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Leave None to Claim the Land
A Malthusian Catastrophe in Rwanda?

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A Malthusian Catastrophe in Rwanda?*

Marijke Verpoorten†‡

August 2011

Abstract

More than 200 years after its first publication, the Malthusian thesis is still much debated, albeit in a modified form. Rather than predicting a global catastrophe, most neo-Malthusians stress the local character of the relationship between population pressure, natural resource scarcity, and conflict as well as its dependency on the socio-political and economic context. This softened version of Malthus' thesis has received little empirical support in cross-country studies. In contrast, a number of sub-national analyses have provided some evidence for local conditional Malthusian catastrophes, although "catastrophe" is a big word since these studies have largely focused on low-intensity violence. This article adds to the small body of sub-national studies, but focuses on a high-intensity conflict, the Rwandan genocide. In particular, it provides a meso-level analysis of the relation between population pressure and the intensity of violence measured by the death toll among the Tutsi across 1,294 small administrative units. The results indicate that the death toll was significantly higher in localities with both high population density and little opportunity for young men to acquire land. On the one hand, this finding can be interpreted as support for the neo-Malthusian thesis. On the other hand, it is possible that another mechanism played, i.e. in

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densely populated areas it may have been relatively easy for the elite to mobilize the population, because of dependency relations through the land and labor market. Alternatively, in densely populated areas, there may have been more lootable assets, and the violence may have been opportunistic rather than driven by need or by fear.

Introduction

"The power of population is so superior to the power of the earth to produce subsistence for man that premature death must in some shape or other visit the human race. The vices of mankind are active and able ministers of depopulation. They are the precursors in the great army of destruction, and often finish the dreadful work..." (Malthus, 1798: 13). The idea of Thomas Malthus that population is checked by famine, disease, or war in order to keep the per capita food production above the subsistence level was hugely influential and controversial even at the time of its first publication, receiving praise from John Stuart Mill and fierce criticism from David Ricardo, Karl Marx, and Friedrich Engels. By the end of the 19^{th} century, when the Industrial Revolution and the transformation of agriculture that it had brought about allowed rapid population growth to go hand-in-hand with increases in food production per capita, the facts seemed to prove Malthus wrong and, for a while, he was perceived by many as a failed prophet of doom. However, for at least two reasons, Malthus's "Essay on the Principle of Population" continues to fuel scholarly debate today.

First, the industrial revolution was largely based on cheap, readily available energy contained in coal and later in other fossil fuels. As these non-renewable resources are shrinking, the question emerges as to how the current food-production system can continue to satisfy growing demand. Moreover, the burning of fossil fuels has raised environmental concerns, with climate scientists warning of global warming and its adverse effects on food production. Joined with other forms of environmental degradation and the population explosion in the Third World, these observations have led to renewed claims about the end of prosperity by a number of Neo-Malthusians, who predict that rapid population growth in combination with environmental degradation will lead to widespread hunger and armed conflict (e.g., Ehrlich, 1969; Kaplan, 1994). Much as in the case of Malthus, this doomsday scenario is heavily criticized, most prominently by the "resource optimists" or "cornucopians", who argue that resource scarcity is largely exaggerated and that, if it occurs, scarcity can be dealt with by market pricing and innovation (Simon, 1981; Lomborg, 2001; Matthew, 2002).

Second, although the industrial revolution unleashed the greatest increase in food pro-

duction ever seen, enabling the population to increase sevenfold since Malthus's day, hunger, famine, and malnutrition are with us still. This observation has fed the idea that, rather than a global Malthusian catastrophe, the world may experience local catastrophes if local market and non-market institutions fail to enable households to meet their subsistence requirements and cannot resolve the tensions that may stem from this failure. The most well-known proponent of this idea is Thomas Homer-Dixon, who qualifies the impact of scarcity on conflict by stressing its conditionality on the form of resource scarcity and the context in which it occurs: the developing versus the developed world, the level of ethnic or religious fractionalization in society, and the absence of institutions that provide a peaceful alternative for resolving the scarcity problem (Homer-Dixon, 1999).

Many efforts have been made to test this more moderate Neo-Malthusian view empirically. Most of these efforts have relied on cross-country analysis and explained the onset or incidence of armed conflict in terms of country-level measures of population density, population growth, deforestation, soil degradation, and water scarcity (e.g., Collier & Hoeffler, 1998; Urdal, 2005; Theisen, 2008). Overall, these studies have provided very little evidence in support of a causal relationship between a decline in resource quantity or quality and violent conflict, even when including low-intensity conflicts in the sample (using a threshold of 25 battle-related deaths per year instead of the more conventional 1,000). The latter is done to account for the Neo-Malthusian view that resource scarcity leads to low- rather than high-intensity internal conflicts (Homer-Dixon, 1999). A recent study by Esteban, Morelli & Rohner (2010) looks at the other extreme by focusing on mass killings using a minimum threshold of 50,000 fatalities. Analyzing country and ethnic-group-level panel data (1960-2007), the authors do find that, ceteris paribus, high population density is a significant predictor of mass killings.

The scarce empirical evidence for the neo-Malthusian hypothesis in large-N studies may be partly due to the inability of such studies to account fully for the local nature and conditionality of the tension between resource supply and demand. For example, national figures may hide local scarcities, and unobserved country characteristics can bias the results, e.g., good institutions may foster both peace and population growth. Hence, scholars have started to focus on local-level analyses. Pioneering work by Thomas Homer-Dixon has taken the case-study approach in studying Pakistan, Mexico, Gaza, Rwanda, and South Africa. Overall the conclusion on the basis of the case studies is that "environmental scarcity causes violent conflict" (Homer-Dixon, 1994:39). However, the case-study approach has been strongly criticized for sample selection bias and its inability to determine causal relations (Gleditsch, 1998; Gleditsch & Urdal, 2002).

This criticism has triggered more rigorous quantitative analyses. First, using geo-referenced time-series data, Raleigh & Urdal (2007) examine the relationship between resource scarcity and conflict at the level of geographical squares of 100 km×100 km and find that population growth and density are associated with increased risk of conflict, although the effects of land degradation and water scarcity are inconclusive. Second, Urdal (2008), looking at the variation of low-intensity conflict across 27 Indian states in the period from 1956 to 2002, finds a positive link between resource scarcity and conflict. Third, analyzing data for 25 Indonesian provinces for the period from 1990 to 2003, Østby et al. (2011) find that the risk of low-intensity conflict is higher in provinces where both population growth and inequality are high, while each of these factors is not significant in isolation. Finally, Bundervoet (2009) finds that communal land pressure significantly increased the probability of being killed in the 1993 wave of violence in Burundi, a country that is similar to Rwanda in a number of relevant characteristics, not the least rapid population growth and extreme land scarcity.

The present article adds to this small body of sub-national empirical studies by analyzing the relationship between population pressure and mass killings in the Rwandan genocide at the level of 1,294 small administrative units. It is similar to Bundervoet (2009) in its focus on mass killings in one single year rather than low-intensity conflict over a number of years. In addition, instead of explaining the onset or incidence of violence as in Raleigh & Urdal (2007), Urdal (2008) and Østby et al. (2011), it explains the variation in the intensity of violence, measured by the proportion of Tutsi killed across administrative units. The following section reviews the literature on the role of population pressure and land scarcity in the Rwandan genocide. Next, the research design is presented, including a description of the empirical framework and the data used. The final two sections present the results and conclude.

Land scarcity and genocide in Rwanda

Civil war broke out in Rwanda at the end of 1990 when the Rwandan Patriotic Front (RPF), a rebel army consisting mostly of Tutsi exiles, started launching attacks from Uganda. These initial 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. However, on April 6, 1994, the plane carrying President Juvénal Habyarimana of Rwanda was shot down, whereupon Rwanda descended into chaos. Within

hours, the Forces Armées Rwandaises (FAR), the Interahamwe militia[1], 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 recommenced. In the 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, but, until the late 1990s, insurgency and counterinsurgency operations by the FAR and the RPF, respectively, continued in the Northwest along the Congolese border.

