are contradictory and somewhat inconclusive (see Theisen, Gleditsch & Buhaug, 2013; Hsiang, Burke & Miguel, 2013; Dell, Jones & Olken, 2014).[1]

Several aspects contribute to this lack of consensus. First, as pointed out by Theisen, Gleditsch & Buhaug (2013), the causal mechanism behind the climate change/violence relationship varies across societies, regions, and territories. In the eyes of economists, climate change results in exogenous shocks that affect agricultural production, affecting the set of economic opportunities, and thereby the incentives and opportunity cost of individuals. Needless to say, characteristics of agricultural sectors differ significantly among

[1] The literature on the nexus between climate change and violence has increased dramatically in recent years. See among others Gleditsch (2012), Hendrix & Salehyan (2012), Fjelde & von Uexkull (2012), Koubi et al. (2014), Scheffran et al. (2012), Exenberger & Pondorfer (2013).

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countries, regions, and territories, so shaping any potential relationship between agricultural shocks induced by climate change and actual conflict. Secondly, different measures of climate change lead to different interpretations. Among social scientists, climate change has been frequently approximated in the literature on conflict by means of variations in rainfall and mean temperature. In particular, since Miguel, Satyanath & Sergenti (2004), rainfall has been the core variable to explain the relationship between conflict and climatic variations. The explanation rests on the idea that substantial negative variations of rainfall induce drought, so raising the risk of conflict. Burke et al. (2009) shifted the focus onto the temperature, predicting that warming can be considered a strong predictor of civil war in Africa, but Buhaug (2010) showed that the results are not robust if using alternative specifications. Briefly stated, alternative measures of the climatic variables contribute to make the results puzzling and inconclusive. Moreover, actual violence takes several shapes and it can be either influenced or inflamed differently by climatic variables. Consequently, it is not surprising that studies focusing on large panels of countries present inconclusive results. In particular, as noted by Bernauer, Böhmelt & Koubi (2012), drawing general propositions from large-N studies is not appropriate because most of them are not robust to alternative specifications.

In the light of the previous points, we have chosen to restrict our study to a single country with a dominant staple crop and a substantial history of violence. Thus, we focus on Indonesia for the period 1993–2003. Indonesia has a history of violence. In the period under investigation, violence peaked after the fall of Suharto's regime in 1998 and decreased after 2001. The emergence of widespread communal violence has been connected to transition to democracy. However, violence was multifaceted. As noted by Varshney, Panggabean & Tadjoeddin (2004), in the period under investigation, ethno-communal violence has been the most frequent category if looking at the number of incidents (16.6%), and largely the most violent in terms of deaths (89%). Within this category, the interreligious conflict between Christian and Muslims accounted for 72% of incidents, whereas the Madurese/Dayak violence and the anti-Chinese violence accounted for 12% and 5%, respectively. The severe violence between Muslim and Christian communities took place in Central Sulawesi, Maluku (Ambon), and North Maluku. A second scenario of violence has been Kalimantan. In the entire district of Sambas and beyond, and almost the entire province of Central Kalimantan, dominant ethnic groups – Dayak or Malay – have pursued a campaign of ethnic expulsion against the Madurese minority (see van Klinken, 2007). Yet, as explained in Panggabean & Smith (2010), the riots against Chinese in 1998 gained remarkable attention because of the alleged government involvement to create a diversionary strategy to distract people from the anger triggered by the economic crises and the rampant inflation.

Despite their differences, some common features can be highlighted. According to Tadjoeddin (2002), the escalation of violence has been accompanied by three interlinked transitions at the end of the 1990s: (i) political (from autocracy to democracy), (ii) economic (from crony capitalism to a ruled-based market system), and (iii) social (centralized–decentralized). In this context, some studies also highlight the relevance of economic factors. Tadjoeddin & Murshed (2007) explain the emergence of routine violence by pointing out the economic factors associated with everyday violence in Java. Barron, Kaiser & Pradhan (2009) confirm the relevance of economic factors in explaining the emergence of local conflicts together with ethnic reasons in rural areas and religious diversity in urban areas. Østby et al. (2011) find that high rates of population growth increase the risk of routine violence.

While considering the economic aspects of emergence of violence, the second facet taken into account is that the Indonesian economy is heavily dependent on rice crops. Rice has been traditionally the staple crop in Indonesia and rice self-sufficiency had been the objective of the government for many years. Nonetheless, Indonesia has historically been a net importer of rice (McCulloch, 2008). Moreover, rice production constitutes a source of income for a substantial number of households. According to data drawn from the World Development Indicators, employment in agriculture as a percentage of total employment was around 46% between 1994 and 2003. In recent years, agricultural productivity and crops in Indonesia have been increasingly studied in relation to climate change because of the droughts induced by El Niño in 1991, 1994, and particularly 1997 (see among others Naylor et al., 2001; Naylor et al., 2007; Keil et al., 2008; Skoufias, Essama-Nssah & Katayama, 2012).

With these different insights in mind, we investigate the impact of climate change on violence by exploring the causal mechanism of agricultural production. The hypothesis underlying this work is that climate change may negatively affect rice production, rice prices, and eventually food availability and food prices, so influencing positively the emergence of violence. Food availability, defined as the physical availability of food, is one of the four components of food security.[2] The reduction of the rice crop is associated with an increase in violence through a number of links. First, the increase in food prices reduces living standards. Second, the reduction of output leads to a drop in demand for labor, which in turn reduces income for agriculture workers. Taken together, they reduce the opportunity cost of violence, therefore triggering it. Furthermore, Theisen, Holtermann & Buhaug (2011/12) argue that poor harvests reduce government income inducing a decline in the capacity of the state to address the increased demand for services. Reuveny (2007) suggests that an agricultural crisis may foster migration, which can lead to conflict.[3]

We test this hypothesis by exploiting a newly assembled provincial dataset that matches the data provided by the United Nations Support Facility for Indonesian Recovery (hereafter UNSFIR) with climatic data and a set of socio-economic controls over the period 1993–2003.[4] The main novelty we claim for this work is that, drawing insights from the natural science literature, we use variations in minimum temperature rather than mean temperature.

The results show that an increase in the minimum temperature during the core month of the growing season, that is, December, determines an increase in violence fueled by the reduction in rice production. We find support for the hypothesis that minimum temperature negatively affects rice availability (per capita), which in turn inflames violence measured as the number of violent incidents. This evidence is robust to the inclusion of a number of controls. Unfortunately, this work has limitations due to the number of observations available and the lack of data. However, we consider the results robust enough to provide new evidence on the relationship between climate and conflict variables in Indonesia and to warrant further explorations for different countries and crop/temperature bundles.

[2] For a definition of food availability and food security, see Renzaho & Mellor (2010).

[3] On the link between food security and conflict, see Brinkman & Hendrix (2011) and Meierding (2013).

[4] A similar approach is followed by Harari & La Ferrara (2013), who conduct a geographically and temporally disaggregated empirical analysis of civil conflict in Africa, using as units of observation cells of one degree of latitude and longitude. They find that negative climate shocks occurring during the growing season of the main crops cultivated in the cell have a sizeable effect on conflict incidence.

