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Executive summary

Introduction

- Tools for automated quantitative analysis of information are more and more required in the framework of early warning systems, to support political decision makers in making timely evaluations of the risk of severe crises.
- This report describes a scientifically sound approach to build a statistical model to assess quantitatively the risk of intra-state armed conflict in any country in the world.
- Attention is paid to operationalise this approach in early situation assessment.
- Conflict risk assessment studies investigate the causal link between the risk of an armed conflict and a given set of socio-economic indicators such as, among others GDP, GDP growth, exports and imports .
- Some variables may not be causes but simply associated factors (e.g. infant mortality, life expectancy).
- For decision makers the output of a conflict prediction model should be the location, time frame, impacts of conflict and conflict response feedback effects.
- Models using structural data make a static assessment of country level performance, which can then be ranked for conflict risk. The temporal trend provide additional information on the evolution of the situation.

Method

- The study models the incidence of armed conflict; the dependent variable is coded 1 for all periods of ongoing war.

- Twenty structural indicators were selected on the basis of data availability and relevance.
- The indicators have been extensively used in other studies and have been shown to be related more or less to the risk of armed conflict.
- We checked the distribution of all the variables, transformed the data for normalisation and variance stabilization and standardized the data.
- A Markov Chain Monte Carlo or MCMC method was used to impute missing values.
- The regression model estimates the probability that an armed conflict occurs in a specific country in a specific year.
- A variable selection method was applied to reduce the number of variables in the final model and improve its consistency.
- Countries that experience an armed conflict are more prone to another conflict in the future. For each country and for each year, we estimated the probability of conflict due to the conflict history.
- We finally took the average value between the probability estimated with structural factor regression model and that related to the history of conflicts. This can be regarded as the overall risk of armed conflict given the socio-economic situation of the country in the recent past.

Outcome

- We considered several specifications of the model and data processing in order to select the method that offers the best trade-off between quality of fit and completeness in the possibility of prediction.
- The results of the first analysis show that the likelihood of armed conflict is significantly associated with the GDP per capita, the GDP growth rate, the ODA per capita, the ODA per unit of GDP, the exports par unit of GDP, the exports of merchandise, the size of the population, the level of democracy and with the different indices of social fractionalisation/ polarization.
- Time series of estimated risk provide useful information to assess if the situation is improving or worsening for each country.

Conclusion

- The regression model may be used to predict the probability of conflict outbreak and used operationally for warning about the risk of war in any country.
- However, while certain structural conditions may exacerbate already existing political tensions in a country, the mechanisms which then lead to conflict are not well understood and can be highly specific.
- The estimates for some countries must be interpreted with caution as their socioeconomic data were actually sparse. This is especially the case for Iraq and Afghanistan. However, the model can be updated easily as new data become available.
- The method outlined is operational; it can be used for estimation of conflict probability and for prediction of conflict for countries for which structural data exists; results are as good as any currently in use. Estimated probability time series show that our model is consistent over time. Appendix 1 provides an example for the Kenyan case.

Contents

Chapter 1

Bibliographical review

This chapter summarizes previous works on conflict risk assessment. This selective review concentrates on tools and methodologies that could be used to set up an early warning system. After a general introduction on current early warning and risk assessment issues, we review the main approaches to quantitatively assess the risk of an armed conflict.

1.1 Introduction

Communication facilities and broad use of digital documents provide the potential for automated quantitative information analysis to support political decision making. In the field of conflict studies, automated data processing for relevant information extraction becomes critical as a huge amounts of data are being collected on countries, political and lobbying organizations. Quantitative analysis should therefore help decision makers in evaluating the risk of severe crises early enough before their outbreak.

This paper focuses on conflict early warning, including risk assessment. While Yiu and Mabey (2005) suggested to make a distinction between the two topics, we consider that the risk assessment is a part of early warning in the sense it assesses the probability that a stable situation turns into conflict of a certain magnitude (considered as critical by the decision makers). The situation will be classified as of high concern once the probability of outbreak of a conflict reaches a given threshold. An ideal tool should be capable of gradual change in the estimation of the probability that an armed conflict occurs, from low (stability) to high values (imminent war).

Jenkins and Bond (2001), citing Davies and Gurr (1998), make a distinction between early warning and risk assessment as the latter focuses on the structural conditions leading to political tensions while early warning identifies the dynamic factors leading to political crises. This distinction is in some ways equivalent to the one proposed by Schrodt and Gerner (1997) based on the type of the source data variables. Yiu and Mabey (2005) categorize the two concepts as one being *knowable* process (risk assessment) and the other, *complex* process (early warning). Risk assessment seeks to assess the probability of future instability on the basis of estimable relationships between structural risk factors, while early warning seeks to flag emerging crises as early as possible on the basis of monitoring recognisable patterns. The overall objective is however to know if a crisis is likely to occur, and to assign a probability to this event.

Quantitative methods applied to conflict risk assessment can be classified into two categories according to the type of independent variables used to predict or estimate the risk: (i) methods that use structural indicators as independent variables to explain/predict the conflict events; (ii) methods that use past conflict events to estimate the current risk. The last category try to detect changes in the trends of a given measure of (in)stability. The overall objective of these studies is to provide means of estimating the probability that a latent conflict deteriorates into an armed conflict or a major crisis. This definition does not however correspond exactly to the concept of *risk*. The risk assessment should include also estimation of the conflict impact which is not taken into account in this study.

1.2 Classification of quantitative methods

The following sections will provide the reader with a summary of studies on inter-state and intra-state conflict. Researchers often separate both types of conflict because it is assumed that the mechanisms behind their development are quite different. This separation is not always obvious as inter-state conflict may be the source of intra-state instability and war or the reverse. We focus on studies that involve quantitative analysis. They can be grouped into three categories according the method used to estimate the risk of armed conflict or to understand the effect of the factors or causes of conflicts. We should also classify in the later category studies aiming to understand the correlation between the conflict prevalence and measurable structural or dynamic indicators.

1.2.1 Conflict risk-measuring index

Conflict risk-measuring indicators have been often used since they are readily interpreted. The method consists in aggregating several basic indicators.

The indices differ according the basic indicators used and the aggregation method. We will examine two indices already used or applied to conflict studies – the Conflict-Carrying Capacity (CCC) proposed by Jenkins and Bond (2001) and the CIFP[1] risk index (Ampleford et al., 2001)– and one applied to environmental studies but which can be easily adapted to conflict studies, the Environmental Sustainability Index (Esty et al., 2005).

The Conflict-Carrying Capacity index

The CCC index (Jenkins and Bond, 2001) is defined as a measure of the ability of the state to regulate intense internal conflict without loss of system integrity. In practice, it is based on the frequency of civil contentious actions, state contentious actions and violent contentious actions. If C_c is the number of civil contentious actions during a given time interval, e.g. one month, S_c is the number of state contentious actions, C_v is the number of civil contentious violent actions, S_v is the number of state contentious violent actions, and C and S are the total civil and state actions, then,

$$CCC = 1 - \frac{C_c}{C}.\frac{S_c}{S}.\frac{C_v + S_v}{C_c + S_c}. \tag{1.1}$$

According to the authors of this index, CCC scores above 90% represent relatively stable situations. They provide a range of realistic combinations of the three components of CCC and a description of the situation. The basic data used to construct the CCC index are extracted from press reports. The index was applied to the KEDS/PANDA data set[2] obtained by automated coding and classification of global news reports on social, political and economic actions. The success of such an index is highly dependent on the quality of the data, mainly on effective classification of the events. Furthermore, the event count measures are vulnerable to media coverage bias in which critical events go unreported due to issue attention cycles–the *media fatigue* phenomenon– and the withdrawal of reporters.

The CIFP risk index

The CIFP risk index is an aggregation of a number of socio-economic structural indicators. The aggregation function is the weighted mean of 9 composite indicators built from 47 basic indicators. Each basic indicator is an average of the rank scores achieved by the country during the last five years on a 9-point scale. The basic indicator is corrected to take into account the

[1]Country Indicators for Foreign Policy

[2]http://www.wcfia.harvard.edu/ponsacs/research/PANDA_IDEA.htm

trend over the last five years (+1 if the indicator is worsening and -1 if it is improving) and the variability also over the last five years (+2 for high variability and +1 for low variability). The basic indicators are grouped into 9 composite indicators and averaged. Finally, the overall index is calculated as a weighted mean of the 9 composite indicators. The weights are assigned on the basis of the postulated magnitude of its impact upon overall risk.

Since this index is based on ranking countries and dividing the sample into 9 equal categories, it must be applied on the same countries each year. Otherwise the index value for a country could change because it is compared to a different country dataset. It is designed to monitor the stability performance of a country among a group of at-risk countries. In fact, the CIFP project monitors 130 developing countries. The most recent data covers the period 1985-2004. The dataset is normally up-dated each year.

The CIFP database contains a number of structural indicators broadly used in studies aiming to model quantitatively the risk of a conflict. While being relatively simple in its definition, the CIFP index produces results almost similar to those of more sophisticated statistical models. Its main limitation is that it requires expert judgment for the ranking of some basic indicators and for the trend and variability scores.

As a quantitative tool to estimate the risk of conflict, the CIFP index must be carefully interpreted. The analysis of the CIFP country ranking of 2002 showed that the overall index values varied between 3.60 (Antigua and Barbuda) and 7.80 (Democratic Republic of the Congo) on a 0-12 scale. All the 106 monitored countries are therefore classified in medium and high risk categories. Furthermore, all countries (17 countries) with a score greater than 6.90 (high risk category) in 2002, were indeed at war in 2002, excepted for Iran. But countries that experienced civil war after 2002 like Haiti, Ivory Coast, Yemen, are in the medium risk category together with all the 86 remaining countries.

Environmental sustainability index

Although the topic of this paper is conflict risk assessment, we may gain insights in exploring other fields using multiple variable composite indicators like environment studies. The *Environmental Sustainability Index–ESI* (Esty et al., 2005) is one of such composite indicators combining a large number of variables. It is intended to benchmark the ability of countries to protect the environment over the next several decades. In this sense, its concept may be transposed to conflict studies because we are interested in the evaluation or benchmarking of the conflict risk in a given country relative to others.

Details on building this index and its sensitivity analysis are given in Esty et al. (2005). We focus in the next section on its computation.

The ESI score represents an equally weighted average of 21 indicator scores. Each indicator is also an equally weighted average of between 2 and 12 underlying variables, for a total of 76 variables. The variables are firstly standardized by subtracting the mean from the observation (if the variable *contributes positively* to the overall score) or by doing the opposite subtraction (if the variable *contributes negatively* to the overall score), and dividing the result by the standard deviation. The authors decided to settle uniform weighting because a such simple aggregation is transparent and easy to understand. Moreover, there was no supporting theory or objective mechanism to determine the weight allocation among the basic variables. But this two-level aggregation gives actually greater weight to variables included in composite indicators made up with few variables than ones with more variables. The impact on the overall score is however low as a large number of indicators is retained.

The main discussion is finally about relative performance of the different countries according to their ESI score rather than the absolute value of the score. Thinking in terms of conflict risk assessment, a similar index would be based on the assumption that peaceful countries will always be the majority so that the ranking allows to identify countries at risk, i.e. those on the top or on the bottom of the ranking. However, a benchmarking indicator can be misleading in risk assessment as it will suggest that there are always "good" and "bad" performances even if the overall situation has noticeably improved.

1.2.2 Regression approach

Conflict studies aiming to find a causal relation between structural indicators (independent variables or factors) and the risk of conflict (dependent variable or response) rely basically on regression analysis. The dependent variable is generally coded in a binary way: war (1) and peace (0). The logistic regression approach has been widely used in conflict risk studies (see e.g. Beck et al., 2000; Bennett and Stam, 2000; Goldstone et al., 2000; Elbadawi and Sambanis, 2002). These studies aim usually to find the relation between the risk of conflict and a given set of indicators related to one or a few topics. The most studied explanatory variables are economic indicators (GDP, GDP growth, exports and imports), demographic and societal indicators (total population, population density, life expectancy, infant mortality, school enrollment, social fractionalization, etc.), political indicators (regime type and duration, involvement in international organizations, peace duration, political rights, neighboring countries in war, etc.) and environmental variables (spatial dispersion of the population, mountainous terrain, forest cover, cropland area, irrigated land, etc.).

From this list, which is not exhaustive, we can already see that some variables are not actually explanatory variables, but just correlates of risk of war (e.g. infant mortality, life expectancy). We must, therefore, be careful in interpreting the regression results. For instance, in the *State Failure* study (Goldstone et al., 2000), it has been shown that the following variables were significantly associated with the risk of state failure: infant mortality, regime type, total population, population density, bordering countries with major conflict and trade openness (sum of imports and exports divided by the GDP). The authors propose logically to interpret the infant mortality variable as a measure of economic development and well-being. As the *State Failure Task Force* proposed a model to forecast the risk state failure, we can use their results to evaluate its performance, five years later.

Once the regression model is estimated, it might be used to predict the probability of conflict outbreak and used operationally for warning about the risk of war in any country. However, most of these studies limit their investigations on the effect of the independent variables in the model (causal explanation), and they don't discuss the prediction, or forecast, issue. This shortcoming was already pointed out by Beck et al. (2000) but most of later studies did not consider the issue (see e.g. Collier and Hoeffler, 2004, 2002b; Elbadawi and Sambanis, 2002; Fearon, 2005). Regression models are evaluated solely on the basis of their quality of fit. Beck et al. (2000) evaluated accuracy in predicting the risk of conflict on the basis of a complex neural network model. They showed that they were able to forecast 17% of the international conflicts, that it is in 17% of the cases, the predicted probability was greater than 0.50 and the conflict did occurr as well. However, they didn't show the proportion of false alerts. We will discuss the model assessment issue in more detail later.

In order to have insights on what could yield a model like one proposed by Collier and Hoeffler (2004), I computed the predicted probability of civil war using the same model and data as in the cited paper. A map of such probabilities by country for the period 1995-1999 is shown in figure 1.1. This map shows that there are 10 countries for which the predicted probability is greater than 0.20 (this threshold corresponds to a sensitivity of the model of about 50% whereas its specificity remains sufficiently high, more than 90%). They are in the decreasing order of the predicted probability: RDC, Nigeria, Ethiopia, Rwanda, Nicaragua, Sierra-Leone, India, Zimbabwe, Mozambique and Romania. Among these 10 countries, two (RDC and Sierra-Leone) were considered as having experienced a war initiation between 1994 and 1999. According to the data used in this study, we know also that Ethiopia, Rwanda, Mozambique, Nicaragua and India had been at war in the precedent 5-year period. However, a strict analysis should consider that the model fit well for only two countries and that it was unable to predict any future war. Indeed, none of the 10 countries has experienced a war initiation in the subsequent 5-year period (2000-2005). Some of them remained however instable. Thus, we could interpret the output as a measure of risk of instability rather than as the risk of war initiation.