Although the Rwandan genocide was concentrated in a relatively short period of time, April 1994 - June 1994, all the regions were affected and the death toll among Tutsi was staggeringly high, it being estimated at around 800,000 or approximately 75% of Rwanda's Tutsi population (e.g. Prunier, 1995; Verpoorten, 2005). According to Eck & Hultman (2007), this figure makes the Rwandan genocide the largest example of one-sided violence in the post-Cold War era. Many have tried to understand this massive violence from a political, social, anthropological, cultural or economic point of view (e.g., André & Platteau, 1998; Des Forges, 1999; Mamdani, 2001; Newbury, 1998; Olson, 1995; Prunier, 1995; Verwimp, 2005). None of these studies fail to mention that, in the years preceding the genocide, the Rwandan rural population was fighting an uphill battle against land scarcity and soil degradation.

In particular, on the eve of the genocide, Rwanda was Africa's most densely populated non-island nation and, due to both high fertility rates and a young population, the annual population growth rate remained high at around 3%. Moreover, despite high population pressure, the Rwandan population had remained overwhelmingly rural and dependent on agriculture, with over 90% of the people relying on small-scale farming. For a number of decades, Rwandan peasants had responded to population pressure by expanding the area under cultivation and by intensifying agricultural production by means of evolving to a system of near-continuous cropping and mixed cropping, intense crop maintenance, and fertilization with manure to increase productivity. Until the mid-1980s, these responses enabled the food production to increase at the same rate as did the population (Olson, 1995).

However, by the end of the 1980s, almost all of the marginal land had been taken up for cultivation and many of the intensification techniques had reached their limits. For example, because of the lack of pasture land, it became increasingly difficult to keep livestock for

[1] 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.

manure (Clay, 1996). At the same time, no significant progress was made towards modern agricultural intensification, leaving the use of improved seeds and fertilizer in Rwanda well below that of the Sub-Saharan average. Consequently, not only the average farm size but also farm productivity was drastically decreasing (Clay, 1996). Furthermore, the rural poor and landless had few opportunities to earn income outside agriculture, partly because the few jobs in the non-farm sector were largely monopolized by the rural elite through patronage relationships (André & Platteau, 1998). At the same time, falling coffee prices in combination with a liberalization policy as part of a Structural Adjustment Program added to the economic hardship.

The strong correlation between the timing of the genocide and the failure to maintain per capita food production in the face of population pressure has led scholars to hypothesize that land scarcity was an important ingredient in explaining the mass killings (e.g. Newbury, 1998; Mamdani, 2001; Prunier, 1995). This hypothesis is backed up by a large amount of anecdotal evidence. For example, the 595-page Human Rights Watch report "Leave None to Tell the Story" mentions the word "land" 54 times, i.e. on average almost once every 10 pages (Des Forges, 1999). Reading through the passages, the opportunity to acquire land emerges as an important incentive for the killers:

> Authorities offered tangible incentives to participants. They delivered food, drink, and other intoxicants, parts of military uniforms and small payments in cash to hungry, jobless young men. They encouraged cultivators to pillage farm animals, crops, and such building materials as doors, windows and roofs. Even more important in this land-hungry society, they promised cultivators the fields left vacant by Tutsi victims. (Des Forges, p. 10-11)

Land also emerges as a very particular asset, not only because – unlike other lootable property – it is immobile and cannot be easily divided by the killers but also because of strong de facto inheritance rights and the absence of de jure private property rights, meaning that all the land reverted to the community and could be redistributed only after all its Tutsi "owners" were killed or chased away:

> As early as mid-April in some places, burgomasters ordered their subordinates to prepare inventories of the property of Tutsi who had been killed or driven away. One reason for the lists of people killed, initiated also at this time, was to identify which households were completely eliminated, meaning that their property was

> available for redistribution, and which had some survivors, meaning the land would be available only after further killing. (Des Forges, p. 299)

At first sight, the anecdotal evidence suggests that land scarcity played a significant role in accounting for the mass killings in Rwanda. However, there is an important competing hypothesis that is based on the drastic change in the political climate in Rwanda in the years preceding the genocide. By 1992, the war with the RPF had considerably weakened Habyarimana's authority and, due to pressure from both inside and outside Rwanda, he was forced to enter a coalition with domestic opposition parties and negotiate a peace settlement with the RPF. The Peace Agreement, signed in Arusha in August 1993, stripped many powers from the office of the President, transferring them to the transitional government in which opposition parties as well as the RPF received a large number of cabinet posts.

Percival & Homer-Dixon (1995) and Olson (1995), among others, argue that, with the prospect of having to share power, a part of the elite decided to take matters into their own hands and carefully planned both the genocide and politicide, i.e. the killing of Tutsi, who were perceived as RPF sympathizers, as well as moderate Hutu and Hutu of opposition parties. Hence, although, in their account of events leading up to the genocide, Percival & Homer-Dixon (1995: 1) acknowledge that "environmental scarcity and population growth are critical issues in Rwanda" and that "before the recent violence, they clearly threatened the welfare of the general population", they argue that "many factors were operating in this conflict, and environmental and population pressure had at most a limited, aggravating role." Instead, they attribute a central role to the insecurity of the regime and the elite generated by the civil war with the RPF and the Arusha peace accords.

I will comment in detail on this argumentation further on, but first I turn to two studies that provide micro-empirical analyses of the relationship between land scarcity and genocide in Rwanda.

André & Platteau (1998) studied the impact of land scarcity on the land-tenure system and intra-community tensions and disputes in Rwanda at the eve of the genocide. They rely on an in-depth study of a small community in Northwest Rwanda, where, both in 1988 and in 1993, detailed information was collected for 87 out of the 124 households living in the community. Among other things, the authors found evidence for a drastic decrease in per capita landholdings, increasing inequality in land endowments, a strikingly high number of land conflicts, and a lack of access to off-farm alternatives to help quasi-landless households make ends meet. In addition, it is demonstrated that young men belonging to the lower

landownership classes were postponing marriage for lack of land. For instance, between 1988 and 1993, the percentage of women and men aged 20 to 25 still living with their parents increased from 39 to 67 and from 71 to 100 percent, respectively. Based on the quantitative information as well as their day-to-day observations of life in the community, the authors argue that due to extreme land scarcity, intra-community tensions - land disputes in particular - were rising and becoming increasingly difficult to settle.

After the genocide, the authors collected information about the whereabouts and experiences of the individuals in their sample. Of particular importance for the purpose of the present study is that the findings indicate that a disproportionately large number of the victims of the 1994 violence belonged to households with relatively large landholdings or to households that were involved in pre-1994 land conflicts. With respect to the profile of the perpetrators, the authors report that "the most violent people tend to be young and to come from poor, yet not the most extremely poor family backgrounds." In order to interpret these findings, it is important to note that the community under study included only one Tutsi. The authors considered this ethnic homogeneity to be an advantage for their analysis of the link between land scarcity and violence, since abstraction could be made of ethnic hatred as a motivation for the killings.

Verwimp (2005) studied the profile of perpetrators in a sample of 402 Hutu adult males across three Rwandan provinces. He found that those men living in a household that rented a lot of land for cultivation relative to its own as well as the relatively well off with a high percentage of income earned off-farm were disproportionately represented among the genocide perpetrators. However, neither the size of landholdings owned nor the soil quality significantly predicted the likelihood of being a genocide perpetrator, a result that is somewhat in line with the findings of André & Platteau (1998) that it was not the poorest who participated most in the violence. Interpreting his findings, Verwimp (2005) hypothesized that the relatively high participation of the local elite can be explained by their having had the most to defend, i.e. their privileged economic and political position, certainly in view of the changing macro-political situation in the early 1990s. On the other hand, the quasi-landless peasants who depended on the land-rental and labor market had something to gain but also had to defend the little they had, which left little choice but to obey the local elite whom they depended on for land rental and wage work.

Among the studies discussed above, Percival & Homer-Dixon (1995) most explicitly downscaled the causal role of land in the Rwandan genocide. The authors made three arguments in support of their view: (1) there is no evidence for large popular participation in the geno-

cide; (2) violence broke out first in and around Kigali City and in the northern region before spreading to the southern region, where the population density was highest; and (3) the planners of the genocide belonged to the economic and political elite who arguably suffered the least from the country's scarce natural resource base.

Each of these arguments needs to be qualified. First, since the study of Percival & Homer-Dixon (1995), there has been mounting evidence of widespread popular participation in the genocide. For example, based on detailed fieldwork in five administrative communes and in-depth interviews with prisoners, Strauss (1994) estimated that there were 175,000 to 210,000 perpetrators, and, in 2000, the government held 109,499 detainees on genocide charges, while the number of accused persons not detained was 49,066 (Office of the Prosecutor, 2002). In 2005, the number of genocide suspects emerging from the information round of the transitional justice system (Gacaca) was as high as 510,000 suspects[2].

