LICOS Centre for Institutions and Economic Performance

Centre of Excellence

LICOS Discussion Paper Series

Discussion Paper 254/2009

# Detecting Hidden Violence: The Spatial Distribution of Excess Mortality in Rwanda

*Marijke Verpoorten*

**Katholieke Universiteit Leuven**

LICOS Centre for Institutions and Economic Performance
Huis De Dorlodot
Deberiotstraat 34 – mailbox 3511
B-3000 Leuven
BELGIUM

TEL: +32-(0)16 32 65 98
FAX: +32-(0)16 32 65 99
http://www.econ.kuleuven.be/licos

# Detecting Hidden Violence: The Spatial Distribution of Excess Mortality in Rwanda

Marijke Verpoorten*

Catholic University of Leuven, Belgium

January, 2010

**Abstract**

Rwanda experienced several forms of internal violence, including civil war, genocide, reprisal killings and (counter-)insurgency. While these events all occurred in 1990-1998, their geographic location within Rwanda differred, with the genocide especially severe in the South of the country, the civil war and reprisal killings mostly taking place in the North and East, and the (counter-)insurgency concentrated in the Northwest. In order to assess the relative impact of the different forms of violence, this article derives a detailed spatial pattern of excess mortality from the population census. In line with previous evidence on the death toll of armed conflict in Rwanda, we find significant high-high excess mortality clusters in the southern province of Butare, in and around Kigali City, and in the eastern province Kibungo. Furthermore, we present the first quantitative evidence to date of high excess mortality in the northwestern porvince Gisenyi, indicating that the 1995-1998 (counter-)insurgency inflicted a much higher death toll on the population than presently acknowledged by the Rwandan government, the UN and large western donors.

## 1 Introduction

Armed conflict is often characterized by different forms of violence, e.g. random violence, ethnic violence and political violence (Davenport & Stam (2009), Fearon & Laitin (2003)).

*Research scholar of the fund for Scientific Research - Flanders, Belgium (FWO), Center for Economic Studies, Centre for Institutions and Economic Performance LICOS, KULeuven. e-mail: marijke.verpoorten@econ.kuleuven.be

Each form of violence is likely to be associated with excess mortality, although the affected population might differ by ethnic affiliation, political color, geographic 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 the population (Straus (forthcoming)).

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 conquered parties. Furthermore, victims of indirect effects of violence, such as the disruption of health services and refugee streams, may be less visible than victims of direct violence. Finally, areas that are relatively well accessible or areas in which large scale massacres took place may receive more and better coverage compared to less accessible areas and areas where killings were dispersed.

In the Rwandan conflict cycle of the nineties, the 1994 genocide has by far received most non-scholarly and scholarly attention. Many have tried to understand its causes and consequences from the political, social, anthropological, cultural and economic viewpoint (e.g. André & Platteau (1998), Baines (2003), Des Forges (1999), de Walque & Verwimp (2009), Newbury (1998), Straus (2004), Verpoorten & Berlage (2007), Verwimp (2005), ). In addition, several efforts have been made to estimate the genocide's death toll amongst Tutsi (e.g. Prunier (1998), Verpoorten (2005)). Only two recent scholarly publications give a more central role to the other forms of violence, including reprisal killings committed by the Rwandan Patriotic Front (RPF), political violence and the spillover of violence to eastern Congo (Reyntjens (2009), Davenport & Stam (2009)).

For several reasons, it is understandable that the genocide received most attention. First, the ethnic cleansing campaign of Tutsi was partly executed by ordinary civilians (Straus (2004)). Second, an astonishingly large number of people belonging to one ethnic group were killed in a very short time period (Verpoorten (2005)). Third, some of the atrocities committed were of the most extreme brutality one can imagine (Des Forges (1999)). 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 (Des Forges (1999)).

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 bilateral aid and turning a blind eye to human rights violations committed by the conquering party (the RPF). Consequently, while Hutu must shoulder an immense collective blame, reprisal massacres against Hutus in the mid-1990s received few attention and are not publicly acknowledged[1]. Very concretely, while the new RPF-led Rwandan government organized up to three different surveys to count the victims and survivors of the genocide (Davenport & Stam (2009), Government of Rwanda (2008)), imprisoned more

[1] One of the most well-know examples is the Kibeho massacre where the RPA allegedly killed more than 5000 Hutu (Prunier (1998)).

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, a recent study demonstrates that ingenuity and some additional work can bring us closer to a complete assessment of the Rwandan conflict cycle. Davenport & Stam (2009) compile data on casualties from different sources[2] and match the timing and location of reported killings in these records with army intelligence information on battle fronts and battle zones. They conclude that while "the bulk of killings were undertaken within the jurisdiction of the extremist Rwandan government (approximately 891, 295 deaths), (...) we also find that there are many killings that took place under the territorial jurisdiction of the RPF (approximately 77,043 deaths) as well as on the front line of FAR+[3] and RPF engagements (approximately 93,426 deaths)".

This approach is very valuable in providing information on other than genocide-related violence in Rwanda. However, it faces two drawbacks. First, the compiled data sources mainly focus on recording the ethnic cleansing of Tutsi, rather than other human rights violations. Second, the records cover violations committed in the territory of Rwanda in 1994, omitting an important number of violations committed outside this period as well as violations committed across the border with neigboring countries. Therefore, if anything, the other-than-genocide related violence is still under-reported.

This paper is related to the work of Davenport & Stam (2009) in the sense that it aims to contribute to providing a more balanced view of the impact of distinct forms of violence that occurred in Rwanda in the 1990s. However, we deviate in four important ways. First, we rely on population census data, which is arguably less biased towards certain forms of violence than the records used by Davenport & Stam (2009). Second, we do not only focus on 1994 excess mortality, but aim to capture excess mortality in the period 1990-1998, officially designated as a period of civil war by the UCDP/PRIO armed conflict database (Harbom & Wallensteen (2007)). Third, rather than focussing only on killings, we look at a broadly defined measure of excess mortality that includes both direct and indirect victims of armed conflict, e.g. including those that died from deprivation (in refugee camps). Fourth, we study spatial distribution of excess mortality at the level of a smaller administrative unit, i.e. the sector level (N=1547) instead of the commune level (N=143)[4].

Compared to Davenport & Stam (2009), the present study has two limitations. First, the

[2]The Ministry of Education in Rwanda, Ministry of Youth, Culture and Sports in Rwanda, IBUKA (an association of Tutsi survivors), African Rights (the international human rights organization) and Human Rights Watch (the international human rights organization)

[3]Davenport & Stam (2009) use FAR+ to denote the group of extremist Hutu, including members of the Rwandan Armed Forces (FAR), Presidential Guard, national police, as well as affiliated militias, e.g. the Interahamwe and Impuzamugambi.

[4]In the administrative subdivision of Rwanda Anno 1994, "prefectures" are followed by "communes", "sectors" and "cells", the smallest codified administrative unit. "Cells" count on average 150 households, while "sectors" have an average population size of 4550 inhabitants

population census data lack a time dimension. Therefore, in contrast to Davenport & Stam (2009), who rely on both variation in time and space to identify the impact of several forms of violence, we only rely on spatial variation. Second, rather than providing an absolute estimate of sector level excess mortality, we provide a sector level index of excess mortality on a less to more scale.