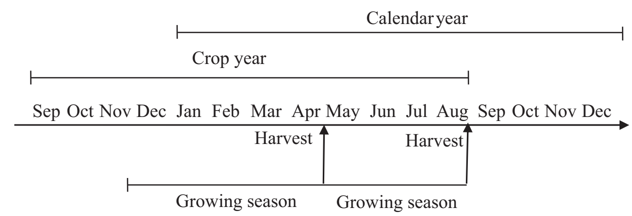

Figure 1. The crop year

Source: Adapted from Falcon et al. (2004).

The rest of the article develops as follows. The second section illustrates from the perspective of natural science the relationship between minimum temperature and rice production. A following section provides an overview of the dataset focusing on temperature and violence. Then, rice policy in Indonesia is presented. Next, the empirical strategy is explained. Eventually we present the main results and some robustness checks, and provide some final concluding remarks.

Rice growing and minimum temperature

Here, we present a sketch of the rice-growing calendar. The calendar (Figure 1) begins with the monsoon onset in August, necessary for land preparation. This stage involves plowing and harrowing to 'till' or dig-up, mix, and overturn the soil, and leveling it. Pre-germinated seedlings are grown in a seedbed before being transplanted to the wet field. The main seeding occurs from October to December, the core of the growing season; in 60–120 days the sprouts reach maturation. Finally, from January to March the rice is harvested. Between the planting and the harvest there is a period called 'paceklek', characterized by an increase in rice prices. If a shock occurs during the growing season, the crop is negatively affected; for example, if the temperature rises, the monsoon is delayed and the plants lack water. A shift onwards in the calendar of the growing season generates an extension of the 'paceklek'. If no shocks occur, the 'dry' growing season starts in April, and the harvest is expected in June. The timing of this second, smaller planting season is entirely dependent on the performance of the growing season.

During the growing season, rice completes two distinct growth phases: vegetative and reproductive. The vegetative phase is subdivided into germination, early seedling growth, and tillering; the reproductive phase is subdivided into the time before and after heading. The time after heading is better known as the ripening period. Potential grain yield is primarily determined before heading. Ultimate yield, which is based on the amount of starch that fills the spikelets, is largely determined after heading. Hence, it is convenient to regard the life history of rice in terms of three growth phases: vegetative, reproductive, and ripening (Global Rice Science Partnership, 2013).

With this in mind, we analyzed the natural science literature in order to verify what climatic factors are expected to affect rice growing. It suggests that variations in minimum temperature affect cereal production in general. Since minimum temperature is reached at night, using mean temperature might fail to consider the actual transmission channels to conflict.

Higher minimum temperatures increase the maintenance respiration requirement of the crops and shorten the time to maturity, thus reducing net growth and productivity. Welch et al. (2010) studied farm-managed rice fields in six major producer countries and found that a 1°C increase in minimum temperature during the vegetative phase reduced yield by 185 kg*ha^{-1}.[5] Although this result holds for other Southeast Asian countries, studies that focus on China find that an increase in temperatures, especially minimum temperatures (Tao et al., 2008), increases rice yields. This apparent contradiction depends on the fact that climate warming may raise yields in cooler climates and lower them in warmer climates. The aggregate world effect in the period 1961–2002, as estimated by Lobell & Field (2007), is negative but close to zero, given the different impact across countries. In a subsequent work, extending the dataset to 2008, Lobell, Schlenker & Costa-Roberts (2011) confirm that global warming reduces rice and soybeans production in Indonesia. In a simulation study on Java, Amien et al. (1996) suggested that the observed slight increase in minimum temperature will significantly decrease the yield by 1% per year until 2050.

Lal (2011) confirms the presence of such a biological mechanism in South Asia; there is also direct evidence that rainfall and temperatures affect rice yields in Indonesia. Yet, rainfall is the most common variable exploited in empirical studies. Evidence of a negative correlation between sea surface temperature anomaly (SSTA) and rainfall has been provided by Naylor et al. (2007) in a study of Java and Bali, and Roberts et al. (2008) in the Philippines. Naylor et al. (2001) quantify the connections between El Niño Southern Oscillation (ENSO) indices, rainfall, and rice production for Java – Indonesia's main rice-growing region. They find that El Niño causes drought, due to the deep atmospheric convection associated with the Indonesian low shifts eastward, and threatens rice production.

El Niño events delay rainfall by as much as two months, thereby delaying rice plantings and extending the pre-harvest season when rice prices characteristically rise in consumer markets (Ellis, 1993). The timing of rainfall in the growing season tends to dictate rice planting patterns for the next 8–9 months, because delayed plantings in the growing season also defer plantings of the dry season crop. The temporary crop reduction is associated with an increase in food prices; therefore conflict is more likely to occur in warmer years.

Violence and climate data

We use the UNSFIR dataset on violent events, covering 14 provinces for the years 1993–2003. As explained in Varshney, Panggabean & Tadjoeddin (2004: 7), the dataset considers only collective violence defined as 'violence perpetrated by a group on another group (as in riots), by a group on an individual (as in lynchings), by an individual on a group (as in terrorist acts), by the state on a group, or by a group on organs or agencies of the state'. It provides detailed information about the date of any event, namely, among others: the exact location, the number of killed and injured individuals, the involvement of the army, the material consequences of the event (arrested individuals, burned houses, shops, and public buildings), and the source of the data. The data are drawn from 19 newspapers at the provincial level. The UNSFIR dataset records incidents of collective violence and listed communal, separatist, state–community, and industrial relations violence. It focuses on a specific type of violence, that is, 'group violence'. In particular, the dataset includes 3,608 events of social violence. We have aggregated the violence data at the yearly level so obtaining 12 * 11 = 131 observations per province. If we look at the territorial patterns of violence, all the provinces show decreasing levels of violence in the last years of the dataset, except for East Java and Riau. Figure 2 reports the number of incidents that are unevenly distributed across time, peaking in the years around the transition and then decreasing.

Table I reports the descriptive statistics of violence disaggregated at the provincial level. We observe a large heterogeneity. First, the region of Java is the most violent

[5] Peng et al. (2004) find that also increased night-time temperatures associated with global warming cause rice yields to fall in the dry season, but this was based on 12 observations and failed to control for radiation (Sheehy, Mitchell & Ferrer, 2006).

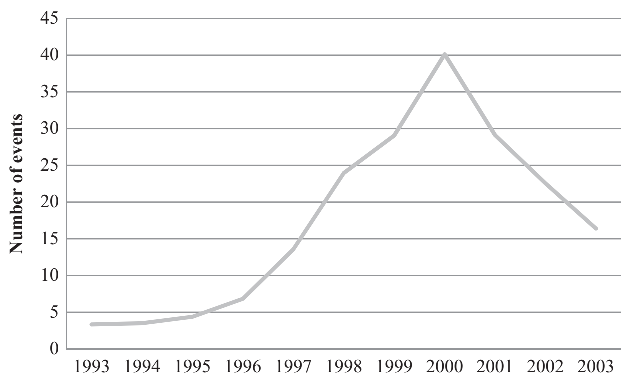

Figure 2. Yearly frequency of violence

Source: UNSFIR data (downloaded from www.conflictand development.org).