Second, one cannot draw conclusions based on a comparison between the northern and southern regions without controlling for factors other than population density. In particular, several political and historical factors can account for the commencement of the killings in and around Kigali City and the Northwest rather than the most densely populated South. Most importantly, the South was the site of the pre-colonial Tutsi kingdom that had ruled since the 15^{th} century, whereas the North had remained dominated by Hutu kingdoms until the end of the 19^{th} century (Newbury, 1998). Hence, the share of Tutsi in the southern provinces was relatively large, and the ethnic groups were inter-connected through family and friendship relations, two factors that may explain why, despite higher population densities, resistance against mass killings was stronger in the southern provinces.

Third, even though there is by now widespread agreement that elite security in the face of the Arusha accords is likely to be the most important factor explaining the onset of violence (given ample evidence that the genocide was planned and orchestrated by the Hutu elite), elite insecurity can hardly account for the intensity of the violence, since the militia and FAR army could not openly have killed 800,000 people in barely three months without the active or passive support of a large part of the population. Furthermore, it can be argued that the civil war with the RPF and the subsequent peace agreement was a proximate rather than a root cause for elite insecurity. The RPF consisted mostly of Tutsi exiles, who fled previous waves of violence between 1959 and 1990[3] and several scholars stress that these previous

[2] The Gagaca data on suspects is prone to misreporting. For a detailed discussion on the Gacaca information round, I refer to the data section of this article and the online data appendix.

[3] Watson (1991) estimates that in 1959, at the time of the Hutu revolution, about 150,000 Tutsi fled the country. Interestingly, Yanagizawa (2010: p.7) argues that it was "after it had been decided that Rwandan

violent encounters can be explained by the resentment of Hutu towards the concentration of wealth in the hands of Tutsi. For example, Tutsi kept complete control over land use and access to land and reserved large land areas as pasture. When they were driven away, the vast areas that had been pasture were converted to crops, an extensification process that contributed significantly to rising food production (Olson, 1994; Newbury, 1998)[4].

In sum, since 1994, there has been mounting evidence of widespread popular participation in the genocide in both the North and the South, and historical facts suggest that the origin of the RPF army is rooted in an inter-ethnic power struggle over land and other resources. This suggests that, whereas the proximate cause for the onset of the genocide was elite insecurity, the latter may itself have been rooted in a struggle over scarce natural resources, and, when it comes to explaining the intensity of the violence, the root causes were likely to be ethnic polarization (manipulated and transformed into ethnic hatred by the extremist elite), the struggle over control of scarce resources, or both. It seems that the latter cannot be discarded as an important factor in view of the findings of the study of André & Platteau (1998) in an ethnically homogenous community. On the other hand, both in André & Platteau (1998) and Verwimp (2005), the profile of perpetrators does not coincide with that of the poorest or most land-deprived households. This suggests that the role of land in explaining the civilian participation in mass killings is complex and that the underlying mechanisms still remain largely uncovered.

Research design

From this review of the anecdotal evidence and previous studies, I infer that, both at the macro- and the micro-level, neither land scarcity nor elite insecurity were sufficient factors in isolation. At the macro-level, elite insecurity put the bandwagon in motion, channeling existing grievances towards Tutsi hatred and unleashing the underlying tension over access to land to add to the scale and intensity of the genocide. At the micro-level, a large part of the local elite feared losing their privileged status and therefore actively supported the killings and could easily persuade those depending on them for access to land and wage work to join in.

refugees were to be excluded from owning land in Uganda, that the decision to invade Rwanda and to regain the right of citizenship was taken".

[4]The argument can even be taken further by tracing the origins of ethnicity, which according to the now dominant theory of ethnic origins in Rwanda, is a social construct derived from work-related activity and ownership of land and cattle (Newbury, 1998).

If this assessment holds true, we should find that killings were more severe in areas where the underlying tension over land was highest and where many depended on the local elite for access to land. This cannot be directly tested because of the lack of detailed data on land conflicts, land tenure, and land inequality, but it is plausible to assume that these features were more prevalent in areas with high population density, high population growth, or both, as well as the areas where landlessness was prevalent (among the young generation). The testable hypotheses therefore are:

H1: The genocide intensity was greater in localities with higher population densities

H2: The genocide intensity was greater in localities with higher population growth

H3: The genocide intensity was greater in localities where a large proportion of young men were single (for lack of sufficient land to marry).

Regarding H1 and H2, it is important to note that, in 1994, localities with high population density were not necessarily those with high population growth. In fact, it is documented that population pressure in the most densely populated rural areas led to demographic responses of the affected population, including lower fertility rates and migration towards less densely populated areas (Olson, 1994). In addition, communities with similar degrees of population density and population growth may still differ with respect to landlessness among young men because of distributional issues. Hence, apart from including the explanatory variables of interest in isolation, they will be included jointly as well as in interaction.

A final note to make is that, besides the decimination of Tutsi, other forms of violence took place in Rwanda. However, since lack of documentation on these forms of violence constraints their measurement, the empirical analysis in this article focuses on the killings of Tutsi, which may lead to an underestimation of the impact of population pressure on violence (provided that the genocide on Tutsi is positively correlated with other forms of violence, e.g. revenge killings, killings of moderate Hutu, etc.).

Empirical framework

Although small in geographical size, Rwanda has a very diverse ecosystem with many different micro-climates. In addition, in many areas, one finds hills with steep slopes where population density and intensified cultivation have led to severe erosion. Hence, one of the

main challenges in the empirical framework is to control for subnational differences in climate, soil type and soil degradation. In the main specification, I estimate the empirical relation between population pressure and mass killings at the level of the smallest codified administrative unit, i.e. for 1,294 rural administrative sectors, which have a mean size of 13.5 km^2 and counted on average 4,824 inhabitants in 1991[5]. In order to reduce the influence from unobserved heterogeneity in soil and climate, I add fixed effects for each of the 137 Rwandan rural communes included, which is one administrative unit above the sector, with a mean size of 135.5 km^2 and on average 48,681 inhabitants in 1991.

The estimated model can be written as follows:

$$genocide\_toll_{1994,ic} = \alpha_0 + \alpha_1 pressure_{1991,ic} + controls_{ic}\Pi' + \eta_c + \varepsilon_{ic}, \quad (1)$$

with $genocide\_toll_{1994,ic}$ the death toll among Tutsi in sector i : 1...1294, located in commune c : 1...137, $pressure_{1991,ic}$ pre-genocide population density in sector i; and $controls_{ic}$ including the 1991 sector-level population size as well as the distance of a sector to the nearest provincial capital city and main road. The latter two variables are included to capture the variation in access to non-farm work, which is likely to be higher close to roads and urban centers, but it may also account for the genocidal campaign having been orchestrated by the central and local administration. Finally, η_c are commune fixed effects and ε_{ic} are idiosyncratic errors.

In the second specification, I replace the commune fixed effects by province fixed effects, η_p in order to run the test with $pressure_{1991,ic}$ measured as commune-level population growth and marriage delay, two measures for which sector-level data is not available. The second model can be specified as follows:

$$genocide\_toll_{1994,ic} = \beta_0 + \beta_1 pressure_{1991,ic} + controls'_{ic}\Omega' + \eta_p + \varepsilon'_{ic}, \quad (2)$$

with $pressure_{1991,ic}$ now equaling the 1991 sector-level population density, the 1978-91 commune-level population growth, the 1991 commune-level proportion of young single men (age 20-35), or a combination of these variables. To account for inter-commune variation, $controls_{ic}$ now also includes the proportion of Tutsi in a commune as well as all or a subset of

[5]These are my own calculations from the 1991 population census. At the time of the genocide, Rwanda was divided into 10 prefectures, 145 communes, 1,565 sectors, and more than 9,000 cells, but the cells were not codified. In this article, I restrict the sample to rural sectors because of the focus on the scarcity of agricultural land.

the following variables: (1) the 1991 commune-level infant mortality to control for baseline wealth, (2) the 1991 commune-level proportion of young men that have little education to further reduce heterogeneity and because a large pool of poorly educated young men has been associated with armed conflict in the literature (e.g. Collier & Hoeffler, 1998), and (3) the percentage of inter-ethnic marriage in the population to account for the inter-connectedness between Hutu and Tutsi.