This index is constructed in three steps. Our starting point is the 2002 population census from which we derive the following five sector level excess mortality proxies: mortality of sons, mortality of daughters, orphanhood, widowhood and disability due to war or genocide. We carefully select on age categories of respondents in order to capture as much as possible excess mortality in wartime. In a second step, we clean these proxies from remaining peacetime variation in excess mortality using pre-conflict and post-conflict excess mortality proxies. Thirdly, we aggregate the resulting wartime excess mortality proxies into an index by subjecting them to principal component analysis (PCA).

To assess the significance of local geographic concentration in excess mortality, we turn to Local Indicators of Spatial Association - LISA (Anselin (1995)). We find significant high-high clusters in some (but not all) 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, we provide the first quantitative evidence of high excess mortality in Gisenyi province, the place of alleged severe human rights violations on the part of the Rwandan Patriotic Army (RPA)[5] and armed opposition groups in the period 1995-1998. Our findings are robust to the inclusion of controls for baseline excess mortality, migration and survival bias.

The remainder of this paper is structured as follows. Section 2 gives an overview of Rwanda's conflict cycle. Section 3 discusses previous assessments of the death toll of the Rwandan armed conflict. Section 4 derives the excess mortality index along the three steps outlined above. Section 5 illustrates and discusses the spatial distribution of the index. Section 6 presents robustness checks. Section 7 concludes.

## 2 The 1990-1998 Rwandan conflict cycle

Civil war broke out in Rwanda at the end of 1990, when the RPF started launching attacks from Uganda. Intermittent hostilities and negotiations between the government and the RPF led to a cease-fire in July 1992 and a power sharing agreement. But on April 6, 1994 the plane carrying President Habyarimana was shot down. Thereafter, Rwanda sunk into chaos. Within hours, the military, administrators, the Interahamwe militia, and ordinary people started to kill Tutsi and moderate Hutu. Simultaneously the war between the Rwandan army and the RPF restarted.

Late in June 1994, the RPF took power and the massive killings and the war came to an end. The balance of the events was shocking: an estimated 800,000 Tutsi and moderate

[5] After its conquest of Rwanda, the RPF was split into a political division which retained the RPF name, and a military one, called the Rwandan Patriotic Army (now the Rwandan Defence Forces).

Hutu killed in the genocide, two million people displaced and more than 100,000 prisoners suspected of participation in the genocide. In addition, tens of thousands of people died from deprivation in refugee camps and several sources mention reprisal killings by the RPF both inside Rwanda and across the border with Congo. Comprehensive readings on the genocide and its aftermath include Des Forges (1999), Prunier (1998), Mamdani (2001), Reyntjens (2009), Davenport & Stam (2009).

Even when relative peace was established in Rwanda by the end of 1994, the RPF remained military active close to and across the border with Congo, partly because former Interhamwe and FAR militia used Congo as a basis for sporadic attacks until the late nineties. In addition, up to two years after the genocide, 1.7 million Rwandans continued to live in refugee camps outside their country. An estimated 1.4 million returned massively between June 1996 and June 1997, partly due to continued threats of attacks on refugee camps (Reyntjens (2009), Prunier (1998)).

Most of these 1996/1997 returnees had fled their country during the upheavals in April 1994. Statistics refer to them as "new caseload" refugees, as opposed to the "old caseload" consisting of refugees who had fled the country in several waves since 1959 following sporadic outbursts of ethnic violence and repression (Prunier (1998)). An estimated 800,000 old caseload refugees already returned since the second half of 1994. To facilitate resettlement, the Rwanda government engaged in a massive resettlement program, constructing grouped village settlements, the so-called umudugudu.

Another major challenge for the newly installed government was setting up a transitional justice system to trial more than 100,000 alleged genocide perpetrators or accomplices. Trying them through ordinary courts of law would take more than a century. To speed up genocide trials, Rwanda established a system of community based courts referred to as *gacaca* (Pitsch (2002), Wolters (2005), Ingelaere (2007)).

# 3 The literature on the death toll of the 1990-1998 Rwandan armed conflict

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 2,000 battle deaths in 1990, the number increases to 3,200 in 1991 and 1992, and drops to 1,600 in 1993. In 1997 and 1998, respectively 3,000 and 6,000 battle deaths are counted. In 1999 the number of battle deaths does not exceed 1,000, which means an end to civil war according to the definition used[6].

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 omitted.

[6] Civil war is defined as a war between organized groups within a single nation state having more than 1,000 battle deaths in a single yearGleditsch et al. (2002).

Another source on the civil war, Akresh et al. (2007), looks at morbidity instead of mortality, concluding that the impact of civil war (1990-1993) in Rwanda had a significantly negative effect on children's height-for-age z-scores who were living in Ruhengeri and Byumba in the early nineties.

Several efforts have been made to estimate the death toll of the 1994 genocide amongst Tutsi. Prunier (1998) makes use of demographic data, starting from the 1991 population census, which reported 596,400 Tutsi living in Rwanda, or 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[7]) 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). She demonstrates 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 (among both Tutsi and Hutu) by the genocidal regime stems from a compilation of data on casualties from different sources: the Ministry of Education in Rwanda, the Ministry of Youth, Culture and Sports in Rwanda, IBUKA (an association of Tutsi survivors), African Rights (the international human rights organization) and Human Rights Watch (the international human rights organization). Davenport & Stam (2009) apply a Bayesian latent variable model to the data in order to obtain estimates on the number of killings taking place in each commune 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 human rights violations at the address of the RPF (Des Forges (1999), Prunier (1998), the "Gersony report"[8]). However, these estimates are likely to be at

[7] 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).

[8] 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 5,000 and 10,000 persons each month from April through July and 5,000 for the month of August" Des Forges (1999).

the lower end given that the data sources used were mostly concerned with reporting acts of genocide that occurred in 1994.

As mentioned above, violence continued also after 1994. In the course of 1995-1998, a large number of Rwandan civilians became victims of an intensifying conflict between the RPA 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 amongst civilians, taking place mainly in the North West 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[9].

Besides the high direct death toll of the Rwandan armed conflict, many died from deprivation in the mid nineties. The death toll in refugee camps was probably very high due to the rapid spread of infectious diseases and the shortage of food. For example, the cholera epidemic in Goma is believed to have taken around 30,000 lives (Prunier (1998)). In addition, given the intensity of the conflict and its nationwide impact, many may have died prematurely following the collapse of health care, social and economic systems[10]. The indirect death toll of violence taking place in Gisenyi and Ruhengeri may have been higher than elsewhere because these provinces experienced a longer period of violence (respectively 1994-1998 and 1990-1998)[11]. Furthermore, Gisenyi was the corridor of millions of refugees fleeing to Congo in 1994 and back to Rwanda in 1996/1997, which probably added to the spread of infectious deceases and accute food shortages in this province[12].

