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Detecting hidden violence: The spatial distribution of excess mortality in Rwanda[☆]

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A B S T R A C T

Existing sub-national studies on the geography of armed conflict mainly focus on observed battle events. Other dimensions of the conflict cycle, including battle events that remain undetected in news reports, one-sided violence against civilians and the indirect death toll, have gone largely unstudied due to lack of systematic data. This article demonstrates how these different dimensions of a conflict cycle can be detected and how their relative importance can be assessed. The basic tools include population census data, principal component analysis and spatial analysis. When applied to the Rwandan case, the method reveals high excess mortality from the civil war, genocide, (counter)insurgency and the refugee crisis. Hidden violence is detected by presenting the first quantitative evidence to date of high excess mortality in Gisenyi, the northwestern province which was the location of (counter)insurgency and served as a corridor for more than a million refugees. The spatial regression analysis indicates that both the refugee crisis and (counter)insurgency contributed to a high death toll in Gisenyi. This latter finding is important because it provides empirical weight in support of contentious qualitative reports by various human rights groups.

Introduction

Armed conflict is often characterized by different forms of violence, e.g. political violence, ethnic violence and random violence (Davenport & Stam, 2009; Fearon & Laitin, 2003). Each form of violence is likely to be associated with excess mortality, although the affected population might differ by ethnic affiliation, political color or socioeconomic characteristics. Both from a historical point of view and for the sake of post-conflict reconstruction and reconciliation, it is important to recognize the occurrence of different forms of violence and to evaluate their impact on (segments of) the population (Straus, 2007). In addition, different forms of violence are likely to be associated with different underlying causes. Hence, any empirical study of the determinants of violence necessarily needs to start from the identification and measurement of violence in its different forms.

However, it is more rule than exception that some events in a conflict cycle receive more attention than others (Cramer, 2007). For example, in the aftermath of conflict, victims belonging to the conquering party are more likely to be heard and cared for than victims affiliated with the defeated parties. Furthermore, victims of indirect effects of violence, such as the disruption of health services and refugee streams, may be less visible than direct victims of violence. Finally, areas that are relatively well accessible or areas in which large-scale massacres took place may receive more and better news coverage compared to less accessible areas and areas where killings were dispersed. Using the case of Rwanda, this paper shows how one can achieve a more complete assessment of a conflict cycle with a balanced coverage of its distinct dimensions by relying on widely available data, i.e. population census data, and commonly used data analysis techniques, including Principal Component Analysis (PCA), Local Indicators of Spatial Association (LISA) and regression analysis.

This exercise is complementary to the recent explosion of studies that use spatial statistics for the study of the internal dynamics of armed conflicts, in particular civil wars. Examples

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include Buhaug and Gates (2002), Buhaug and Lujala (2005), Buhaug and Rod (2006), Murdoch and Sandler (2002), O'Loughlin (2004: 85–112 pp.), Raleigh and Hegre (2009), Raleigh and Urdal (2007), Rustad, Rød, Larsen, and Gleditsch (2008), and Ward and Gleditsch (2002). These studies have highlighted the importance of geography in explaining the location of armed conflict. For example, in Buhaug and Rod (2006), a study on the spatial determinants of African civil wars, it is shown that the distance to the capital city, the distance to state borders, road density as well as the geographic concentration of minority ethnic groups play an important role in explaining the location of armed conflict. Furthermore, it is argued that this role depends on the type of conflict. For example, whereas open warfare and conflict over state governance is more likely to be intense near the capital city and main roads, insurgency is favored by local characteristics that are often distant from the capital city and main roads, e.g. rough terrain, sparsely populated hinterland and cross-border sanctuaries.

As argued by Buhaug and Lujala (2005), the explosion of this type of studies is largely made possible by new developments in GIS software as well as the increasing availability of accurate sub-national geographic data on battle events. One of the most widely used datasets is the Armed Conflict Dataset, which provides sub-national systematic information on the incidence and location of battle events by screening news reports, at times complemented with information on the number of battle deaths (Gleditsch, Wallensteen, Eriksson, Sollenberg, & Strand, 2002; Harbom & Wallensteen, 2007). However, the currently available sub-national data on armed conflict has two major shortcomings. Firstly, news reports may be biased. Although care is taken to select information from independent sources, it is entirely possible that measurement error exists due to differing degrees of coverage of some regions or some forms of violence. Secondly, battle events are often only a fraction of the violence taking place and battle deaths only a fraction of the death toll in civil wars. As such, it is widely recognized that one-sided violence against civilians is frequently occurring in civil wars and that the indirect death toll of civil wars often far outnumbers the direct death toll. However, to the best of my knowledge, there is no systematic way to accurately measure the indirect death toll of armed conflict, either within or across countries. And, while there are two datasets documenting the country level incidence of one-sided violence against civilians and mass killings, neither of these datasets provides sub-national information (Eck & Hultman, 2007; Political Instability Task Force, 2010).

Although establishing an absolute measure of the direct and indirect death toll of different forms of violence is out of reach of the currently available data, the exercise for Rwanda will show that it is possible to develop a relative sub-national measure of excess mortality that, by means of an analysis of its spatial distribution, allows insight into the relative importance of different dimensions of the conflict cycle. The proposed method can be applied to other countries that experienced internal strife and hence can open new avenues for the sub-national study of armed conflict. Admittedly, the set of countries for which the method can be applied will be a nonrandom subset of post-conflict countries, i.e. countries where violence resulted in high excess mortality and where post-conflict institutions are sufficiently (co)operative to collect and release population census data.

The Rwandan conflict cycle of the nineties included civil war, genocide, reprisal killings, (counter)insurgency (i.e. rural guerilla warfare) and a major refugee crisis. Civil war broke out in Rwanda at the end of 1990, when the RPF (Rwandan Patriotic Front), a rebel army consisting mostly of Tutsi exiles, started launching attacks from Uganda. These first attacks were followed by a two-year period of intermittent hostilities and negotiations between the government and the RPF, which eventually led to a cease-fire in July 1992 and a power sharing agreement. But on April 6, 1994 the plane carrying President Habyarimana of Rwanda was shot down. Thereafter, Rwanda sunk into chaos. Within hours, the military (FAR – Forces Armées Rwandaises), the Interahamwe militia,[2] administrators and ordinary people started to kill Tutsi and moderate Hutu. Simultaneously with the onset of genocide, the civil war between the FAR and the RPF restarted. In areas where the RPF "liberated" the population from the genocidal regime, the RPF allegedly engaged in reprisal killings of Hutu. Late in June 1994, the RPF took power and the massive killings came to an end. However, until the late nineties, violence continued in the Northwest which was the locus of insurgency and counterinsurgency operations on the part of respectively the FAR+ (FAR and Interhamwe militia) – who used Congo as a basis for sporadic attacks, and the RPF – who remained military active close to and across the border with Congo in order to fight the insurgents.

Among the events in the Rwandan conflict cycle, the genocide has by far received most non-scholarly and scholarly attention. Many have tried to understand its causes and consequences from a political, social, anthropological, cultural or economic viewpoint (e.g. André & Platteau, 1998; Baines, 2003; Des Forges, 1999; Mamdani, 2001; Newbury, 1998; Straus, 2004; Verpoorten & Berlage, 2007; Verwimp, 2005). In addition, several efforts have been made to estimate the genocide's death toll among Tutsi (e.g. Prunier, 1998; Verpoorten, 2005). Two recent scholarly publications give a more central role to the other forms of violence, including reprisal killings committed by the RPF and the spillover of violence to eastern Congo (Davenport & Stam, 2009; Reyntjens, 2009). For several reasons, it is understandable that the genocide received most attention. First, an astonishingly large number of people were killed in a very short time period. Second, the ethnic cleansing campaign of Tutsi was partly executed by ordinary civilians. Third, some of the atrocities committed were of the most extreme brutality one can imagine. Fourth, a clear, large-scale and brutal crime against humanity occurred in front of the public eye without spurring an intervention of the international community. However, a less justifiable reason also plays a role. The western failure to halt the genocidal slaughter left the international community with a legacy of guilt, resulting in donors piling in aid and turning a blind eye to human rights violations committed by the conquering party (the RPF). Consequently, while the new RPF-led Rwandan government organized up to three different surveys to count the victims and survivors of the genocide (Government of Rwanda, 2008), imprisoned more than 100,000 alleged genocide perpetrators and put in place community level tribunals for judging them, no such efforts were taken to do justice to victims of other forms of violence.

The lack of an open debate on all forms of violence makes it difficult to collect equally accurate information on the different types of violence and assess their relative impact on the population. However, this paper aims to do just that. Relying on both the 1991 and 2002 population census, I construct a detailed spatial pattern of wartime excess mortality by subjecting a series of excess mortality proxies (1991–2002 differences in sector level mortality of sons and daughters, widowhood and orphanhood, and 2002 disability due to armed conflict) to principal component analysis. The first principal component provides us with a wartime excess mortality index (WEMI) on a less to more scale for approximately 1500 administrative sectors, which are, after the cell, the lowest administrative units in Rwanda with an average population size of about 5000 inhabitants. The significance of local geographic concentration in excess mortality is assessed by Local Indicators of Spatial Association – LISA (Anselin, 1995). In a regression analysis, the spatial pattern of excess mortality is related to the location and size of refugee camps as well as to the spatial determinants of different forms of violence (e.g. distance to Kigali City, the RPF advancement, distance to a main road, the geographic concentration of Tutsi, the location of alleged extrajudicial killings).