Note that the proportion of Tutsi in a commune and the percentage of inter-ethnic marriage in the population also account for possible measurement error in the genocide death toll, which is explained below and in detail in the online appendix. However, these control variables are not crucial as the results remain similar when excluding them.

The dependent variable

The outcome variable $genocide\_toll_{1994,ic}$ proxies the death toll among Tutsi in a sector. It is calculated based on information about the pre-genocide Tutsi population, the surviving Tutsi population and the natural death rate. Using this information, the sector-level estimate of the number of Tutsi killed in proportion to the 1994 Tutsi population can be specified as follows:

$$genocide\_toll_{1994,ic} = (1 - \frac{(genocide\_survivors_{i2005})(1-d_n)^{-11}}{Tutsi\_population_{i1994}}) - d_n, \qquad (3)$$

with $genocide\_survivors_{i2005}$ being the sector-level number of genocide survivors alive in 2005 taken from the Gacaca - the transitional justice system in Rwanda (Government of Rwanda, 2005); d_n a national level estimate of the natural death rate between 1994 and 2005 based on the 2000 DHS (Timaeus & Jasseh, 2004); and $Tutsi\_population_{i1994}$ an estimate of the pre-genocide sector-level Tutsi population derived from the 1991 population census (Government of Rwanda, 1991; Minnesota Population Center, 2010.)[6].

The variable $genocide\_toll_{1994,ic}$ is subject to several sources of measurement error. In the online appendix, I give a detailed discussion of the possible causes and consequences of measurement error. In summary, the sources of error include the following: (i) d_n is a national level estimate of the natural death rate and may not be appropriate if there is large sub-national variation in post-genocide death rates; (ii) $genocide\_survivors_{i2005}$ may include

[6] $Tutsi\_population_{i1994} = \left(pop_{i1991} * (pop\_growth_{c1978-1991})^3\right) * share\_Tutsi_{c1991}$ with pop_{i1991} the 1991 sector level total population, $pop\_growth_{c1978-1991}$ the 1978-91 commune level annual population growth rate, and $share\_Tutsi_{c1991}$ the 1991 commune level proportion of Tutsi.

Hutu widows who were married to Tutsi; and (iii) the accuracy of $Tutsi\_population_{i1994}$ hinges on the reliability of the 1991 population census and the extent of unobserved within commune variation in the population growth and the share of Tutsi in the population.

These sources of errors probably account for 96 anomalous cases (out of the 1390) for which $genocide\_toll_{1994,ic}$ is negative. I removed these anomalous cases from the sample in the main results of this article, and I performed a series of robustness checks when including them (see below). A number of the control variables included in $controls'_{ic}$ attenuate the impact of possible measurement error. For example, the 1991 commune-level proportion of inter-ethnic marriages is likely to be positively related to the number of Hutu counted as survivors; the commune-level infant mortality rate accounts for part of the sub-national variation in natural death rates; and the sector-level distances to the nearest road and town may capture part of the within commune-level variation in population growth.

The calculated genocide death toll averages 63.1% across the 1,294 rural sectors (and 56.0% when the 96 sectors with anomalous values are included). When weighted by the share of Tutsi in the population of each of the sectors, we find a nationwide death toll of approximately 66.6%. Furthermore, when taken into account the under-reporting of Tutsi in the 1991 population census and repeating the calculation with a higher estimate for $Tutsi\_population_{i1994}$, I find a nationwide death toll of 75.5% which is very close to the estimates put forward by Prunier (1995) and Verpoorten (2005)[7].

Importantly for the purpose of testing the above hypotheses, $genocide\_toll_{1994,ic}$ exhibits substantial variation across sectors. This is evident from the kernel density plot in Figure I, the province level summary statistics in Table I, and the quintile map displayed in Figure II. The map displays high values in many sectors in the North, where the genocidal regime had its largest support base and Tutsi were a small minority. In particular, high values can be detected in the northern and eastern areas where the Bahima and Bagogwe clans lived, which were pastoralists and usually identified as Tutsi[8]. In addition, Table I and Figure II indicate high values for the genocide's death toll in sectors of Butare, Gikongoro, and Kibuye, three provinces where the share of Tutsi in the population was historically high. In Gitarama, another province with a relatively high share of Tutsi in the population, we find very few sectors with a high death toll amongst Tutsi. This is in line with other evidence on

[7] As explained in the online Appendix, there is evidence for under-reporting of Tutsi of up to 40%. Both Prunier (1995) and Verpoorten (2005), who estimate the genocide's death toll at the national level using population census data, argue that, taking this into account, the genocide's death toll increases from an estimated 500,000 to 800,000 Tutsi killed.

[8] In contrast, in other parts of the country, Tutsi could not be distinguished from Hutu based on cattle ownership, economic activities, customary practices or language (Newbury, 1998).

the genocide's death toll, which indicates that resistance against the genocide was strongest in Gitarama and an estimated 50% of Tutsi survived, whereas in the other provinces with a high share of Tutsi in the population, the reported survival rate was no higher than 25%.[9].

The explanatory variables

Population pressure is proxied on the basis of 1991 population density and 1978-91 population growth. The former is available at the sector-level from the 1991 population census; the latter was calculated from the 1978 and 1991 population census and is only available at the commune level. There is no information available on land inequality at the level of these small administrative units. Instead, landlessness is proxied by the commune-level proportion of men aged 25-35 who are not married, which is taken from the 1991 population census.

Summary statistics for the explanatory variables are presented in Table II. The average 1991 population density in the 1,294 sectors included in the analysis is approximately 430 inhabitants/km^2 while annual population growth was about 2.9% during 1978-91, and 26% of the men aged 25-35 were still single. Figure III plots the kernel-density function of these three explanatory variables of interest and indicates considerable variation across sectors.

It is noteworthy that the three explanatory variables of interest are interrelated. As a result of demographic responses to population pressure, the relation between population density and population growth is negative. In particular, from a regression of population growth on population density, controlling for province fixed effects, it is found that an increase of population density by 100 inhabitants/km^2 is associated with a decrease in population growth by 0.19 percentage points, corresponding to 6.6% of the average of 2.9% population growth. In contrast, the relation between population density and unmarried men is positive: an increase of population density by 100 inhabitants/km^2 is associated with an increase in the proportion of single young men by 2.5 percentage points, which corresponds to a 10% increase of the average of 25%.

The sector-level control variables distance to nearest town and road are calculated using numerical maps in GeoDa and average 26.7 km and 8.1 km, respectively. The commune-level control variables, including measures for the share of Tutsi in the population, infant mortality and schooling level, are calculated on the basis of the 1991 population census data.

[9]Based on detailed population data of the local administration, Verpoorten (2005) and Des Forges (1999) estimate the Tutsi survival rate at 25% for Gikongoro and Butare. Based on a small household panel dataset, Verwimp (2003) found that more than 50% escaped the killings in Gitarama, while in Gikongoro fewer than 15% survived. Based on data from the genocide-survivor organization, IBUKA, Verwimp (2006) found survival rates as low as 15% in Kibuye.

The sample average for the proportion of Tutsi is 7.6% (or 10.6% when correcting for under-reporting of Tutsi in the 1991 census). The infant mortality rate was on average 55 per thousand live births in 1991 and only 13% of men aged 15-25 had received some secondary education.

Results[10]

Main results

Panel A of Table III presents the estimation results for Equation 1 (Models 1-4). In Model 1, including only 1991 sector-level population density and commune fixed effects as explanatory variables, the estimated coefficient α_1 is positive and strongly significant, suggesting that an increase of 100 inhabitants/km^2 adds 1.2 percentage points to the genocide's death toll. When including controls for population size, distance to town and/or road in Models 2-4, the coefficient remains significant and the estimated impact varies between 1.1 and 1.6 percentage points. Regarding the control variables of distance to town and road, it is noteworthy that the results indicate that killings were more severe in remote areas, a finding that goes somewhat against the idea that the genocide was orchestrated top-down and may be explained by the absence of non-farm work to compensate for land scarcity in these localities. In Panel B of Table III, I repeat the estimates of Panel A, but account for spatial correlation in the error terms, using a distance-based spatial weighting matrix. The results remain qualitatively the same.