# 4 Identifying 1990-1998 sector level excess mortality

## 4.1 Excess mortality proxies

A first set of excess mortality proxies are taken from the 2002 population census, which includes information on approximately 8.1 million individuals belonging to about 1.8 million households (). From the individual level data, we identify five sector level excess mortality proxies (for summary statistics, see Table 1):

[9] Amnesty International has probably provided the most complete coverage in reports with fitting titles "Rwanda: Civilians trapped in armed conflict", "Hidden violence", and "Ending the silence" (Amnesty International (1997*b*), Amnesty International (1997*a*), Amnesty International (1998))

[10] 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 et al. (2007)).

[11] Amnesty International reports that, as part of the counter-insurgency 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 oppoistion groups, the RPA prevented farmers from harvesting and marketing their crops (Amnesty International (1997*b*), Amnesty International (1997*a*), Amnesty International (1998)).

[12] In this respect, Montalvo & Reynal-Querol. (2007) argue that for each 1,000 refugees there are between 2,000 and 2,700 additional cases of malaria in the refugee-receiving country.

- $(EM1)$ "Mortality of sons" : the sector level mean of boys died/boys born for women aged 50 to 90 in 2002
- $(EM2)$ "Mortality of daughters" : the sector level mean of girls died/girls born for women aged 50 to 90 in 2002
- $(EM3)$ "Widowhood" : the proportion of widows among women aged 40 to 70 in 2002
- $(EM4)$ "Double orphanhood" : the proportion of double orphans among children aged 8 to 28 in 2002
- $(EM5)$ "Disability" : the proportion of the 2002 population reporting a handicap due to war or genocide

The age categories for the excess mortality proxies $(EM1)-(EM4)$[13] are chosen in order to capture as much as possible excess mortality in the period 1990-1998, in which violence was concentrated, while reducing the effect of excess mortality after 1998, the official end of civil war in Rwanda (Gleditsch et al. (2002)).

For example, in $(EM1)-(EM2)$, we set the lower bound to 50, in order to reduce the effect of child mortality after 1998. The upper bound, 90, is chosen to reduce the effect of mortality due to old age after 1998. With respect to widowhood, $(EM3)$, we exclude women that were younger than 40 in 2002 because they are less likely to have been married in 1990-1998 or more likely to have remarried upon widowhood. We don't consider widowers because the large majority of them remarries upon widowhood. The upper age limit is set at 70 to avoid picking up a large number of deaths due to old age. The age limits of orphanhood, $(EM4)$, are set at 8 and 28, because, on the one hand, we want to exclude children not yet born in 1994 as well as children whose parents are likely to have died from old age.

### 4.2 Filtering out peacetime variation in excess mortality

Although we have taken care of choosing age groups that maximize the wartime component of $(EM1)-(EM4)$, it is not excluded that these excess mortality proxies pick up sector level variation in life expectancy caused by factors other than the intensity of violence, i.e. time-invariant sector level characteristics (e.g. climate) as well as time-variant peacetime characteristics (e.g. state of the health infrastructure).

More formally, the variation in $EM_i$ $(i = 1-4)$ across sectors $j$ $(j = 1-1484)$ is not only explained by direct and indirect wartime effects of violence, $V_j$ , but also by peacetime sector level characteristics, $P_j$.

$EM_{ij} = \alpha_i + \beta_i V_j + \gamma_i P_j$

We aim to capture only the variation due to $V_j$. Therefore, we define a set of four peacetime post-conflict mortality proxies $(EM1')-(EM4')$ from the 2002 population census

[13] For measure $(EM5)$ we don't need to set age limits since the cause of the handicap was reported in the census.

that are determined by $P_j$, but not by $V_j$ (for summary statistics, see Table 1). For example, orphanhood of children who were unborn in 1998 is related to $P_j$, but − after controlling for $P_j$−, not to $V_j$.

- ($EM1^{'}$) "2001/2002 Infant mortality": mortality of children born during the 12 months prior to the 2002 population census
- ($EM2'$) "Paternal orphanhood after 1998" : the proportion of children aged 0 to 4 in 2002 whose father died but whose mother is still alive
- ($EM3^{'}$) "Maternal orphanhood after 1998" : the proportion of children aged 0 to 4 in 2002 whose mother died but whose mother is still alive
- ($EM4^{'}$) "Double orphanhood after 1998": the proportion of children aged 0 to 4 in 2002 bereaved of both father and mother

We filter out the effect of $P_j$ on $EM_{ij}$, by regressing $EM_{ij}$ on the vector $(EM1')-(EM4')$ and retain the unexplained part as our wartime excess mortality proxies, $EM^*_i{}_j$, summarized in Table 1.

### 4.3 Aggregation of excess mortality proxies into a sector level excess mortality index (EMI)

The challenge we face is to aggregate the information embodied in the five wartime excess mortality proxies ($EM1^* - EM4^*, EM5$) into a meaningful index of excess mortality. To overcome arbitrariness and safeguard maximum variation, several studies have persuasively argued for the use of principal component analysis (PCA) (Hibbs (1973), Filmer & Pritchett (2001), Alesina & Perotti (1996)). 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. Consequently, besides providing a non-arbitrary weighting for aggregation, the advantage of using PCA is that sectors for which the excess mortality proxies are highly correlated receive the highest weight, which reduces the effect of measurement error and outliers in each of the proxies separately.

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[14]. For our objective, i.e. defining an index

[14]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 $\alpha_{11}, a_{12}, ..., \alpha_{1p}$ and $\prime$ denotes transpose.
$PC1 = \alpha_1' x^* = \alpha_{11} x_1^* + \alpha_{12} x_2^* + ... + \alpha_{1p} x_p^*$,
Mathematically, the vector $\alpha_1$ maximizes $var[\alpha_1' x^*] = \alpha_1' \Sigma \alpha_1$, with $\Sigma$ the covariance matrix of $x^*$,which corresponds to the correlation matrix of the vector $x$ of the original, unstandardized variables. For the purpose

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 $(EM1^* - EM4^*, EM5)$ to PCA results in the following first PC: $EMI = 0.51 \times EM1^* + 0.45 \times EM2^* + 0.48 \times EM3^* + 0.46 \times EM4^* + 0.31 \times EM5$. This first PC explains upt to 50% of the total variation in $(EM1^* - EM4^*, EM5)$. In addition, given that it has positive loadings on all excess mortality proxies, it can be interpreted as an "excess mortality index". Figure 1 gives its kernel density distribution.

# 5 The spatial distribution of wartime excess mortality: Illustration and discussion

## 5.1 Province level excess mortality

Table 2 lists the province level average of the excess mortality proxies $EM_{ij}$ and $EM^*_{i\,j}$ as well as the excess mortality index $EMI$. The provinces Butare and Kibungo have the largest value for the excess mortality index, followed by Kigali City and Gisenyi. Gitarama and Cyangugu score lowest, followed by Gikongoro and Kibuye.

Table 3 compares the ranking of provinces according to the excess mortality index with the ranking of provinces according the estimate of the number of killings by Davenport & Stam (2009). In both cases, Butare, which was the scene of the most extensive ethnic cleansing in 1994, is ranked highest. However, Gisenyi, Byumba, Kigali City and Ruhengeri are ranked markedly higher according to the excess mortality index, while the reverse is true for Gitarama and Kibuye.