Table I. Violence by province: Descriptive statistics

Province	*Mean*	*Std. dev.*	*Min.*	*Max.*
Bengkulu	0.091	0.302	0	1
Central Java	45.455	45.612	0	145
Central Kalimantan	5.636	11.465	0	39
East Java	56.000	37.216	13	105
East Nusa Tenggara	4.727	5.061	1	18
Jakarta	16.182	14.344	0	45
Jambi	0.091	0.302	0	1
Maluku	30.182	43.772	0	107
Riau	14.818	16.370	0	41
South Kalimantan	0.091	0.302	0	1
West Java	74.727	58.119	12	189
West Kalimantan	7.000	8.390	1	28
West Nusa Tenggara	16.909	12.308	3	37
Yogyakarta	0.182	0.405	0	1

in terms of number of events. Second, there is a huge variability between the least violent and the most violent provinces. Third, the most (least) violent regions show also the largest (smallest) standard deviations, suggesting that violence is not constant over time.

We draw the climatic variables from the National Oceanic Atmospheric Administration's (NOAA) Global Historical Climatology Network (GHCN) – Daily (NOAA, n.d.), an integrated source of information from land surface stations.[6] There are 17 climatic stations in Indonesia, which are widespread around the whole archipelago, covering a large area of the country. Figure 3 highlights the location of the stations. Only seven districts host a climatic station in their own territory. We therefore matched stations with provinces, by associating a province to the closest station on the map. Table II reports the matching.

The NOAA dataset includes detailed information on: (1) daily rainfall in millimeters; (2) minimum temperature in degrees Celsius. Figures 4 and 5 provide climate patterns; in particular, they plot the deviation of observed rainfall and minimum temperature from the monthly average.[7] The minimum temperature jumps above the average from 1993 to 1996 (see Figure 4). The latest years of the dataset are characterized by another wave of winter warmth, of about +0.9°C in minimum temperature. Figure 5 indicates also a reduction of rainfall in the latest years. The months of October and November in 1992 were much rainier than the average of all the Octobers and Novembers; the same months in 1997 were much less rainy than their average.

Rice policy and rice production in Indonesia

Rice is a staple crop in Indonesia. In fact, food constitutes around 70% of expenditure for about half of the population and rice stands as the most important food item – more than 25% of food expenditure for households in the bottom half of the expenditure distribution. Indeed, rice expenditure is estimated to constitute over one-quarter of all expenditure for the poorest 20% of the population, compared with only 5.5% of total expenditure for the top quintile (McCulloch, 2008).

Therefore, since independence rice self-sufficiency has been a major concern and a specific goal for Indonesian economic policy since 1951. According to Mears (1984), in the late 1960s, under the New Order implemented by Suharto, plans for rice self-sufficiency were enriched by a policy of price stabilization and massive public investments. Rice policy was based on three measures: (i) subsidies, (ii) public investments, and (iii) protectionism. First, the National Food Logistics Agency, namely *Badan Urusan Logistik* (hereafter Bulog), was given the mandate to stabilize rice prices, and both consumers and farmers benefited from stable prices. Bulog was allowed to use the following policy measures: (i) monopoly control over the international rice trade; (ii) procurement of rice by

[6] Data source: http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/.

[7] To reduce the influence of outliers when calculating the mean we follow a common practice in the literature (e.g. Hendrix & Salehyan, 2012; Benjaminsen et al., 2012) and extend the reference period from 1990 through 2003. The starting year is intermediate with respect to two extreme El Niño events in 1982–83 and 1997–98 (McPhaden, 1999).

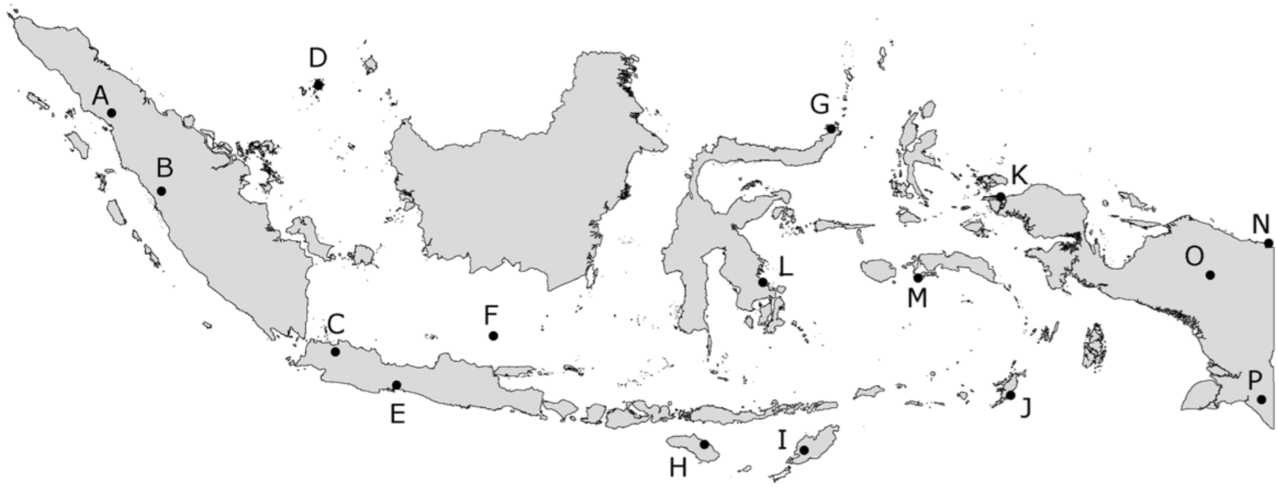

Figure 3. Map of the NOAA-GHCN stations in Indonesia

Table II. Description of the climatic stations in Indonesia

Name of the station	*Associated province*	*Reference on the map*
Sibolga/Pinangsori	North Sumatra	A
Tarempa	Riau	C
Padang/Tabing	West Sumatra	D
Jakarta/Observatory	Jakarta (Special City District)	E
Cilacap	Central Java	F
Sangkapura Bawean	East Java	G
Menado/Sam Ratulan	North Sulawesi	H
Kendari/Wolter Mong	South-East Sulawesi	I
Waingapu/Mau Hau	East Nusa Tenggara	J
Kupang/Eltari	East Nusa Tenggara	K
Sorong/Jefman	West Papua	L
Biak/Frans Kaisiepo	Papua	M
Wamena	West Papua	N
Jayapura/Sentani	Papua	O
Ambon/Pattimura	Maluku	P
Saumlaki/Olilit	Maluku	P
Merauke/Mopah	Papua	B

local agencies (DOLOGs); (iii) seasonal storage of rice. Bulog set floor and ceiling prices to dictate the boundaries within which private actors were allowed to operate. Interventions were allowed if prices were moving outside the boundaries. Bulog has been successful in playing this role of price stabilization (Timmer, 1996; Marks, 2010) even if the contribution to overall economic growth has been questionable. In addition, the government implemented a massive policy of subsidies and infrastructural investment. In particular, fertilizers have been heavily subsidized – a high burden in budgetary costs (Warr & Yusuf, 2014). Second, huge public spending on irrigation system and other infrastructure was undertaken in the 1970s and early 1980s. Technology improvement of the green revolution determined that the gross added value of food crops between 1970 and 2003 had increased by 157% (van der Eng, 2010).

Despite the government's objectives and commitment, self-sufficiency had been reached only in a few years. To understand the issues of rice policy in the long run, we refer to Simatupang & Timmer (2008) who explain relevance, trends, and phases of rice production between the late 1970s and the early 2000s. Between 1977 and 1982 rice production experienced a significant growth rate (+7% on average), whereas in the period 1982–98 the rice production growth rate, albeit positive, declined steadily to stabilize between 1998 and 2005 to 1.2%.