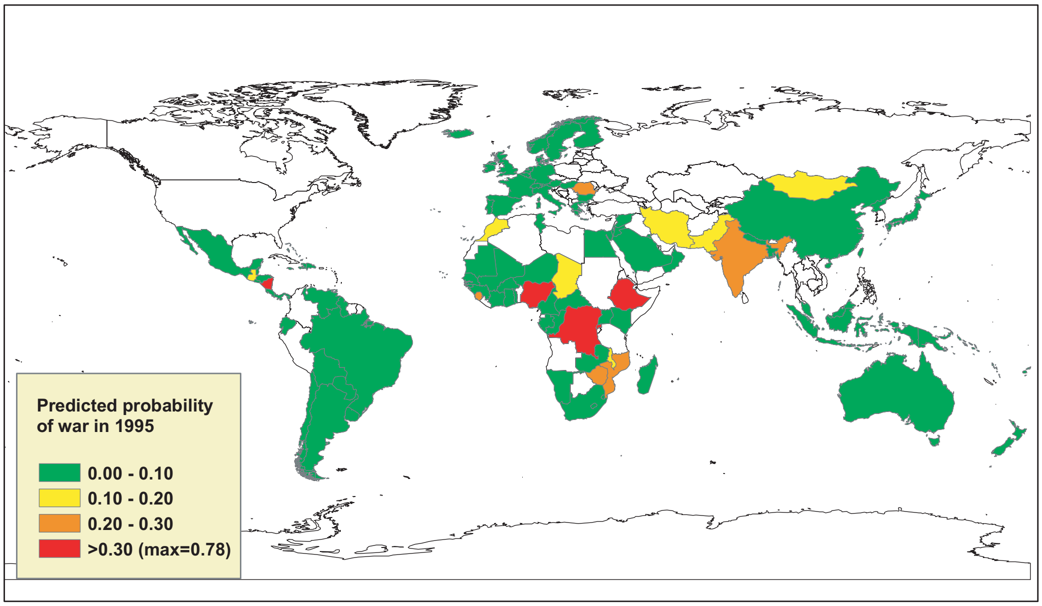


Figure 1.1: Probability of war, for the period 1995-1999, estimated on the basis of data from Collier and Hoeffler (2004).

In this category of conflict related studies we should mention the several studies trying to understand the link between conflict occurrences (or duration) and particular group of factors, e.g. natural resources (Olsson and Fors, 2004; Lujala et al., 2005; Snyder and Bhavnani, 2005; Urdal, 2005; Weinstein, 2005), demography (Slack and Doyon, 2001), environmental factors (Toset et al., 2000; Buhaug and Lujala, 2005), etc.

1.2.3 Clustering approach

The purpose of cluster analysis is to place objects into groups or clusters suggested by the data, not defined a priori, such that objects in a given cluster tend to be similar to each other in some sense, and objects in different clusters tend to be dissimilar. The groups resulting from a cluster analysis must be meaningful, otherwise the analysis is useless for decision making, or for phenomenon understanding. We are therefore interested in finding groups of countries enough separated/separable so that each group can be associated with one and only one level of conflict risk, and vice versa.

Though it seems to be a simple solution to use clustering methods to classify countries into different categories of conflict risk on the basis of structural indicators (economic, social, demographic and environmental indicators), only few studies that have actually used this approach are reported. In this category, we may cite the works by Wolfson et al. (2004) which tried to find clusters of states based on their political, economic and conflict characteristics. The study used a dataset of 18 variables and 127 countries, compiled from four sources:

1. Polity IV dataset: it contains coded annual information on regime and authority characteristics for all independent states (with greater than 500,000 total population) in the global state system and covers the years 1800-2003. It's available at `http://www.cidcm.umd.edu/inscr/polity/`.

2. Penn World Table: it provides purchasing power parity and national income accounts converted to international prices for 168 countries for some or all of the years 1950-2000 (Heston et al., 2002). It may be found at `http://pwt.econ.upenn.edu/`.

3. PRIO/Uppsala Conflict Data Project: it provides detailed information on armed conflicts, trends and peace agreements, from 1946 (Gleditsch et al., 2002; Harbom and Wallensteen, 2005). It is updated each year and it may be found at `http://www.prio.no/cwp/ArmedConflict/`.

This study found that some clusters, like those grouping industrialized countries, were very stable across the time, indicating that some patterns could be recognized in a consistent way. However, the interpretation of many other clusters is not clear.

The clustering approach may be relevant for dynamic indicators because they are mainly based on counting of events. Thus it is straightforward to compute a distance measure for a such variable. However, the cluster objects are different if dynamic indicators are used. The dynamic indicators clustering try to identify phases of stability/instability for a given country or group of countries of interest, namely those involved in the same conflict. For instance, Schrodt and Gerner (1997) applied this approach to an event data set in attempting to show that these events tend to form temporally-delineated clusters and that the movement of points in those clusters can be used as an early warning indicator. The region of interest was the Middle-East in the period 1979-1996, and the involved countries/actors were Egypt, Israel, Jordan, Lebanon, the Palestinians, Syria, United States and Soviet Union/Russia. They identified a number of phases in the time-series of the event scores. The phases could be related to particular events that were particularly highly covered by the media. This study provides actually a method to find patterns in the time series of events data.

1.2.4 System dynamics modelling

The regression methods presented in section 1.2.2 treat the conflict problem in a static manner. They consider the effect of socio-economic and environmental factors to the risk of conflict, but they ignore the feed-back effect of the conflict on the values of those factors. The periods of violent conflicts are usually removed from the time series data used in regression analysis to avoid the bias introduced by a such feed-back effect. However, one could argue that this effect remains for long time after the end of the violent conflict so that it can not be totally eliminated by simply selecting peaceful periods. Indeed, the causes and consequences of conflict are highly interconnected. From this point of view, the risk of conflict should be modelled in a more dynamic manner.

System dynamics is a methodology for studying and managing complex feedback systems. Feedback refers to the situation of X affecting Y and Y in turn affecting X, perhaps through a chain of causes and effects. One cannot study the link between X and Y and, independently, the link between Y and X and predict how the system will behave. Only the study of the whole system as a feedback system will lead to correct results. From a theoretical point of view, the system dynamics approach seems to be the best suited to study the link between the risk of conflicts and structural indicators.

Wils et al. (1998) proposed simulations of internal and international violent conflicts based on their theory of lateral pressure and system dynamics modelling. Their model was based on four basic indicators on the country level: the population size, the level of technology (measured by the purchasing power parity per person), the natural resources (measured by the land area[3]) and the military expenditure (as a percentage of the GDP). They applied the model to seven African countries (Angola, Botswana, Burundi, Mozambique, Rwanda, South Africa and Zambia) and 6 countries members of the Organisation for Economic Co-operation and Development – OECD (France, Germany, Netherlands, Sweden, United Kingdom and United States). Their model *predicts* multiple internal conflicts in Burundi and Rwanda between 1960 and 2060, whereas no conflict is *foreseen* for the other countries, because of high internal tensions (due to high population densities) in the former. It *predicts* also several international conflicts for all the OECD countries, except for Sweden, because of their growing population densities and higher levels of technology[4].

The main advantage of the system dynamics approach is that it allows a clear description of the problem and the interactions between causes and consequences of conflicts. Feedback interactions are not well taken into account in the other approaches.

However, the advantage of using a system dynamics approach rather than using classical regressions coupled with a time series forecasting method is not obvious from this study. System dynamics approach suffers the same limitations as regression methods, i.e. data quality and availability, and purely theoretical background of the relationship between the risk of conflict and structural factors. Furthermore, the specification of parameters and equations of the system may be highly subjective.

1.3 The international dimension of local conflicts

One of the main limitations of current quantitative methods is the country-level analysis which does not take into consideration external intervention. In his book on the diffusion of conflict, integration, and democratisation, Gleditsch argues that the domestic processes within countries, taken in isolation cannot account for the observed variation in distribution of political democracy over time and space. The likelihood of transitions is strongly related to changes in neighboring countries and the prior history of the region (Gleditsch, 2002). As far as armed conflicts are concerned, external interventions are an almost universally common factor of all so-called internal

[3]The authors underline that this term is not a precise representation of the resource notion, but that they used it in the absence of data of other natural resource variables.

[4]One assumption of the authors states that the technology growth contributes to the increase of the risk of international conflict.

conflicts. These interventions are not limited to neighbouring countries. Interventions can be direct or consist in different kind of support of one party in the conflict.

The PRIO dataset contains 31 intrastate armed conflicts in 2005, occurring in 22 countries. A brief review of actors, and admitted/presumed external interventions in these conflicts reveals interventions including troop engagement, funding, training providing a territory for training and organising attacks, and/or diplomatic support in international fora.

1. Philippines vs. CPP: This conflict opposes the Philippines's governement and the Communist Party of the Philippines (CPP). It is founded on the Marxist-Leninist ideology and affirms to carry revolutionary war to combat the US imperialism, among others objectives. The US Government considers it as a terrorist organisation. At this level, it is already clear that this conflict has an international dimension. It should not be analysed solely in the Philippines national framework. The US are providing military support to the government forces. Are rebels also receiving support from a foreign state? The rebel group is active in the north of the main island.

2. Philippines vs. ASG and the Moro Islamic Liberation Front (MILF): This separatist conflict is taking place on the territory of Mindanao. The US provide support to governmental troops in this conflict, and, according to the US Institute for Peace, the MILF received support from Libya and Malaysia in the 1990s, and had or still has ties with Al-Qaeda and Jemaah Islamiyah.[5] Libya and Malaysia are indeed still heavily involved in peace talks between the MILF and the government. There is external input on both sides in the conflict.

3. India vs. several organisations active in the North-East: These organisations are the National Socialist Council of Nagaland-Khaplang (NSCN-K), the United Liberation Front of Asom (ULFA), the NSCN-K is a Naga separatist movement and its goal is an independent Nagaland state (North of India) consisting of all Naga territories (in India and Myanmar) with a socialist government. The ULFA, which fights for a sovereign independent state of Assam, is said to receive support from Pakistan and Bangladesh.[6] Another hot point is the Kashmir region, which is disputed between India and Pakistan.

[5] http://www.usip.org/fellows/reports/2005/0609_abuza.html
[6] http://www.globalsecurity.org/military/world/war/assam.htm

4. Myanmar vs. KNPP, KNU and SSA: The Karenni National Progressive Party (KNPP) is a separatist movement fighting for independent state of Karen (south-east of Myanmar, border with Thailand). The Shan State Army on its part fights for an independent Shan state. The Karen National Union is fighting for Karen people autonomy. A rapid search of information did not provide evidence of foreign support to rebels or to governmental troops.

5. Iraq: This is clearly an intrastate conflict driven by external intervention. The internal conditions are far from being the main explanatory factor.

6. Sudan: The conflicts in Sudan carry also an international dimension in that sense some rebel groups are said to receive/have received support from Chad, and others from Uganda. The diplomatic relations between Sudan and these countries have been troubled by mutual accusations of supporting rebel groups on both sides as the Sudanese government is also said to support Chadian and Ugandan rebels.

7. Uganda: see the Sudanese case above.

8. Chad: see the Sudanese case above.

9. Israel: the case is well documented. The palestinian movements receive support from different states, and the conflict has involved neighbouring countries at several times.

10. Nepal vs. CPN-M/UPF: This conflict opposes Nepali governmental forces to the Maoist rebels of the Communist Party of Nepal (CPN-M) and the United People's Front. Whereas Nepal is an important piece in the China-India rivalry, it seems that China did not support openly the rebel movement while India supported the governmental side. [7]

11. Burundi vs. FNL/Palipehutu: Involvement of other countries in this conflict has been low, but it is known that the burundian rebellion received full support from Rwanda (until 1994) and Tanzania, and that they used the DRC's territory to organise themselves when they began targeting objectives in the western region of the country.[8] [9]

[7] `http://www.monitor.upeace.org/archive.cfm?id_article=341`
[8] `http://www.crisisgroup.org/home/index.cfm?id=1656&l=1`
[9] `http://www.iss.co.za/Af/profiles/Burundi/SecInfo.html`

12. Colombia vs. FARC and ELN: This conflict opposes the Colombian governmental army and two left-wing guerrilla groups, the Revolutionary Armed Forces of Colombia (known by their Spanish initials, FARC) and the National Liberation Army (ELN). The governmental side receives military and financial assistance from the USA in the framework of their international narcotics control strategy.[10] [11] It is not clear if the rebel side receives also external aid.

13. Ethiopia vs. ONLF: This conflict opposes the governmental army to the rebels of Ogaden National Liberation Front, which is fighting for an independent state in the Ogaden region dominated by Somali people. It has direct connections with the Ehiopia-Somalia conflict.

14. Turkey vs. PKK: This conflict can be viewed as having an international dimension as the PKK (Kurdistan Workers Party) has its bases in Turkey, Iraq, Iran and Syria. The PKK is fighting for independent state of Kurdistan, comprising part of Turkey, Iraq, Iran and Syria.

15. Azerbaijan vs. Republic of Nagorno-Karabakh. The latter is supported by Armenia.

16. Afghanistan vs. Taleban: the conflict involves troops of several western countries on the governmental side.

17. Sri Lanka vs. LTTE: There are some claims that the Liberation Tigers of Tamil Eelam (LTTE) receive support from Eritrea and Indonesia.[12].

18. Indonesia vs. GAM (Free Aceh Movement): A rapid search of information did not provide evidence/claims of foreign support to GAM rebels or to governmental troops.

19. Russia vs. Republic of Chechnya: A rapid search of information did not provide evidence of foreign support to rebels or to governmental troops.

While bearing in mind this shortcoming, we consider nevertheless that purely internal factors can provide information on state fragility, high conflict opportunity and low coping capacity that can be used to estimate the risk of an armed conflict. The estimates will provide a baseline for experts and analyst to refine assess the actual risk level.

[10] http://www.insightonconflict.org/conflict_area/colombia/index.html

[11] http://fpc.state.gov/documents/organization/49081.pdf

[12] http://www.news.lk/index.php?option=com_content&task=view&id=3328&Itemid=44

Chapter 2

Data issue in conflict studies

In the previous chapter, we underlined the limitations of some quantitative structural approaches due to lack of suitable data. In this chapter we give an overview of these limitations. We discuss firstly on the measurement of the level of country stability or instability (the dependent variable). Secondly, we review the main data sources for independent (explanatory) variables and their link with the risk of armed conflict.

2.1 How to measure the (in-)stability of a country?

Conflict risk assessment studies have usually considered the occurrence of war as the main variable to analyse. They use a binary variable, i.e. war or no war. This is the simplest way of quantifying the instability if the value "war" is clearly defined. Let us consider the civil war case. Scholars have adopted a working definition of *civil war*: an internal conflict with at least 1000 combat-related deaths per year. In order to distinguish wars from massacres, both government forces and an identifiable rebel organization must suffer at least 5% of these fatalities (Collier and Hoeffler, 2004, citing Small and Singer (1982)).