How do these deviations relate to the location of different forms of violence? The last three columns of Table 3 give a qualitative assessment of the impact of genocide, civil war and (counter-)insurgency on population decline for each province. This information is taken from a study by Justino & Verwimp (2006) who base their assessment on event data. We find a clear pattern in the deviations between both rankings: in general, provinces affected by genocide move downward in the excess mortality index compared to the findings of Davenport & Stam (2009), while provinces affected by civil war and (counter-)insurgency move upward.

This finding may indicate that the estimates of Davenport & Stam (2009) of killings under the jurisdiction of the RPF or in battle zones between the RPF and the FAR+ are at the lower end, probably because they are based on data sources that mainly focus on

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 $\Sigma$ corresponding to the largest eigenvalue of $\Sigma$, $\lambda_1$ and $var[\alpha_1'x^*] = \alpha_1'\Sigma\alpha_1 = \lambda_1$.

To interpret the PC in terms of the original variables, each coefficient $\alpha_{1l}$ 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 $\alpha_{1l}/s_l$.

For a detailed exposition of principal component analysis we refer to Jolliffe (2002) and Dunteman (2001).

1994 ethnic violence. Alternatively, this finding may result from a high indirect death toll of violence in provinces with fierce encounters between the RPF and the FAR+, either because these encounters resulted in destruction of vital infrastructure, either because, in contrast to the ethnic cleansing campaign, civil war and (counter-)insurgency were more spread out in time.

### 5.2 Quantile maps, global clustering and local clusters

The province level averages may hide important differences within provincial borders. Map 1 plots quintiles of $EMI$. We observe a large number of top quintile sectors in Butare, in and around Kigali City, as well as in the northwestern corner of Kibungo and Gisenyi. In addition, we find smaller local clusters in the West of Kibuye and Cyangugu, on a North-South axis through Ruhengeri, and in the southeastern corner of Gitarama and Gikongoro.

The significance of local clusters can be assessed by means of Local Indicators of Spatial Association (LISA). LISA analysis allows us to identify 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 from this analysis (Anselin (1995))[15].

Map 2 depicts the locations with significant high-high (dark grey) and significant low-low clusters (light grey), using a first order rook-contiguity based weighting matrix for neighbors[16]. We note a very large low-low cluster that covers large parts of northern Cyangugu, northern Gikongoro, southern Kibuye, northwestern Gitarama and northern Rural Kigali. Possible explanations of this low-low cluster include (1) the French intervention, "Opération Turquoise", to set up a "safe zone" in the triangle Gikongoro-Cyangugu-Kibuye, (2) the lower popular participation in the genocide and less severe RPF-FAR+ encounters in Gitarama [17], as well as (3) the skewed concentration of Tutsi, even within provinces where they accounted for a relatively high average proportion of the population [18].

The significant high-high clusters confirm the pattern detected from Table 3 and Map 1: Butare, Kigali City, Kibungo and Gisenyi stand out, while smaller high-high clusters can be found in parts of Kibuye, Ruhengeri, Gikongoro and Rural Kigali.

[15] The procedures employed to assess statistical significance consists 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 95h percentile it is said that the relation found is significant at 5%.

[16] According to the first order rook-contiguity criterium, sectors are neighbors when they share a border. Significance is defined at p = 0.05.

[17] With respect to Gitarama, Justino & Verwimp (2006) argue that "The unfolding of the genocide in the province of Gitarama in Central Rwanda was different from other provinces. More Tutsi were saved in Gitarama compared to other provinces, for historical reasons, such as intermarriage, but also because of the resistance of Hutu and Tutsi at several locations in the province (Des Forges, 1999). Gitarama was the scene of fighting between enemy armies, but fighting was not as fierce as in the east. Killings of Tutsi and Hutu took a lot of casualties, but less compared to the south in the case of Tutsi, and less compared to the east in the case of Hutu."

[18] With respect to Gikongoro, Verpoorten (2005) provides evidence on the variation of the genocide's death toll within the province and demonstrates that differences in the proportion of Tusi played a role as well as differences in the attitude of local authorities (either cooperating or opposing the genocidal regime).

To complete the spatial analyisis, we note that the $EMI$ is characterized by rather high global clustering, i.e. the general trend is one of clustering. This is visualized by means of a Moran scatterplot, with $EMI$ on the x-axis versus the rook contiguity-based spatial lag of $EMI$ on the y-axis. The slope of the regression line corresponds to a rather high value for Moran's I, 0.58, indicating significant positive spatial autocorrelation (Moran (1950)).

# 6 Robustness checks

We perform several robustness tests to check the sensitivity of our results to alternative specifications of the $EMI$. First, we clean the excess mortality proxies $(EM1) - (EM4)$, denoted $EM_{ij}$, from variation in province level baseline excess mortality $(p = 1 - 12)$. To this end, we calculate the same proxies using province level information from the 1991 population census. Summary statistics for these baseline mortality proxies, referred to as $(EM1'') - (EM4'')$ or $EM''_{ip}$, as well as their first PC, are listed in columns 1-5 of Table 4. We subtract $EM''_{ip}$ from $EM_{ij}$, which should remove any differences stemming from province level pre-conflict peacetime characteristics as well as province level time invariant characteristics. Then we proceed as explained under 4.2 and 4.3.

Columns 3 and 4 of Table 5 give the resulting province level values and rankings for the adjusted excess mortality index. Compared to the base result for $EMI$, the order of the top-4 provinces is reversed, with Kigali City and Gisenyi now coming first, followed by Kibungo and Butare. This reversed order is due to lower 1991 excess mortality in the former two compared to the latter two.

Second, we derive a migration-adjusted $EMI$. Our baseline $EMI$ was calculated using 2002 sector of residence, which may differ considerably from wartime residence given the massive displacement and resettlement in the period 1990-2002. For example, within Kigali City and Umutara, approximately one third of the sector level 2002 population are newcomers since 1991 (see the last two columns of Table 4). The migration-adjusted $EMI$ is calculated using the 1991 sector of residence, which can be derived from 2002 information on the migrants' sector of origin.

Comparing column 1 with column 5 in Table 5, we find that, compared to the baseline $EMI$, the migration-adjusted excess mortality index is markedly higher for Kigali City and Umutara Province, indicating that excess mortality was higher among the 1991 residents of these provinces than among the newcomers. However, in terms of ranking, only Umutara is affected, climbing up two places.

A limitation of the migration-adjusted $EMI$ is that it can not adjust for cross-border emigration. Consequently, we cannot control for possible bias stemming from the combination of different mortality rates among cross-border emigrants and spatial heterogeneity of sectors of origin of cross-border emigrants.

Third, in order to attenuate the effect of survival bias, we increase the weight of sectors that are close to sites of large-scale massacres. Given that our approach is based on infor-

mation from the surviving population, mortality is under-reported. It is plausible to assume that this survival bias is higher in sites close to large-scale massacres because, in these sites, the probability that entire families were exterminated is likely to be higher. We can take the proximity to a large-scale massacre into account by adding the distance to the nearest massgrave to the set of variables subjected to PCA[19]. The massacre-adjusted $EMI$ is given by the following linear combination: $EMI_{(massacre-adjusted)} = 0.50 * EM1^* + 0.45 * EM2^* + 0.47 * EM3^* + 0.45 * EM4^* + 0.30 * EM5 - 0.18 * EM6$, with $EM6$ "distance to massgrave" (expressed in km, see column 7 of Table 4).