The spatial pattern reveals significant high–high excess mortality clusters in some provinces affected by the 1994 genocide, as well as in the East, which was the location of heavy fighting between the FAR+ and the RPF in 1994. Moreover, I provide the first quantitative evidence of high excess mortality in the Northwest. This area was not only the place of alleged severe human rights violations on the part of the RPF and FAR+ during the 1995–1998 (counter)insurgency, but it also served as the corridor for approximately one million refugees. The results of the regression analysis indicate that both the (counter)insurgency and the refugee crisis contributed to high excess mortality in the Northwest.

The next section gives an overview of previous assessments of the death toll of the Rwandan conflict cycle. In Section "Identifying wartime excess mortality", I calculate a measure for wartime excess mortality on a less to more scale for approximately 1500 administrative sectors in Rwanda. Section "The spatial pattern of wartime excess mortality" illustrates and discusses the spatial pattern of excess mortality. Using regression analysis, Section "Spatial analysis of excess mortality" establishes a relationship between the spatial pattern of excess mortality and a set of distinct spatial determinants that are associated with the different events in the Rwandan conflict cycle. Section "Conclusion" concludes.

The death toll of the Rwandan conflict cycle

Several efforts have been made to estimate the death toll of the 1994 genocide among Tutsi. Prunier (1998) makes use of demographic data, starting from the 1991 population census, which reported 596,400 Tutsi living in Rwanda (8.4 percent of the population). Taking into account an annual population growth of three percent, the number of Tutsi would have been 650,900 at the end of July 1994 (under the no-genocide scenario). Subtracting the number of survivors (an estimated 150,000)[3] from the estimated Tutsi population under the no-genocide scenario, gives an estimate of 500,900 dead, or 77.0 percent of the Tutsi population. This estimate is likely to be at the lower end, because of the alleged under-reporting of Tutsi in the 1991 census. Verpoorten (2005) provides evidence for this allegation, indicating that there was up to 40% under-reporting of Tutsi, either by the Habyarimana regime (in order to keep the school and public employment quotas of Tutsi low), either by Tutsi themselves (in order to avoid discrimination). It is demonstrated that, when repeating the same exercise as above with a larger Tutsi population in 1991, the estimated death toll of the genocide increases to a range of 600,000 to 800,000 Tutsi killed, depending on the exact extent of under-reporting.

The most recent estimate of the 1994 killings includes both Tutsi and Hutu victims and stems from a compilation of data on casualties from different sources: the Rwandan Ministry of Education, the Rwandan Ministry of Youth, Culture and Sports, IBUKA (an association of Tutsi survivors), African Rights (the international human rights organization) and Human Rights Watch (the international human rights organization). Davenport and Stam (2009) apply a Bayesian latent variable model to the data in order to obtain estimates on the number of killings taking place in 164 administrative communes during April–June 1994. The sum of victims in communes under the jurisdiction of the FAR is estimated at approximately 890,000, which adds to the evidence of a high death toll under the jurisdiction of the genocidal regime. Davenport & Stam (2009) use the same approach to estimate the number of killings that took place in 1994 within the zones under RPF control and the zones contested by the RPF and FAR+. They arrive at estimates of respectively 80,000 and 90,000, which confirm previously made allegations of 1994 human rights violations, in particular reprisal killings, at the address of the RPF (Des Forges, 1999; Prunier, 1998, the Gersony report[4]).

In contrast to the relatively detailed documentation of the 1994 death toll, the documentation of the death toll of the 1990–1993 civil war and 1995–1998 (counter)insurgency is much scarcer. The UCDP/PRIO battle deaths database details the number of battle deaths in Rwanda for the period 1990–2002, with important omissions for 1994, 1995 and 1996 (Harbom & Wallensteen, 2007). Starting at 2000 battle deaths in 1990, the number increases to 3200 in 1991 and 1992, and drops to 1600 in 1993. In 1997 and 1998, respectively 3000 and 6000 battle deaths are counted. In 1999 the number of battle deaths does not exceed 1000 which means an end to civil war according to the definition used (Gleditsch et al., 2002). The UCDP/PRIO data is not well suited for assessing the intensity of violence in Rwanda, not only because data is lacking for 1994–1996, but also because violence against civilians, which was by far the most important form of violence in Rwanda, is largely omitted (Restrepo, Spagat, & Vargas, 2006).

According to accounts of Amnesty International, in the course of 1995–1998, a large number of Rwandan civilians became victims of the intensifying conflict between the RPF and armed opposition groups believed to be allied to the former FAR+. Both parties are accused of severe human rights violations and large-scale massacres among civilians, taking place mainly in the Northwest of the country. However, most of the alleged massacres cannot be investigated because of the Rwandan Government's tight control on the dissemination of information relating to the human rights situation. The accounts of killings therefore remain tentative and incomplete. Amnesty International has probably provided the most complete coverage in four reports with fitting titles "Alarming resurgence of killings", "Civilians trapped in armed conflict", "Ending the silence" and "The hidden violence: disappearances and killings continue" (Amnesty International, 1996, 1997a, 1997b, 1998).

Besides the high direct death toll of the Rwandan armed conflict, many may have died prematurely following the collapse of health care, social and economic systems in the mid-nineties.[5] Furthermore, the death toll in refugee camps was very high due to the rapid spread of infectious diseases. For example, the cholera epidemic in Goma (at the border of RD Congo and Rwanda) is believed to have taken around 30,000 lives (Prunier, 1998). The indirect death toll in Gisenyi and Ruhengeri may have been higher than elsewhere because these northwestern provinces did not only serve as the corridor of approximately one million refugees fleeing to Congo in 1994 and back to Rwanda in 1996/1997, but they also experienced a relatively long period of violence as well as important disruptions in economic activities. In this respect, Amnesty International reports that, as part of the counterinsurgency strategy, a scorched earth policy was being carried out in many areas in the Northwest, where homes and fields were being burned. In addition, they report that, in an attempt to cut food supplies to armed opposition groups, the RPF prevented farmers from harvesting and marketing their crops (Amnesty International, 1997a).

Identifying wartime excess mortality

I follow a long standing tradition in the demographic literature to infer excess mortality from characteristics of the surviving population, a method referred to as indirect mortality estimation (Hill & Trussell, 1997; Timaeus, 1986). However, instead of aiming at the usual absolute countrywide estimate of excess mortality, the proposed method aims at capturing relative excess mortality, i.e. its spatial distribution within a given country on a less to more scale.

Mortality proxies

I derive five sector level mortality proxies (*MP*) from the 2002 population census, which includes information on approximately 8.1 million individuals living in 1544 administrative sectors (Government of Rwanda, 2002). The five *MPs* are the following:

- ($MP1$) Mortality of sons: total number of boys died/number of boys born (for all women who ever gave birth);
- ($MP2$) Mortality of daughters: total number of girls died/girls born (for all women who ever gave birth);
- ($MP3$) Widowhood: the proportion of widows among women ($\geq$30 years);
- ($MP4$) Double orphanhood: the proportion of double orphans among children and youngsters ($<$30 years);
- ($MP5$) Disability: the proportion of the population reporting a handicap due to war or genocide.

($MP1$)–($MP4$) may pick up sector level variation in mortality caused by factors other than the intensity of violence, i.e. peacetime characteristics (e.g. climate or health infrastructure). More formally, the variation in MP_{ij} ($i = 1–4$) across sectors j ($j = 1–1544$) is not only explained by direct and indirect wartime effects of violence, V_j, but also by peacetime sector level characteristics, P_j. Aiming to capture only the variation due to V_j, I take the difference between MP_{ij} and baseline mortality proxies, MP'_{ij}, taken from the 1991 population census. Due to data limitations, the baseline mortality proxies are defined at the commune level instead of the sector level. The commune still is a very small administrative unit, with an average size of 174 km^2 and counting on average 5.8 sectors. Summary statistics for MP_{ij} and MP'_{ij}, as well as their first differences ($MP_{ij} - MP'_{ij}$), denoted ΔMP_{ij}, are reported in Table 1. It is noteworthy that I find strong evidence for high wartime excess mortality: compared to 1991, the 2002 mortality proxies of sons and daughters are higher by eight and six percentage points respectively, the proportion of widows increased by 13 percentage points (from 0.18 to 0.31) and the proportion of double orphans more than doubled (from 0.02 to 0.05).

An important note to make is that the aftermath of the Rwandan conflict was characterized by a huge refugee crisis and considerable internal and external migration. For example, the newly established government organized a massive villagization program for resettlers. The newly created villages are referred to as imidugudu (umudugudu in singular form), of which most are located in the East close to the National Park as well as the Northwest at the border with RD Congo, while a number of smaller imidugudu are located in the interior of the country close to sites with many genocide survivors (Government of Rwanda, 2002). To gauge the impact of this villagization program and other forms of migration on the results, I calculate the 2002 mortality proxies both including and excluding individuals who changed residence over the period 1990–2002. The latter can be derived from the 2002 census by combining individual-level information of current residence, previous residence and duration of current residence. Since the purpose is to retrieve a spatial pattern of wartime excess mortality, the baseline *MPs* are calculated excluding individuals who changed residence over the period 1990–2002, which leaves a sample of 7.4 million individuals (91%). In a robustness check, I analyze the data including migrants.