The Political Instability Task Force (PITF) used a similar binary measure which included revolutionary wars, ethnic wars, genocides, politicides and adverse regime changes. The dependent variable had two values "state failure" and "non-failure" if it experienced or not at least one of the cited events in the considered year (Goldstone et al., 2000).

If the observation unit is the country, the number of conflicts satisfying the above definitions –civil war or state failure– each year are actually too few for robust statistical analysis. In order to overcome this limitation, all studies use the country-year combination as the observation unit. This raises, however, the problem of *anachronistic* analysis and autocorrelation in the regressors. The autocorrelation problem may be technically resolved by its explicit modelling. It remains to verify if the assumption that the mechanisms behind the violent conflict genesis are similar across time.

The use of a binary variable is convenient for studies on *war prevalence* because the use of the well documented logistic regression is straightforward. However, the limitations of this approach in practical assessment of the risk of armed conflict, or on the risk of aggravation of on-going "low-intensity" conflicts, in the context of conflict prevention or humanitarian intervention have been noted. Scholars have tried to code the intensity of a conflict, war as well as *low-intensity* conflict, on an ordinal multilevel scale. For instance, the KOSIMO database (Pfetsch and Rohloff, 2000) codes the intensity of conflicts on a 5-level scale. In the UCDP/PRIO Armed Conflict Dataset (Gleditsch et al., 2002), the conflicts are classified into 3 groups based on their intensity, that is the number of casualties they have caused.

The instability measure can be operationally substituted with the probability of war as far as we can assume that the link function is monotonic and increasing. The estimation of this probability can be carried out on the basis of the number of on-going wars (frequency approach) or from another theoretical model (bayesian approach).

2.2 Structural (explanatory) factors

In this section we provide a framework of a conceptual model to estimate the risk of instability on the country level. The model is based on structural indicators and could be extended with dynamic indicators and serve as an operational early-warning system. The dependent variable of the model has been discussed in section 2.1, this part focuses on the independent variables.

Our aim is to select from the conflict literature the most important structural features of countries which have experienced armed violence in order to draw some conclusions about which structural characteristics or factors increase the probability of conflict. A further aim is to understand the interaction of factors using concepts from the main empirical studies. As Vasquez (2000) points out, this is a complex problem: conflict could be the result of unique and changing combinations of multiple factors, and there may well be different causal paths to war where factors that are important in one sequence have no bearing on another sequence (Levy, 2000). This notwithstanding, the study will describe the theoretical concepts behind our choice of factors and connect theories to empirical evidence from the main large-N studies from the field of political science and international relations. The main challenge will be to produce a meaningful overview from studies sometimes using different definitions, datasets, and methodologies at different levels of analysis.

As our study is concerned with macro level effects on international and internal conflicts, it will try to draw some conclusions which apply globally, at country level and over time. The analysis is static, and is limited to the country level, which means that theories covering the international system level such as polarity, power balance, system transition are not taken into account. The relationships between actors in conflict, though extremely important, have also not been considered in any detail.

To avoid the usual trap of building a theoretical model but useless because of the lack of reliable data, we will try to use as input those indicators that are regularly and consistently reported in the different statistics services of international organizations (UN, World Bank, etc.). The indicators are grouped into nine categories corresponding to main studied factors of armed conflicts. They are the political system, state capacity, external influences, economy, geographical features, demography, human capital, experience of conflict and environmental features.

2.2.1 Economic indicators

In recent years there have been a large number of quantitative studies addressing the economic aspects of conflict. Some have been from economists drawing on concepts from human capital or rational choice theory (Collier and Hoeffler, 2004; Østby, 2005; Geller, 2000; Brecher et al., 2000). They argue that poor macro-level economic conditions or their deterioration (growth) may provide motivation for conflict especially if the costs of rebellion are low. Two indicators are usually used to account for the economic factor in conflict models: the gross domestic product (GDP) and its growth rate. Some studies suggested also a relationship between trade flows (exports, imports, foreign investment) and the risk of conflict (or instability).

GDP per capita

Some scholars consider that one of the root causes of violent conflict is the scarcity of resources. When *sufficient* resources are *distributed equally* among a population, there is no incentive for conflict. The GDP per capita can measure the level of available resources per capita –sufficiency– but not distribution equity. It can be also a proxy of the capacity of the country to manage conflicts. It is almost always included in regression models that we have reviewed.

GDP growth

The hypothesis is that when the economic situation worsens, internal tensions rise and the risk of conflict does as well. Among studies including this variable in their models are for instance Collier and Hoeffler (2002a, 2004); Fearon (2005); Poe et al. (2006). The effect of this variable is reported to be consistent as it is shown to be among a set of 18 robust variables explaining the risk of civil wars in the sensitivity study by Hegre and Sambanis (2006). However, the change of growth rate does not show particular pattern for countries having experienced armed conflicts compared to countries of the same income group (figure **??**). The growth rate of unstable economies change usually varies sharply because when there is an economic shock, the growth rate reaches very low negative values (less than -10%), and pass again to about +10% in the next year. In the context of conflict studies, economic instability should be more meaningfull than the level of economic growth. Growth rate variance over a given period, longer than two years of course, could be a usefull indicator.

2.2.2 Socio-demographic indicators

This section gathers variables that are related to demography and human (or social) development. Some of them could are in somehow identity-related, but we propose to keep them in this section because they are measured on the basis of the population distribution among different groups.

Total population

The population size is often included in conflict models as either a control variable to weigh other variables, or as a factor of the risk of conflict. Indeed, it is assumed that the risk of rebellion or civil crisis is, *ceteris paribus*, higher in large populations than in small populations. Another justification of the use of the population size in the regression model is that the definition of armed conflict implies a threshold in battle-related deaths that is more likely to be attained in large size population than in small size population.

Population density

Some authors have argued that population density is positively correlated to risk of civil war (de Soysa, 2002; Hauge and Ellingsen, 1998; King and Zeng, 2001b; Goldstone et al., 2000), but others find that its effect was not significant (Collier and Hoeffler, 2004) or do not include it in their analysis at all (Elbadawi and Sambanis, 2002; Ross, 2006; Urdal, 2004). In Urdal (2005), the coefficients of the population density factor in the regression model are even negative, suggesting that there would be less risk of armed conflict in countries with high population density. These contradicting conclusions may be due to model specification and the way that conflicts are coded. As this variable is easily calculated (from the total population), we propose to include it in our tests and verify what is its real relationship with the risk of armed conflict.

Youth bulge

Some studies have tested claims that youth bulges may be causally linked to internal armed conflicts. The main hypothesis is that countries that experience youth bulges are more likely to experience internal armed conflict than countries that do not (O'Brien, 2002; Urdal, 2004). Demography-based conflict models explain instability as a consequence of an interaction between the proportion of age groups and the ability of the labour market to absorb larger, more educated youth cohorts. Urdal (2004) specifies that conflict may occur in circumstances where employment opportunities are limited after expectations have been raised from expansion of educational opportunities and there is little chance to influence the political elite. In his model however, economic performance turned out to have only a very weak effect on youth bulge conflict risk. Collier and Hoeffler (2004) disagree with Urdal (2004). Their thesis is that frustrated young males, with low educational opportunities mean that there is a low opportunity cost (young rebels have little to lose) of joining rebel movements. Urdal (2004) introduces the notion of collective group action based on a strong sense of identity and two other factors from Kahl (1998): lack of peaceful means to bring about change or express dissent (although youth bulge does not vary in effect with different levels of democracy) and opportunities for violent actions against the system. Urdal (2004) also introduces the idea –from Goldstone (2001)– that educated youth provide a core leadership in popular mobilisation, bridging gaps between social groups to cause revolts; an explanation which may account for successful recruitment strategies of rebel groups and terrorist organisations. Other studies suggest youth bulges interact with ethnicity (Huntington, 1996; Urdal, 2004; Esty et al., 1998). As a measure of the youth bulge, we will use the proportion of young people (15-24 years) to the total adult population as suggested by Urdal (2004).

School enrollment

This is one of the indicators of human capital. The concept of human capital describes the contribution made to a society by its people in highly developed countries. This is said to be the most valuable economic input, also when financial and natural capital are taken into account. Educated citizens contribute to strong economy, reflect and support high state capacity and economic performance. Informed citizens can hold politicians accountable and choose between political competitors on the basis of credible promises (Stromberg, 2004; Besley and Prat, 2002; Adsera, 2003). The hypothesis is that low school enrollment means that a large proportion of young people are jobless and may be easily mobilised for violent demonstrations and recruited in military operations (either by the eventual rebels or by government army). Moreover, they are more vulnerable to propaganda than those who are occupied with studies. We will use mainly the secondary school enrollment rate because it concerns the category of young people from which propagandist and rebels try to recruit. Other variables –like years of schooling (King and Murray, 2001), percentage of population completing tertiary education– have been suggested but are sparsely covered in open source databases. The literacy rate that is largely used in assessing social development has been rarely used in conflict models. Apart from the CIFP global index, we did not find other study including the literacy rate in its analysis.

Infant mortality rate (IMR)

This indicator has been widely used in conflict models as a proxy of social welfare level (Goldstone et al., 2000; O'Brien, 2002; Harff, 2003; Urdal, 2005) or a proxy of state capacity (King and Zeng, 2001b). It measures the probability of a child dying between birth and the age of one, expressed per 1000 live births. Another variable that can be used similarly is the *under-five mortality rate* where the age interval considered is between birth and five years. The relationship between the IMR and the risk of armed conflict could be summarised as follows: high IMR value denotes a low-capacity country, and as a consequence, higher risk of conflict. The IMR is highly correlated to the GDP. Both variables are not usually used together in regression models. Some scholars have preferred the IMR to the GDP as a proxy of state capacity (Urdal, 2005, e.g.) because it should capture better the diverse aspects of development than the GDP, but it is worth noting that IMR consistent data were estimated for 10-year periods[1].

[1] More details can be found at http://www.childinfo.org/areas/childmortality/index.php

Ethnic polarisation

Ethnic differences have been widely discussed as a motivation for conflict (Horowitz, 1985; Reynal-Querol, 2002; Sambanis, 2001; Vanhanen, 1999; Elbadawi and Sambanis, 2002; Ellingsen, 2000; Urdal, 2004; Collier and Hoeffler, 2004; Goldstone et al., 2000; Harff, 2003; Fearon and Laitin, 2003; de Soysa, 2002, see e.g.). However, quantitative studies report contradicting results about the importance of the ethnicity in the onset of civil wars. For instance, Elbadawi and Sambanis (2002) found that the ethnic fractionalisation had a highly significant effect on the prevalence of civil wars, whereas Fearon and Laitin (2003); Collier and Hoeffler (2004); Montalvo and Reynal-Querol (2005) found that this effect was not statistically significant. The model specifications vary a lot so that it is not easy to compare the different studies. Horowitz (1985), which is a seminal reference on the issue of ethnic conflict, argues that the relationship between ethnic diversity and civil wars is not monotonic: there is less violence in highly homogeneous and highly heterogeneous societies and more conflicts in societies where a large ethnic minority faces an ethnic majority. If this is so then an index of polarisation should capture better the likelihood of conflicts, or the intensity of potential conflict, than an index of fractionalisation. Montalvo and Reynal-Querol (2005) proposed an index of ethnic polarisation:

$$RQ = 4\sum_{i=1}^{N} \pi_i^2(1-\pi_i), \tag{2.1}$$

where π_i is the is the proportion of people who belong to the ethnic group i, and N is the number of groups. Several studies use an index of fractionalisation calculated as follows:

$$FRAC = \sum_{i=1}^{N} \pi_i(1-\pi_i). \tag{2.2}$$

This formulation of polarisation index is rigid because it depends only on the demographic composition of groups. A more general index of polarisation should include a measure of distance between the groups. The distance would be measured in a chosen dimension(s). In this formulation, a discrete distance belong/not belong to the group has been used. Thus, this indicator can be regarded as a measure of potential polarisation. The risk of conflict due to ethnic polarisation is not constant over time as it depends on the actual use of ethnicity in explaining the causes of other social problems. Even if other factors are acting, ethnic differences are used by the groups in conflict for recruitment and mobilisation of fighters (Weinstein, 2005). Finally, the operationalisation of this polarisation index suffers from the poor quality of data sources.

The most used data on ethnic fractionalisation is the dataset compiled by the State Geological Committee of the USSR in *Atlas Narodov Mira* published in 1964. The ethno-linguistic fractionalisation (ELF) index has been built from this atlas, but sometimes authors use also the *Encyclopedia Britannica* or the *World Christian Encyclopedia*. This index has been widely used but is also criticised by several authors. One of the most shortcoming of this index, and its source, can be summarized as this: "Ethnic groups are now recognized to be social constructions with histories of expansion and contraction, amalgamation and division. If ethnic groups can grow and shrink, emerge and disappear, then the ethnic demographies they collectively define will be fluid. A measure of ethnic diversity built from data collected in the early 1960s may not accurately reflect the shape of a countryś ethnic landscape several decades later." (Posner, 2004). Fearon and Laitin (2003) proposed an alternative measure and dataset of ethnic diversity based on what he calls *ethnic groups* that are not limited to cultural and language differences. He includes a kind of membership consciousness as a criteria of defining an ethnic group. This measure is quite highly correlated to ELF (correlation coefficient of 0.75) when considering the whole dataset, but there are large differences concerning North-Africa and Middle-East countries. Posner (2004) proposed also another index based on Politically Relevant Ethnic Groups (PREG). The idea was to build a dataset of ethnic groups by country that are politically relevant. This allows change over time in the proportion of the groups because some groups can merge or split on political ground. The work has been done for 48 African countries and from the ethnic groups that had been firstly described in the *Atlas Narodov Mira*. The PREG index is less correlated to the ELF than the Fearon's index (correlation coefficient of 0.67). There is not yet a convincing index of ethnic diversity that is suitable for conflict studies and the ELF is still widely used despite that it does not evolve and despite the coding errors existing in its original source.

Religious polarisation

This indicator is quite similar to the ethnic polarisation indicator and the discussion on the quality of data can be transposed similarly. The most used data are taken from the *Encyclopedia britannica*, the *World Christian Encyclopedia* and *L'état des religions dans le monde*. Collier and Hoeffler (2004) use a social fractionalisation measure that combines both ethnic and religious aspects. There is no clear conclusion from quantitative studies on the effect of religious fractionalisation on the risk of conflict. Reynal-Querol (2002) finds a positive and significant effect of religious polarisation in explaining the incidence of civil war, and insists on the use of a polarisation index rather than a fractionalisation index. It is however worth noting that she limited her analysis on what are coded as "ethnic civil wars". And, surprisingly, some formulations of the model in the same study (Reynal-Querol, 2002) lead to a positive and significant effect of the GDP. Montalvo and Reynal-Querol (2005) finds that the effect of religious fractionalisation/polarisation is not significant. Their analysis includes all civil wars, not only ethnic wars as in Reynal-Querol (2002). Ellingsen (2000) finds that religion, as well as ethnic and linguistic diversity, has a significant effect when the second-largest group represents 5%–20% of the population as compared to the case of small second-largest group (less than 5%), whereas the effect is not significant if the second-largest group represents more than 20%. This finding is in contradiction with the hypothesis of Horowitz (1985). Elbadawi and Sambanis (2002); Collier and Hoeffler (2004); Lujala et al. (2005) report also results where the religious fractionalisation has no significant effect on the incidence or onset of civil war. In Goldstone et al. (2000), this effect is not significant when it is tested in the global model. The results of these quantitative studies seem to contradict the general beliefs on religion-based conflicts.