The resulting province level values and rankings for the massacre-adjusted $EMI$ are reported in columns 7 and 8 of Table 5. Note that the $EMI$ values increase for provinces that were characterized by the highest genocide intensity: Butare, Cyangugu, Gikongoro and Kibuye, i.e. the provinces that were denoted with the value "2" for genocide in Justino & Verwimp (2006) (see Table 3). For the latter three provinces, the ranking increases marginally.

Finally, since the exact delimitation of the age groups used in (A1)-(A4) is somewhat arbitrary, we perform a sensitivity analysis, with the age limits set 5 years lower/higher. The results remain qualitatively the same, in the sense that the rankings of provinces and the geographical positioning of high-high clusters do not change (these results are not reported).

# 7 Conclusion

During the nineties, Rwanda experienced a sequence of different interrelated forms of violence: civil war, genocide, reprisal killings and (counter-)insurgency. The 1994 genocide has by far received most non-scholarly and scholarly attention. The challenge taken in this study is to provide a more balanced view of the impact of all forms of violence, by studying the spatial distribution of excess mortality in Rwanda.

We develop a fine spatial measure for excess mortality in Rwanda relying mostly on information from the 2002 population census. In particular, we subject sector level mortality of sons and daughters, widowhood, orphanhood, and disability to principal component analysis. The first principal component provides us with an index of sector level excess mortality on a less to more scale. By selecting on age categories of respondents and filtering out variation explained by peacetime excess mortality proxies, this index captures mostly excess mortality in wartime (1990-1998).

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. These clusters may be explained by different events, since these areas were the scene of genocide, civil war as

[19] The distance to the nearest massgrave is calculated in km at the sector level by overlaying a geo-referenced administrative map with the location of 71 massgraves in Rwanda taken from the Yale Genocide Studies website.

well as reprisal killings.

The main contribution of this 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 Tusi among its population (2.9%). Instead, Gisenyi was the scene of fierce fighting between the RPA and remains of the FAR+ during the 1995-1998 (counter-)insurgency.

The detection of high excess mortality in Gisenyi is controversial, 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 focus attention on 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.

## Acknowledgments

I'm grateful to Geert Dhaene, Koen Decancq, Romain Houssa, Pieter Serneels and participants at the LICOS seminar for very helpful comments. I owe thanks to the Rwandan National Service of Gacaca Jurisdiction and the Rwandan National Census Service for making available the data used in this study. All errors and opinions expressed remain my own.

Government of Rwanda

## References


Akresh, R., Verwimp, P. & Bundervoet, T. (2007), Civil war, crop failure, and child stunting in rwanda, Policy Research Working Paper Series 4208, The World Bank.

Alesina, A. & Perotti, R. (1996), 'Income distribution, political instability, and investment', *European Economic Review* **40**(6), 1203–1228.

Amnesty International, . (1997*a*), "rwanda: Civilians trapped in armed conflict", Technical Report AI Index AFR 47/43/97, Research Department.

Amnesty International, . (1997*b*), "rwanda: Ending the silence", Technical Report AI Index AFR 47/32/97, Research Department.

Amnesty International, . (1998), The hidden violence: "disappearances" and killings continue ", Technical Report AFR 47/023/1998, Research Department.

André, C. & Platteau, J.-P. (1998), 'Land relations under unbearable stress: Rwanda caught in the malthusian trap', *Journal of Economic Behavior and Organization* **34**(1), 1 – 47.

Anselin, L. (1995), 'Local indicators of spatial association Ű lisa', *Geographical Analysis* **27**, 93–115.

Baines, E. (2003), 'Body politics and the rwandan crisis', *Third World Quarterly* **24**(3), 479–493.

Cramer, C. (2007), *Violence in developing countries: war, memory, progress.*, Bloomington: Indiana University Press.

Davenport, C. & Stam, A. (2009), Rwandan political violence in space and time, Technical report, mimeo.

de Walque, D. & Verwimp, P. (2009), The demographic and socio-economic distribution of excess mortality during the 1994 genocide in rwanda, Policy Research Working Paper Series 4850, The World Bank.

Des Forges, A. (1999), *Leave None to Tell the Story: Genocide in Rwanda*, New York: Human Rights Watch.

Dunteman, G. H. (2001), *Prinicpal Components Analysis*, Sage university papers, Quantitative applictions in the social sciences, Sage.

Fearon, J. & Laitin, D. (2003), 'Ethnicity, insurgency, and civil war', *American Political Science Review* **97**(1), 75–90.

Filmer, D. & Pritchett, L. H. (2001), 'Estimating wealth effects without expenditure data–or tears: An application to educational enrollments in states of india.', *Demography* **38**(1), 115 – 132.

Gleditsch, N. P., Wallensteen, P., Eriksson, M., Sollenberg, M. & Strand, H. (2002), 'Armed conflict 1946–2001: A new dataset', *Journal of Peace Research* **39**(5), 651–637.

Government of Rwanda, . (2008), Recencement des rescapés du génocide de 1994: rapport final, Technical report, Service National de Recensement.

Harbom, L. & Wallensteen, P. (2007), 'Armed conflict, 1989–2006', *Journal of Peace Research* **44**(5), 623–634.

Hibbs, D. (1973), *Mass Political Violence: A Cross-national Causal Analysis*, John Wiley & Sons.

Ingelaere, B. (2007), *L'Afrique des Grands Lacs: annuaire 2006/2007*, L'Harmattan, chapter A la recherche de la vérité dans les juridictions Gacaca au Rwanda.

Jolliffe, I. (2002), *Principal Component Analysis*, number XXIX *in* 'Springer Series in Statistics', 2nd edn, Springer, NY.

Justino, P. & Verwimp, P. (2006), Poverty dynamics, violent conflict and convergence in rwanda, HiCN Working Papers 16, Households in Conflict Network.

Mamdani, M. (2001), *When Victims Become Killers*, Princeton University Press, Princeton.

Montalvo, J. G. & Reynal-Querol., M. (2007), 'Fighting against malaria: Prevent wars while waiting for the "miraculous" vaccine."', *The Review of Economics and Statistics* **89**(1), 165–177.

Moran, P. (1950), 'Notes on continuous stochastic phenomena', *Biometrika* **37**, 17–33.

Newbury, D. (1998), 'Understanding genocide', *African Studies Review* **41**(1), 73–97.

Pitsch, A. (2002), The gacaca law of rwanda: Possibilities and problems in adjudicating genocide suspects, Technical report, Working Paper NUR-UMD Partnership.

Prunier, G. (1998), *The Rwanda Crisis: History of a Genocide.*, London: Hurst & Company.

Reyntjens, F. (2009), *The great African war: Congo and regional geopolitics, 1996-2006*, New York, N.Y.: Cambridge University Press.

Roberts, L., Ngoy, P., Mulumba, F. & authors ., C. (2007), Mortality in the democratic republic of congo: An ongoing crisis, Technical report, New York: International Rescue Committee.

Straus, S. (2004), 'How many perpetrators were there in the rwandan genocide? an estimate', *Journal of Genocide Research* **6**(1), 85–98.