Wartime excess mortality index (WEMI)

The challenge is to aggregate the information embodied in the five wartime excess mortality proxies ($\Delta MP1 - \Delta MP5$) into a meaningful index of wartime excess mortality. To overcome arbitrariness and safeguard maximum variation, several studies have persuasively argued for the use of principal component analysis (PCA) (Alesina & Perotti, 1996; Filmer & Pritchett, 2001; Hibbs, 1973). PCA has the desirable property of reducing the dimensionality of a data set while retaining as much as possible of the variation present in the data set. More precisely, from a set of variables, PCA extracts orthogonal linear combinations that capture the common information in the set most successfully. The first principal component (PC) identifies the linear combination of the variables with maximum variance, the second principal component yields a second linear combination of the variables, orthogonal to the first, with maximal remaining variance, and so on.[6]

For our objective, i.e. defining an index of excess mortality, we are interested in the first PC, which will be an appropriate summary of excess mortality if it captures a relatively high percentage of the total variance present in the excess mortality proxies set and the "loadings" of that PC have roughly equal values. Subjecting ($\Delta MP1 - \Delta MP5$) to PCA results in the following first PC:

$$WEMI = 0.49 \times \Delta MP1 + 0.47 \times \Delta MP2 + 0.47 \times \Delta MP3 + 0.47 \times \Delta MP4 + 0.32 \times \Delta MP5$$

which explains up to 57% of the total variation of the variable set ($\Delta MP1 - \Delta MP5$) and has significant loadings on all excess mortality proxies.

Robustness checks

I perform several robustness tests to check the sensitivity of *WEMI* to the inclusion of alternative excess mortality proxies. First, WEMI is calculated including migrants, which results in very similar factor loadings and an index denoted $WEMI_{mi}$. Second, I calculate the 2002 mortality proxies ($MP1$)–($MP5$) at the commune level instead of the sector level. Then I proceed as above, taking first differences using the commune level 1991 excess mortality proxies. Third, in order to attenuate the effect of survival bias on *WEMI*, I increase the weight of sectors that are close to sites of large-scale massacres. In these sites, the probability that entire families were exterminated is likely to be relatively high, causing mortality inferred from the surviving population to be under-reported. The

Table 1
Sector level excess mortality proxies (1533 administrative sectors).

Variable	Description	2002 census $MP1$–$MP5$		1991 census $MP1'$–$MP5'$		First difference $\Delta MP1$–$\Delta MP5$	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Mortality of sons	Total number of boys died/number of boys born	0.28	0.05	0.20	0.03	0.08	0.05
Mortality of daughters	Total number of girls died/number of girls born	0.24	0.05	0.18	0.03	0.07	0.05
Widowhood	Widows among women ($\geq$30 years) (%)	0.31	0.07	0.18	0.03	0.12	0.07
Double orphanhood	Double orphans among children ($<$30 years) (%)	0.05	0.02	0.02	0.01	0.03	0.02
Disability	Disabled due to war or genocide (%)	0.003	0.003	0.000	0.000	0.003	0.003

proximity to a large-scale massacre is taken into account by adding the natural logarithm of the distance to the nearest mass grave to the set of variables subjected to PCA. This distance is calculated in km at the sector level by overlaying a geo-referenced administrative map with the location of 71 mass graves in Rwanda taken from the Yale Genocide Studies website.

The resulting first principal components for these robustness checks are given by the following linear combinations:

$$WEMI_{mi} = (0.50,\ 0.46,\ 0.46,\ 0.47,\ 0.32) \times (\Delta MP1',\ \Delta MP2',\ \Delta MP3',\ \Delta MP4',\ \Delta MP5')'$$

$$WEMI_{com} = (0.48,\ 0.46,\ 0.43,\ 0.46,\ 0.48,\ 0.38) \times (\Delta MP1'',\ \Delta MP2'',\ \Delta MP3'',\ \Delta MP4'',\ \Delta MP5'')'$$

$$WEMI_{mg} = (0.48,\ 0.45,\ 0.45,\ 0.46,\ 0.32,\ -0.23) \times \Delta MP1,\ \Delta MP2,\ \Delta MP3,\ \Delta MP4,\ \Delta MP5,\ \Delta MP6'$$

with $MP6$ denoting log(distance to mass grave). The loadings of the first PC are similar across *WEMI*, $WEMI_{mi}$, $WEMI_{com}$ and $WEMI_{mg}$. Moreover, all four indices yield the same qualitative results in the spatial regression analysis below. Besides these robustness checks, I also performed a sensitivity analysis with respect to the age limits for the excess mortality proxies $\Delta MP3$ and $\Delta MP4$, and I find that setting the age limits 5 years lower (at 25) or 5 years higher (at 35) does not alter the qualitative results (not reported).

The spatial pattern of wartime excess mortality

The first two columns of Table 2 list the average of *WEMI* and its ranking across provinces. To facilitate the interpretation of the index, its values are rescaled to fit the interval [0,1]. Gisenyi has the largest value for *WEMI*, followed by Kibungo, Kigali City and Butare. Cyangugu scores lowest, followed by Gikongoro and Byumba. The ranking of provinces is similar for the alternative excess mortality indices $WEMI_{mi}$, $WEMI_{com}$ and $WEMI_{mg}$ (not reported).

How does this ranking compare with the ranking of provinces based on the available information on killings in 1994? To address this question, the remaining columns of Table 2 compare the ranking of provinces according to *WEMI* with the ranking of provinces according to the estimated 1994 killings by Davenport & Stam (2009) which was discussed in detail in Section “The death toll of the Rwandan conflict cycle”. Gisenyi, Kigali City and Ruhengeri are ranked markedly higher according to the *WEMI*, while the reverse is true for Kibuye and Gikongoro (and to a lesser extent Butare, Cyangugu and Gitarama).

How do these differences in ranking relate to the location of different forms of violence? The last three columns of Table 2 give a qualitative assessment of the intensity of genocide, civil war and (counter)insurgency for each province. This information is taken from a study by Justino and Verwimp (2006) who base their assessment on event data from new reports and reports of human rights organizations. I find a clear pattern in the deviations between both rankings: in general, the *WEMI* rank of provinces severely affected by genocide is lower than their ranking according to the estimated 1994 killings, while the reverse holds for provinces affected by civil war and (counter)insurgency. This finding suggests that the focus on 1994 killings does not do justice to (direct and indirect) victims of civil war and (counter)insurgency.

The province level averages may hide important differences within provincial borders. Fig. 1 plots the quintiles of the *WEMI* on a sector level map of Rwanda. A large number of top quintile sectors are located in Butare, in and around Kigali City, in Gisenyi, in the northwestern corner of Kibungo and in the southwestern corner of Umutara. In addition, smaller local clusters can be spotted in the West of Ruhengeri and Kibuye and in the Southeast of Gitarama and Gikongoro. The significance of these local spatial clusters can be assessed by means of Local Indicators of Spatial Association (LISA). LISA identifies areas with high values of a variable that are surrounded by high values on the neighboring areas, i.e. high–high clusters. Concomitantly, the low–low clusters are also identified (Anselin, 1995).[7]

Fig. 2 depicts the locations with significant high–high (dark gray) and significant low–low clusters (light gray). It shows a rather large low–low cluster that covers parts of Cyangugu, western Gikongoro and southern Kibuye. In order to explain this low–low cluster, two different arguments can be made. First, it can be verified that the low–low cluster covers the parts of Cyangugu, Gikongoro and Kibuye that are characterized by a relatively low proportion of Tutsi: 6.7%, 5.8% and 7.7% respectively compared to 15.5%, 18.1% and 13.3% for the areas of Cyangugu, Gikongoro and Kibuye that are not covered by the low–low cluster. Second, from 4 July 1994 until 22 August 1994, the French intervention “Opération Turquoise” set up a “safe zone” in the triangle Cyangugu – southern

Table 2
Province level WEMI and its comparison with the 1994 death toll.

Province	WEMI		Estimated 1994 death toll as % of 1994 population (Davenport and Stam (2009))		Difference in ranking (1) & (2)	Qualitative assessment of the impact of different forms of violence on population decline (Justino and Verwimp (2006))		
	Values	Ranking (1)	Values	Ranking (2)		Genocide	Civil war	Counterinsurgency
Butare	0.48	7	0.50	12	−5	2	0	0
Byumba	0.42	4	0.00	1	3	0	1	0
Cyangugu	0.36	2	0.02	4	−2	2	0	0
Gikongoro	0.37	3	0.05	6	−3	2	0	0
Gisenyi	0.58	12	0.02	3	9	0	0	1
Gitarama	0.45	5	0.09	8	−3	1	0	0
Kibungo	0.56	10	0.18	9	1	1	1	0
Kibuye	0.46	6	0.34	11	−5	2	0	0
Rural Kigali	0.51	9	0.22	10	−1	1	1	0
Kigali City	0.56	11	0.04	5	6	NA	NA	NA
Ruhengeri	0.49	8	0.01	2	6	0	1	1
Umutara	0.36	1	0.08	7	−6	NA	NA	NA

WEMI is the first PC of the sector level wartime excess mortality proxies ($\Delta MP1$–$\Delta MP5$); Davenport and Stam (2009) apply a Bayesian latent variable model to data on 1994 casualties (see Section “The death toll of the Rwandan conflict cycle” for details); Justino and Verwimp (2006) use event data for their qualitative assessment of the location of genocide, civil war and (counter-)insurgency; they do not provide a separate assessment for Kigali City and Umutara Province, a province which was created only after 1994 by joining parts of Kibungo and Byumba.