It must be noted that during the years under investigation (1993–2003), rice policies changed dramatically because of the severe financial crisis that occurred in 1997. Bulog's monopoly on rice imports was removed as a collateral condition for IMF loans. In fact, protection of the rice sector did not disappear. In 1999 an *ad valorem* 20% tariff on rice imports was imposed but it was eventually converted into a specific tariff set at Rp430 per kg. In 2000 the nominal rate of protection has been estimated to be 14% and it jumped to 33% in 2003 (Fane & Warr, 2008). The crisis increased poverty and consequently the relevance of rice as a staple food among Indonesians. Between 1996 and 1999 the percentage of poor people increased from 17.5%

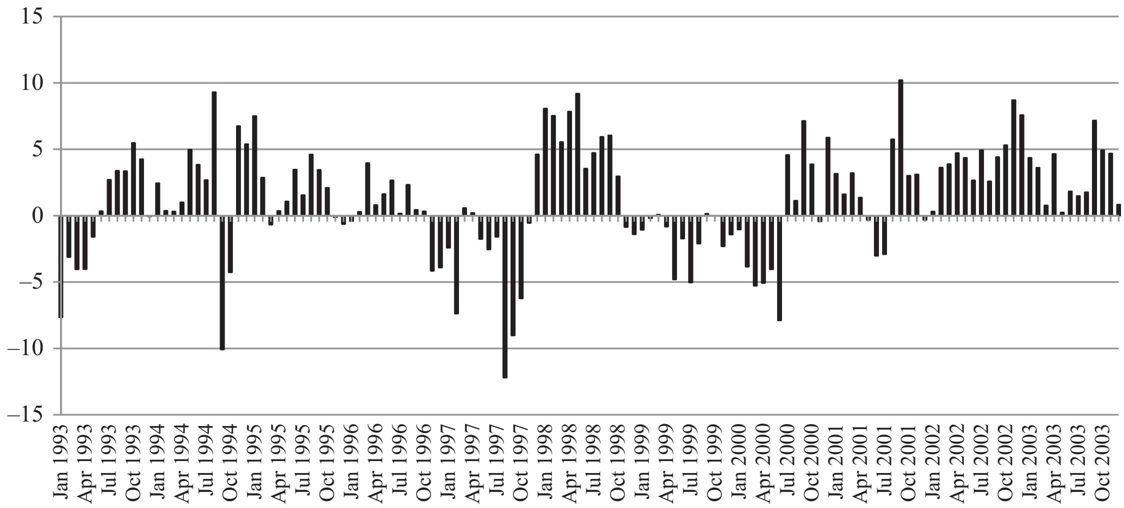

Figure 4. Monthly deviation of minimum temperature in Indonesia
Deviations in °C*10.
Source: NOAA.

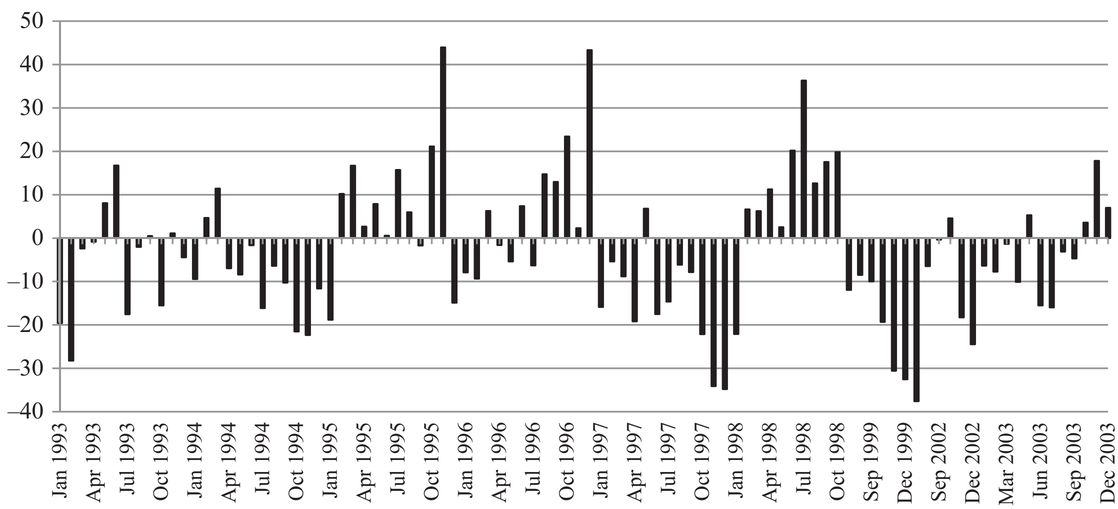

Figure 5. Monthly deviation of rainfall in Indonesia
Deviations in mm*10 rainfall.
Source: NOAA.

to 23.45% and particularly from 19% to 26% in rural areas.[8] According to Dhanani & Islam (2002), between 1997 and 1999 the household budget share for food rose from 50% to 56% in urban areas and from 67% to 73% in rural regions. By August 1998, the government introduced a targeted rice subsidy (OPK program) that allowed low-income households to buy a certain amount of rice at a subsidized price from the government. According to Tabor & Sawit (2001), the program reached almost 50 million persons in 1999.

Table III summarizes some information on rice production in the period under investigation.[9] In 1993–2003, rice production rose on average by 0.75%. In the period 1993–97 it increased by 0.54%

[8] Source: Badan Pusat Statistik (BPS), Statistics Indonesia (http://www.bps.go.id/linkTabelStatis/view/id/1494) last accessed August 2015.

[9] For a general discussion on data issues for rice production see Rosner & McCulloch (2008).

Table III. Facts about rice in Indonesia (1993–2003)

	1993–2003	*1993–97*	*1998–2003*	*1997–98*	*1998–99*
Rice production	50,103	49,009	51,015		
(1,000s tons, yearly average)					
average % change	0.752	0.538	0.930	−0.284	3.309
Harvested Area	11,444	11,179	11,664		
(1,000s Ha, yearly average)					
average % change	0.348	0.131	0.529	5.292	1.986
Yield	43,789	43,836	43,749		
(Hg/Ha)					
average % change	0.428	0.403	0.451	−5.298	1.298
Rice Import	1,748	1,257	2,160		
(1,000s tons, yearly average)					
average % change	329	547	148	778	62
UREA price paid by farmers	1,293*	690	2,047**		
(Lcu 1,000s/Mt) average					
average % change	24*	15	36**	6	148

Source: FAO (2005); *1993–2001; **1998–2001.