Straus, S. (forthcoming), Origins and aftermaths: The dynamics of genocide in rwanda and their post-crime implications, Technical report, Simon Chesterman, Béatrice Pouligny, and Albrecht Schnabel, eds., Mass Crimes and Post-Conflict Peace-Building (Tokyo: United Nations University Press).

Verpoorten, M. (2005), 'The death toll of the rwandan genocide: a detailed analysis for gikongoro province', *Population* **60**(4), 331–368.

Verpoorten, M. & Berlage, L. (2007), 'Economic mobility in rural rwanda: A study of the effects of war and genocide at the household level', *Journal of African Economies* **16**(3), 349–392.

Verwimp, P. (2005), 'An economic profile of peasant perpetrators of genocide: Micro-level evidence from rwanda', *Journal of Development Economics* **77**(2), 297 – 323.

Wolters, S. (2005), The gacaca process: Eradicating the culture of impunity in rwanda, Situation report, Institute for Security Studies.

**Table 1: Sector level excess mortality proxies (8.1 million individuals, 1547 administrative sectors)**

| Variable | Description | Mean | St. Dev. |
|---|---|---|---|
| **(A) Excess mortality proxies from the 2002 population census (for 1547 sectors)** | | | |
| (EM1) Mortality of sons | Mean of boys died/boys born for women aged 50 to 90 in 2002 | 0.430 | 0.060 |
| (EM2) Mortality of daughters | Mean of girls died/girls born for women aged 50 to 90 in 2002 | 0.357 | 0.053 |
| (EM3) Widowhood | Widows among women aged 40 to 70 in 2002 (%) | 0.365 | 0.084 |
| (EM4) Double orphanhood | Double orphans among children aged 8 to 28 in 2002 (%) | 0.077 | 0.032 |
| (EM5) Disability | Disabled due to war or genocide (%) | 0.004 | 0.004 |
| **(B) Peacetime (1998-2002) excess mortality proxies from the 2002 population census (for 1547 sectors)** | | | |
| (EM1') Infant mortality 2001/2002 | Infants died among infants born during August 2001 - August 2002 (%) | 0.075 | 0.033 |
| (EM2') Paternal orphanhood after 1998 | Children aged 0 to 4 in 2002 whose father died but whose mother is still alive (%) | 0.099 | 0.030 |
| (EM3') Maternal orphanhood after 1998 | Children aged 0 to 4 in 2002 whose mother died but whose father is still alive (%) | 0.017 | 0.007 |
| (EM4') Double orphanhood after 1998 | Double orphans among children aged 0 to 4 in 2002 (%) | 0.006 | 0.003 |
| **(C) Unexplained part of EM1-EM4 from a regression of EM1-EM4 on [EM1'- EM4']** | | | |
| (EM1*) Mortality of sons | We run seperate regressions of the mortality proxies EM1, EM2, EM3 and EM4 on the vector of peacetime excess mortality proxies, [EM1', EM2', EM3', EM4'] and retain the sum of the constant and the error term as the wartime excess mortality proxies EM1*, EM2*, EM3*, and EM4*. | 0.356 | 0.056 |
| (EM2*) Mortality of daughters | | 0.319 | 0.052 |
| (EM3*) Widowhood | | 0.249 | 0.077 |
| (EM4*) Double orphanhood | | 0.029 | 0.028 |

Source: 2002 population census (Government of Rwanda (2002))

**Table 2: Province level averages of EM, EM* and EMI**

| Province | EM1 | EM2 | EM3 | EM4 | EM5 | EM1* | EM2* | EM3* | EM4* | EMI |
|---|---|---|---|---|---|---|---|---|---|---|
| Butare | 0.47 | 0.39 | 0.43 | 0.09 | 0.004 | 0.39 | 0.35 | 0.31 | 0.04 | 1.15 |
| Kibungo | 0.45 | 0.38 | 0.41 | 0.09 | 0.004 | 0.38 | 0.34 | 0.29 | 0.05 | 1.04 |
| Kigali City | 0.42 | 0.33 | 0.42 | 0.13 | 0.007 | 0.34 | 0.30 | 0.29 | 0.07 | 0.87 |
| Gisenyi | 0.46 | 0.38 | 0.40 | 0.10 | 0.005 | 0.38 | 0.34 | 0.27 | 0.05 | 0.87 |
| Rural Kigali | 0.42 | 0.34 | 0.37 | 0.08 | 0.005 | 0.34 | 0.31 | 0.25 | 0.03 | -0.05 |
| Ruhengeri | 0.45 | 0.36 | 0.36 | 0.07 | 0.004 | 0.37 | 0.32 | 0.23 | 0.02 | -0.12 |
| Byumba | 0.42 | 0.35 | 0.33 | 0.06 | 0.002 | 0.36 | 0.32 | 0.24 | 0.02 | -0.25 |
| Umutara | 0.39 | 0.32 | 0.37 | 0.07 | 0.005 | 0.33 | 0.29 | 0.27 | 0.03 | -0.32 |
| Kibuye | 0.43 | 0.35 | 0.32 | 0.07 | 0.005 | 0.35 | 0.32 | 0.20 | 0.02 | -0.51 |
| Gikongoro | 0.42 | 0.36 | 0.30 | 0.06 | 0.003 | 0.35 | 0.33 | 0.20 | 0.01 | -0.67 |
| Cyangugu | 0.40 | 0.34 | 0.31 | 0.05 | 0.003 | 0.34 | 0.31 | 0.21 | 0.01 | -0.75 |
| Gitarama | 0.39 | 0.31 | 0.35 | 0.07 | 0.003 | 0.31 | 0.27 | 0.22 | 0.02 | -1.27 |
| Total | 0.43 | 0.36 | 0.37 | 0.08 | 0.004 | 0.36 | 0.32 | 0.25 | 0.03 | 0.00 |

Notes: For definitions of EM and EM* see Table 1, EMI is the first prinicpal component of (EM1*-EM4*, EM5)

**Table 3: EMI, the estimated 1994 death toll by Davenport and Stam (2009) and the qualitative assessment of the intensity of genocide, civil war and (counter-)insurgency by Justino and Verwimp (2006)**

| | EMI (first PC of excess mortality proxies EM1*-EM4*, EM5) | | 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)) | | |
|---|---|---|---|---|---|---|---|---|
| Province | Values | Ranking (1) | Values | Ranking (2) | | Genocide | Civil war | Counter-insurgency |
| Butare | 1.15 | 12 | 0.50 | 12 | 0 | 2 | 0 | 0 |
| Kibungo | 1.04 | 11 | 0.18 | 9 | 2 | 1 | 1 | 0 |
| Kigali City | 0.87 | 10 | 0.04 | 5 | **5** | NA | NA | NA |
| Gisenyi | 0.87 | 9 | 0.02 | 3 | **6** | 0 | 0 | 1 |
| Rural Kigali | -0.05 | 8 | 0.22 | 10 | -2 | 1 | 1 | 0 |
| Ruhengeri | -0.12 | 7 | 0.01 | 2 | **5** | 0 | 1 | 1 |
| Byumba | -0.25 | 6 | 0.00 | 1 | **5** | 0 | 1 | 0 |
| Umutara | -0.32 | 5 | 0.08 | 7 | -2 | NA | NA | NA |
| Kibuye | -0.51 | 4 | 0.34 | 11 | **-7** | 2 | 0 | 0 |
| Gikongoro | -0.67 | 3 | 0.05 | 6 | -3 | 2 | 0 | 0 |
| Cyangugu | -0.75 | 2 | 0.02 | 4 | -2 | 2 | 0 | 0 |
| Gitarama | -1.27 | 1 | 0.09 | 8 | **-7** | 1 | 0 | 0 |