2.2.3 Resources and their distribution

Vertical and horizontal inequality

There are multiple dimensions of inequality relating social status, education and income. Within states this idea can be applied to distribution of income or non-income resources such as land. Relative deprivation of one group compared to the other, when perceived by groups as such, reduces social cohesiveness and increases the risk of between-group conflict. When "sufficient" resources (absolute amount above a defined level are perceived to be distributed "neutrally" (without link to group identity) among a population, there is little incentive for conflict. When political power, territory or scarce resources are perceived to be disproportionately and systematically controlled by clearly identifiable groups of a population there is an incentive for conflict. The most common measure of inequality used so far in quantitative studies is the Global Inequality Index (GINI). Unfortunately, GINI is a measure of *vertical inequality*, i.e. inequality between individuals, and is very limited in coverage. There have been conflicting results from both qualitative and quantitative studies. Collier and Hoeffler (2004); Fearon and Laitin (2003) find no effect of vertical inequality on conflict onset, but find a positive effect on duration. Hegre et al. (2003) find no link between income inequality and conflict onset. Recent quantitative studies have also constructed measures of between-group inequality or *horizontal inequality*, with some finding positive correlations between horizontal inequality and conflict. Montalvo and Reynal-Querol (2005); Ostby (2005) find "between-group" inequality positively correlated with conflict risk. Murshed (2004); de Soysa and Neumayer (2003); Østby (2005) find ethnically based unequal social opportunities like education are positively correlated with conflict risk, more strongly than with economic/asset measures (income, land inequality). Results seem to depend on the inequality dimension measured and on scale; group distribution does not usually coincide with state boundaries. There is no readily available dataset for subnational social opportunity. While this is a promising approach, there is at present little data on non-income or asset dimensions of vertical or horizontal inequality, particularly at subnational level. The only existing dataset is the GINI data at country level.

Natural resources

The control of natural resources like land, water, subsoil resources is probably the most ancient factor of armed conflicts. It has been simply referred to as territorial control because natural resources are linked to territory in contrast to, for example, human resources that are not tightly linked to a territory. Conflict studies on this topic had been led mainly by the malthusian theory on resource scarcity (Homer-Dixon, 1999; Renner, 1996). However, recent studies suggest that the relationship between natural resources and the risk of conflict depends on the nature of the resources.

A number of studies have shown that the abundance of lootable natural resources increases the risk of armed conflict (Collier and Hoeffler, 2004; Le Billon, 2001). By lootable natural resources they mean mainly minerals, oil, natural gas, timber, and even drug crops and medicinal plants. Collier and Hoeffler (2004) finds that countries with economy dependent on natural resources are at high risk of civil war, as lootable resources allow rebels to generate conflict financing. They introduced a measure of dependence on natural resources which is the ratio between *primary commodity* exports and GDP. The measure covers exports of minerals, oil, coal, natural gas, crude materials, beverages, tobacco as well as agricultural products (Fearon, 2005). This study raised much debate in the political scientist community due to its major policy implications. According to Fearon (2005), the Kimberley Process to end trade in "conflict diamonds" is an important policy initiative consistent with the argument of Collier and Hoeffler (2004). Elbadawi and Sambanis (2002); Fearon (2005); Hegre and Sambanis (2006) show that the results from (Collier and Hoeffler, 2004) are not robust.

Other studies focused on specific natural resources like oil (Fearon, 2005; Ross, 2004, 2006), diamonds and other precious stones (Lujala et al., 2005; Ross, 2004; Snyder and Bhavnani, 2005). These provide alternative interpretation of the widely accepted explanation that some rebellions are motivated by the opportunity of lootable resource, but the results are not robust enough for generalisation. For instance, Ross (2006) notes that "the association between *Primary diamonds* and civil war is quite robust. Still, civil wars in diamond-producing states are quite rare, which should make us exceedingly cautious about generalisations. Of the 90 civil wars that began between 1960 and 1999, only 12 took place in countries that produced diamonds in nontrivial quantities. Of these 12, only 7 happened in 3 countries that produced primary [and secondary] diamonds[2]: the Democratic Republic of Congo (DRC), Russia and South Africa". The other 5 civil wars occured in 4 countries that produce only secondary diamonds: Angola, Liberia, Sierra Leone and Central African Republic. Furthermore, it is questionable if the civil wars in Russia and in South Africa were primary motivated by the control of diamonds. Even in the DRC, the civil war of 1996 is not likely to have been motivated by the control of the natural resources. Rather, it may be more accurately described as a continuation of the Rwandan civil war.

However, we can not reject the control of natural resources as a factor of armed conflict, not only in civil wars, but also interstate wars. The conflict and killings that took place in the beginning of the colonisation period (end of the 19th century and beginning of the 20th) were clearly driven by the search for natural resources. The ongoing wars in the Middle East can be also linked to the control of oil resources. The secession wars in the DRC also are examples of conflicts that can be regarded as attempts to control mineral resources, where internal rebel groups as well as foreign mineral companies and governments are involved. However, as mineral resources are never the only factor and cases where the lootable resources are the main cause are rare, it is difficult to derive valid inferences. The same remarks can be formulated about ethnic and/or religious diversity.

The risk of conflict related to the abundance of natural resources seems to be conditional upon government effectiveness. We could test the use of a conditional regression model but there are too few documented cases. Data on natural resources are very disparate and imprecise, and the most used proxies are more appropriate to proxy other concepts. The most commonly used measure is the ratio of primary commodities exports to the GDP; both variables are generally reported in the World Bank's database. This ratio can

[2] Primary diamonds are mined from kimberlite shafts whereas secondary diamonds are scattered over alluvial plains

be actually interpreted as the measure of the dependence of the country's economy to the primary sector. High values of this measure denote weak economies. Other studies tried to split the primary commodities pool and use specific measures for each natural resource. Fearon (2005) suggests to use fuel exports (available in the World Bank's database) share in the GDP, Lujala et al. (2005) uses dummy binary variables indicating if and when diamonds have been found and exploited in producing countries. Humphreys (2005) uses diamond production (in metric carats) and the oil production and reserve (in barrels), compiling data from reviews of professionals involved in the extraction of diamonds and oil. Ross (2006) uses diamond production per capita (in USD/person) data from Humphreys (2005) and goes into more details by specifying if they are primary or secondary diamonds. de Soysa (2002) uses the stock of natural capital (in USD) which measures the entire environmental patrimony of a country; the data comes from the World Bank's database. These examples illustrate the difficulty to generalise from results of different studies with different measures.

2.2.4 Geographical context

The geographical context is a key factor in the course of armed conflicts, and its study has been clearly taken into account in interstate conflict studies. Several theories and conceptual frameworks have been developed to explain the geographical factors in armed conflicts. Stephenne and Ehrlich (In review) proposed a comprehensive review of these studies. In this part, we discuss mainly indicators (measures) that are usually employed to operationalise the geographical concepts. There is a set of indicators that measure the proximity of the conflict actors. Considering interstate conflicts, we can cite the distance between the capitals (Lemke, 1995), the minimum distance between the borders of each pair of countries provided this distance is less than 950 km (Gleditsch and Ward, 2001), contiguity or shared borders (Richardson and Wright, 1960), length, number and nature (constraint elements, civil and military infrastructure near the border, etc.) of borders (Wesley, 1962; Starr and Thomas, 2002; Furlong et al., 2006), terrain characteristics like its roughness (Buhaug and Lujala, 2005; Collier and Hoeffler, 2004; Fearon and Laitin, 2003; Montalvo and Reynal-Querol, 2005; Starr and Thomas, 2002) and land cover (Buhaug and Lujala, 2005; de Rouen and Sobek, 2004).

Proximity and nature of the border

Brecher et al. (2000); Brecher (1993) maintain, that spatial contiguity and proximity increase interactions and opportunities (willingness) for war. Hensel

(2001) counters this argument by maintaining that any pairs of stated are more likely to fight over territory, including states that border each other. Huth and Allee (2002) argues that ethnicity interacting with territorial claims involving groups that spread across borders, are most prone to escalate to war, and is supported by Brecher et al. (2000). Gleditsch and Ward (2005) further introduces the notion of ethnic, political, economic transnational linkages. Gleditsch et al. (2002); Sambanis (2001); Ward and Gleditsch (2002); Esty et al. (1998) have all discussed the notion of conflict contagion but the specific factors unclear. Collier and Hoeffler (2004) speculated about arms availability, which would affect all countries in region equally.

However geographical factors measuring the proximity can not be used directly to assess the risk of conflict in a country. The attempt to use these factors is usually driven by their positive correlation with the frequency of armed conflicts because interstate wars are more likely between neighbours than between distant countries (Gartzke and Gleditsch, 2006; Mousseau et al., 2003; Russett et al., 2000). The results of regression models are not robust, however. For instance, Furlong et al. (2006) find that the existence of shared river has a significant effect on the probability of MID when considering a very large period (1880-1992), but the effect disappears for a shorter time period (1980-1992). Moreover, they find that the border length effect is not significant contrary to the results of Starr and Thomas (2002). The latter considers that rather than the nature of the border being important, the length of the border is the primary distinguishing factor between conflict borders and non-conflict borders. The longer a border is, the greater the opportunity for interaction and, therefore, conflict. We think that what matters is the diffusion of the conflict from one country to another, and the propensity to conflict escalation when there is any incompatibility between countries sharing a border. Thus, the number and the political situation (stability/instability) of the neighbours should be more important than the length of the border. This formulation can also be applied to internal armed conflicts, whether internationalised or not, in the framework of a global model. The nature of the border can be captured by quantifying its permeability for military operations in a similar way as Stephenne and Pesaresi (2006) modelled the border permeability to illegal crossings. It seems difficult to use detailed characterisation of the neighbourhood of each country in a global model. For this, we need data on indicators of the neighbourhood of each country. Some simple indicators can however be set up: binary variables indicating if there is an armed conflict in the neighbourhood, if the country is a potential target of one of the actors of the conflict in neighbouring countries. We will use only the former variable –based on armed conflict database– because getting data on the latter variable implies reviewing the history of all countries, a task that is beyond the scope of this paper.

Terrain characteristics

It is generally known that rebel groups are more often based in mountainous and/or densely forested areas, not easily accessible to governmental forces. Several studies made the hypothesis that the proportion of zones with high difficulty of access is correlated to the risk of civil war in the country. In this respect, Fearon and Laitin (2003) found that mountainous terrain is significantly related to higher rates of civil war whereas Collier and Hoeffler (2004) and Montalvo and Reynal-Querol (2005) found that the terrain effect was not significant, nor was the forest coverage effect. Again, quantitative analysis provides inconsistent results with reference to a "generally known" fact. This can be attributed in part to the way the analysis is done. Buhaug and Lujala (2005) point out the scale effect in studies involving geographical factors, and propose to take into account the exact location of the conflicts. However, this study concludes that conflict zones are –contrary to general belief– less mountainous and forested than the countries in which they occur. Buhaug and Lujala (2005) found that a mountainous terrain tends to extend the duration of civil wars. Almost all these studies used the proportion of mountainous areas within a country. We think that the area of mountainous zones is a more appropriate measure because the rebel groups need some territory to operate regardless what percentage this territory represents in the country. The area of mountainous zones should be more appropriate but it does not account for the location of the mountainous zones. If these zones are far from the capital (especially near the border), they offer more opportunity for rebellion hosting than if they were near the capital. Thus, we propose to use an index of accessibility from the capital. It is calculation is explained in section 2.3.3.

2.2.5 Regime type

Democratic peace theory is one of the most influential schools of thought in international relations. It holds that mature democracies are more peaceful than autocracies, both in their interactions with other democracies and internally (Oneal and Russett, 2005; Ray, 2000; Vasquez, 2000). The age of democracy seems to be significant, with three years given by some studies as a threshold for maturity (Russett, 1993; Rummel, 1997). The quality of democracy in the region also seems to make a difference.

Regime type affects conflict likelihood, with political representation having a negative effect on risk of war (Gleditsch and Hegre, 1997; Russett, 1993). Countries with a middle-level democracy or countries in transition either towards democracy or autocracy have a higher probability of suffering a civil war. These findings are consistent with Collier and Hoeffler (2004), Sambanis (2001), Russett et al. (2000), Hegre et al. (2001) and Ellingsen (2000).

The intuition behind these results is firstly, that for starting a civil war some level of freedom is needed to let people organized and secondly, that the opportunity costs of rebellion are higher in more inclusive systems Reynal-Querol (2002). In highly democratic and highly autocratic countries there is more certainty about possibility to effect political change and thus little incentive for conflict. There has been little examination of representativeness of the various forms of democratic government, as high heterogeneity among democracies (plural, proportional, high/low electoral margins) makes generalisation and comparison very difficult.

However, Hegre (2002) show that the political system effect tends to become insignificant when controlling for income. Similar results are reported by Collier and Hoeffler (2004), Elbadawi and Sambanis (2002) and Ostby (2005). This is probably due to the strong correlation between democracy score and income.

The level of democracy that is extracted from Polity IV dataset[3] is by far the most used data source for regime type indicator. It is coded in 20 levels (from -10 to 10) where the score -10 is given to absolute autocracy and +10 to full democracy. The evaluation is based on six variables that are assumed to characterise the level of democracy of the regime: (i)regulation of executive recruitment, (ii)competitiveness of executive recruitment, (iii)openness of executive recruitment, (iv)executive constraints, (v)regulation of participation and (vi)competitiveness of participation. The values given to these variables are based on judgments of the authors of the dataset and may be questionable. As an alternative, the new dataset on political institutions from the World Bank may be useful. It provides six governance composite indicators based on several "independent" sources[4], for every two years between 1996 and 2004.

[3] http://www.cidcm.umd.edu/inscr/polity/

[4] http://www.worldbank.org/wbi/governance/wp-governance.htm

2.2.6 History of armed conflict

It is generally assumed that countries having experienced an armed conflict are prone to another conflict because either the contention has not been completely resolved, the after-conflict regime has low capacity to contain new insurgency, the issue of the conflict generated new dispute topics and also because of the experience of organising armed conflicts that people acquired during previous wars. Brecher et al. (2000) claims that protracted conflicts, with repeated crises between pairs are more likely to end in war. A number of studies have found, that a higher number of parties involved in a multi-party dispute brings a higher likelihood of war (Vasquez, 1993; Cusack and Eberwein, 1982; Brecher, 1993). States with violent independence struggles are also found to be at higher risk of crises leading to war.