Table IV gives the results of several specifications of Equation 2 (Models 5-11), in which the commune fixed effects are replaced with province fixed effects and a control for the pre-genocide share of Tutsi in the population is added. In the first column (Model 5), population pressure is measured again by means of sector-level 1991 population density, and we find that the estimate for β_1 (0.015) is very similar to the estimates for α_1 in Model 1. In Models 6 and 7, 1991 population density is replaced by commune-level 1978-91 population growth and the proportion of men aged 25-35 who were still single, respectively. The estimated coefficients on these alternative measures are positive, but the former does not yield a significant effect, while the latter is only weakly significant, suggesting that a ten-percentage-point increase in the proportion of single young Hutu men increases the death toll by 2.4 percentage points.

In Models 8 and 9, population density is added as an explanatory variable jointly with one

[10] **The regression analysis was executed in STATA 10.1.**

of the alternative measures of population pressure. Only the estimated impact of population density is significantly positive. In Models 10-11, the interaction terms between population density and population growth and the share of single young men, respectively, are included. Only the latter interaction term is significantly different from zero, while statistical significance on both of the individual variables fades and their sign even reverses. This suggests that it is not population density as such that intensified the killings, but rather the specific combination of high population pressure and a large proportion of single young men (~landless).

Robustness checks

In Table V, I present the same models as in Table IV but after adding three additional commune-level control variables: infant mortality, the proportion of young men without secondary schooling and the proportion of inter-ethnic marriages. The results remain qualitatively the same, except for Model 9' where the coefficient on the proportion of unmarried young men is now also significantly different from zero, be it only at the 10% level.

Table VI lists five robustness checks for Model 5. First, population density is replaced by its natural logarithm. Second, all 96 observations with anomalous values for the calculated death toll are included. Third, all these anomalous observations are included but censored to zero. Fourth, to account for possible measurement error in the genocide death toll stemming from the inclusion of close Hutu relatives of Tutsi victims among the genocide survivors, the share of inter-ethnic marriages is added as a control variable. Fifth, to account for the possible impact of the RPF advancement which put an end to the genocide, I included a variable that takes on the number of days the sector was under RPF control in the 109-day period that the genocide took place[11]. Finally, Model 5 is estimated using the commune-level calculation of the genocide's death toll instead of the sector-level calculation to rule out the results being driven by within-commune measurement errors in $genocide\_toll_{1994,ic}$. In all cases, the qualitative result that greater population density leads to a higher estimated death toll remains. The results for the proportion of unmarried young men are also robust for the same checks (not reported).

[11] This variable is constructed on the basis of information provided by the genodynamics project (www.genodynamics.com; Davenport & Stam, 2009). For example, sectors in the North close to the Ugandan border that were already 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.

Conclusion

The debate over the Malthusian hypothesis has shifted from a global to a local level and centers around the question on what conditions really matter. In particular, the neo-Malthusian hypothesis states that, under certain conditions such as ethnic fractionalization and a political deadlock, resource scarcity may be conducive to violence.

In the case of Rwanda, one may argue that the perfect storm that could lead to an unfolding neo-Malthusian local disaster was present. First, since the mid-1980s, food production per capita started to decline as almost all marginal land was being taken under cultivation and as intensification of production had remained very limited. Second, the rural poor and landless had few opportunities to earn income outside of agriculture. Third, the Rwandan society had a history of violent encounters between the Hutu majority and the Tutsi minority. Fourth, in the years leading up to the genocide (1990-93), sporadic attacks from Tutsi exiles at the border with Uganda and the following power sharing arrangement led to a tense political climate that divided the government party between radical and moderate Hutu.

The prospect of having to share power with the opposition parties and the RPF triggered the genocidal campaign of the Hutu extremists, who carefully planned, prepared, and organized the killings of both moderate Hutu and Tutsi. However, the elite's genocidal plans could only succeed with a fair amount of support, active or passive, from the general population. Unfortunately, the Hutu radicals succeeded in obtaining such support by playing the ethnicity card and free-riding on the underlying tensions over the extreme scarcity of land and economic opportunities.

By how much did land intensify the genocide? Analyzing the genocide's death toll across 1,294 administrative units, I found that an increase in pre-genocide population density by 100 inhabitants per km^2 leads to a rise of the genocide's death toll by 1 to 2 percentage points. Furthermore, in areas where many young men remain single, which may arguably be an indication of landlessness, fewer Tutsi survived the genocide. The estimates indicate that a 10 percentage point increase in the share of young men that are still single, increases the genocide's death toll by approximately 2.5 percentage points. Importantly, the results of the empirical model that includes the interaction term of population density and landlessness suggests that these factors did not operate in isolation, but it is their combination that contributed to the killings.

These findings do not indicate that extreme scarcity of land resources caused the onset of the genocidal campaign, but they clearly indicate that, once the bandwagon was set

in motion, resources were a significant factor in explaining the intensity of the violence. This conclusion can be interpreted as support for the neo-Malthusian hypothesis, i.e. vices resulting from a tension between subsistence needs and scarce resources. On the other hand, rather than driven by need, the killers may have been driven by the opportunity to loot or by the fear to lose the little they had, two alternative motives that may have been especially strong in high density areas with many landless men. Thus, whereas this meso-level analysis has provided empirical support for a local-level relation between violence and population density, detailed individual-level analysis, based on both quantitative and qualitative evidence, is required in order to unravel the exact mechanisms underlying this relationship.

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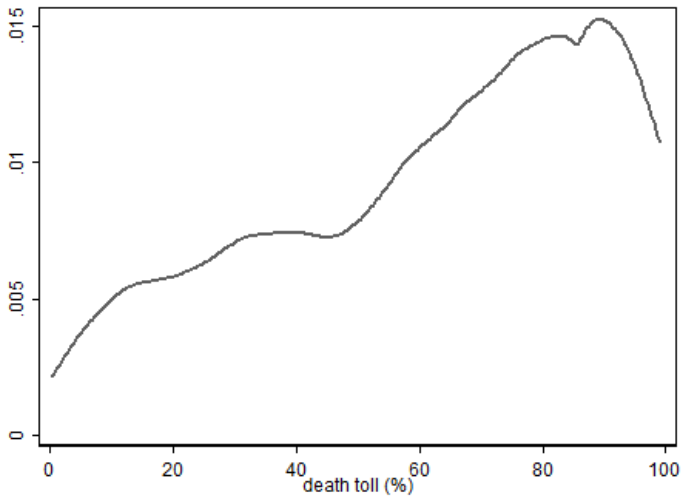
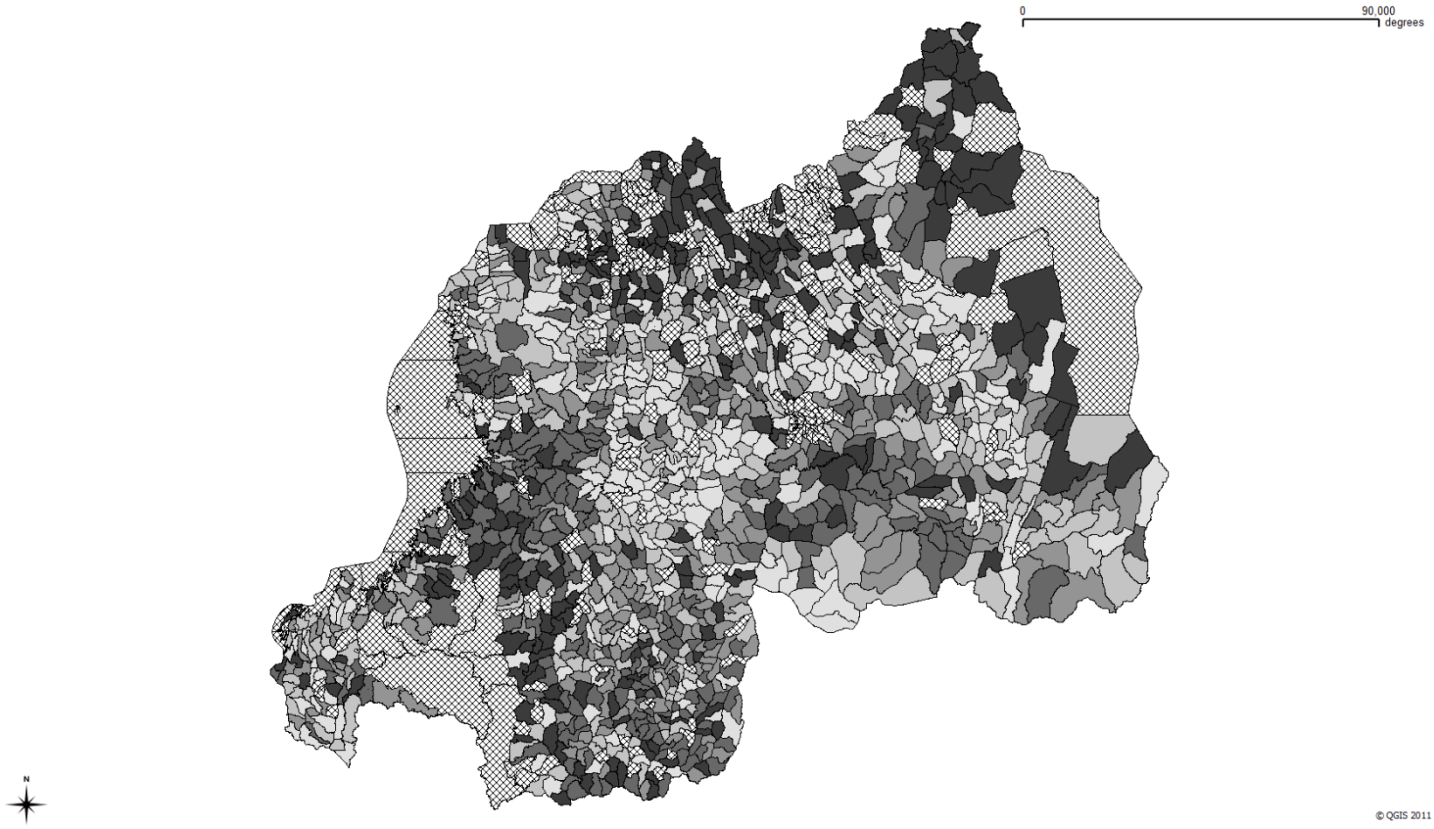
Figure I. Kernel density of the genocide death toll