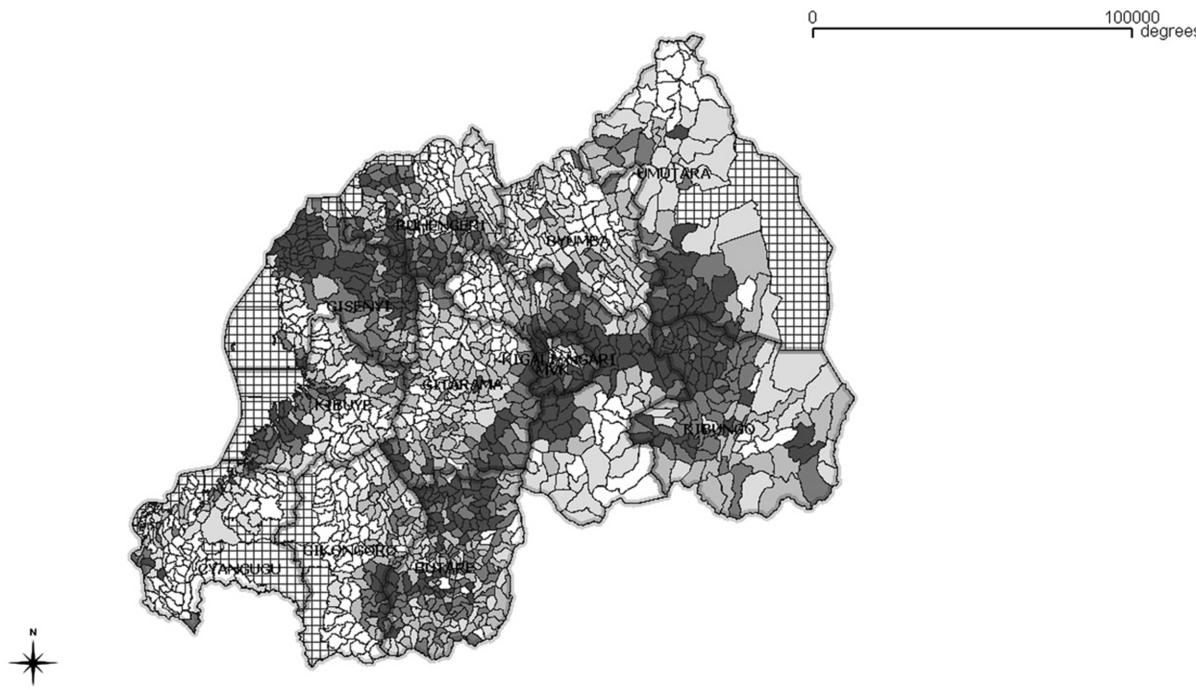

Fig. 1. Quintiles of WEMI (top quintiles are in darkest gray). Own calculations in GeoDa and Quantum GIS. The checkered areas are left out of the analysis. They include the national park, forest areas and lakes.

Kibuye – western Gikongoro. However, the intervention was heavily criticized, among others for not demilitarizing the zone and for serving other than humanitarian purposes, and it is estimated that it saved (only) 15,000 to 17,000 lives.[8]

In order to gauge the relative importance of the two explanations, I will revert to multivariate analysis in the subsequent section. Besides, an additional factor that needs to be taken into account is the large inflow and outflow of Internally Displaced Persons (IDPs) following respectively the start and end of Opération Turquoise. It is estimated that when Opération Turquoise ended on 22 August, some 390,000 IDPs remained in 33 camps. The forced closures of these remaining camps took place between August 1994 and April 1995 and were allegedly accompanied with severe human rights violation. It is by now well documented that, in the case of the closure of Kibeho in mid-April 1995, a massacre took place among the IDP population with estimates ranging between

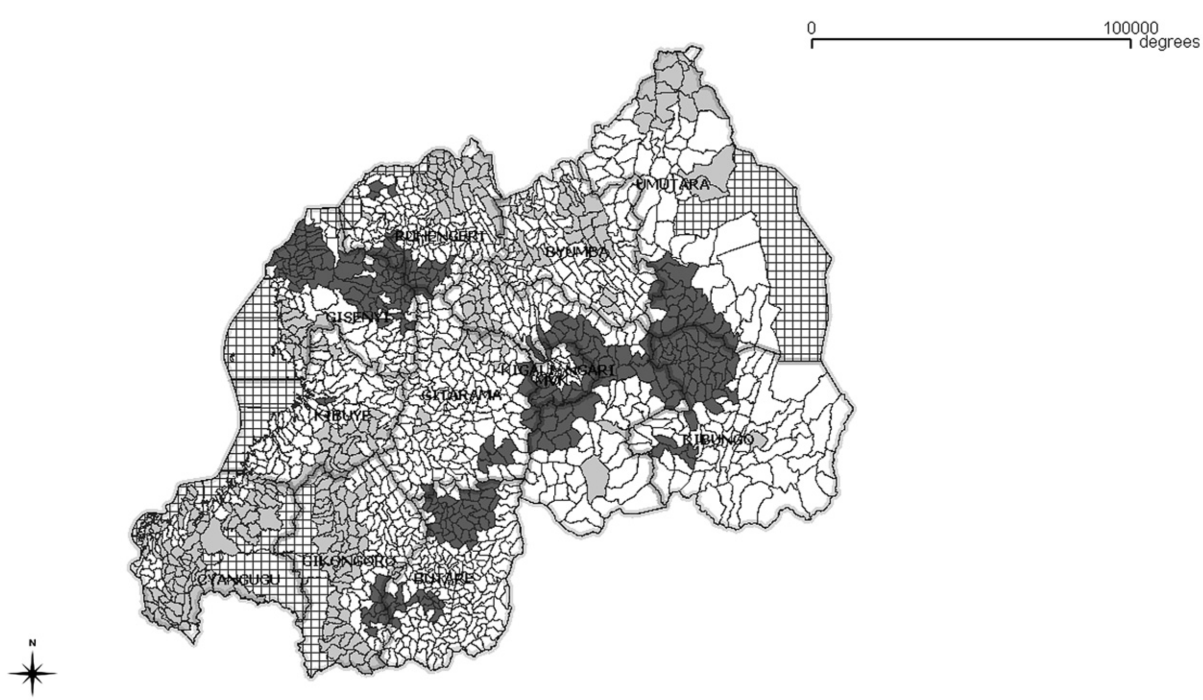

Fig. 2. Significant high-high (dark gray) and low-low clusters (light gray) of WEMI. Own calculations in GeoDa and Quantum GIS. The checkered areas are left out of the analysis. They include the national park, forest areas and lakes.

2000 and 5000 dead (Prunier, 1998). The IDP camp in Kibeho was located in Gikongoro Province, close to the borderline between the safe zone and the zone controlled by the RPF (see Fig. 3). It was the largest camp within Rwanda, spreading nine square kilometers and containing between 80,000 and 100,00 people. In the multivariate analysis below, I include an indicator variable for the location of the camp in order to isolate its impact on excess mortality from the other variables of interest. Unfortunately, no data is available on the location of the smaller IDP camps.

The significant high–high clusters in Fig. 2 confirm the pattern detected from Table 2 and Fig. 1: Butare, Kigali (both City and Rural), Kibungo and Gisenyi stand out, while smaller high–high clusters can be found in parts of Ruhengeri, Umutara, Gikongoro, Gitarama and Kibuye. It is noteworthy that the high–high cluster detected in southeastern Gikongoro coincides with the location of the Kibeho IDP camp. However, Kibeho is also located in the commune (Mubuga) with the highest share of Tutsi (57% compared to an average of 8%), a fact that may as well account for the high–high cluster. To complete the description of the spatial pattern, I note that *WEMI* is characterized by global clustering, i.e. the general trend is one of clustering with a rather high value for Moran's I (0.63) indicating significant positive spatial autocorrelation (Moran, 1950).