The conflict history factor is sometimes confused with the factor of time-dependence of the risk of conflict if a country has been at war previously. For instance, Raknerud and Hegre (1997) take into account all disputes in which force has been used, and all recurring disputes between pairs. They construct a measure of years since last conflict divided by years at peace since first data point (time dependency), with conflict effect decaying relative to a half time parameter. This variable that Mousseau et al. (2003) call *brevity of peace* equals $2^{-x/A}$, where x is the number of years after the end of the last conflict, and A is the "half-life" parameter. Leng (2000), Hensel et al. (2000), Mousseau et al. (2003), and Gleditsch and Ward (2005) set the parameter A to 5 years. Urdal (2005) considers that the effect of previous conflict is decaying over time following a negative exponential function. He assumes, that the decay rate parameter is 4, implying that the risk is halved approximately every 3 years[5]. Furthermore, he argues that different specifications of this function, i.e. different values of the rate parameter, do not change the results of his analysis. These approaches aim normally to correct for the trend in the probability-of-war time series, and are applied on the dependent variable. The problem is that with binary series, there is no way to assess the correlation structure of the observations without events (peaceful years). We propose to estimate separately the risk related to the history of armed conflicts rather than including it in the structural model. We can therefore assess the effect of the structural conditions and the effect of past conflicts independently. Each module can be tuned independently. Details of the method are given in section 3.4(page 40).

[5]Both formulations are actually equivalent excepted that there is a factor of Ln(2) between the "half-life" parameter values

2.3 Overview of the main data sources

This study relies exclusively on open source data collected by international organizations or by research centres. For armed conflict data, we use the PRIO dataset. For independent variables, the World Bank is a major contributor through its annual reports on World Development Indicators. This section reviews the different indicators, the extent of available data, their completeness, and eventually their statistical properties.

2.3.1 Armed conflict database

The PRIO dataset contains data on armed conflicts since 1946. They are classified into four categories: interstate, internal, internationalised internal and extra-systemic. Interstate conflict occurs between two or more states; internal conflict occurs between the governement of a state and one or more internal opposition group(s) without the intervention of other states; internationalised internal conflict occurs between the government of a state and one or more internal opposition group(s) with intervention from other states on one or both sides; and, extra-systemic conflict occurs between a state and a non-state group outside its own territory. In this study, we retained two categories, internal and internationalised internal conflicts. These categories are more likely to be related to structural factors of the country that the conflict targets. The time range was limited to 1971-2005 because most of the structural indicators lack information on the previous period.

Every year, on-going conflicts are recorded with their location (country), approximative start date, intensity, type, engaged parts, etc. The location country and the year of reporting were retained as the main fields for further analysis. We are indeed interested in the relationship between the structural characteristics of a country and the probability of an armed conflict. In this dataset, location is actually defined as the government side of a conflict, and should not be interpreted as the geographical location of the conflict. However, for internal and internationalized internal conflicts, only one country name is listed. This is the country whose government or territory is disputed. For certain conflicts, such as in the Kurdistan, the disputed territory is divided between different countries. They have been coded as different conflicts for each country.

At this stage, the actors are not included in the modelling. This may however be questionable. For instance, if we consider the Iraqi conflict since 2003, it is clear that the internal conditions could not alone explain (predict) the risk of the conflict. Moreover, the PRIO dataset records an internationalized internal conflict for 2001, 2002, 2004 and 2005, between the USA and Al-Quaeda, with the USA as location. We considered this conflict as an extra-systemic conflict and excluded it from the list because it involves a state (USA) and a non-state group (Al-Quaeda) outside the USA territory.

The number of countries that are affected by internal conflicts each year is depicted in figure 2.1. This number ranges from 15 in 1973 to 34 in 1992. Since 1992, it is diminishing and in 2003 it was on almost similar level as in the 1970s'. Its increase in the beginning of the 1990s' is related to the collapse of the Soviet Union.

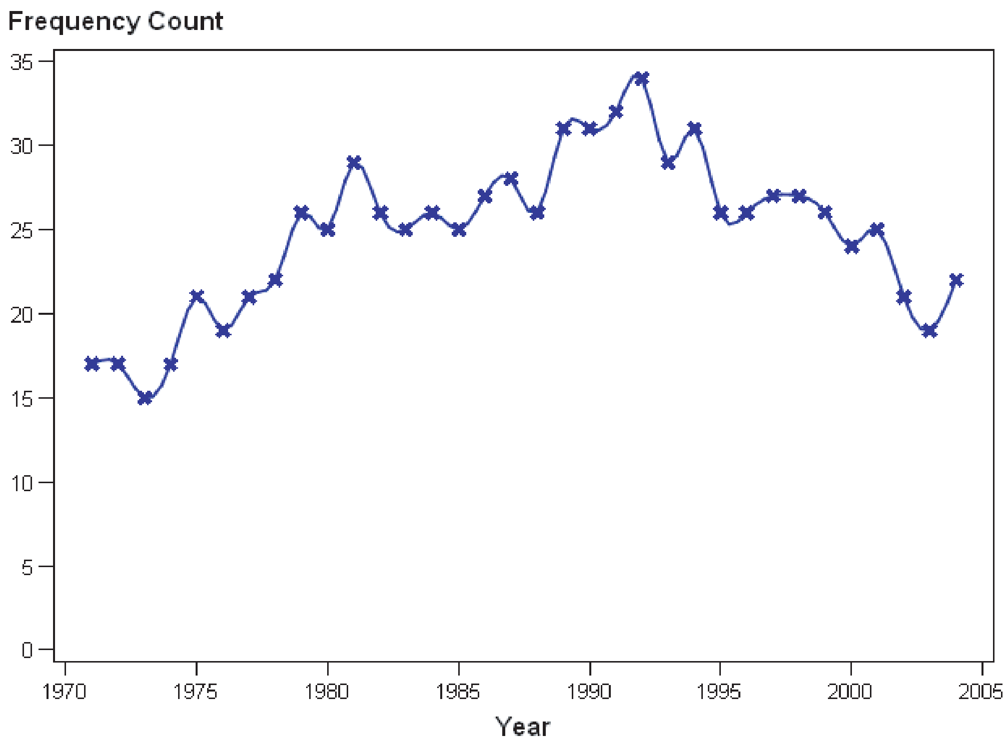


Figure 2.1: Number of countries involved in at least one armed conflict.

2.3.2 World Development Indicators

The World Bank publishes every year the largest compilation of data about development. The 2006 edition of *World Development Indicators* includes more than 900 indicators for 208 entities (states and territories)[6]. We used

[6]For details, see `http://www.worldbank.org/data`

this dataset for all data on economic and socio-demographic indicators. However, many indicators miss data for several countries and several years. The most complete variable is the total population by country and by year. Data for this variable are primary derived from national population censuses and estimates based on demographic models. The GDP is a key economic indicator which is well covered in the WB datasets. It's usually missing for few cases.
Other indicators extracted from this dataset are:

Merchandise exports : the value of goods provided by a country to the rest of the world. In the framework of conflict studies, this indicator can be considered as a proxy of the openness of a country and the state of its economy.

Exports of goods and services : exports of goods and services as a percent of GDP represents the value of all goods and other market services provided by a country to the rest of the world, as a percentage of its gross domestic product (GDP). Exports include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services.

Merchandise imports : the cost, insurance, and freight value of goods received from the rest of the world. In the framework of conflict studies, this indicator can be considered as a proxy of the openness of a country and the state of its economy. It can reflects also the level of confidence of the economic operators in the country.

Imports of goods and services : imports of goods and services as a percent of GDP represents the value of all goods and other market services received by a country from the rest of the world as a percentage of its Gross Domestic Product (GDP). Imports include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services.

Fuel exports : fuel exports as a percent of merchandise exports is the percentage of the total value of all merchandise leaving a given country's borders attributable to fuel commodities.

Total external debt : that is debt owed to nonresidents of a country repayable in foreign currency, goods, or services. This variable was limited to developing countries. Relevant observations of this variables are completely covered. Missing values on the country-year list were therefore set to zero. These missing cases are for example developed countries, years before independence/existence of the country.

Foreign direct investment : foreign direct investment is net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor.

Official development assistance and official aid : net official development assistance consists of disbursements of loans made on concessional terms and grants by official agencies of the members of the Development Assistance Committee (DAC-OECD), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in part I of the DAC list of recipients. Net official aid refers to aid flows from official donors to countries and territories in part II of the DAC list of recipients: more advanced countries of Central and Eastern Europe, the countries of the former Soviet Union, and certain advanced developing countries and territories. This indicator can be a proxy for the dependence level of a country to external assistance, and denote a risk of weak institutions. This variable was limited to developing countries. It was set to zero for developed countries, i.e. members of the Development Assistance Committee of the OECD.

Secondary school enrollment : the gross enrollment ratio is defined as the total school enrollment, regardless of age, expressed as a percentage of the school-aged population. Data are available for years 1999 to 2004 and 1990. We used linear interpolation to estimate the school enrollment for the years which have not reported, between 1990 and 1999. The case of missing data for reporting years is discussed in section 3.2 devoted to the treatment of missing data.

As noted in section 2.2.5, the World Bank published a dataset on political institutions that can be used to study the effect of the regime type on the risk of armed conflict. This dataset contains six composite indicators: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption. It covers 213 countries and territories for 1996, 1998, 2000, and annually for 2002-2005. Details about these indicators are given in Kaufmann et al. (2006). We used this dataset for validation (see 4.4).

2.3.3 Terrain accessibility index

We defined an accessibility index based on terrain characteristics. The underlying hypothesis is that the opportunity of hosting a rebellion or other military activities that are hostiles to a country is greater on rough terrain, far from the capital and near the border. For each point in the country, we calculate the distance from the capital, weighing it for terrain roughness. The terrain roughness is measured by the range of elevation values within a 7×7 window. We used the DEM from the GTOPO30 dataset[7], in Plate Carrée projection (equidistant cylindrical projection), with a pixel size of 930 m (=30 arc-seconds at the equator). The index was calculated at the same ground sampling distance.

Formally, this index can be regarded as a geodesic distance from a pixel to the source point, i.e the capital. The geodesic distance $d(p, q)$ between two pixels p and q in a connected domain S is defined as the length of the shortest path from p to q which is totally included in the domain. A path between pixels $p = p_1$ and $q = p_n$ is defined as the ensemble $P = \{p_1, p_2, \dots, p_n\}$ so that p_i and p_{i+1} are connected neighbors for $i \in \{1, 2, \dots, n-1\}$, and p_i belong to the domain for all i. The path length $l(P)$ is defined as

$$l(P) = \sum_{i=1}^{i=n-1} d_E(p_i, p_{i+1}), \tag{2.3}$$

where d_E is the euclidean distance between adjacent pixels. The distance d_E is equal to the pixel size for the vertical and horizontal neighbours, and to $\sqrt{2}$ times the pixel size for the diagonal neighbours. In our case, we introduce a cost c_i to pass through pixel i, which is simply its value in the elevation range data. Equation 2.3 becomes

$$l_c(P) = \sum_{i=1}^{i=n-1} \frac{c_i + c_{i+1}}{2} \, d_E(p_i, p_{i+1}). \tag{2.4}$$

We further constraint the distance calculation within a polygon defining the territory of a country. The borders are introduced in the process as barriers. However, it is not possible to calculate the geodesic distance on the entire land territory of some countries, like Indonesia, that are made up by several non-connected parts. We used the index of the polygon containing the capital, and in most of the cases, this polygon was by far larger than the other components of the country territory. Notable underestimation can be noted for Indonesia, Philippines, Malaysia, New Zealand, Japan and Danemark.

[7] `http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html`

Figure 2.2 shows a global map of raw index values, whereas figure 2.3 shows the average index values by country. These average values are finally used as accessibility indicator (variable *geog*) in the regression model. Other summary statistics at the country level (range and standard deviation) were highly correlated to the mean so that we kept only the mean values for further analysis.

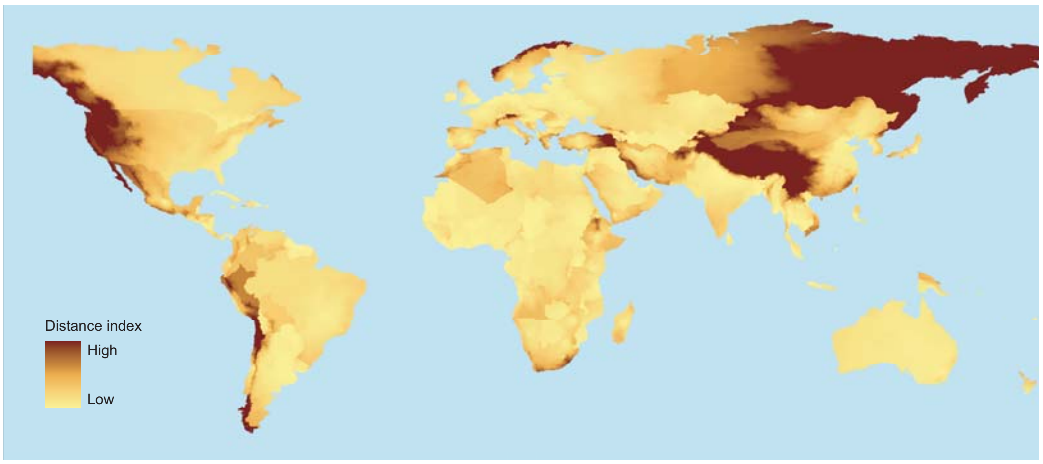


Figure 2.2: Distance index from the capital by country, weighted by terrain roughness

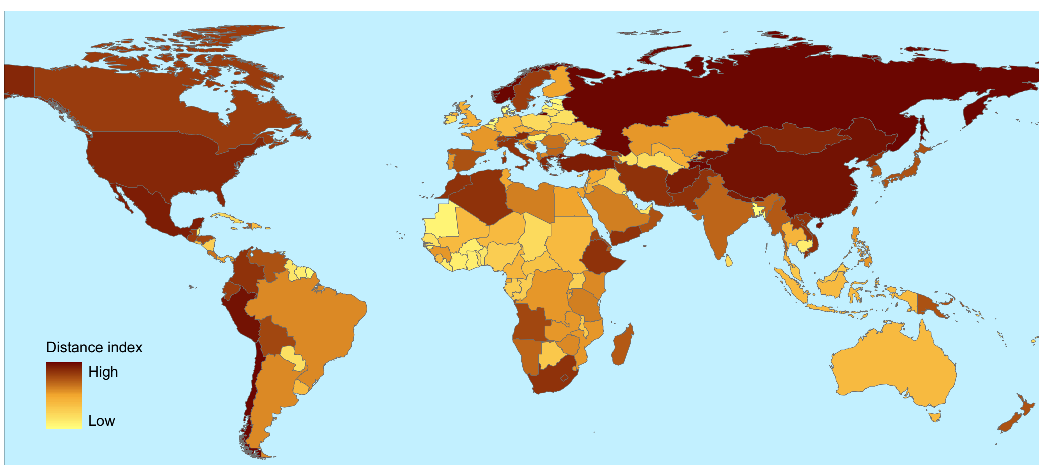


Figure 2.3: Average distance index values by country

Chapter 3

Method

3.1 Variable selection and experimental design

Most empirical conflict studies aimed to predict the probability of conflict onset based on a set of risk factors. In that case, the dependent variable is commonly coded 0 for all country-years records with no war, 1 for the year a war started, and missing for periods of ongoing war (Hegre and Sambanis, 2006; Collier and Hoeffler, 2004; Beck et al., 2000; Goldstone et al., 2005; Bennett and Stam, 2000), whereas some authors code these periods as 0 (Fearon and Laitin, 2003). Other studies consider modelling the *incidence* of armed conflict and the dependent variable is coded 1 for periods of ongoing war (Reynal-Querol, 2002; Elbadawi and Sambanis, 2002; Hauge and Ellingsen, 1998; Urdal, 2005). The first approach seems to be theoretically the most appropriate if one is interested in modelling the probability of conflict onset, that is the risk of a new "country-conflict". However, in practice, it turns out to be unfeasible. Firstly, the start and end dates of a conflict are not always obvious because the PRIO datasets records a conflict when and only while it reaches the death threshold. Secondly, removing periods of ongoing war reduce the sample, and specially the number of cases. This is critical because the number of cases is already small. For instance, we have 843 cases in total between 1971 and 2004 whereas there were only about 70 new cases, compared to about 7600 total country-years records. Some scholars argued that the different approaches gave similar results at least when studying the effect of particular factors (Urdal, 2005; Hegre and Sambanis, 2006), but did not provide details of their evidence. In this study, we preferred the third design and coded as ones all ongoing war periods.