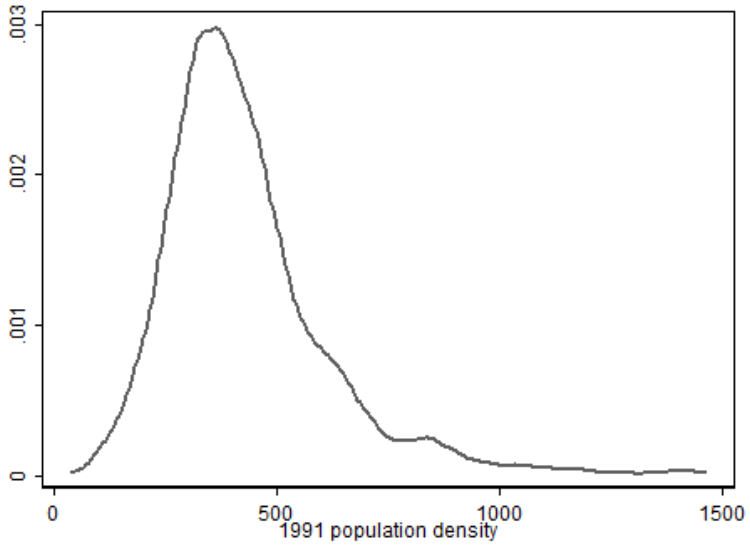
The genocide's death toll gives the death toll among Tutsi across 1,294 administrative sectors. The number of points at which the density function is estimated is 50 (default in STATA), with intervals of bandwidth 6 (the optimal bandwidth calculated in STATA).

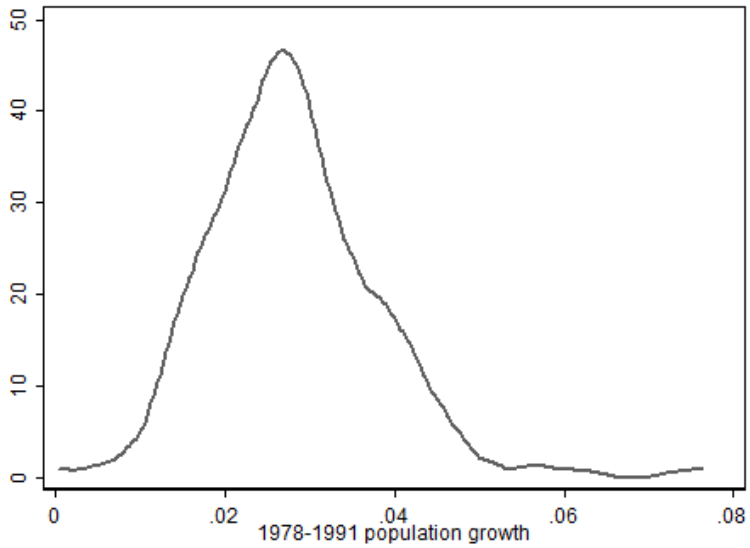
Figure II. Sector-level quintiles of the genocide death toll (highest quintile in dark grey)



The checkered areas are left out of the analysis. They include the national park, forest areas and lakes, Kigali city, the provincial capital areas and 96 sectors with anomalous values.

Figure III. Kernel densities of explanatory variables of interest





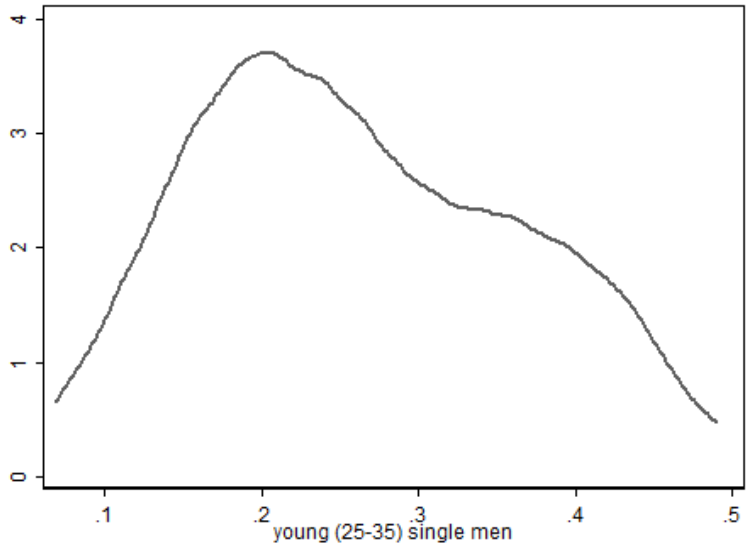


Table I. The share of Tutsi in the population and the genocide death toll

	Commune level Tutsi population (1991, %)		Sector level death toll	
Province	Uncorrected	Corrected[a]	Uncorrected	Corrected[a]
Butare	0.15	0.21	0.69	0.78
Byumba	0.01	0.02	0.68	0.77
Cyangugu	0.10	0.14	0.59	0.70
Gikongoro	0.14	0.19	0.71	0.79
Gisenyi	0.02	0.03	0.54	0.67
Gitarama	0.07	0.10	0.46	0.61
Kibungo	0.06	0.09	0.57	0.69
Kibuye	0.12	0.16	0.78	0.84
Rural Kigal	0.07	0.10	0.60	0.71
Ruhengeri	0.01	0.01	0.75	0.82
Total	0.08	0.11	0.63	0.73

N=1,294 rural sectors included in the analysis; [a] the correction adjusts for the under-reporting of Tutsi in the 1991 population census by 40%.

Table II. summary startistics (N = 1,294 sectors, 137 communes)

Variable name	Description	Souce	Mean	St.dev	Min	Max
Genocide death toll	Sector level estimate of % of Tutsi killed in 1994	Gacaca records and 1991 population census	0.63	0.28	0.00	0.99
Population density, 1991	Sector level population density, inhabitants/km²	1991 population census	430	188	38	1,461
Population growth, 1978-1991	Average annual commune level population growth	1978 and 1991 population census	0.029	0.012	0.000	0.080
Single young men, 1991	Commune level % of men aged 25-35 that are not yet married	1991 population census	0.26	0.10	0.07	0.49
Tutsi population, 1991	Commune level % of Tutsi in the total population	1991 population census	0.076	0.084	0.000	0.575
1991 population size	Sector level total population	1991 population census	4,824	2,265	836	32,686
Distance to town	Sector level distance to nearest provincial capital or Kigali City, km	Own calculation in GeoDa	26.7	17.4	1.1	101.3
Distance to main road	Sector level distance to nearest road (type 1 road), km	Own calculation in GeoDa	8.1	5.9	1.0	40.5
Infant mortality rate, 1991	Commune level infant mortality rate per thousands of children born allive	1991 population census	55.4	27.9	12.0	206.2
Low-educated young men, 1991	Commune level % of men aged 15-25 that have no education beyond primary schooling	1991 population census	0.87	0.04	0.76	0.94
Inter-ethnic marriage (%)	Commune level % of inter-ethnic marriage in couples with at least one Tutsi	1991 population census	0.50	0.20	0.00	1.00
Days under RPF control	Number of days that the sector was under RPF control during April-July 1994	Davenport & Stam (2009)	39.8	41.8	0.0	109.0