Spatial analysis of excess mortality

Spatial determinants

Now that I have established a detailed spatial pattern of excess mortality in Rwanda, I seek to understand how this pattern relates to the different events of the Rwandan conflict cycle. To this end I identify a set of spatial determinants that are associated with the four major events in the Rwandan conflict cycle, i.e. civil war, genocide, (counter)insurgency and the refugee crisis:

1. Civil war started in 1990, in the North of Rwanda at the border with Uganda. In 1994, the RPF moved eastwards to make a circular movement around the capital, Kigali City, which it eventually took over (Davenport & Stam, 2009). Thus, a relevant spatial determinant for civil war is the distance to the capital city. Besides, since much of the 1990–1994 civil war was open warfare, its intensity is likely to be high near main roads (Buhaug & Rod, 2006). In addition, I construct a fine measure to capture the RPF advancement. Relying on information about the location of the RPF-FAR+ battle-front in Rwanda provided by the genodynamics project (www.genodynamics.com), I construct a categorical variable that takes on values equal to the number of days that the sector was under RPF control between the start and the end of the 1994 RPF advancement (a 109-day period: April, 1, 1994–July, 19, 1994). For example sectors in the North close to the Ugandan border that were under control of the RPF by the end of April 1994 take on values between 79 and 109, while sectors that only came under control by the RPF in July, take on values between 1 and 19.
2. The genocide mainly targeted Tutsi and an estimated 75% of the entire Tutsi population was killed in 1994 (Verpoorten, 2005). A suitable determinant for the intensity of genocide is the commune-level proportion of Tutsi in 1991, which is calculated based on a 10% sample of the 1991 population census (provided by Minnesota Population Center, 2010). In addition, the distance to Kigali may also be related to the intensity of the

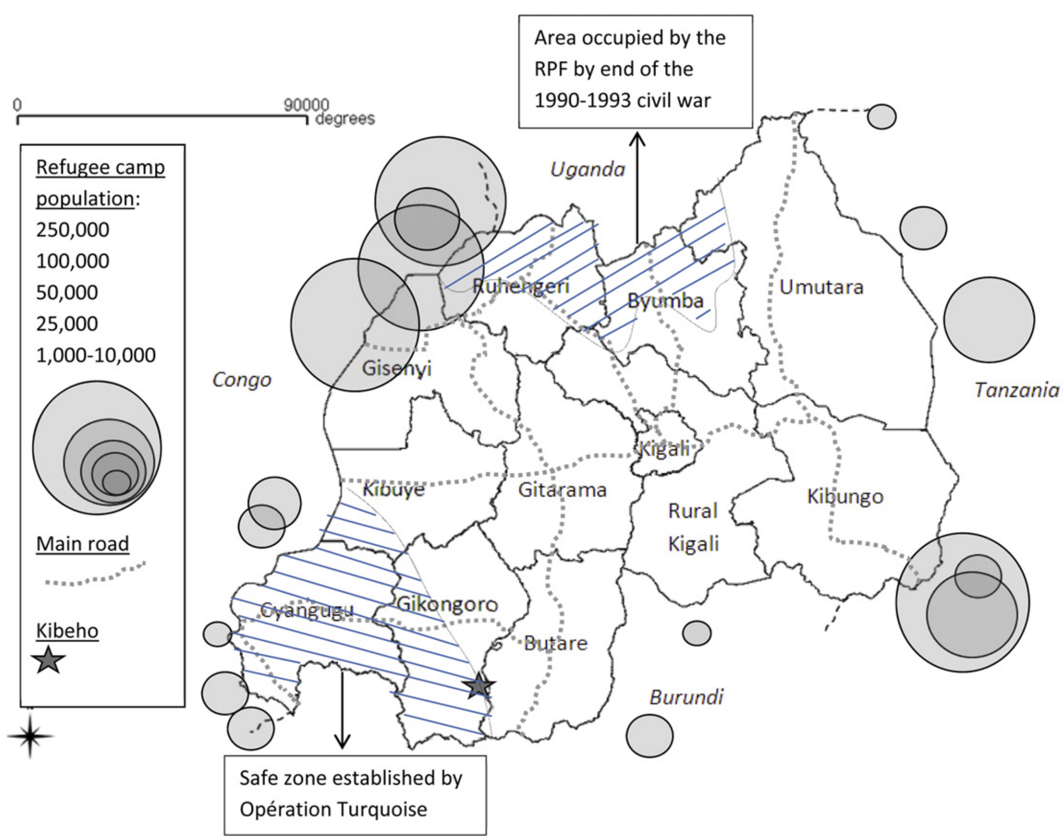

Fig. 3. Administrative map of Rwanda with the location of relevant spatial determinants of excess mortality. Own compilation by overlaying an administrative map of Rwanda with a UNHCR map of the location of refugee camps (UNHCR, 2000, chap. 10) and with a map of the genodynamics project that gives information on the position of the RPF and Opération Turquoise; In total , there are 34 small camps (1,000–10,000), but I only display the three small camps that are relevant for the analysis, i.e. those which are the closest refugee camp for at least one Rwandan sector. The other 31 small camps are located further from the border or at least as far as a larger refugee camp.

genocide, because the ethnic cleansing was orchestrated by the central administration and gradually spread from the capital city to the countryside.

3. The refugee crisis was nationwide, but more intense at the borders with RD Congo and Tanzania, two neighboring countries that hosted an estimated 1,200,000 and 580,000 refugees, respectively. Burundi also hosted a considerable number of refugees (270,000) while Uganda hosted no more than 10,000 refugees (UNHCR, 2000, chap. 10). Both the proximity to a refugee camp and its size are likely to affect excess mortality. Therefore, besides including the distance to the nearest camp, I distinguish between the distance to a small camp (1000–25,000), a medium camp (50,000–100,000 refugees) and the distance to a large camp (≥250,000). Besides externally displaced, there were also a large number of internally displaced. For the largest IDP camp within Rwanda (Kibeho), I calculate an indicator variable taking one for sectors that are within a range of 10 km from Kibeho sector, a cut-off value chosen to reflect the size of the camp (about 90 km^2).
4. (Counter)insurgency took place close to the northwestern border with DR Congo, in the provinces of Gisenyi and Ruhengeri. For these provinces I create separate indicator variables taking one for sectors located in Gisenyi or Ruhengeri and zero otherwise. However, since the Northwest (in particular Gisenyi) also served as a corridor for massive refugee streams, I need to add a finer variable that reflects the intensity of counterinsurgency within the northwestern provinces. To this end, I compile information on the number and location of alleged extrajudicial killings of civilians during (counter) insurgency from four Amnesty international reports (Amnesty International, 1996, 1997a, 1997b, 1998). This information is used to construct a commune-level proxy for the intensity of (counter)insurgency within the northwestern provinces (see example below).

Finally, two additional variables enter the analysis. First, I include an indicator variable taking 1 for 139 northern administrative sectors that were already under RPF control during the civil war of the early 1990s, and zero otherwise. This is to account for the fact that the civil war started off in October 1990, which is a couple of months prior to the implementation of the August 1991 population census. Hence, the baseline excess mortality proxies, MP'_{ij}, may be biased upward for the northern sectors. Second, I include an indicator variable taking 1 for the 205 sectors that made up the safe zone of Opération Turquoise, and zero otherwise.

All distance variables are calculated at the sector level using GeoDa (Anselin, 1995). Table 3 provides summary statistics. Fig. 3 provides an administrative map of Rwandan provinces with indications of borders with neighboring countries, the location of main roads, the location of the Kibeho IDP camp, the safe zone under Opération Turquoise, the 1990 civil war zone and the refugee camps across the borders with neighboring countries. The map depicts four large refugee camps hosting as many as 250,000 refugees. Three of these refugee camps were located at the northwestern border with Congo (near Goma), while one was located close to the southeastern border with Tanzania. Each of these locations was also hosting a medium size refugee camp (50,000–100,000 refugees). In addition, there were seven camps of about 25,000 refugees, of which four were located close to the southwestern border with Congo (near Uvira and Bukavu). Finally, almost all of the 34 remaining small refugee camps – hosting between 1000 and 10,000 refugees – were located in Burundi and across the southwestern border with Congo, near Uvira and Bukavu. In Fig. 3, I only display the three small camps that are relevant for the analysis, i.e. those which are the nearest refugee camp for at least one Rwandan sector – for the other 31 small camps one can find a medium sized or large refugee camp that is closer to the border (UNHCR, 2000, chap. 10).

Table 3
Summary statistics of the spatial determinants ($N = 1533$ sectors).

Variable	Description	Mean	St. Dev.
WEMI	Wartime Excess Mortality Index = first principal component of ($\Delta MP1$–$\Delta MP5$)	0.47	0.13
WEMI_mi	WEMI, including individuals who changed residence between 1990–2002	0.44	0.15
Death toll	An estimate for the sector level absolute death toll, derived from WEMI assuming a nationwide death toll of 1,000,000	653.7	188.4
RPF_days	Number of days under RPF control between April, 1, 1994 and July, 19, 1994 (from genodynamics project)	42.1	43.1
Distance to Kigali	Distance to the Kigali City (km)	63.39	29.51
Distance to main road	Distance to main road (=national road) in 1991 (km)	7.86	5.80
Tutsi_%	Commune level 1991 sector share of Tutsi in the population (from 1991 population census)	0.07	0.08
Distance to nearest RC	Distance to nearest refugee camp (km)	40.26	18.05
Distance to small RC	Distance to camp counting 1000 to 10,000 refugees (km)	77.11	26.77
Distance to medium RC	Distance to camp counting 25,000 to 100,000 refugees (km)	57.23	26.03
Distance to large RC	Distance to camp counting 250,000 refugees or more (km)	70.23	29.78
Kibeho_10 km	An indicator variable taking 1 for sectors within 10 km or less from Kibeho (the Kibeho camp was 90 km^2)	0.02	0.13
Executions in Northwest	Alleged extrajudicial executions in the communes of Ruhengeri and Gisenyi (taken from four Amnesty International reports)	81.9	359.7
1991 population density	Calculated from the 1991 population census	505.53	843.48
RPF_1990	An indicator variable taking 1 for the area controlled by the RPF at the end of the civil war in the early nineties (from the genodynamics project)	0.09	0.29
Opération Turquoise	An indicator variable taking 1 for the safe zone of Opération Turquoise (from the genodynamics project)	0.13	0.34
Urban	Indicator variable taking 1 for urban sectors	0.02	0.14
Migrants_%	Share of 2002 sector population that changed residence between 1990–2002 (from the 2002 population census)	0.16	0.20
Old caseload_%	Share of 2002 sector population that changed residence between 1990–2002 & that were born abroad (from the 2002 population census)	0.04	0.10
Other migrants_%	Migrants_%-Old caseload_% (from the 2002 population census)	0.12	0.14
Umudugudu_%	Share of 2002 sector population living in umudugudu (from the 2002 population census)	0.18	0.31

All distance measures are calculated in GeoDa.