Our dependent variable Y_{it} takes value 1 if the country i is experiencing one or more armed conflict(s) in year t, and takes value 0 otherwise. The independent variables that initially we selected are the GDP per capita (*gdpc*), GDP growth (*gdpg*), merchandise exports (*expm*), exports of goods and services as a percent of GDP (*expgdp*), merchandise imports (*impm*), imports of goods and services as a percent of GDP (*impgdp*), fuel exports ($expf$), foreign investment (*inve*), official development assistance par capita (*odac*), official development assistance as percentage of Gross National Income (*odag*), total external debt (*debt*), total population (*popu*), population density (*pdens*), population growth (*pgro*), secondary school enrollment (*secs*), religious fractionalisation index (ref), religious polarisation index (*rep*), ethno-linguistic fractionalisation index (elf), ethno-linguistic polarisation index (*elp*), democracy level (*democ*) and accessibility index (*geog*). Summary statistics of these variables are provided in table 4.1.

We checked the distribution of all the variables and when it departures far from the normal distribution, we took a transformed variable. They were then standardised to mean 0 and variance 1. For some variables, some observations were missing because they had not been reported in the data sources at our disposal. For example, if exports data are missing for a country and for some years, we can reasonably assume that this country actually exported for some value those years, but did not report the statistics. We can therefore try to find a way to gather this information or to estimate the missing export values. The next section discusses a little bit this topic. In other cases, data are missing because the combination variable-country-year is not relevant. For example, the countries of the former soviet republics that became independent in the 1990's lack information on most economical indicators before 1990. Such entries are therefore kept empty or set to zero.

3.2 Imputation of missing data

Missing data is very common phenomenon in social sciences because the main data sources are inquiries. In our case, we work with data provided either by national statistical services to international organizations or with data collected by different institutions in the framework of activities that are not related to conflict studies. The list of countries and the periods that are covered by these datasets vary widely. The national statistics services do not report or publish regularly their data. This happens more often for countries with low capacity governments, those indeed that are more prone to political instability. Removing cases with missing data on one or more indicators can therefore exclude a significant number of important cases. List wise deletion may bias results because the remaining data may not be representative of the total sample. An alternative simple and widely used method to handle missing data was the substitution of the missing observations by plausible values (location statistics or regression predictions). This method tends to parameter standard errors that are too small, p-values that are artificially low, and rates of type I error that are higher than nominal levels.

Instead of filling in a single value for each missing value, multiple imputation (Rubin, 1987) replaces each missing value with a set of plausible values that represent the uncertainty about the right value to impute. The multiply imputed data sets are then analyzed by using standard procedures for complete data and combining the results from these analyses. Missing values for any variable are predicted taking into account the correlation between all variables used in the imputation model. Multiple imputation preserves therefore the relation between variables, and accounts for uncertainity in the model by creating different complete datasets. Several methods can be used in multiple imputation, depending on the pattern of missingness. For a data set with a monotone missing pattern, one can uses for example the regression method. A monotone missing pattern is not necessary guaranteed. With an arbitrary missing pattern (either monotone or not), a Markov Chain Monte Carlo (MCMC) method (Schafer and Olsen, 1998) that assumes multivariate normality is used to impute all missing values. We used the MCMC method to impute all missing data because the pattern of missingness was not monotone. We created 5 versions of imputed data sets, and combined the results of their analysis.

3.3 Modelling the risk related to structural factors

Let Y be the dependent variable. If π is a measure of the risk of state instability, and λ a threshold of instability over which an armed conflict will occur, the dependent variable for a country j can be defined as follows:

$$Y_j = \begin{cases} 0 & \text{if } \pi_j < \lambda, \\ 1 & \text{if } \pi_j \geq \lambda \end{cases} \tag{3.1}$$

Thus, $Y_j \sim Be(p_j)$, with p_j being the probability of an armed conflict in country$j$. The parameter $p_j = P(\pi_j \leq \lambda)$ can be regarded as a value of the cumulative distribution function of π_j. We need to predict Y_j on the basis of some explanatory variables $\mathbf{X_j} = (X_{1j}, X_{2j}, ..., X_{rj})$. Assuming that Y is fully discribed by a Bernoulli law, it is sufficient to have an estimate of the parameter p. The parameter of the Bernouilli distribution p is frequently modelled with a logistic function.

$$p = \frac{\exp(\beta'\mathbf{x})}{1 + \exp(\beta'\mathbf{x})} \tag{3.2}$$

where β is the vector of parameters and x is the matrix of explanatory variables. The subscript j in the previous formula and notations must be understood as referring to a country-year observation because we have decided to do a panel analysis instead of a cross-sectional analysis.

3.4 Modelling the risk related to previous conflicts

Countries that experience an armed conflict are more prone to an other conflict in the future. This effect is usually taken into account by including a variable that reflects the history of conflicts (Mousseau et al., 2003; Gleditsch and Ward, 2005; Urdal, 2005). Our objective is to estimate the risk of armed conflict. In that sense, we propose to separate the effect of past conflicts from the effect of other independent variables. We propose to model the risk related to past conflicts in a innovative way inspired by capture-recapture methods used in Ecology studies (Jolly, 1982; Seber, 1982).

We consider Ω the set of World countries, and its subset C of countries that are prone to armed conflict for a given short period (one year or five years for example). We constraint our analysis on limited period in the history, say for example from 1971 to 2005. The number of countries in the World is generally more or less stable during the considered period with some exceptions like the dissolution of the USSR. The number of elements in C cannot be known in advance. We know only that it is between 0 and the cardinal number of Ω. However, the cardinal number of C has been up-to now much smaller than the one of Ω as it can be seen on figure 2.1.

Let's consider that a country becomes element of C if it has experienced an armed conflict at any time in the period of interest. The set C can be regarded as a semi-open space because it allows individual to become member but does not allow them to get out. We explain later how this constraint could be relaxed. Let's define some notations and parameter relationships. The subscript i will refer to time, while j refer to country. We recall that Y_{ij} takes value 1 if the country j is at war in year i (another time unit could be used also), and 0 otherwise.

s_i : the total number of countries at war in year i.

$$s_i = \sum_{j=1}^{n} Y_{ij}. \tag{3.3}$$

m_i : the number of countries that are "at war" in year i and have previously experienced at least one armed conflict.

$$m_i = \sum_{j=1}^{n} Y_{ij} \quad \text{if} \quad Y_{ij} = 1 \quad \text{and} \quad \exists k < i | Y_{kj} = 1. \tag{3.4}$$

z_i : the number of countries that have experienced an armed conflict before year i, they are not "at war" in year i, but are reported to have experienced another conflict later.

$$z_i = \sum_{j=1}^{n} Y_{ij} + 1 \quad \text{if} \quad Y_{ij} = 0 \quad \text{and} \quad \exists k < i, l > i | (Y_{kj} = 1, Y_{lj} = 1). \tag{3.5}$$

r_i : the number of countries "at war" in year i that are reported to be again/still "at war" at any later period.

$$r_i = \sum_{j=1}^{n} Y_{ij} \quad \text{if} \quad Y_{ij} = 1 \quad \text{and} \quad \exists k > i | Y_{kj} = 1. \tag{3.6}$$

S_i : the total number of countries that are prone to armed conflict in year i. One should expect this number to be equal to the total number of countries in the international system (about 200 countries), but the experience has showed that armed conflicts occur in a much less number of countries each year. This number can not be directly observed. It needs to be estimated.

M_i : the theoretical number of countries that have previously experienced an armed conflict ad are prone to another conflict in the future. In other words, this is an estimate of the number of countries in year i that could return to armed conflict in the future because they are more prone to armed conflicts than others.

p_i : the probability that an armed conflict in a country member of the set C in year i. This probability is based only on occurences of armed conflicts and its modelling does not include any ancillary information.

$$p_i = \frac{s_i}{S_i} = \frac{m_i}{M_i} \tag{3.7}$$

We are interested in the estimate of this probability.

A maximum likelihood estimator of p_i is:

$$\hat{p}_i = \frac{m_i}{\hat{M}_i}, \tag{3.8}$$

where

$$\hat{M}_i = m_i + \frac{s_i z_i}{r_i}. \tag{3.9}$$

Thus,

$$\hat{p}_i = \frac{m_i r_i}{m_i r_i + s_i z_i}. \tag{3.10}$$

The estimator is however biased. Seber (1982) recommended to correct it as follows:

$$\hat{M}_i = m_i + \frac{z_i(s_i+1)}{r_i+1}, \hat{p}_i = \frac{m_i(r_i+1)}{m_i(r_i+1)+z_i(s_i+1)}. \tag{3.11}$$

Similarly, we can estimate the total number of countries that are prone to armed conflicts as follows:

$$\hat{S}_i = \frac{\hat{M}_i(s_i+1)}{m_i+1}. \tag{3.12}$$

We calculated these parameters from the PRIO dataset. We estimated the risk α_{kj} related to previous conflict as follows. Let's consider the first year i a country has experienced a conflict ($Y_{ij} = 1$), and $k > i$ so that $Y_{kj} = 0$. Then,

$$\alpha_{kj} = \prod_{l=i}^{l=k} p_l \tag{3.13}$$

Finally, the overall risk was the average between the risk related to previous conflicts (α_{ij}) and the risk related to structural factors (π_{ij}). The combination of both risk estimates could also be done by taking the maximum, max(α_{ij},π_{ij}), instead of the average of the two estimates.

Chapter 4

Results

4.1 Variable distribution exploration

As a first step, we provide a brief description of the variables distribution. Summary statistics are shown in table 4.1, while figures 4.1 and 4.2 summarize the distributions of the explanatory variables before standardization and imputation of missing values.

From table 4.1 it can be noted that some variables could not be used in the model at all because the missing data proportion is too high. We excluded variables that lack data for more than 20% of the observations in the conflict cases. These variables are *expf*, *gdppc* and *secs*. Location statistics of most factors are in the line of the expected trends, even if the differences in mean values are often small in comparison with their standard deviation. As for the indicators of religious fractionalisation and polarisation, their mean values are lower in "conflict" than in "non-conflict" cases.

The boxplots (figures 4.1 and 4.2) reveal also some interesting information regarding the hypotheses that are usually posed in conflict studies literature. The GDP per capita is, as expected, lower in the "conflict" sample than in the "non-conflict" sample. The latter shows however larger variability. This raises indeed the usual question of causal relationship between poverty and armed conflicts. Secondly, the GDP growth distributions do not show significant differences between "conflict" cases and "non-conflict" cases, whereas substantial differences can be noted for the indicators related to commercial exchanges, share of imports and exports of merchandise in the GDP. Countries that are involved in armed conflicts participate in commercial exchanges less than others. Moreover, reduction in trade flows could indicate lack of confidence of economic operators that is often related to political instability.

Table 4.1: Summary statistics of the explanatory variables and the World Bank's stability index

	Conflict	Nomiss	Miss (%)	Mean	Median	Std
gdpc	1	745	11	2148	787	4011
	0	4497	32	5789	1910	8126
gdpg	1	738	12	0.0	1.6	7.6
	0	4583	31	1.8	2.0	6.0
expm	1	828	1	10284	1472	24131
	0	4997	25	19984	1049	66593
impm	1	826	2	10993	2154	25600
	0	4988	25	20505	1383	75248
expf	1	498	41	16.6	2.6	32.8
	0	3278	51	17.4	3.1	29.0
expgdp	1	725	14	23.6	20.4	15.2
	0	4329	35	37.2	31.9	23.6
impgdp	1	725	14	29.1	25.4	16.1
	0	4327	35	44.1	37.6	24.9
inve	1	808	4	724	33	3539
	0	4707	29	1858	23	11215
odag	1	738	12	5.9	2.4	9.1
	0	4272	36	7.3	2.3	12.8
odac	1	815	3	29.9	13.4	53.9
	0	4761	28	69.8	18.8	195.6
debt	1	717	15	16767	4083	31275
	0	3787	43	7535	909	22477
popu	1	839	0	59279	18380	156551
	0	6542	1	18751	3234	85944
gdppc	1	667	21	3246	1872	3920
	0	3801	43	6976	4083	7692
secs	1	39	95	40.3	48.0	28.6
	0	560	92	64.7	72.0	25.8
REF	1	839	0	0.40	0.43	0.23
	0	5537	16	0.44	0.47	0.23
REP	1	839	0	0.57	0.64	0.26
	0	5537	16	0.62	0.71	0.26
ELF	1	835	0	0.50	0.51	0.23
	0	5322	20	0.42	0.42	0.25
ELP	1	835	0	0.59	0.64	0.20
	0	5322	20	0.54	0.60	0.25
democ	1	839	0	0.03	0.00	6.32
	0	6626	0	0.20	0.00	6.08
geog	1	838	0	34.96	22.94	36.01
	0	4678	29	31.35	18.29	39.79
stability	1	117	86	-1.32	-1.35	0.75
	0	774	88	0.20	0.26	0.87

Note: The total number of observations was 7465, among which 839 (11%) conflict cases (ones in the second column).