Table IV. Rice production growth rates

	Average			
Province	*1993–2003*	*1993–97*	*1997–2003*	*1997–99*
Bengkulu	15.886	7.124	8.178	−1.286
Central Java	−1.220	1. 219	−2.410	−0.355
Central Kalimantan	56.211	20.979	29.122	−6.831
East Java	3.488	−1.163	4.706	1.546
East Nusa Tenggara	33.385	21.271	9.989	0.748
Jakarta	1.185	0.396	0.785	−2.517
Jambi	−4.803	−5.803	1.061	−5.405
Maluku	−39.238	−65.17	74.455	33.939
Riau	−5.056	−4.621	−0.456	1.252
South Kalimantan	27.273	9.090	16.667	6.313
West Java	−20.000	−9.090	−12.000	−3.017
West Kalimantan	29.847	7.657	20.612	5.286
West Nusa Tenggara	16.667	8.333	7.692	2.564
Yogyakarta	−73.469	−42.112	−54.169	−2.645

Source: BPS (http://www.bps.go.id/linkTableDinamis/view/id/865).

and between 1998 and 2003 it slightly rose by 0.93%. In this period a boost has been reported in 1995 (+6%), whereas the worst outcome occurred in the crisis years, namely 3.4% in 1997 and –0.3% in 1998. However, in the whole period, given the stagnant productivity (+0.4%), the increase in production has been due to the expansion of harvested area. In particular, production recorded a modest average increase of 0.3% in the period 1993–2001 followed by two years of improvement of 1.75% in 2002 and 2003. The lowest figure was recorded in 1998 (–5.3% with respect to 1997). However, trends in production were largely asymmetric and staggering across provinces. Table IV reports figures on growth rates in the provinces considered in this study.

Therefore, stagnant productivity did not compensate either the losses induced by drought in 1997 or the strong reduction in the governmental subsidy of fertilizers, leading to the need to rely on imports (FAO, 2005). Urea, the main fertilizer for paddy rice, recorded a massive increase in the price paid by farmers, so reducing demand for it. In 1998, rice imports reached almost three million tons, increasing by 778% with respect to the previous year, and in 1999 the value of imports was around 4.67 million tons. In this context, prices increased dramatically. The consumer price index for food increased by 162% between 1996 and 1999, whereas the general CPI increased by 102.45%.[10,11]

[10] Source: Bank of Indonesia: http://www.bi.go.id/sdds/series/cpi/index_cpi.asp.

[11] It is worth noting that the deviation in minimum temperature in December is positively and significantly correlated with the national CPI (the correlation coefficient is 0.526 with a *p*-value of 0.000). To further highlight the correlation between our instrument and the level of prices we have computed the average deviation of the minimum temperature in December among the Indonesian provinces for the period 1993–2003, producing a national measure. The correlation coefficient between this average and CPI is 0.597. Running a univariate regression with Newey-West standard errors (with 1 lag) we found that $CPI = 33.96 + 2.12$ *average deviation of minimum temperature*$_{t-1}$ and the coefficient shows a *p*-value of 0.001.

Table V. Variables: Definitions, sources and descriptive statistics

Variable	*Description*	*Source*	*Obs.*	*Mean*	*Std. dev.*	*Min.*	*Max.*
Violence	Number of violent incidents per year	UNSFIR (Varshney, Panggabean & Tadjoeddin, 2004)	154	19.435	33.936	0	189
Deviation of the minimum temperature (December *t*–1)	Deviation of the minimum temperature from the average value in the period 1990–2003 in the past December, °C*10	Our calculations from NOAA	143	1.524	8.508	−14.544	25.922
Deviation of the rainfall (December *t*–1)	Deviation of the rainfall from the average value in the period 1990–2003 in the past December, mm*10	Our calculations from NOAA	122	−8.637	36.064	−52.970	86.230
Population	Provincial population	BPS (2015a)	154	9,869,811	12,700,000	1,179,122	39,200,000
GDP	Provincial GDP (per thousand inhabitants)	Østby et al. (2011)	132	1,907.929	9,729.053	13.301	75,113.830
Improved water source	Share of households by access to sources of improved drinking water	BPS (2015b)	153	42.203	9.882	20.130	66.640
Share of area by household	Percentage of households by area of occupancy per capita at most equal to 7.2 m^2	BPS (2015c)	153	19.072	10.080	3.440	45.010
Paddy tons per capita	Paddy production per capita (in tons)	Our computation*	154	0.207	0.122	0.002	0.484
Decentralization	Dummy for decentralization reform from 2001 onwards	Our coding	154	0.273	0.447	0	1
Share of poor population	Share of population below the poverty threshold	Taodjeddin & Murshed (2007)	154	22.946	11.623	2.352	46.734

*Data on paddy rice production have been downloaded from BPS at page http://www.bps.go.id/site/pilihdata. There is a dynamic table only in Indonesian. Select the subject 'Tanaman Pangan' (Crops) and eventually 'Produksi(Ton)' (Production in tons), Padi (Paddy rice), and the number of years. Once the variables are added to the query window, you will be asked to select the provinces and the layout of tables to be downloaded. Eventually we computed the rice production-to-population ratio.

The empirical specification

This section illustrates the empirical strategy adopted to analyze the impact of climate on violence. To rule out a direct impact of climate, we estimate a reduced-form equation of the type:

$$Violence_{it} = a_0 + a_1 Violence_{t-1} + a_2 Climate_{it} + a_3 X_{it} + \varepsilon_{it} \quad (1)$$

where *Violence* is a count variable that denotes the number of violent incidents in province i at time t. We include the first lag of the dependent variable to control for persistence. $Climate_{it}$ is a set that includes the deviations of both rainfall and minimum temperature during the growing season. The rationale for them is described below, and we expect to find a coefficient for a_2 that is not statistically significant. X is the set of covariates.

The choice of covariates depends on the established literature and data availability (Table V lists definitions of variables, sources, and descriptive statistics). First we include a logged measure of population. A positive sign is expected to be associated to the variable *Population*. We capture the overall economic scenario through a measure of provincial GDP, and the degree of income inequality through the *Share of poor population*. Following Murshed, Tadjoeddin & Chowdury (2009), we include a dummy variable for the decentralization reform, equal to 1 from 2001 onwards (*Decentralization*). Finally, we included two variables that take into account living standards: *Improved water source* and *Share of area by household*. The first is the share of households with access to improved sources of water, while the latter is the percentage of households by area of occupancy per capita at most equal to 7.2 m^2. The first is expected to exhibit a negative association with violence whereas the latter can be expected to exhibit a positive one.

To test our main model we estimate the following violence equation:

$$Violence_{it} = \beta_0 + \beta_1 Violence_{t-1} + \beta_2 Paddy\ tons\ per\ capita_{it} + \beta_3 X_{it} + \varepsilon_{it} \tag{2}$$

where *Paddy tons per capita* measures the actual production of rice per capita and X is the same vector of socioeconomic variables as before.

We apply an instrumental variable (IV) approach. We select the instruments by looking at the rice calendar (Figure 1). We use the deviation of both rainfall and minimum temperature during the growing season as instruments for the current year's rice production. As the rice calendar shows, the core of the growing period is represented by the last three months of the year. If a shock occurs at this stage of the process, future crops are severely affected. Specifically, the instruments indicate how much the past December has been more or less rainy and warmer or colder, when compared to the average December. In particular, we use deviations recorded in December because it overlaps with the vegetative phase of the season. The first stage regression of Equation (2) in a 2SLS model would be:

$$Paddy\ tons\ per\ capita_{it} = f\Big(Deviation\ of\ the\ minimum\ temperature\ (December\ t-1), Deviation\ of\ the\ rainfall\ (December\ t-1), X_{it}\Big) \tag{3}$$

The correlation between the past December variation of the minimum temperature and rice production per capita is negative and significant as expected (–0.15, p-value 0.05). In contrast, the pairwise correlation between *Deviation of the minimum temperature (December t–1)* and the dependent variable does not show this feature,[12] removing the doubts about the weakness of the instruments.[13]

The instrumental variable approach and the binary nature of violence drive our choice of the estimator. Specifically, we implement a generalized linear model (GLM) that controls for the potential endogeneity of rice production through a set of instruments and accounts for the negative binomial (NB) distribution of the dependent variable. We prefer this model to the Poisson distribution because violence shows overdispersion (see Table V).