Notes: For details on de derivation of EMI, see tables 1 and 2; Davenport and Stam (2009) apply a Bayesian latent variable model to data on 1994 casulaties (see Section 3 for details); Justino and Verwimp (2006) use event data for their qualitative assessment of the location of genocide, civil war and (counter-)insurgency, defined respectively as ethnic cleansing of Tutsi in 1994, invasion and early advancement of RPF in 1990-1994, and post-1994 fighting between the RPA and the remains of the FAR+. Justino and Verwimp (2006) provide no seperate assessment for Kigali City and Umutara Province, a province which was created only after 1994 by joining parts of Kibungo and Byumba.

**Table 4: Province level baseline excess mortality, (distance to) massgraves and migration**

| | Sector level excess mortality proxies from the 1991 population census (1) | | | | First PCA of (EM1''-EM4'') | Number of massgraves in a province (2) | Distance from a sector to the nearest mass-grave (3) | Sector level immigrants between 1990-2002 (4) | Sector level emigrants between 1990-2002 (4) |
|---|---|---|---|---|---|---|---|---|---|
| | EM1'' | EM2'' | EM3'' | EM4'' | EMI'' | | | | |
| Province | Mean | Mean | Mean | Mean | Mean | Sum | Mean | Mean | Mean |
| Butare | 0.35 | 0.33 | 0.30 | 0.04 | 2.31 | 15 | 6 | 0.08 | 0.08 |
| Kibungo | 0.35 | 0.32 | 0.24 | 0.03 | 0.49 | 14 | 9 | 0.17 | 0.09 |
| Kigali City | 0.30 | 0.28 | 0.20 | 0.04 | -2.90 | 7 | 3 | 0.32 | 0.14 |
| Gisenyi | 0.35 | 0.33 | 0.19 | 0.02 | -0.44 | 3 | 10 | 0.07 | 0.06 |
| Rural Kigali | 0.34 | 0.31 | 0.23 | 0.02 | -0.67 | 3 | 12 | 0.10 | 0.10 |
| Ruhengeri | 0.35 | 0.32 | 0.21 | 0.02 | -0.41 | 2 | 14 | 0.03 | 0.06 |
| Byumba | 0.35 | 0.32 | 0.22 | 0.02 | 0.15 | 0 | 25 | 0.05 | 0.08 |
| Umutara | 0.35 | 0.32 | 0.23 | 0.03 | 0.32 | 1 | 38 | 0.33 | 0.09 |
| Kibuye | 0.33 | 0.32 | 0.21 | 0.02 | -1.07 | 9 | 7 | 0.04 | 0.06 |
| Gikongoro | 0.36 | 0.32 | 0.23 | 0.03 | 0.46 | 7 | 8 | 0.05 | 0.09 |
| Cyangugu | 0.37 | 0.34 | 0.29 | 0.03 | 2.23 | 4 | 8 | 0.04 | 0.06 |
| Gitarama | 0.30 | 0.29 | 0.23 | 0.02 | -2.72 | 6 | 10 | 0.05 | 0.08 |
| Total | 0.34 | 0.32 | 0.24 | 0.03 | 0.00 | 71 | 12 | 0.09 | 0.08 |

Notes: (1) Own calculations based on the 1991 population census; for definitions of EM1-EM4, see Table 1; , (2) Yale genocide studies, (3) Own calculations by overlaying a geo-referenced administrative map with the location massgraves; (4) Own calculations based on the 1991 and 2002 population census

**Table 5: Robustness checks**

| | EMI | | EMI adjusted for 1991 province level baseline excess mortality | | EMI adjusted for 1991-2002 sector level migration | | EMI adjusted for sector level distance to nearest massgrave | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Values | Ranking | Values | Ranking | Values | Ranking | Values | Ranking |
| Butare | 1.15 | 12 | 0.41 | 9 | 1.14 | 12 | 1.23 | 12 |
| Kibungo | 1.04 | 11 | 0.94 | 10 | 1.09 | 11 | 1.08 | 11 |
| Kigali City | 0.87 | 10 | 1.66 | 12 | 1.04 | 10 | 1.00 | 10 |
| Gisenyi | 0.87 | 9 | 1.07 | 11 | 0.87 | 9 | 0.89 | 9 |
| Rural Kigali | -0.05 | 8 | 0.15 | 8 | -0.07 | 8 | -0.05 | 8 |
| Ruhengeri | -0.12 | 7 | 0.01 | 7 | -0.21 | 6 | -0.15 | 7 |
| Byumba | -0.25 | 6 | -0.21 | 5 | -0.31 | 5 | -0.46 | 5 |
| Umutara | -0.32 | 5 | -0.36 | 4 | -0.01 | 7 | -0.74 | 2 |
| Kibuye | -0.51 | 4 | -0.18 | 6 | -0.55 | 4 | -0.42 | 6 |
| Gikongoro | -0.67 | 3 | -0.79 | 2 | -0.63 | 3 | -0.59 | 4 |
| Cyangugu | -0.75 | 2 | -1.40 | 1 | -0.80 | 2 | -0.68 | 3 |
| Gitarama | -1.27 | 1 | -0.59 | 3 | -1.31 | 1 | -1.22 | 1 |

Notes: For a definition of EMI, see Tables 1 and 2; for details on baseline excess mortality, migration and the location of massgraves, see Table 4