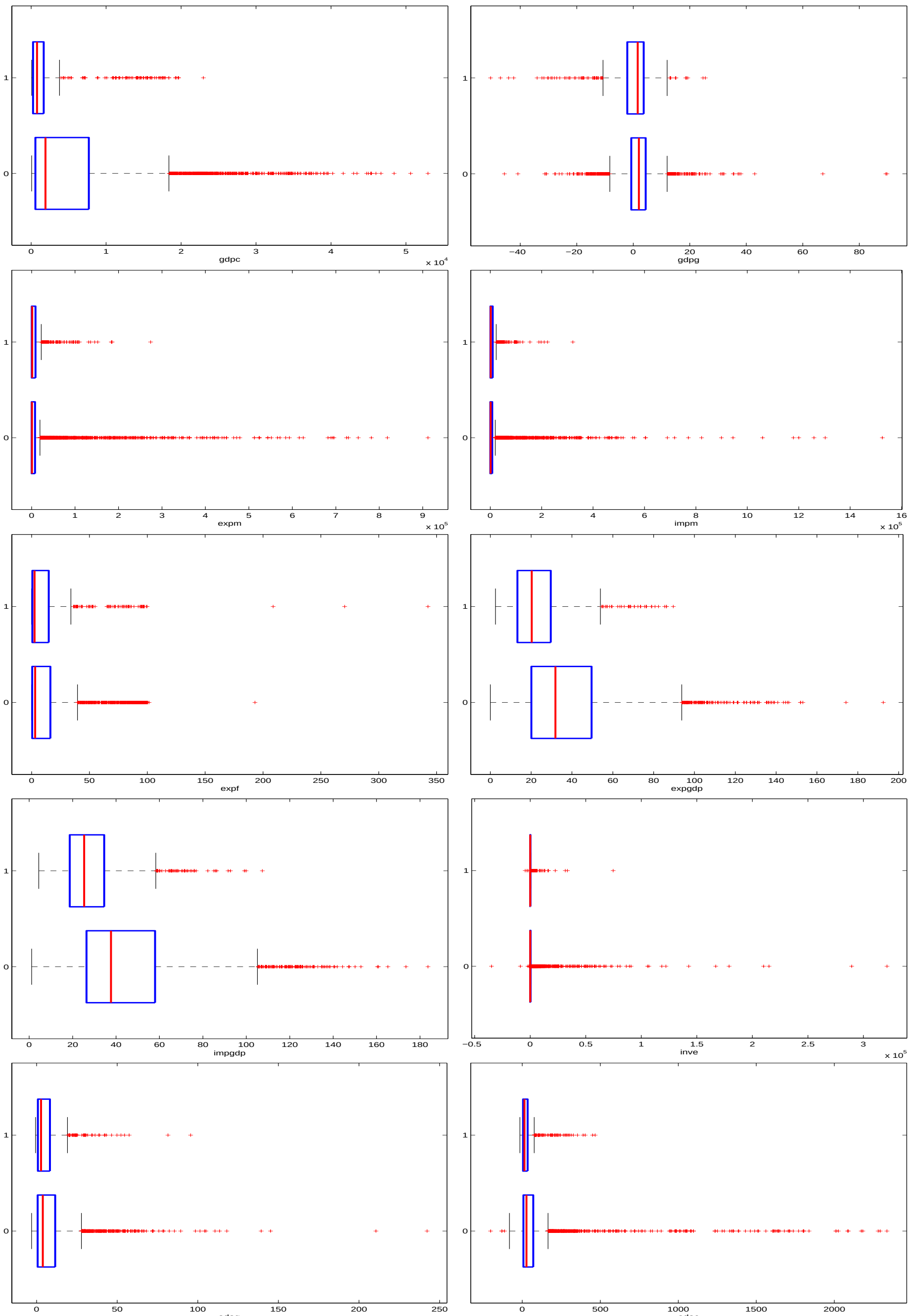


Figure 4.1: Summary of the distributions of the explanatory variables. See text for the explanation of the symbols. (continued)

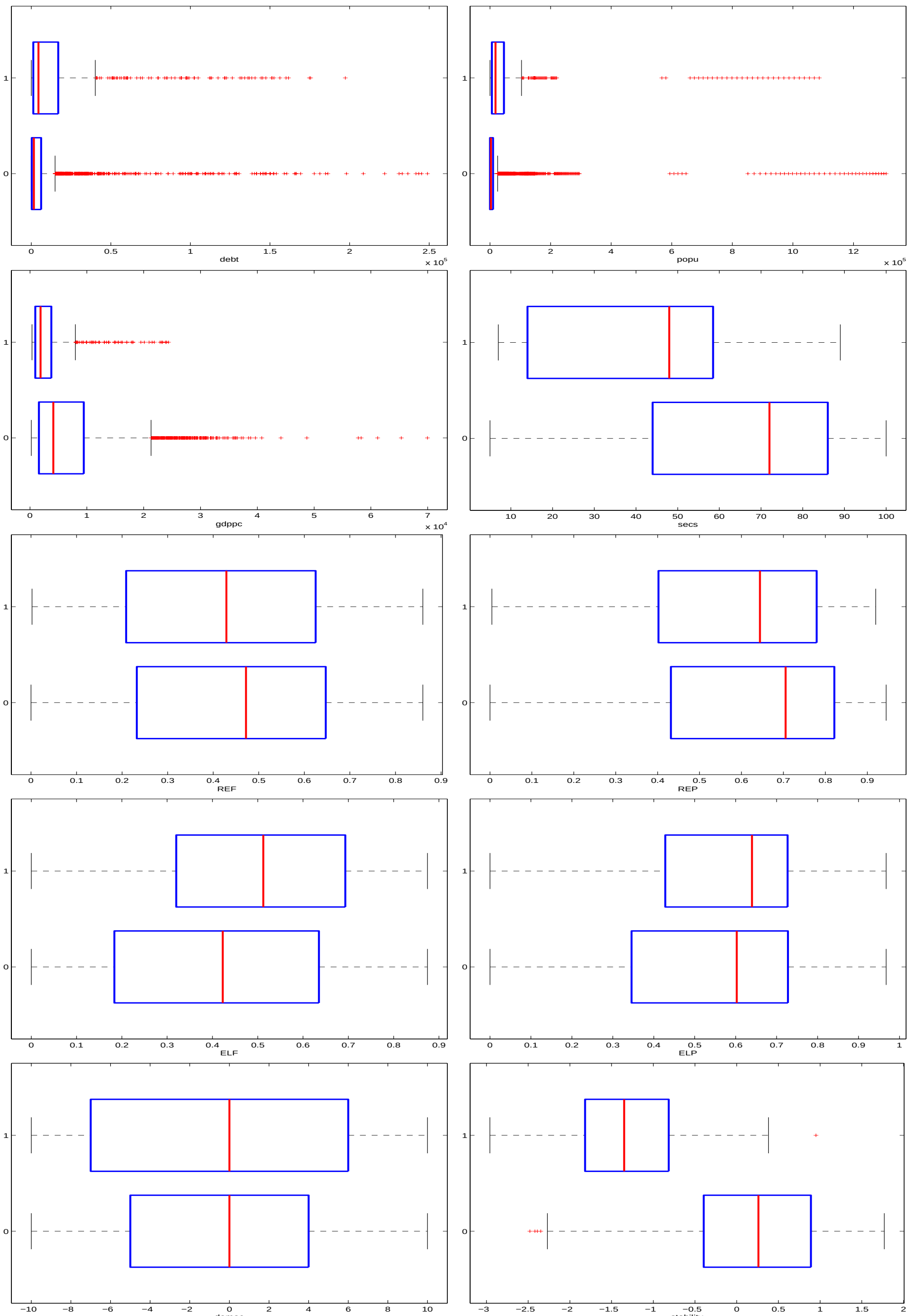


Figure 4.2: Summary of the distributions of the explanatory variables (2).

The official development assistance data (*odag* and *odac*) do not show differences in their distribution between "conflict" and "non-conflict" cases even if the median values do not differ. They both show higher variability in "non-conflict" than in conflict cases. This is because the former category includes countries with very different level of economic development, from the poor peaceful countries like Niger, Mali, etc. to emerging rich developing countries like Brazil, Saudi Arabia, China, etc. Especially, the new economic and demographic giants like China, Brazil and India receive insignificant amount of ODA/GDP or ODA per capita. The debt service tends also to be higher for conflict cases.

Again, indicators of social (ethno-linguistic and religious) fractionalisation and polarisation are quite similar in their distributions for both samples, especially location parameters of the polarisation indices. The ELF index tends however to be higher in the conflict cases, but this is almost masked in the polarisation index.

4.2 Regression analysis

We considered several specifications of the model and data processing in order to select the method that offers the best trade off between quality of fit and completeness in the possibility of prediction. We began with the naive model, including all the explanatory variables and using the original dataset before imputation of missing values. The observations with at least one missing variable were excluded from the analysis. The results of this first analysis are reported in table 4.3. They show that the likelihood of armed conflict is significantly associated with the GDP growth rate, the ODA per capita, the ODA per unit of GDP, the level of foreign investment, the size of the population, the level of democracy and with the different indices of social fractionalisation/polarisation, excepted for the ethno-linguistic polarisation index. The overall model fitting statistics denote an acceptable model. The coefficient of determination R^2, adjusted according to Nagelkerke (1991), of 0.28 is an acceptable value in social sciences. The Hosmer-Lemeshow statistics (Hosmer and Lemeshow, 2000) is enough small (not statistically significant) denoting an overall good fitting.

However, when we examine the coefficient estimates of the different regressors, we can note some "inconsistencies" with our initial hypotheses. The sign of the coefficient of *lodag* (ratio ODA/GDP) is negative (less assistance is associated with higher risk of armed conflict) whereas the sign for *lodac* is positive (more assistance is associated with higher risk of armed conflict). We expected similar signs for both variables. The religious fractionalisa-

Table 4.2: Summary statistics of the explanatory variables after transformation, standardisation and imputation of missing values

	Conflict	Nomiss	Miss (%)	Mean	Median	Std
lgdpc	1	839	0	-0.52	-0.51	0.86
	0	5369	19	0.03	0.00	1.02
gdpg	1	839	0	-0.19	0.01	1.16
	0	5369	19	0.02	0.04	0.97
lexpm	1	839	0	0.13	0.18	0.82
	0	5369	19	-0.03	-0.05	1.03
limpm	1	839	0	0.14	0.10	0.82
	0	5369	19	-0.03	-0.14	1.03
lexpf	1	839	0	-0.05	-0.27	1.12
	0	5369	19	-0.09	-0.22	1.09
lexpgdp	1	839	0	-0.52	-0.45	0.92
	0	5369	19	0.10	0.16	1.02
limpgdp	1	839	0	-0.51	-0.54	0.89
	0	5369	19	0.14	0.13	1.06
inve	1	808	4	-0.04	-0.22	0.90
	0	4707	29	0.01	-0.24	1.01
lodag	1	839	0	0.00	-0.09	0.83
	0	5369	19	0.01	-0.10	1.00
lodac	1	839	0	-0.13	-0.09	0.72
	0	5369	19	0.02	0.15	1.02
ldebt	1	839	0	0.47	0.56	0.75
	0	5369	19	-0.16	0.05	1.04
lpopu	1	839	0	0.80	0.79	0.55
	0	6542	1	-0.10	0.12	1.00
lgdppc	1	773	8	-0.50	-0.51	0.87
	0	4777	28	0.00	0.03	1.01
secs	1	39	95	40.31	48.00	28.56
	0	560	92	64.72	72.00	25.82
lref	1	839	0	-0.16	0.25	1.17
	0	5503	17	0.02	0.35	0.97
lrep	1	839	0	-0.17	0.27	1.20
	0	5503	17	0.03	0.38	0.96
lelf	1	833	1	0.30	0.48	0.70
	0	5290	20	-0.05	0.30	1.03
lelp	1	833	1	0.24	0.45	0.63
	0	5290	20	-0.04	0.37	1.04
democ	1	839	0	0.03	0.00	6.32
	0	6626	0	0.20	0.00	6.08
lgeog	1	838	0	0.19	0.23	0.88
	0	4678	29	-0.03	0.04	1.01
stability	1	117	86	-1.32	-1.35	0.75
	0	774	88	0.20	0.26	0.87

Note: The total number of observations was 7465, among which 839 (11%) conflict cases (ones in the second column).

tion index has also an "unexpected" negative coefficient whereas the associated polarisation index coefficient is in the expected direction. Montalvo and Reynal-Querol (2005) observed the same pattern and interpreted this as meaning that, conditional on a given degree of polarization, more religious diversity decreases the probability of a civil war. Indeed, a high number of different groups increases the coordination problems and, therefore, given a level of polarization, the probability of civil wars may be smaller.

Another "inconsistency" with our initial hypotheses is that the coefficients of most of the economic indicators (income, exportation and importation volumes, debt service) are not statistically significant at 5% level. Some have either "unexpected" signs. Thus, *lgdpc*, *lexpm* and *limpm* are not significant but have the expected sign, whereas *ldebt* is not significant and has an "unexpected" sign. This is may be due to multicollinearity problem.

We found also that the observations of several countries in recent years (namely in 2004, the last reporting year) were discarded because of missing data. We could speculate on the availability of data in the future, but this is a factor that we can not control. We tested the model with a dataset augmented by imputation of missing data.