Fig. 4 plots the number of alleged 1995–1998 extrajudicial killings of civilians for each of the communes located in Ruhengeri and Gisenyi. The figure reveals a high variation in the number of alleged killings across communes. The communes with the highest figures are Nkuli in Ruhengeri and Kanama in Gisenyi. To illustrate how I compiled the number of extrajudicial executions from the Amnesty International reports, I list two quotes on killings in these communes:

> (1430 executions) "Between 9 and 11 May 1997, at least 1430 civilians were reportedly killed by RPA soldiers in the secteurs of Ryinyo, Kintobo, Gatore, Gatovu, Rukoma, Gitwa, Runigi and Mukamira in Nkuli commune, in Ruhengeri. Amnesty International has received a list, drawn up by local sources, of the names of around 525 victims of these massacres - including at least 90 children - primarily in Ryinyo secteur. In addition to those named, at least 553 were reportedly killed in Kintobo secteur, 127 in Gatovu secteur, 120 in Rukoma secteur and 114 in Runigi secteur. These killings were reportedly preceded by several days of fighting between RPA forces and armed opposition groups around military camps in the area." (Amnesty International, 1997a, p. 5).

> (300 executions) "Sources in Kanama commune, Gisenyi, have reported that on 8 August 1997, several hundred people, including many civilians, were killed in and around a busy marketplace at Mahoko. The killings - most of which have been attributed to the army - reportedly followed the arrival of a group of armed "infiltrators" who looted shops and stalls. The RPA intervened and many civilians were killed in the hours that followed as the RPA reportedly fired towards the market from two military vehicles stationed nearby. Some victims may have been killed in the cross-fire; however, others appear to have been killed indiscriminately by the security forces. The exact number of victims is not confirmed; one source estimated that around 300 bodies were counted. Some were shot in the marketplace, others in nearby streets. The victims included François Munyempame, the family of a trader named Védaste, a representative of a non-governmental organization Emmanuel Tuyisenge, and two inspecteurs de police judiciaire (judicial police inspectors)." (Amnesty International, 1997a, p. 7).

Regression analysis

The dependent variable for the regression analysis is the wartime excess mortality index *WEMI* (rescaled to fit the interval 0–1). Since *WEMI* is derived from PCA its interpretation is rather cumbersome. Therefore, I provide a second set of results with an alternative dependent variable, i.e. an absolute sector level death toll derived from *WEMI*. The derivation is straightforward once I make an assumption on the total nationwide death toll of the Rwandan conflict cycle. For example, assuming a nationwide death toll of 1,000,000 (11.6% of the 1994 population) or an average sector level death toll of 648, the death toll for each sector can be derived from $WEMI_j$ as follows:

Fig. 4. Number of alleged 1995–1998 extrajudicial killings of civilians for administrative communes located in Ruhengeri and Gisenyi. Own compilation of commune-level alleged extrajudicial killings from four Amnesty International reports (Amnesty International 1996, 1997a, 1997b, 1998).

$$Deathtoll_j = \frac{WEMI_j}{\sum WEMI_j} \times 1,000,000$$

One can easily perform a sensitivity analysis with alternative death toll estimates. For example, assuming a nationwide death toll of 1,500,000, the estimated coefficients of the regression analysis should be multiplied by 1.5.

The aim is to test whether all four main events in the Rwandan conflict cycle contribute to explaining the observed spatial pattern in excess mortality. To this end, I formulate testable hypotheses for each of the events by relying on their association with distinct spatial determinants. This approach yields the following set of hypotheses:

1. Civil war
   *H*1*a*: the number of days under RPF control is positively associated with excess mortality
   *H*1*b*: distance from the nearest main road is negatively associated with excess mortality
   *H*1*c*: distance from Kigali City is negatively associated with excess mortality
2. Genocide
   *H*2*a*: the 1991 commune-level proportion of Tutsi in the population is positively associated with excess mortality
   *H*2*b*: distance from Kigali City is negatively associated with excess mortality
3. Refugee crisis
   *H*3*a*: distance from the nearest refugee camp is negatively associated with excess mortality
   *H*3*b*: the larger the refugee camp, the stronger its association with excess mortality
   *H*3*c*: sectors close to the largest IDP camp have a relatively large excess mortality
4. Counter(-insurgency)
   *H*4*a*: location within Gisenyi or Ruhengeri is positively associated with excess mortality
   *H*4*b*: the number of alleged extrajudicial killings is positively associated with excess mortality

Table 4 reports the main results of the regression analysis with $WEMI_j$ as the dependent variable. Model 1 gives the most parsimonious specification. It includes only the variables associated with the hypotheses above (except for *H*3*b* which is the subject of the next subsection) without additional controls. I find that only two hypotheses are not supported by the data, *H*1*b* and *H*3*c*, since the coefficients on the variables *Distance_to_main_road* and *Kibeho*_10 km are not significantly different from zero. As argued above, Kibeho sector was the site of a massacre among the population of an IDP camp but also hosted the largest share of Tutsi in its population, which causes a severe multicollinearity problem. When dropping *Tutsi_%* from the regression, the estimated coefficient on *Kibeho*_10 km is 0.136 and highly significant (not reported). The other estimated coefficients are in line with the hypotheses that excess mortality increases with *RPF_days*, *Tutsi_%*, *Executions_in_Northwest*; decreases with *Distance_to_main_road* and *Distance_to_nearest_RC*; and is higher in the Northwestern provinces *Gisenyi* and *Ruhengeri*.

These qualitative results remain throughout Models 2–5 for which the set of explanatory variables is gradually expanded to include *Opération_Turquoise*, *RPF*_1990, *Population_ density*_1991 and *Urban*. The results for these additional control variables are in itself interesting: the estimated impact of Opération_Turquoise on excess mortality is negative and significant in Models 2 and 3 suggesting that the operation was at least partially successful; the estimated coefficients on *RPF*_1990 indicate that WEMI is lower in areas that were already occupied by the RPF during the early civil war which reflects the upward bias on the baseline mortality proxies; WEMI is found to be lower in urban areas and to increase with *Population_density*_1991, a finding that is in line with the often made hypothesis that land scarcity plays an important role in explaining violence in Rwanda (André & Platteau, 1998; Prunier, 1998; Verpoorten, 2011). Model 6 indicates that all of these results, except for the significantly positive coefficient on RPF_days, are robust to including province fixed effects.

Table 5 repeats the results of Table 4, but taking $deathtoll_j$ as the dependent variable, which provides us with a more tangible interpretation for the estimated coefficients. For example, assuming an average of 648 dead in a sector, the estimated additional death toll in the provinces experiencing counterinsurgency, Gisenyi and Ruhengeri, varies between respectively 186–232 and 114–152 across the six different models. Furthermore, within these provinces, for every additional 1000 alleged extrajudicial executions within a commune, which corresponds to an average of 90 alleged extrajudicial executions within a sector, a sector's death toll

Table 4
Spatial determinants of excess mortality in Rwanda.