The GLM is a flexible generalization of the linear regression that allows response variables to have errors non-normally distributed (Nelder & Wedderburn, 1972). In particular, a link function describes the relationship between the linear model and the dependent variable. The *qvf* routine in Stata (Hardin & Schmiediche, 2003) performs this estimation using maximum quasi-likelihood. The *qvf* and *glm* commands 'produce equivalent results for model fits where there are no instrumental variables. There may be numeric differences in results due to different convergence criteria' (Hardin & Schmiediche, 2003: 3).

It is worth noting that *ivreg2*, which is commonly used to fit 2SLS IV models, is not suited for limited dependent variables; in addition, *xtnbreg*, which estimates a panel NB model, does not allow for the introduction of instrumental variables. The *qvf* routine, on the other hand, overcomes both these limitations. In a set of preliminary regressions we tested the consistency of the results using both *ivreg2* (IV) and *qvf* (IV-NB). The coefficients associated with the independent variables show the same sign across the models, but they gain statistical significance when moving from the IV to the IV-NB model, as expected.[14]

Recent literature supports the use of *qvf*: Dube & Vargas (2013) estimate the impact of climate-related changes of coffee intensity on civil conflict in Colombia. A limitation of *qvf* is that coefficients are not generally interpretable and marginal effects cannot be computed. Hence, albeit in the presence of statistically significant coefficients, we are able only to infer a qualitative relation between our variables of interest.

Differently from the IV via 2SLS (*ivreg2*), the IV-NB with GLM (*qvf*) estimates the parameters by means of a numerical convergence algorithm, the iteratively reweighted least squares. In IV models estimated via GLM, the joint modeling of the distribution of the dependent and the endogenous variables gives consistent and efficient estimates (Marra & Radice, 2011). The procedure develops into simultaneous rather than subsequent steps, and it does not produce first stage estimates comparable to the first stages of *ivreg2* (Hardin & Schmiediche, 2003: 2). To discuss the validity of the climatic instruments we have to rely on the approach of Dube & Vargas (2013) and estimate a set of OLS estimations of Equation (2) that emulate the first stages of *ivreg2*. From a methodological point of view, the coefficients of these

[12] Appendix 1 provides a set of scatter plots suggesting no correlation. Furthermore, conditional correlation in Appendix 2 verifies the lack of any significant correlation.

[13] Further robustness checks and the results of the diagnostics test for the fit of the instruments are in a following section.

[14] These results are available at http://www.prio.org/jpr/datasets.

Table VI. Reduced form: Emergence of violence and climate variables

Dep. var.: Violence	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Deviation of the minimum temperature (December *t*–1)	0.136	0.209	0.284	0.249	0.194
	(0.199)	(0.217)	(0.166)	(0.170)	(0.149)
Deviation of the rainfall (December *t*–1)	−0.044	−0.031	−0.025	−0.022	−0.036
	(0.038)	(0.038)	(0.038)	(0.037)	(0.033)
Population (ln)	3.773	5.145			
	(2.491)	(3.795)			
GDP	−0.674	0.102	−2.749*		−2.432†
	(1.000)	(1.827)	(0.964)		(1.268)
Share of poor population	0.201	0.217	0.281	0.203	
	(0.217)	(0.265)	(0.214)	(0.183)	
Share of area by household		−0.156	−0.275	−0.269	−0.181
		(0.221)	(0.179)	(0.182)	(0.135)
Improved water source		−0.192	0.025	−0.053	0.047
		(0.165)	(0.134)	(0.132)	(0.109)
Decentralization	−20.470	−24.513	−14.202	−11.746*	−13.135
	(15.350)	(16.041)	(21.212)	(5.395)	(21.676)
Violence, *t*–1	0.901**	0.870**	0.909**	0.957**	0.931**
	(0.173)	(0.167)	(0.158)	(0.134)	(0.158)
Constant	−58.372†	−66.446	−5.132	8.441	−1.051
	(32.345)	(47.655)	(7.654)	(7.042)	(8.606)
Observations	110	108	108	119	108
R-squared	0.683	0.695	0.690	0.683	0.684

Standard errors clustered at the provincial level in parentheses; $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.1$.

regressions, reported in Appendix 2, help us assessing whether and how climatic change affects rice production.

Empirical results

Reduced form: Violence and climate variables

Before a detailed discussion of the IV-NB results, we assess the lack of direct correlation between violence and climate with a reduced form regression of violence as in Equation (1). Appendix 1 graphically suggests the absence of any significant relationship between violence and deviation of both the minimum temperature and rainfall during past December. Results of the reduced form are reported in Table VI. As expected, no significant relation appears between the count of violent incidents and climate variables. In the light of this evidence, we are confident in using the opportunity of trying an IV estimation.

IV estimation

This section presents the results of Equation (2). The four models differ according to the covariates included; they all have standard errors clustered at the provincial level. Results show a negative and significant association between the count of violent incidents and paddy production per capita: whenever food availability increased, violence decreased. Whenever significant, control variables exhibit the expected sign. *Population* always exhibits a positive sign, and land pressure (proxied by percentage of households by area of occupancy per capita) seems to increase the number of violent incidents (Model 4).[15] In addition, as expected, current violence is positively associated with past violence.

As matter of comparison, we estimated a set of 2SLS models via *ivreg2*. The introduction of the instruments (from OLS to 2SLS) corrects the sign of the relationship, but it still treats the number of events as a continuous variable that might take also negative values, affecting the standard errors. If we replicate this exercise with NB via *xtnbreg* and IV-NB via *qvf*, the coefficients are the same and as expected they gain significance in the IV-NB model. The diagnostic tests for IV-OLS, that is, Kleibergen-Paap LM statistic and the Hansen J, which test respectively underestimation and overestimation, confirm the fit of the model. Kleibergen-Paap LM statistic *p*-values range from 0.02 to 0.08 and

[15] These results are robust to the use of the harvested area, as expected. The correlation between paddy tons and harvested area is positive, significant, and very high (0.98, *p*-value: 0.000). Tests are not disclosed, but are available at http://www.prio.org/jpr/datasets.