Table III. Sector level population density and genocide intensity

Dependent variable: the genocide death toll	1	2	3	4
Panel A: OLS estimates				
1991 population density[a]	0.012**	0.011**	0.012**	0.016***
	(0.006)	(0.006)	(0.006)	(0.006)
1991 population size[b]		0.016	0.015	0.004
		(0.025)	(0.025)	(0.025)
Distance to town[b]			0.093***	0.064**
			(0.032)	(0.032)
Distance to main road[b]				0.059***
				(0.020)
Commune fixed effects	Yes	Yes	Yes	Yes
Obs	1,294	1,294	1,294	1,294
R^2	0.341	0.341	0.347	0.353
Panel B: spatial error regression models by maximum likelihood				
1991 population density[a]	0.013**	0.013**	0.013**	0.016***
	(0.005)	(0.005)	(0.005)	-0.005
1991 population size[b]		0.015	0.014	0.004
		(0.025)	(0.025)	-0.022
Distance to town[b]			0.092***	0.062**
			(0.03)	-0.031
Distance to main road[b]				0.060***
				-0.021
Commune fixed effects	Yes	Yes	Yes	Yes
Spatial error	Yes	Yes	Yes	Yes
Obs	1,294	1,294	1,294	1,294

Robust standard error between brackets; the spatial weights matrix used in the estimation of the spatial regression model is a 1,294 by 1,294 matrix taking values 1 for pairs of sectors that are less than 20 km apart and zero otherwise; significant at the ***1%, **5% and *10% level; [a]expressed in 100 inhabitants/km²; [b]logged values

Table IV. Sector level population density, commune level population growth, commune level single young men and genocide intensity

Dependent variable: the genocide death toll	5	6	7	8	9	10	11
1991 population density[a]	0.015***			0.015***	0.014***	0.027**	-0.009
	(0.005)			(0.005)	(0.005)	(0.012)	(0.012)
1978-1991 population growth		0.941		1.200		2.516*	
		(0.834)		(0.832)		(1.453)	
Single young men (%)			0.238*		0.195		-0.191
			(0.126)		(0.127)		(0.219)
(1991 population density*						-0.004	
1978-1991 population growth)						(0.004)	
(1991 population density*							0.082**
Single young men (%))							(0.037)
Tutsi population (%)	0.634***	0.667***	0.549***	0.668***	0.559***	0.662***	0.587***
	(0.096)	(0.097)	(0.103)	(0.098)	(0.105)	(0.098)	(0.106)
1991 population size[b]	-0.019	-0.013	-0.007	-0.026	-0.018	-0.027	-0.020
	(0.023)	(0.023)	(0.022)	(0.023)	(0.023)	(0.023)	(0.022)
Distance to town[b]	0.030**	0.025*	0.036**	0.028*	0.038**	0.027*	0.033**
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)
Distance to main road[b]	0.046***	0.032***	0.038***	0.044***	0.049***	0.045***	0.051***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.013)	(0.012)	(0.013)
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	1,294	1,294	1,294	1,294	1,294	1,294	1,294
R^2	0.161	0.155	0.156	0.162	0.162	0.163	0.165

Robust standard error between brackets; significant at the ***1%, **5% and *10% level; [a]expressed in 100 inhabitants/km²; [b]logged values

Table V: The relation between sector level population density, commune level population growth, commune level single young men and genocide intensity; controlling for a large number of commune level characteristics

Dependent variable: the genocide death toll	5'	6'	7'	8'	9'	10'	11'
1991 population density[a]	0.016***			0.016***	0.015***	0.028**	-0.010
	(0.005)			(0.005)	(0.005)	(0.012)	(0.012)
1978-1991 population growth		0.947		1.154		2.439*	
		(0.837)		(0.834)		(1.449)	
Single young men (%)			0.265**		0.238*		-0.195
			(0.129)		(0.130)		(0.220)
(1991 population density*						-0.004	
1978-1991 population growth)						(0.004)	
(1991 population density*							0.095**
Single young men (%))							(0.038)
Tutsi population (%)	0.664***	0.685***	0.562***	0.691***	0.574***	0.683***	0.615***
	(0.112)	(0.111)	(0.117)	(0.113)	(0.119)	(0.113)	(0.122)
1991 population size[b]	-0.022	-0.013	-0.008	-0.028	-0.022	-0.029	-0.025
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.022)
Distance to town[b]	0.027*	0.024	0.035**	0.025*	0.035**	0.025*	0.029*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)
Distance to main road[b]	0.045***	0.031***	0.037***	0.043***	0.048***	0.044***	0.049***
	(0.013)	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)
Infant mortality rate (%)	-0.354	-0.288	-0.312	-0.366	-0.381	-0.357	-0.404
	(0.303)	(0.304)	(0.307)	(0.302)	(0.304)	(0.303)	(0.305)
Poorly educated youg men (%)	0.237	0.071	0.184	0.199	0.304	0.202	0.417*
	(0.241)	(0.238)	(0.240)	(0.241)	(0.242)	(0.241)	(0.250)
Inter-ethnic marriages (%)	0.001	0.018	0.002	0.003	-0.011	-0.001	-0.016
	(0.047)	(0.048)	(0.048)	(0.047)	(0.048)	(0.047)	(0.048)
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	1,294	1,294	1,294	1,294	1,294	1,294	1,294
R^2	0.162	0.156	0.157	0.163	0.164	0.164	0.169

Robust standard error between brackets; significant at the ***1%, **5% and *10% level; [a]expressed in 100 inhabitants/km²; [b]logged values

Table VI. Robustness checks model 5

Dependent variable: the genocide death toll	Logged population density 5_rob1	Anomalous values included 5_rob2	Anomalous values inlcuded, censored to zero 5_rob3	Controlling for the % of inter-ethnic marriages 5_rob4	Controlling for the days sector was under RPF control 5_rob5	Using the commune level genocide death toll[c] 5_rob6
log(1991 population density[a])	0.066***					
	(0.021)					
1991 population density[a]		0.015**	0.016***	0.015***	0.015***	0.009*
		(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Inter-ethnic marriages (%)				-0.003		
				(0.047)		
Days under RPF control					0.000	
					(0.000)	
Tutsi population (%)	0.628***	0.971***	0.839***	0.631***	0.637***	0.891***
	(0.096)	(0.126)	(0.110)	(0.102)	(0.096)	(0.083)
1991 population size[b]	-0.018	0.052	0.003	-0.019	-0.021	0.028**
	(0.022)	(0.038)	(0.024)	(0.023)	(0.023)	(0.014)
Distance to town[b]	0.029**	0.042**	0.035**	0.030**	0.030**	0.021**
	(0.014)	(0.020)	(0.016)	(0.014)	(0.014)	(0.010)
Distance to main road[b]	0.047***	0.066***	0.051***	0.046***	0.046***	0.043***
	(0.012)	(0.018)	(0.013)	(0.012)	(0.012)	(0.009)
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Obs	1,294	1,390	1,390	1,294	1,294	137
R^2	0.160	0.103	0.140	0.161	0.161	0.398

Robust standard error between brackets; significant at the ***1%, **5% and *10% level; [a]expressed in 100 inhabitants/km²; [b]logged values; [c]the data from 136 communes are weighted with frequency weights equal to number of sector in each commune and the sector level explanatory variables are averaged at the commune level.

Appendix (only for publication online)

The calculation of the genocide's death toll

The sector-level number of Tutsi killed proportional to the 1994 Tutsi population can be calculated as follows:

$$genocide\_toll_{1994,i} = (1 - \frac{(genocide\_survivors_{i2005})(1 - d_n)^{-11}}{Tutsi\_population_{i1994}}) - d_n, \quad (1)$$

with $genocide\_survivors_{i2005}$ the sector-level number of male and female survivors, d_n the annual post-genocide natural death rate, and $Tutsi\_population_{i1994}$ the 1994 pre-genocide sector-level Tutsi population.

In what follows, I explain each of the three components at the right hand side of this equation in detail and discuss the possible causes and consequences of measurement error.