Dependent variable: WEMI	(1)	(2)	(3)	(4)	(5)	(6)
RPF_days[a]	0.011*** (0.002)	0.005* (0.003)	0.013*** (0.003)	0.017*** (0.003)	0.017*** (0.003)	0.002 (0.005)
Distance to main road[a]	−0.003 (0.005)	−0.002 (0.005)	−0.002 (0.005)	0.006 (0.005)	0.005 (0.005)	0.001 (0.005)
Distance to Kigali[a]	−0.098*** (0.010)	−0.096*** (0.010)	−0.081*** (0.010)	−0.068*** (0.011)	−0.082*** (0.010)	−0.113*** (0.015)
Tutsi_%	0.578*** (0.054)	0.555*** (0.056)	0.549*** (0.055)	0.529*** (0.055)	0.534*** (0.055)	0.479*** (0.052)
Distance to nearest RC[a]	−0.042*** (0.007)	−0.046*** (0.007)	−0.035*** (0.007)	−0.028*** (0.007)	−0.033*** (0.007)	−0.035*** (0.009)
Kibeho_10 km	−0.009 (0.027)	−0.012 (0.026)	−0.008 (0.026)	−0.003 (0.026)	0.002 (0.026)	0.027 (0.024)
Executions in Northwest[b]	0.035*** (0.008)	0.033*** (0.008)	0.030*** (0.008)	0.032*** (0.008)	0.032*** (0.008)	0.030*** (0.008)
Gisenyi	0.166*** (0.015)	0.149*** (0.016)	0.164*** (0.016)	0.161*** (0.016)	0.159*** (0.016)	0.133*** (0.018)
Ruhengeri	0.092*** (0.012)	0.087*** (0.012)	0.109*** (0.011)	0.101*** (0.011)	0.096*** (0.011)	0.081*** (0.014)
Opération Turquoise		−0.038*** (0.012)	−0.020* (0.012)	−0.018 (0.012)	−0.017 (0.012)	−0.006 (0.013)
RPF_1990			−0.071*** (0.012)	−0.081*** (0.012)	−0.078*** (0.012)	−0.044*** (0.013)
1991 population density				0.022*** (0.007)	0.037*** (0.008)	0.037*** (0.008)
Urban					−0.147*** (0.035)	−0.132*** (0.040)
Dummies for other provinces[c]	No	No	No	No	No	Yes
Constant	0.920*** (0.062)	0.949*** (0.062)	0.830*** (0.068)	0.598*** (0.093)	0.586*** (0.092)	0.778*** (0.108)
R^2	0.297	0.301	0.315	0.319	0.335	0.398
Obs	1533	1533	1533	1521	1521	1521

Regression estimates with robust *t*-scores in parenthesis. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.
[a] Logged.
[b] Expressed in 1000 alleged executions per commune.
[c] Butare is the excluded province.

Table 5
Spatial determinants of the death toll in Rwanda.

Dependent variable: death toll	(1)	(2)	(3)	(4)	(5)	(6)
RPF_days[a]	14.9*** (3.4)	7.6* (4.2)	18.8*** (4.8)	24.0*** (4.6)	23.2*** (4.6)	3.2 (6.6)
Distance to main road[a]	−4.3 (6.7)	−2.6 (6.8)	−2.1 (6.7)	8.0 (7.3)	6.8 (7.2)	1.3 (7.1)
Distance to Kigali[a]	−136.6*** (13.7)	−134.7*** (13.6)	−113.8*** (14.6)	−95.3*** (15.1)	−114.1*** (14.5)	−158.0*** (21.4)
Tutsi_%	806.9*** (75.4)	775.4*** (78.4)	766.4*** (77.3)	738.6*** (77.1)	746.2*** (76.5)	669.2*** (73.2)
Distance to nearest RC[a]	−58.7*** (9.4)	−63.6*** (9.7)	−49.5*** (10.1)	−39.8*** (10.4)	−45.8*** (10.4)	−48.8*** (12.6)
Kibeho_10 km	−12.8 (37.5)	−17.4 (36.9)	−11.3 (36.5)	−3.9 (36.3)	2.8 (36.5)	38.1 (34.1)
Executions in Northwest[b]	49.5*** (11.3)	46.6*** (11.2)	42.5*** (10.8)	45.2*** (10.9)	45.2*** (10.7)	42.1*** (10.7)
Gisenyi	232.4*** (20.9)	207.6*** (21.9)	229.7*** (21.8)	224.6*** (21.9)	221.4*** (21.8)	185.9*** (25.0)
Ruhengeri	129.1*** (16.6)	121.1*** (16.4)	151.8*** (15.6)	141.5*** (15.8)	134.3*** (15.7)	113.8*** (20.1)
Opération Turquoise		−53.1*** (16.9)	−28.3* (17.0)	−25.7 (16.9)	−23.5 (16.8)	−7.9 (18.3)
RPF_1990			−99.2*** (17.2)	−113.4*** (17.1)	−109.0*** (16.9)	−62.0*** (17.9)
1991 population density				30.8*** (10.3)	51.4*** (10.6)	51.8*** (10.8)
Urban					−205.5*** (49.1)	−184.9*** (56.1)
Dummies for other provinces[c]	No	No	No	No	No	Yes
Constant	1285.8*** (86.2)	1325.8*** (87.1)	1160.1*** (94.8)	835.3*** (129.7)	818.1*** (127.8)	1086.4*** (150.8)
R^2	0.297	0.301	0.315	0.319	0.335	0.398
Obs	1533	1533	1533	1521	1521	1521

Regression estimates with robust t-scores in parenthesis. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.
[a] Logged.
[b] Expressed in 1000 alleged executions per commune.
[c] Butare is the excluded province. The dependent variable is an estimate for the absolute sector level death toll, derived from WEMI, assuming a total nationwide death toll of 1 million.

is estimated to increase with 42–50.[9] A tenfold reduction (e.g. from 10 km to 1 km or from 100 km to 10 km) in the distance to a refugee camp increases the death toll with 40–66. A 10 percentage point higher pre-genocide Tutsi population corresponds with an additional 67–81 dead. A tenfold reduction in the distance to Kigali increases the estimated death toll by 95–158. Finally, an additional day under RPF control leads to an 8–24 unit increase in the death toll. Although these coefficient estimates are indicative for the impact of the different forms of violence and the refugee crisis, their absolute values should be taken with caution, due to the unverified assumption of a one million nationwide death toll and multicollinearity between the explanatory variables.

Accounting for the refugee crisis & other robustness checks

In column 1 of Table 6, I repeat the baseline results of Table 4, column 1. In the remaining columns, I contrast this result with several specifications in order to gauge the impact of displacement and resettlement on the results. First, in column 2, I distinguish between refugee camps of different sizes by replacing the variable *Distance_to_nearest_RC* by three distinct variables: *Distance_to_small_RC*, *Distance_to_medium_RC* and *Distance_to_large_RC*. The results indicate that distance to a small camp has no significant impact on excess mortality, whereas the other two distance variables take on a strongly negative and significant coefficient, with the coefficient for distance from a large camp twice as large in absolute value. This is evidence in support of *H3b*.

In the remaining columns, I replace the dependent variable *WEMI* by $WEMI_{mi}$, i.e. the index that includes the individuals that changed residence between 1991 and 2002 ("the migrants"). This is interesting for two reasons. First, doing so, it can be verified whether the coefficients on the explanatory variables remain unchanged, and hence whether possible omitted variable bias (from migration) is driving the results. The results in column 3

Table 6
Spatial determinants of excess mortality, taking into account refugees, displacement & resettlement.

Dependent variable:	WEMI		WEMI_mi (including 1990–2002 migrants)			
	(1)	(2)	(3)	(4)	(5)	(6)
RPF_days[a]	0.011*** (0.002)	0.010*** (0.002)	0.016*** (0.003)	0.017*** (0.003)	0.018*** (0.003)	0.006** (0.003)
Distance to main road[a]	−0.003 (0.005)	−0.008 (0.005)	−0.004 (0.005)	−0.006 (0.005)	−0.005 (0.005)	−0.013*** (0.005)
Distance to Kigali[a]	−0.098*** (0.010)	−0.095*** (0.010)	−0.097*** (0.010)	−0.097*** (0.010)	−0.093*** (0.010)	−0.106*** (0.009)
Tutsi_%	0.578*** (0.054)	0.645*** (0.054)	0.588*** (0.058)	0.588*** (0.058)	0.576*** (0.058)	0.568*** (0.057)
Distance to nearest RC[a]	−0.042***(0.007)		−0.046*** (0.007)	−0.049*** (0.007)	−0.046*** (0.007)	−0.037*** (0.007)
Distance to small RC[a]		0.006 (0.007)				
Distance to medium RC[a]		−0.043*** (0.009)				
Distance to large RC[a]		−0.092*** (0.009)				
Kibeho_10 km	−0.009 (0.027)	0.001 (0.028)	0.008 (0.029)	0.010 (0.029)	0.009 (0.029)	−0.002 (0.028)
Executions in Northwest[b]	0.035*** (0.008)	0.030*** (0.008)	0.040*** (0.009)	0.041*** (0.009)	0.042*** (0.009)	0.044*** (0.010)
Gisenyi	0.166*** (0.015)	0.095*** (0.017)	0.184*** (0.016)	0.183*** (0.016)	0.185*** (0.016)	0.188*** (0.016)
Ruhengeri	0.092*** (0.012)	0.064*** (0.013)	0.089*** (0.013)	0.085*** (0.014)	0.086*** (0.014)	0.031** (0.012)
Migrants_%				−0.027 (0.019)		
Old caseload_%					−0.119*** (0.031)	−0.134*** (0.030)
Other migrants_%					0.029 (0.028)	−0.034 (0.026)
Umudugdu_%						0.162*** (0.012)
Constant		0.920*** (0.062)	0.949*** (0.062)	0.830*** (0.068)	0.598*** (0.093)	0.586*** (0.092)
R^2		0.297	0.301	0.315	0.319	0.335
Obs		1533	1533	1533	1521	1521

Regression estimates with robust t-scores in parenthesis. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.
[a] Logged.
[b] Expressed in 1000 alleged executions percommune.

confirm that all findings remain basically the same. Secondly, it is now possible to check whether sectors with a large migrant population are characterized by lower or higher wartime excess mortality. In column 4, I add *migrants_%* to the set of explanatory variables and find no significant impact on $WEMI_{mi}$, which indicates that excess mortality is not different in sectors with a high proportion of migrants.