Table VII. Emergence of violence (IV estimation, NB regression)

Dep. var.: Violence	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Paddy tons per capita	−1.174*	−1.028*	−1.311*	−1.219†	−1.181†
	(0.555)	(0.419)	(0.543)	(0.653)	(0.649)
Population (ln)	1.032**	1.473**			
	(0.228)	(0.489)			
GDP	−0.131	0.043	−0.850**		−0.712*
	(0.249)	(0.255)	(0.289)		(0.282)
Share of poor population	0.028†	0.009	0.013	−0.009	
	(0.016)	(0.022)	(0.028)	(0.025)	
Share of area by household		0.092†	0.074	0.051	0.059
		(0.049)	(0.059)	(0.053)	(0.057)
Improved water source		0.011	0.075*	0.022	0.064*
		(0.033)	(0.034)	(0.026)	(0.031)
Decentralization	−0.387	−0.540	3.312†	−0.415	2.736
	(1.305)	(1.092)	(1.859)	(0.474)	(1.832)
Violence, *t*–1	0.024**	0.026**	0.042**	0.071**	0.039**
	(0.007)	(0.007)	(0.014)	(0.024)	(0.013)
Constant	−17.672**	−25.564**	−8.854**	−2.832	−6.898*
	(3.449)	(7.590)	(2.868)	(1.923)	(3.066)
Observations	108	108	108	119	108

Instruments: (a) deviation of the minimum temperature (December *t*–1); (b) deviation of the rainfall (December *t*–1). Standard errors clustered at the provincial level in parentheses; $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.1$.

Hansen J test *p*-values range from 0.46 to 0.87.[16] To evaluate the performance of the climatic variables as instruments, in Appendix 2 we report the emulated first stage regressions of a 2SLS model. The results support the choice of the instruments, so confirming the results in Table VII.

Appendix 3 shows the results obtained through the procedure discussed above for the Poisson distribution, which are weaker than our benchmark. This is not surprising given the worse fit with the data.

Robustness

In this section we present some robustness tests. The strength of our empirical strategy heavily depends on the appropriate choice of instruments. As a first check, we test whether other instruments could be more appropriate. Therefore, we rerun the regressions by employing alternatively: the instruments in cubic form (Table VIII) and the instruments interacted (Table IX).[17] As the coefficients of *Paddy tons per capita* show, the relation between rice and violence remains negative and statistically significant under both the checks. We can thus conclude that our results hold independently of the functional form adopted for the instruments.

Finally, we present the results of a *placebo* test: we use the deviation of maximum temperature as the instrument in place of deviation of minimum temperature. If significantly negative, given the positive effect on crops highlighted by Welch et al. (2010), such a result would contradict our main findings. Table X, however, shows that the deviation of maximum temperature[18] is not correlated with rice production, ruling out the presence of a link between maximum temperature and violence.

Conclusions

This article contributes to the positive analysis of the nexus between climate and violence by focusing on Indonesia for the period 1993–2003. We follow a two-stage approach to analyze the link between climate change and violence in a country with a substantial history of social unrest and a disproportionate dependence on a single crop. In this way we can set aside most of the confoundings that affected previous studies. Paddy rice is the staple

[16] Results are available at http://www.prio.org/jpr/datasets.

[17] Emulated first stage of these sets of estimations are available at http://www.prio.org/jpr/datasets.

[18] Descriptive statistics of deviation of maximum temperature are: obs.: 172; mean: 0.497; std. dev.: 11.723; min.: –33.941; max.: 32.751.

Table VIII. IV-NB estimation, instruments in cubic form

Dep. var.: Violence	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Paddy tons per capita	−1.231*	−1.064*	−1.247*	−1.218†	−1.122†
	(0.584)	(0.425)	(0.575)	(0.659)	(0.658)
Population (ln)	1.042**	1.495**			
	(0.233)	(0.492)			
GDP	−0.154	0.039	−0.849**		−0.705*
	(0.259)	(0.262)	(0.316)		(0.296)
Share of poor population	0.028†	0.009	0.014	−0.009	
	(0.017)	(0.022)	(0.026)	(0.025)	
Share of area by household		0.094†	0.070	0.051	0.056
		(0.049)	(0.059)	(0.053)	(0.055)
Improved water source		0.009	0.074*	0.022	0.063*
		(0.033)	(0.032)	(0.026)	(0.029)
Decentralization	−0.229	−0.454	3.730†	−0.411	2.966
	(1.387)	(1.182)	(2.183)	(0.468)	(1.966)
Violence, *t*–1	0.023**	0.026**	0.041**	0.071**	0.038**
	(0.007)	(0.007)	(0.014)	(0.024)	(0.012)
Constant	−18.023**	−25.950**	−8.627**	−2.819	−6.648*
	(3.449)	(7.624)	(2.921)	(1.937)	(2.991)
Observations	108	108	108	119	108

Instruments: (a) deviation of the minimum temperature (December *t*–1); (b) deviation of the rainfall (December *t*–1); (c) deviation of the minimum temperature (December *t*–1) at the third power; (d) deviation of the rainfall (December *t*–1) at the third power. Standard errors clustered at the provincial level in parentheses; $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.1$.

Table IX. IV-NB estimation, interaction of the instruments

Dep. var.: Violence	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Paddy tons per capita	−1.167*	−0.998*	−1.244*	−1.206†	−1.171†
	(0.558)	(0.388)	(0.508)	(0.637)	(0.644)
Population (ln)	1.035**	1.453**			
	(0.231)	(0.476)			
GDP	−0.125	0.035	−0.844**		−0.709*
	(0.253)	(0.251)	(0.299)		(0.285)
Share of poor population	0.028†	0.009	0.013	−0.009	
	(0.016)	(0.019)	(0.025)	(0.024)	
Share of area by household		0.090†	0.071	0.051	0.059
		(0.048)	(0.058)	(0.052)	(0.057)
Improved water source		0.011	0.074*	0.022	0.064*
		(0.031)	(0.032)	(0.026)	(0.030)
Decentralization	−0.423	−0.453	3.453†	−0.417	2.737
	(1.332)	(1.125)	(1.977)	(0.466)	(1.874)
Violence, *t*–1	0.024**	0.026**	0.041**	0.071**	0.039**
	(0.007)	(0.007)	(0.014)	(0.024)	(0.013)
Constant	−17.683**	−25.207**	−8.568**	−2.787	−6.855*
	(3.478)	(7.436)	(2.793)	(1.884)	(3.061)
Observations	108	108	108	119	108

Instruments: (a) deviation of the minimum temperature (December *t*–1); (b) deviation of the rainfall (December *t*–1); (c) interaction between (a) and (b). Standard errors clustered at the provincial level in parentheses; $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.1$.

Table X. IV-NB estimation, placebo test: deviation of max temperature as instrument

Dep. var.: Violence	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Paddy tons per capita	−0.490	1.581	−0.579	−0.628	−0.766
	(0.894)	(2.155)	(0.703)	(0.755)	(0.677)
Population (ln)	1.074**	−2.280			
	(0.307)	(3.379)			
GDP	0.075	0.102	−0.633**		−0.588**
	(0.328)	(0.634)	(0.154)		(0.181)
Share of poor population	0.035*	0.068	0.029	0.007	
	(0.017)	(0.057)	(0.025)	(0.023)	
Share of area by household		−0.039	0.036	0.022	0.039
		(0.110)	(0.035)	(0.034)	(0.039)
Improved water source		0.173	0.075**	0.032	0.063*
		(0.151)	(0.029)	(0.028)	(0.028)
Decentralization	−1.487	−6.466	1.786	−0.729†	1.899
	(1.669)	(7.039)	(1.264)	(0.428)	(1.359)
Violence, *t*–1	0.023**	0.193	0.038**	0.062**	0.037**
	(0.007)	(0.174)	(0.013)	(0.019)	(0.012)
Constant	−16.383**	30.438	−6.178**	−1.714	−5.207**
	(3.710)	(50.119)	(1.693)	(1.607)	(1.889)
Observations	110	110	110	121	110

Instruments: (a) deviation of the maximum temperature (December *t*–1); (b) deviation of the rainfall (December *t*–1). Standard errors clustered at the provincial level in parentheses; $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.1$.

crop in Indonesia and therefore its scarcity can be blamed for fueling violence. The first stage, which exploits the link between variations in minimum temperature and rice crops as suggested by natural science literature, controls for potential endogeneity. We adopted an IV approach to uncover the impact of variations in minimum temperature on the emergence of actual violence through the effect on food availability, captured by rice crops per capita. Results show that an increase in the minimum temperature during the core month of the growing season (i.e. past December) determines an increase in violence driven by the reduction in future rice production per capita. Results are robust to several robustness checks.