**Figure 1: kernel density of excess mortality index (EMI)**

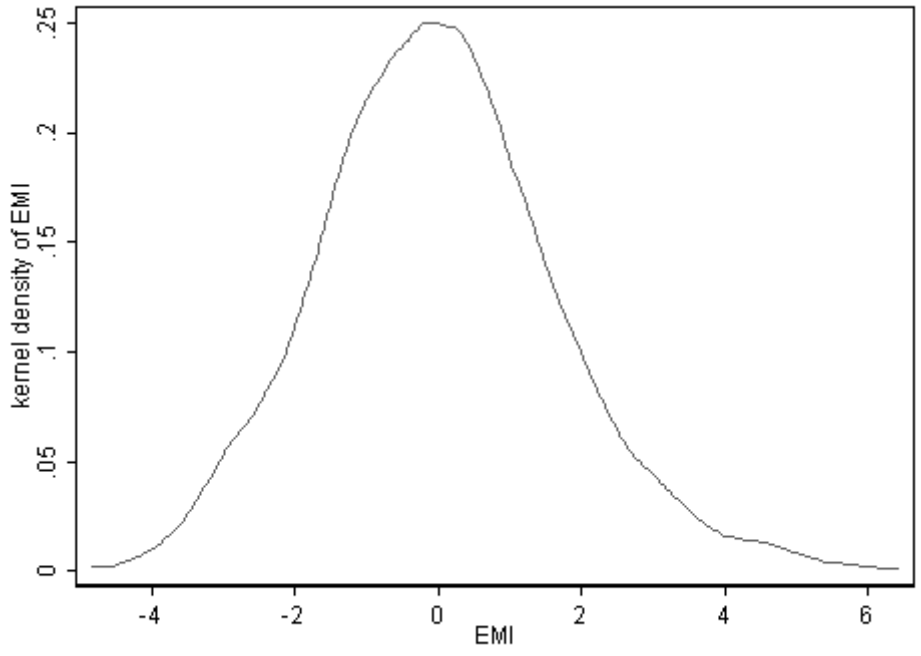
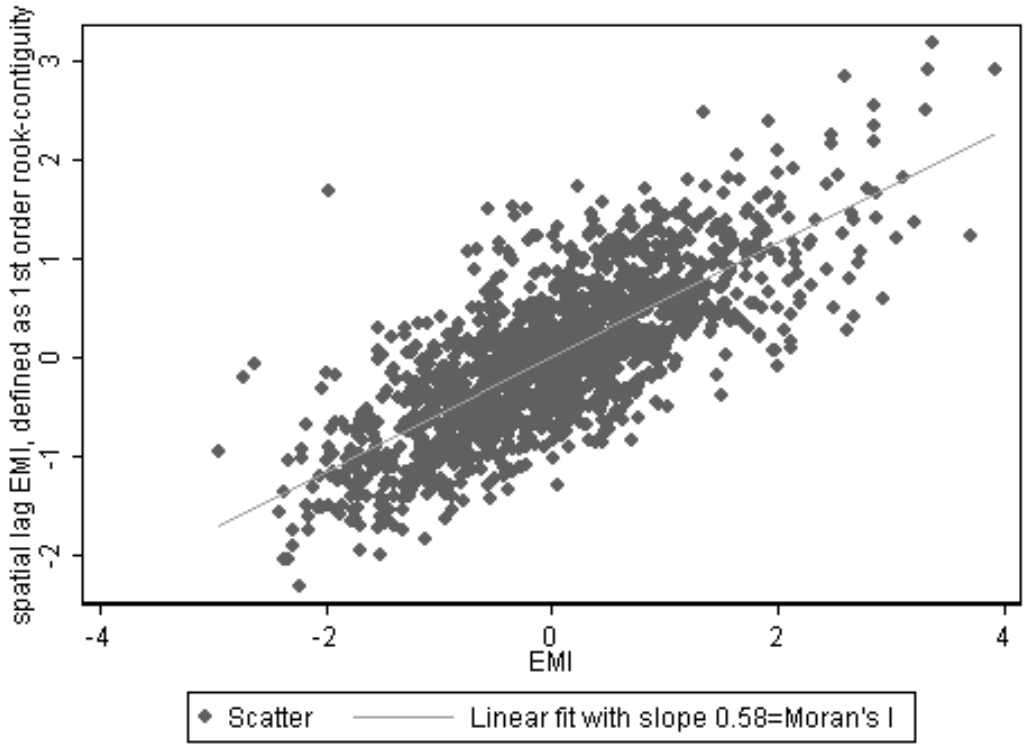
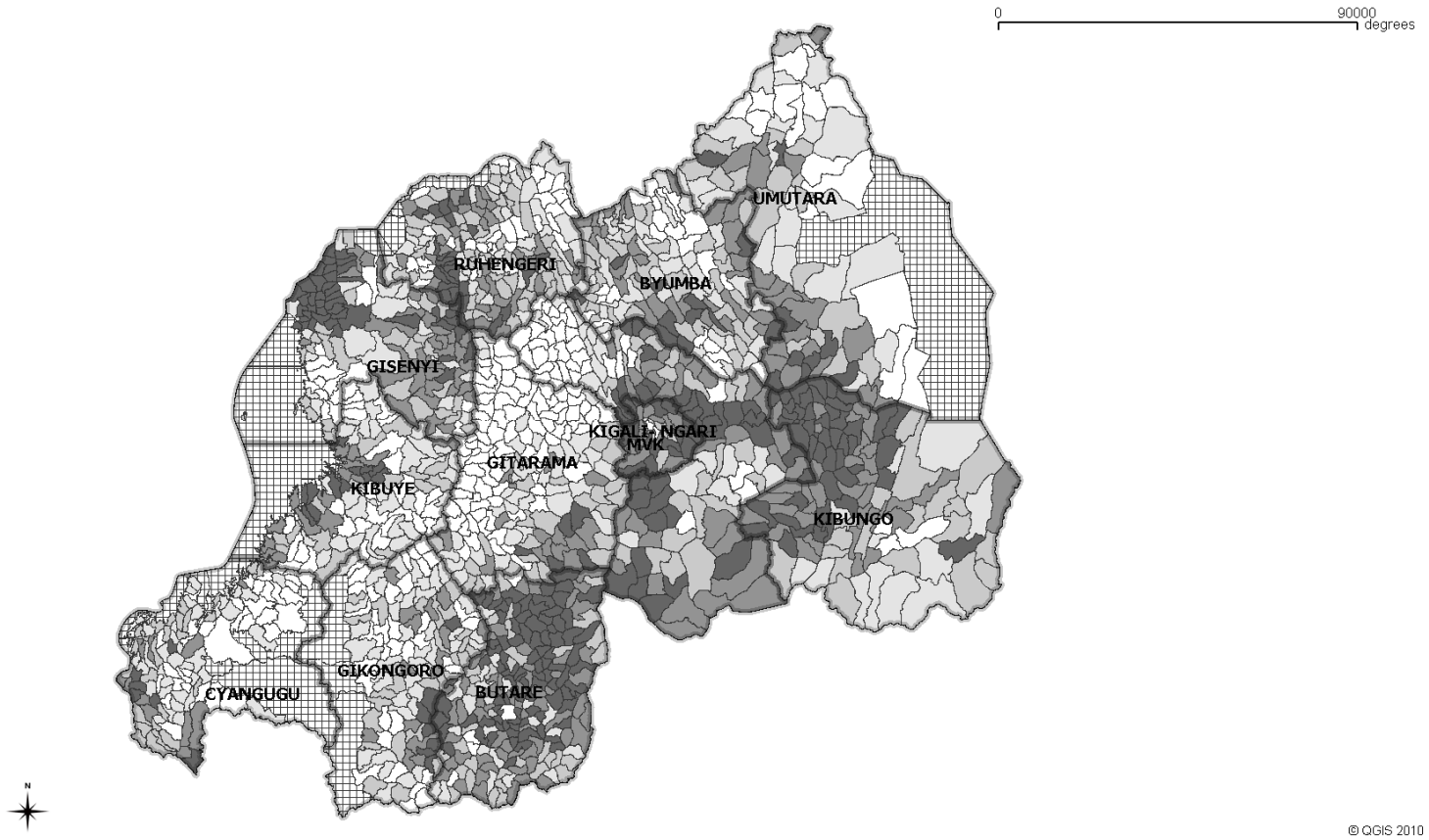



**Figure 2: Moran's I of EMI**



**Map 1: Quintiles of EMI (top quintiles are in darkest grey)**




**Map 2: Significant high-high (dark grey) and low-low clusters (light grey) of EMI**