The number of genocide survivors

The number of sector-level genocide survivors is taken from the Gacaca, the transitional justice system in Rwanda. In 2005, the Gacaca commenced the first phase of its activities, i.e. the phase of collecting information. During weekly sessions with compulsory attendance of all community members, lists were made of suspects and survivors[1]. Part of the results achieved during this phase, including the sector-level number of genocide survivors, was made public in the course of 2007.

As Gacaca proceeded, its operation was criticized for lack of objectivity due to manipulation (Ingelaere, 2009; Longman, 2009; Pitsch, 2002; Wolters, 2005; Penal Reform International, 2003). When reviewing the criticism, it can be concluded that the number of survivors that was recorded by the Gacaca is likely to be more reliable than the number of recorded suspects because – in contrast to the latter – there are no obvious motives for over- or underreporting survivorship[2].

[1] Attendance was initially voluntary, but, after problems with low attendance in the pilot phases, the law was revised, making attendance compulsory (Longman, 2009).

[2] According to critics of the gacaca courts, at least three reasons may have caused over-reporting of the accused. First, late Human Rights Watch adviser Alison Des Forges argued that the concession programme, which requires the naming of all those who participated along with the accused in return for a lighter sentence, led to a multiplication of names. Second, Longman (2009) claims that, over time, gacaca was undermined by government manipulation, aiming at a conviction of the largest possible number of Hutu in order to exclude much of the Hutu from holding public office. Third, several sources, including the Rwandan government, acknowledge that gacaca became a means of taking personal revenge on enemies, which contributed to the steep rise of the number of accused as gacaca proceeded.

On the other hand, most sources evaluating gacaca also acknowledge that individuals may have escaped

The Gacaca does not define a legal age for testifying and there are no legal definitions for genocide survivors. According to a former prosecutor involved in Gacaca, the survivors recorded by the Gacaca information round are Tutsi who were living in the sector at the time of the genocide and survived but can also include Hutu widows (or widowers) who were married to Tutsi[3]. This view corresponds to the perception of Molenaar (2005) in his in-depth study of the Gacaca process.

If, besides Tutsi, a number of Hutu are counted among the survivors, this has implications for the estimation of the genocide's death toll by equation I. More precisely, $genocide\_toll_{1994,i}$ will be biased downward if Hutu relatives are included as survivors, which is likely to occur more in localities in which Tutsi were well integrated. In the empirical application of the article, the possible bias stemming from this form of measurement error is attenuated by including controls for the share of Tutsi in the population and the proportion of inter-ethnic marriages

The pre-genocide Tutsi population

$Tutsi\_population_{i1994}$ is an estimate of the 1994 sector-level Tutsi population, which is calculated on the basis of 1991 sector-level total population (pop_{i1991}), the 1978-1991 commune level annual population growth rate $\left(pop\_growth_{c1978-1991}\right)$ and the 1991 commune-level proportion of Tutsi ($share\_Tutsi_{c1991}$) [4]. More precisely:

$$Tutsi\_population_{i1994} = \left(pop_{i1991} * \left(pop\_growth_{c1978-1991}\right)^3\right) * share\_Tutsi_{c1991} \qquad (2)$$

Within commune variation in $pop\_growth_{c1978-1991}$ and $share\_Tutsi_{c1991}$ will cause measurement error in $Tutsi\_population_{i1994}$. Therefore, in the empirical application of the article, I compare the results from the sector-level analysis with the results of a commune-level analysis in which the death toll is calculated at the commune level.

The accuracy of $Tutsi\_population_{i1994}$ also depends on the appropriateness of projecting

accusation due to intimidation of witnesses, including murder or attempted murder of potential gacaca witnesses. In addition, the fifth report of the PRI research team (Penal Reform International, 2003) in Rwanda on the operation of gacaca makes mention of "very little participation of the population...Above all in towns or around churches where many people were killed...making it difficult to identify the culprits and to know exactly what happened". They find that "it is mainly the survivors who testify, while non-survivors hesitate and when they speak of killings, these usually concern the ones carried out by people who are either in prison or dead, or who have disappeared or fled." It is therefore expected that under-reporting of genocide suspects is especially problematic in those areas with few survivors.

[3] Personal correspondence. The name of the prosecutor is withheld for confidentiality reasons.

[4] $Population_{i1991}$ and $population\_growth_{c1978-1991}$ were obtained from the 1991 and 1978 population census data provided by the Rwandan National Census Service, while $share\_Tutsi_{c1991}$ was downloaded from IPUMS International website (Minnesota Population Center).

pop_{i1991} forward to 1994 using information on population growth between 1978-1991. The two distance measures (sector-level distance to the nearest road and the nearest town) that are included in the empirical analysis are arguably closely related to population growth and may account for differential growth rates between 1991 and 1994.

Finally, the reliability of $Tutsi\_population_{i1994}$ hinges on the reliability of the population census data. Verpoorten (2005) provides evidence indicating that the 1991 population census is highly reliable for total sector-level population numbers, but not for ethnicity-specific numbers. In particular, using data for Gikongoro Province, it is shown that there was on average 40% under-reporting of Tutsi, either by the Habyarimana regime, or by Tutsi themselves[5]. In order to obtain a more accurate figure for the overall death toll, I repeat the calculation of $genocide\_toll_{1994,i}$ using an adjusted measure of $share\_Tutsi_{c1991}$, i.e. $share\_Tutsi_{c1991} * 1.4$.

Sub-national variation in the extent of under-reporting may cause bias. For example, in areas with relatively large under-reporting of Tutsi, the calculated death toll will be biased downward. In the empirical application of the article, such a bias may result in an erroneous estimate of the impact of population pressure on the death toll if under-reporting is correlated with population pressure[6]. However, this is unlikely to be a concern. First, for one province (Gikongoro) for which the national census data can be compared with another data source (the data of the local administration in which there was no under-reporting), the comparison does not reveal that under-reporting of Tutsi varies with population density. Second, the anomalous values (negative values) of the calculated death toll are not concentrated in high or low density areas (see also below). Third, including or excluding a control for the share of Tutsi in the population, leaves the results of the empirical analysis unchanged (see the empirical section of the main article).

The natural death rate between 1994 and 2005

There are no estimates of post-genocide natural death rates among genocide survivors. Therefore, I proxy for d_n using information on adult mortality rates from the general population estimated from the 2000 Rwandan DHS survey (Timaeus & Jasseh, 2004). The estimates equal 8.1 and 11.8 for women and men aged 15 to 60, respectively. Taking a

[5] An undetermined number of Tutsi registered as Hutu in order to avoid discrimination. In addition, the Habyarimana regime is said to have deliberately under-reported the number of Tutsi in order to keep their school enrolment and public employment quotas low.

[6] If under-reporting is highest in areas with relatively high population pressure, then the estimated impact of population pressure on the death toll will be biased downward and vice versa.

weighted average with the weight for women reflecting their approximate share among the survivors recorded in the Gacaca (2/3), I obtain a proxy of 9.2 for d_n.

This proxy is at the national level. Hence, $genocide\_toll_{1994,i}$ will be biased upwards (downwards) in localities with a relatively high (low) post-genocide natural death rate. This bias is partly controlled for in the empirical application by including commune-level infant mortality as a control variable.

Anomalous values and implications for the empirical analysis in the article

The genocide's death toll $genocide\_toll_{1994,i}$ includes a number of anomalous values. In particular, it is negative for 96 administrative units (out of the 1390), which is likely to be due to one or more of the measurement errors discussed above. Importantly for the purpose of the analysis, the distribution of anomalous values is unrelated to population density, which increases confidence that the sources of measurement error are unrelated to population density.

For the main results presented in the article, I restrict the sample to observations for which $genocide\_toll_{1994,i}$ is non-negative. In addition, as indicated above, several control variables may act to attenuate the impact of possible measurement error in the remaining observations, i.e. the commune level share of Tutsi in the population, the 1991 commune level proportion of inter-ethnic marriages, the two sector-level distance measures and the commune level infant mortality rate.

In a first robustness check, I use the complete sample including the negative values for $genocide\_toll_{1994,i}$. In a second robustness check, I use the complete sample, but censor $genocide\_toll_{1994,i}$ to zero. In a third robustness check, I calculate the genocide death toll at the commune level to rule out bias stemming from within commune variation in $pop\_growth_{c1978-1991}$ and $share\_Tutsi_{c1991}$.

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