We must point out some limitations. First, matching the UNSFIR data with NOAA climatic data provides a small number of observations (slightly larger than 100). Moreover, the choice of covariates also suffers from the lack of data at the province level.

The main result we claim for this work is methodological. Under the assumption that climate change affects the emergence of violence through agricultural production, we have chosen to focus on specific characteristics of a staple crop in a specific country, namely paddy rice in Indonesia. From natural science literature we have found that the minimum temperature in a limited period of time (growing season, December) is crucial to rice growing. We modelled our estimation framework upon such evidence. We believe that the robust evidence has emerged because we have taken into account the agronomic specificities of paddy rice. Our work suggests that some inconclusive results in the literature on the climate change–violence nexus could suffer from not considering specificities of different crops. Further research seems necessary to explore other combinations of climate change, crops, and violence in different countries.

Replication data

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.org/jpr/datasets. All analyses were conducted using STATA.

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Appendix 1

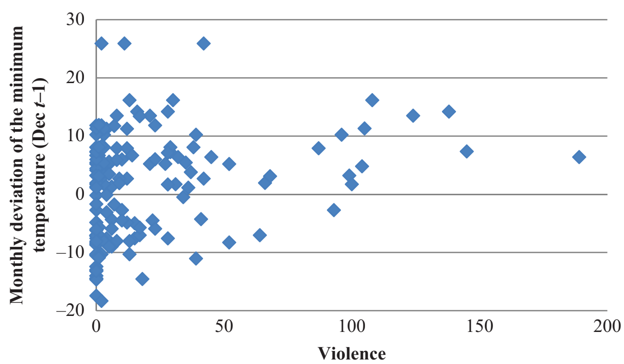

Figure A1. Violence and deviation of the minimum temperature (December t–1)

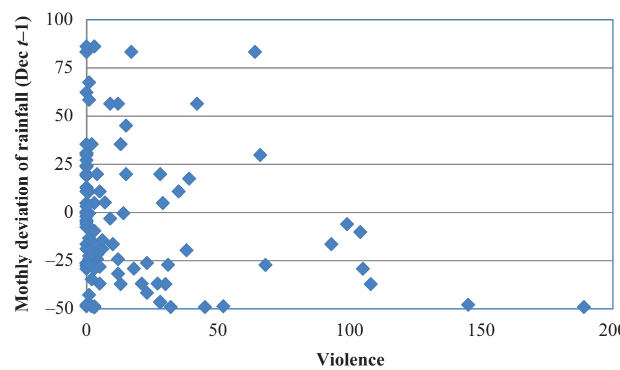

Figure A2. Violence and deviation of rainfall (December t–1)

Appendix 2

Table A1. OLS regression as emulated first stage

Dep. var.: Paddy tons per capita	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Deviation of the minimum temperature (December t–1)	−0.044*	−0.051**	−0.042**	−0.025†	−0.031†
	(0.017)	(0.015)	(0.013)	(0.013)	(0.015)
Deviation of the rainfall (December t–1)	0.001	0.002	0.003*	0.004*	0.004*
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Population (ln)	−0.058	0.626			
	(0.181)	(0.430)			
GDP	−0.335†	0.054	−0.293†		−0.330†
	(0.187)	(0.255)	(0.162)		(0.179)
Share of poor population	−0.018	−0.041†	−0.033	−0.035	
	(0.017)	(0.022)	(0.020)	(0.023)	
Share of area by household		0.069†	0.055	0.053	0.044
		(0.037)	(0.037)	(0.040)	(0.036)
Improved water source		−0.037	−0.010	−0.026	−0.013
		(0.024)	(0.016)	(0.017)	(0.015)
Decentralization	2.132*	1.165	2.420*	0.593†	2.294*
	(0.942)	(1.107)	(0.932)	(0.338)	(1.013)
Violence, t–1	0.005†	0.005†	0.010†	0.017†	0.007
	(0.003)	(0.003)	(0.005)	(0.009)	(0.005)
Constant	−1.829	−10.424†	−2.961*	−1.347	−3.441*
	(2.597)	(5.767)	(1.251)	(0.840)	(1.558)
Observations	108	108	108	119	108
R-squared	0.238	0.499	0.434	0.331	0.357

OLS estimator; standard errors clustered at the provincial level in parentheses; ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$.

To discuss the validity of the climatic instruments we rely on the approach of Dube & Vargas (2013) and present a set of OLS estimations of Equation (2) that emulate the first stages of *ivreg2*. From a methodological point of view, the coefficients of these regressions help us assess whether and how climatic change affects rice production.

Table A1 presents the results. The variables of interest are *Deviation of the minimum temperature (December t–1)* and *Deviation of the rainfall (December t–1)*. To be valid instruments, they must be correlated with rice production. As the coefficients show, minimum temperature is always correlated with the dependent variable at least at the 10% level, while rainfall is significant only in Models 3–5. These variables should also be the only determinants of rice production. Other regressors, the lagged dependent variable, and the decentralization dummy are also correlated with rice production. It is evident that they both indirectly capture the dynamics of the dependent variable, which is impossible to avoid. Hence, we believe that climatic variables can be used as instruments.

Appendix 3

Table A2. IV Poisson estimation

Dep. var.: Violence	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Paddy tons per capita	−0.981*	−0.733†	−0.855†	−1.342†	−0.662
	(0.451)	(0.383)	(0.468)	(0.816)	(0.432)
Population (ln)	0.708**	1.382**			
	(0.172)	(0.406)			
GDP	−0.233	0.184	−0.619**		−0.517**
	(0.218)	(0.251)	(0.234)		(0.178)
Share of poor population	0.009	−0.006	0.006	−0.033	
	(0.015)	(0.016)	(0.016)	(0.031)	
Share of area by household		0.069*	0.025	0.049	0.011
		(0.031)	(0.039)	(0.056)	(0.034)
Improved water source		−0.026	0.042†	−0.021	0.038†
		(0.023)	(0.022)	(0.031)	(0.021)
Decentralization	0.781	−0.606	2.583†	0.064	2.045*
	(1.065)	(1.132)	(1.367)	(0.402)	(1.043)
Violence, *t*–1	0.016**	0.016**	0.022**	0.042**	0.021**
	(0.002)	(0.001)	(0.004)	(0.010)	(0.003)
Constant	−11.942**	−20.461**	−4.188†	−0.109	−2.784†
	(2.142)	(5.481)	(2.193)	(1.421)	(1.664)
Observations	108	108	108	119	108

Instruments: (a) deviation of the minimum temperature (December *t*–1); (b) deviation of rainfall (December *t*–1); standard errors clustered at the provincial level in parentheses; $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.1$.

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