This analysis can be refined by distinguishing between two distinct types of 1990–2002 migrants: (1) those who were born abroad; the so-called old caseload refugees, i.e. Tutsi who fled Rwanda between 1959 and 1990 and came back when the RPF seized power; (2) the other migrants (*migrants_%* − old caseload refugees), which include the new caseload refugees, i.e. the resettled refugees of the 1990–2002 conflict cycle. Column 5 presents the results, which indicate that sectors with a large share of old caseload refugees are characterized with lower excess mortality, a finding that may be explained by the fact that most of the old caseload refugees were not living in Rwanda in 1994 when massive violence occurred.

Even within these two groups of migrants, there is a lot of heterogeneity. For example, some migrants among both old caseload and new caseload refugees were resettled by the government's villagization program and ended up in imidugudu. In column 6, *Imudugudu_%* is added and I find that the share of individuals living in imudugudu is strongly and positively correlated with excess mortality. This can be either because individuals heavily affected by the violence are selected into imudugudu or self-select into imudugudu, or because the living conditions in imudugudu are worse than elsewhere. Identifying the exact channel of causality requires an analysis with individual-level data and is out of the scope of this article.

Finally, the regressions are repeated using $WEMI_{com}$ and $WEMI_{mg}$ as dependent variables. All results remain qualitatively the same (not reported), but it is noteworthy that, in the case of the *WEMI* adjusted for survival bias ($WEMI_{mg}$) the coefficient on *Tutsi_%* increases in absolute value (by almost 10%), which strokes with the idea that survival bias is larger for the genocide because many Tutsi families were entirely exterminated.

Conclusion

Measuring internal violence is not only about observed battle events and battle deaths. Other aspects are important such as one-sided violence against civilians, hidden battle events and the indirect death toll. Yet, due to lack of systematic data, these other aspects have gone largely unstudied in existing sub-national studies. This is clearly a shortcoming, the more so because their spatial distribution is unlikely to be uniform across a country's territory. Hence, failing to identify and measure them not only limits our insights of the internal dynamics of conflict cycles, but may also hinder our understanding of battle events because of important omitted variable bias.

The challenge taken in this study is to provide a more balanced view of a conflict cycle through a sub-national spatial analysis of excess mortality. The illustration focused on Rwanda where, during the nineties, a sequence of different interrelated events occurred: civil war, genocide, reprisal killings, a massive refugee crisis and (counter)insurgency. The "true" death toll of the latter form of violence has been contested between human rights organizations, the UN and the Rwandan government.

I developed a sub-national spatial measure for wartime excess mortality in Rwanda relying on information from the 1991 and 2002 population census. In particular, five excess mortality proxies were subjected to principal component analysis. The first principal component yields an index of sector level excess mortality on a less to more scale. The spatial pattern of the excess mortality index confirms a high death toll of genocide, especially in Butare province. In addition, significant high–high excess mortality clusters are located in and around Kigali City and in the eastern province Kibungo, which may be explained by different events, since these areas were the scene of genocide, civil war as well as reprisal killings.

The main contribution of the Rwandan case study is the finding of a large and significant high–high excess mortality cluster in Gisenyi. This finding cannot be explained by genocide since Gisenyi counted very few Tutsi among its population (2.9%). It neither can be explained by the open warfare between the RPF and the FAR+ in 1990–1994 since civil war took place at the border of Uganda, in the East and around Kigali City. Instead, Gisenyi served as a corridor for approximately one million refugees and was the scene of fierce fighting between the RPF and remains of the FAR+ during the 1995–1998 (counter)insurgency. The multivariate regression analysis indicates that both the refugee stream and the 1995–1998 extrajudicial killings contributed to high excess mortality in Gisenyi.

The detection of high excess mortality in Gisenyi and its demonstrated association with (counter)insurgency is important, because the (counter)insurgency's direct and indirect death toll among civilians has been minimized by the Rwandan government. Human rights watch organizations have tried to draw attention to large-scale massacres among the civilian population as well as other severe human rights violations including the burning of houses and crops, but they were hampered in their efforts by restricted access to information and to the battle zones. Partly due to a lack of hard evidence, the UN and large western donors have failed to acknowledge the real extent of suffering on the part of the Gisenyi population.

Endnotes

[2] Interahamwe literally means "those who stand together" or "those who attack together". This militia was formed by President Habyarimana's political party in 1992, when the party started giving military training to its youth.

[3] At the end of July 1994, head counting in refugee camps resulted in an estimated 105,000 Tutsi survivors. According to Prunier (1998) one should add 25,000 survivors that did not go to camps. Human Rights Watch adds another 20,000 surviving Tutsi in Zaire and Tanzania (Des Forges, 1999).

[4] The "Gersony Report" is the name given to an unpublished report that identified a pattern of massacres by the RPF. The findings in the report were made by a team under Robert Gersony under contract to the United Nations High Commissioner for Refugees. Gersony's personal conclusion was that between April and August 1994, the RPF had killed "between 25,000 and 45,000 persons, between 5000 and 10,000 persons each month from April through July and 5000 for the month of August" (Des Forges, 1999).

[5] There are very few accounts on the indirect death toll of the Rwandan armed conflict. However, the International Rescue Commitee (IRC) has tried to assess the impact of war in DR Congo on excess mortality. Based on several national mortality censuses, they report that "Less than 10 percent of deaths were directly attributable to violence. The vast majority of Congolese died from the indirect public health effects of conflict, including higher rates of infectious diseases, increased prevalence of malnutrition and complications arising from neonatal- and pregnancy-related conditions" (Roberts, Ngoy, & Mulumba, 2007).

[6] Formally, suppose that x is a vector of p random variables and x^* is a vector of the standardized p variables, having zero mean and unit variance, then the first principal component $PC1$ is the linear function $\alpha_1' x^*$ having maximum variance, where $\alpha 1$ is a vector of p constants $\alpha 11, \alpha 12, \ldots, \alpha 1p$ and $'$ denotes transpose. $PC1 = \alpha_1' x^* = \alpha_{11} x_1^* + \alpha_{12} x_2^* + \ldots + \alpha_{1p} x_p^*$, Mathematically, the vector $\alpha 1$ maximizes $var[\alpha_1' x^*] = \alpha_1' \Sigma \alpha_1$, with Σ the covariance matrix of x^*, which corresponds to the correlation matrix of the vector x of the original, unstandardized variables. For the purpose of finding a closed form solution for this maximization problem, a normalization constraint, $\alpha_1' \alpha_1 = 1$, is imposed. To maximize $\alpha_1' \Sigma \alpha_1$ subject to $\alpha_1' \alpha_1 = 1$, the standard approach is to use the technique of Lagrange multipliers. It can be shown that this maximization problem leads to choosing $\alpha 1$ as the eigenvector of Σ corresponding to the largest eigenvalue of Σ, λ_1 and $var[\alpha_1' x^*] = \alpha_1' \Sigma \alpha_1 = \lambda_1$. To interpret the PC in terms of the original variables, each coefficient α_{1l} must be divided by the standard deviation, s_l, of the corresponding variable x_l. For example, a one unit increase in x_l, leads to a change in the 1st PC equal to α_{1l}/s_l. For a detailed exposition of principal component analysis I refer to Jolliffe (2002).

[7] More formally, LISA provides a measure of the extent to which the arrangement of values around a specific location deviates from spatial randomness. A general expression of a LISA statistic for a variable y_i, observed at location i, is: $L_i = f(y_i, y_{Ji})$,

where f is a function expressing the correlation between y_i and y_{Ji}, and y_{Ji} are the values observed in the neighborhood J_i of location i. The specific LISA statistic I use is the local Moran statistic for an observation i: $I_i = (y_i - \bar{y}) \sum_{j=1}^{n} w_{ij}(y_j - \bar{y})$, with w_{ij} a spatial weighting matrix indicating the relevant neighbors for the LISA analysis. The weighting matrix w_{ij} can be defined in different ways, although contiguity-based definitions are by far mostly used. I use a first order rook-contiguity based weighting matrix for neighbors, where w_{ij} equals one for sectors with a common boundary and zero otherwise. By looking explicitly at areas instead of individual sectors, one can to a large extent avoid wrong classification of erroneous outliers. Arbitrariness in identifying "high" is avoided by assessing the significance of high–high clusters. The procedure employed to assess statistical significance relies on a Monte Carlo simulation of different arrangements of the data and the construction of an empirical distribution of simulated statistics. Afterwards the value obtained originally is compared to the distribution of simulated values and, if the value exceeds the 95th percentile, it is said that the relation found is significant at 5%.

[8] The estimates are from the French army itself. According to Des Forges (1999) the number of lives saved by 2500 well-equipped elite French forces – 15,000–17,000 – is low compared to the achievements of the barely 500 U.N. peacekeepers, who were poorly equipped and minimally supplied, but protected about twice that number during the course of the genocide. However, this comparison does not take into account the difference in duration between the very short French intervention and the longer U.N. intervention.

[9] In Ruhengeri and Gisenyi, each commune counts on average 11 sectors, so the sector level equivalent of 1000 alleged extrajudicial executions within a commune is about 90.

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