The imputation model was mainly based on the expected correlation between economic indicators. However, we excluded the variable *inve* from the analysis because it was not used in the imputation model. We should underline that the results of a model similar to the one presented in table 4.3 don't almost change *inve* is put aside. This may indicate that the test of significance of its effect may not be valid probably because its distribution is highly skewed as it can be seen on figure 4.1. The results of the imputed dataset are summarised in table 4.4. Statistics of goodness-of-fit are less good than in Model 1. The coefficient of determination is lower (0.22) and the Hosmer-Lemeshow statistics is higher, even statistically significant at 5% level. Factors with significant effect are almost the same: GDP growth rate, official development assistance, population size, relegious fractionalisation, ethno-linguistic fractionalisation, and democracy level. Only the religious polarisation factor *lrep* is not significant in Model 2 whereas it was in Model 1, and vice-versa for *lexpgdp* (share of exportation of merchandise in the GDP). The "inconsistencies" we noted in Model 1 are also present in Model 2. Coefficient estimates have the same sign, and they are quite similar for both model as it can be seen on figure 4.3. The largest changes are noted for the intercept, *gdpg*, *lexpm*, *lodac*, *lpopu*, $lref$ and *lrep*. The number of imputations has no effect on the model estimates. If the calculation load is an issue (large dataset for example), single imputation will be prefered to multiple imputation. A more detailed sensitivity analysis should allow

Table 4.3: Parameter estimates of the full model using the original dataset, and its goodness-of-fit statistics (Model 1)

Parameter	DF	Estimate	Standard Error	Wald χ^2	$p-$value
Intercept	1	-6.6480	1.8170	13.3872	0.0003
lgdpc	1	-0.1797	0.1242	2.0957	0.1477
gdpg	1	-0.0505	0.0093	29.6620	$< .0001$
lexpm	1	-0.0646	0.1389	0.2165	0.6417
lexpgdp	1	-0.3451	0.2400	2.0677	0.1504
limpm	1	-0.2978	0.1633	3.3250	0.0682
limpgdp	1	0.2983	0.2911	1.0500	0.3055
lodag	1	-0.4351	0.1501	8.4027	0.0037
lodac	1	0.3248	0.1140	8.1162	0.0044
ldebt	1	-0.0065	0.0331	0.0391	0.8432
inve	1	-0.00003	0.000014	4.7356	0.0295
lpopu	1	0.9650	0.1429	45.5839	$< .0001$
lref	1	-1.3843	0.2411	32.9514	$< .0001$
lrep	1	1.2756	0.2648	23.2026	$< .0001$
lelf	1	0.3071	0.1510	4.1367	0.0420
lelp	1	-0.0985	0.1942	0.2571	0.6121
democ	1	0.0282	0.0086	10.7950	0.0010
lgeog	1	-0.0312	0.0539	0.3360	0.5621
Observations (1/0)				623/3003	
Log likelihood				-1330	
Wald χ^2				447.06	
Adjusted R^2				0.28	
Hosmer-Lemeshow χ^2				6.16	

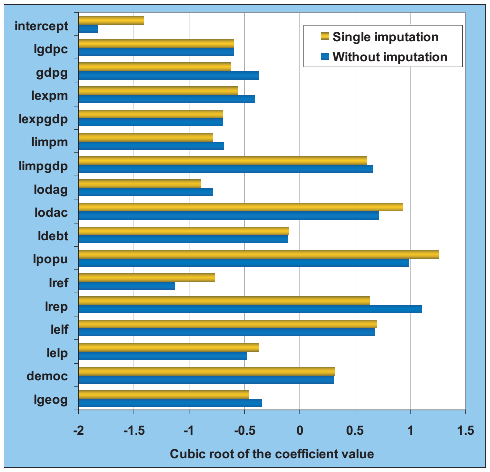
Table 4.4: Parameter estimates of the full model using the imputed dataset, and its goodness-of-fit statistics (Model 2)

Parameter	DF	Estimate	Standard Error	Wald χ^2	$p-$value
Intercept	1	-2.7931	0.0877	1013.6268	$< .0001$
lgdpc	1	-0.2099	0.1202	3.0492	0.0808
gdpg	1	-0.2392	0.0437	29.9952	$< .0001$
lexpm	1	-0.1759	0.2743	0.4111	0.5214
lexpgdp	1	-0.3364	0.1240	7.3596	0.0067
limpm	1	-0.4914	0.2637	3.4718	0.0624
limpgdp	1	0.2224	0.1225	3.2944	0.0695
lodag	1	-0.7090	0.1377	26.5158	$< .0001$
lodac	1	0.7959	0.1446	30.2963	$< .0001$
ldebt	1	-0.00104	0.0822	0.0002	0.9899
lpopu	1	1.9908	0.1640	147.4034	$< .0001$
lref	1	-0.4548	0.1846	6.0673	0.0138
lrep	1	0.2555	0.1810	1.9909	0.1582
lelf	1	0.3387	0.1179	8.2602	0.0041
lelp	1	-0.0514	0.1177	0.1910	0.6621
democ	1	0.0335	0.00687	23.7944	$< .0001$
lgeog	1	-0.0937	0.0511	3.3560	0.0670
Observations (1/0)				832/4141	
Log likelihood				-1896	
Wald χ^2				513.35	
Adjusted R^2				0.22	
Hosmer-Lemeshow χ^2				18.97*	

documenting the variability of the model parameters and the exact effect of missing data imputation.

From a statistical point of view, Model 1 should be preferred to Model 2. However, the model based on imputed dataset can provide estimates of conflict probability for more countries than the one based on the original dataset. If we consider the estimates of 2004, Model 2 provides predictions for 157 countries out of 226 countries/territories whereas Model 1 provides predictions for only 103 countries out of 226 countries/territories. This is an important advantage for operational application.

(A)



(B)

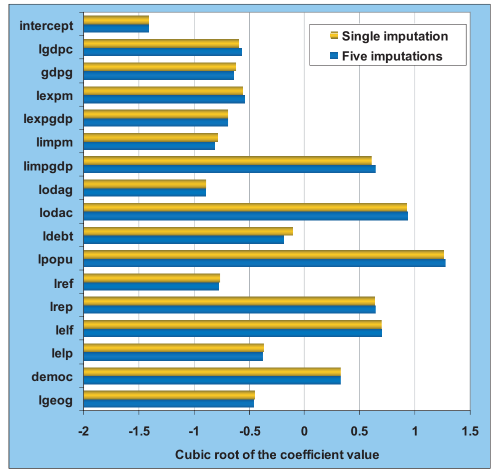


Figure 4.3: (A)Comparison of coefficient estimates of Model 1 (no-imputation) and Model 2 (single imputation), and (B) the effect of the number of imputations (right).

4.2.1 Alternative specifications of the model

We noted that some factors had unexpected coefficient values in the full models that are detailed in the previous section. We tried alternative specifications of the model, trying to reduce any multicollinearity effect.

Firstly, we avoid to use at the same time variables that are expected to measure the same driving force. For example, when the variable *lexpm* that measures the exportation volume is entered into the model, then *limpm* is put aside, and vice-versa, because they are supposed to proxy the trade openness of the country.

This is a subjective variable selection method that rely on the experience of the analyst. We could base the selection on more objective criteria, like explanatory power of the variables. We use a forward stepwise procedure, starting with the simplest model including only the intercept. Next, the procedure computes the chi-square score statistic[1](McCullagh and Nelder, 1989, p. 393) for each variable not in the model and examines the largest of these statistics. If the score statistic is significant at the specified level (we took $\alpha = 0.05$), the variable is added to the model. After a variable is

[1]The *score statistic* is the log-likelihood derivative. In this case, the derivative is taken with respect to each candidate variable. It has an asymptotic χ^2 distribution with r degrees of freedom under the null hypothesis, where r is the number of the tested parameters.

added, the new model is tested and any variable that does not produce a significant effect at the specified level, as measured by the Wald chi-square statistic (Kendall et al., 1991, p. 869), is removed. The procedure stops when no variable satisfies the entry condition and all variables in the model have a significant effect. We assume that factors that are highly correlated should not stay in the model together because one of them will necessary be insignificant.

An other approach is to replace original variables by their principal components. The principal components regression has been indeed used by several authors to deal with multicollinearity among explanatory variables (Massy, 1965; Aguilera et al., 2006; Wold et al., 1984; Heij et al., 2007). In usual principal components analysis, fewer components than the number of original variables are selected based on the amount of variance they convey. For regression analysis, the components are selected according to their explanatory power in the model by using the stepwise selection method described in the previous section.

Results for the alternative specifications of the model

Table 4.5 lists some of alternative models we tested based on subjective selection of factors. Five models are reported and differ in the number of variables included. We keep continuous numbering of the models from section 4.2, so that the first model in the following table is number three. In Model 3 we keep aside the variables which had "unexpected" sign in Model 2, *lodag*, $lref$ and *ldebt*. Indeed, *lodag* is highly correlated to *lodac*$(r = -0.81)$, *lexpm* $(r = -0.80)$, *limpm*$(r = -0.77)$ and *ldgpc*$(r = -0.73)$. We should note also that $lref$ is highly correlated to *lrep*$(r = 0.96)$ as expected. However the correlation of *ldebt* to other variables is rather low. In model 4 we remove *lexpm* which is highly correlated to *limpm* $(r = 0.90)$, and in Model 5 we exclude *limpgdp*, and in Model 6 we separate polarisation and fractionalisation indices. We test also a model based on economic indicators only (Model 7) to assess the possibility of setting a baseline of risk that can be tuned afterwards by taking into account other factors.

The results of table 4.5 show that the alternative specifications lead to quite similar results with regards to overall fitting quality of the model. The suspected multicollinearity effect is evidenced for some factors even if it doesn't seem to affect substantially the overall results. We can note that *limpm* becomes highly significant when *lexpm* is not in the model whereas both factors are not significant in the full model (Model 2) and in Model 3. Similarly, when $lref$ (and $lelf$) is removed, *lrep* (and *lelp*) becomes highly

Table 4.5: Alternative specifications of the regression model

	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	-2.793**	-2.770**	-2.775**	-2.753**	-2.748**	-2.233**
lgdpc	-0.210	0.058	0.062	0.038	0.018	-0.795**
gdpg	-0.239**	-0.241**	-0.239**	-0.234**	-0.239**	-0.219**
lexpm	-0.176	-0.186				-0.199
lexpgdp	-0.336**	-0.152	-0.214**	-0.144**	-0.136*	-0.257*
limpm	-0.491	-0.455	-0.612**	-0.591**	-0.598**	0.808**
limpgdp	0.222	0.046	0.102			-0.150
lodag	-0.709**					-0.274*
lodac	0.796**	0.386**	0.390**	0.418**	0.411**	0.219
ldebt	-0.001					0.334**
lpopu	1.991**	2.022**	2.023**	1.967**	1.969**	
lref	-0.455*					
lrep	0.256	-0.198**	-0.199**	-0.195**	-0.184**	
lelf	0.339**	0.158	0.147	0.126		
lelp	-0.051	0.138	0.147	0.159	0.269**	
democ	0.034**	0.028**	0.029**	0.028**	0.027**	
lgeog	-0.094	-0.080	-0.079	-0.078	-0.081	
Wald χ^2	513.352**	490.192**	490.206**	490.267**	488.916**	529.169**
Adj. R^2	0.221	0.207	0.207	0.206	0.206	0.189
H-L χ^2	18.968*	34.510**	38.337**	42.868**	39.279**	25.647**

significant. It seems that the multicollinearity effect is noticeable when the correlation coefficient is greater than 0.90.

We run the model where fractionalisation indices were put aside keeping only the polarisation indices and we found that the results were similar to ones of Model 6. This confirms that both indices measure actually the same phenomenon and they are interchangeable. This result is contrary to the conclusion of Montalvo and Reynal-Querol (2005) and Reynal-Querol (2002) who argue that the polarisation index is more appropriate than the fractionalisation index. The most interesting thing is that Model 7 (based on economic indicators only) performs almost as well as Model 2 (full model) whereas it is more parsimonious. In this model, the income factor ($lgdpc$) becomes highly significant. The general goodness-of-fit statistics are slightly different except for the coefficient of determination.

Results for stepwise variable selection

Starting with the full model with 16 variables (Model 2), the selection procedure resulted in a 10-variable model (referred to as Model 8 hereafter), with a

Wald χ^2 of 505.1, an adjusted R^2 of 0.22 and H-L χ^2 of 13.03 (not significant at 5% level). The fact that model assessment statistics are close to, even better than, those of the full model indicates that some factors are redundant or don't add much in the explanation of the response variability. The variables that are retained in the final model are *lgdpc*, *gdpg*, *lexpm*, *lexpgdp*, *lodag*, *lodac*, *lpopu*, $lref$, $lelf$ and *democ*. Variables that were firstly seen as candidates for removal from the model on the basis of their correlation to other variables remain in the model. It is worth noting however that the correlation coefficients of these variables with the remaining factors are below 0.90. This is in line with the observation made in the previous paragraph and tends to confirm that the multicollinearity effect may be a problem for correlations stronger than the 0.90 level. The signs of the coefficients of these retained variables are consistent with those reported for Models 1 and 2, confirming their robustness. The case of *lodag* and *lodac* merits further comments.

We noted that higher values of the share of the development assistance in the GDP are associated with lower probability of armed conflicts. The relationship is opposite about the development assistance per capita. This can be interpreted with two assumptions: (i) very poor countries whom economies depend for a large part on foreign assistance are less prone to armed conflicts because there is little incentive to engage an armed conflict, or have no resources to spend at expensive military operations. These countries receive actually small amount of aid per capita compared their richer counterparts. (ii) Countries which receive high amount of development assistance per capita are those that are in transitional situation and/or constitute strategic and geopolitic interests of rich countries. These countries are more prone to armed conflict and military operations that can, in turn, be supported by the development assistance funds. These countries are not necessary the least developed ones. This interpretation is in line with findings by McGillivray and Noorbakhsh (2004) and by Kosack (2003) about the relationship between aid and the human development index. They found that aid was negatively associated with HDI values, and the sign of the coefficient was robust against several alternative specifications.

To illustrate our interpretation, let us look at plots of development assistance indicators evolution over time for Sudan (high strategic/economic interest and middle-income group member) and Mali (low strategic interest and low-income group member)(figure 4.4). In the case of Sudan, there is small difference between *lodag* and *lodac* levels in comparison with other recipients, whereas the difference is larger in the case of Mali. The Mali's pattern is typical of low income group countries, whatever their political situation. The trend of Sudan's time series plot is observed mainly with countries with strong central government and relatively good economy that experience rebellion conflicts without falling into total chaos (Indonesia, Sri Lanka, etc.).

However, when we look at a scatterplot of *lodag* and *lodac* while separating the conflict and no-conflict cases (figure 4.5, top), we can observe that the extent of no-conflict cases in the high values of development assistance indicators is larger than for the conflict cases. It does not seem that conflict cases have higher values of *lodac* than no-conflict ones. We can suspect an interaction with another factor in the model. When we replace *lodag* by *lpopu* (population size indicator), we see that there is indeed a tendency to high values of *lodac* for conflict cases (figure 4.5, bottom).

Results for principal components regression

The selection of components to use in the regression model lead to 9 out of 16 principal components. It is worth noting that the components retained in the model (Model 9) are not necessary ordered according to their eigenvalues. For instance, in the final model we have the first, second and seventh components, but not the others in between (3rd to 6th). Not surprisingly, the overall statistics of model quality were similar to those of the reduced model obtained from the variable selection procedure: a Wald χ^2 of 507.3, an adjusted R^2 of 0.22 and H-L χ^2 of 8.6 (not significant at 5% level). The nine components that we retained account for 63% of the total variance in the explanotory variables. The principal component approach and the stepwise varable selection method can be equally applied. The latter method has however the advantage that it is readly interpretable whereas the PC approach does not have necessary a clear intepretation in terms of inital variables. On the other hand, the PC method could be advantageous in case of high mutlicollinearity.

4.2.2 Receiver operating characteristics curves

Another means of quality assessment for logistic regression models with binary response is the receiver operating characteristics (ROC) curve. The fitted model allows to calculate the event probability (probability of an armed conflict in this case) for each observation (each country-year entry in our model). If the predicted probability exceeds some threshold, the observation is predicted to be an event observation, otherwise is a nonevent. Different classifications can be obtained from the same model by varying the cutpoint value. The classification accuracy can be measured by its *sensitivity* which is the proportion of event responses that were predicted to be events (true positive rate), and its *specificity* which is the proportion of nonevent responses that were predicted to be nonevents (true negative rate). A ROC

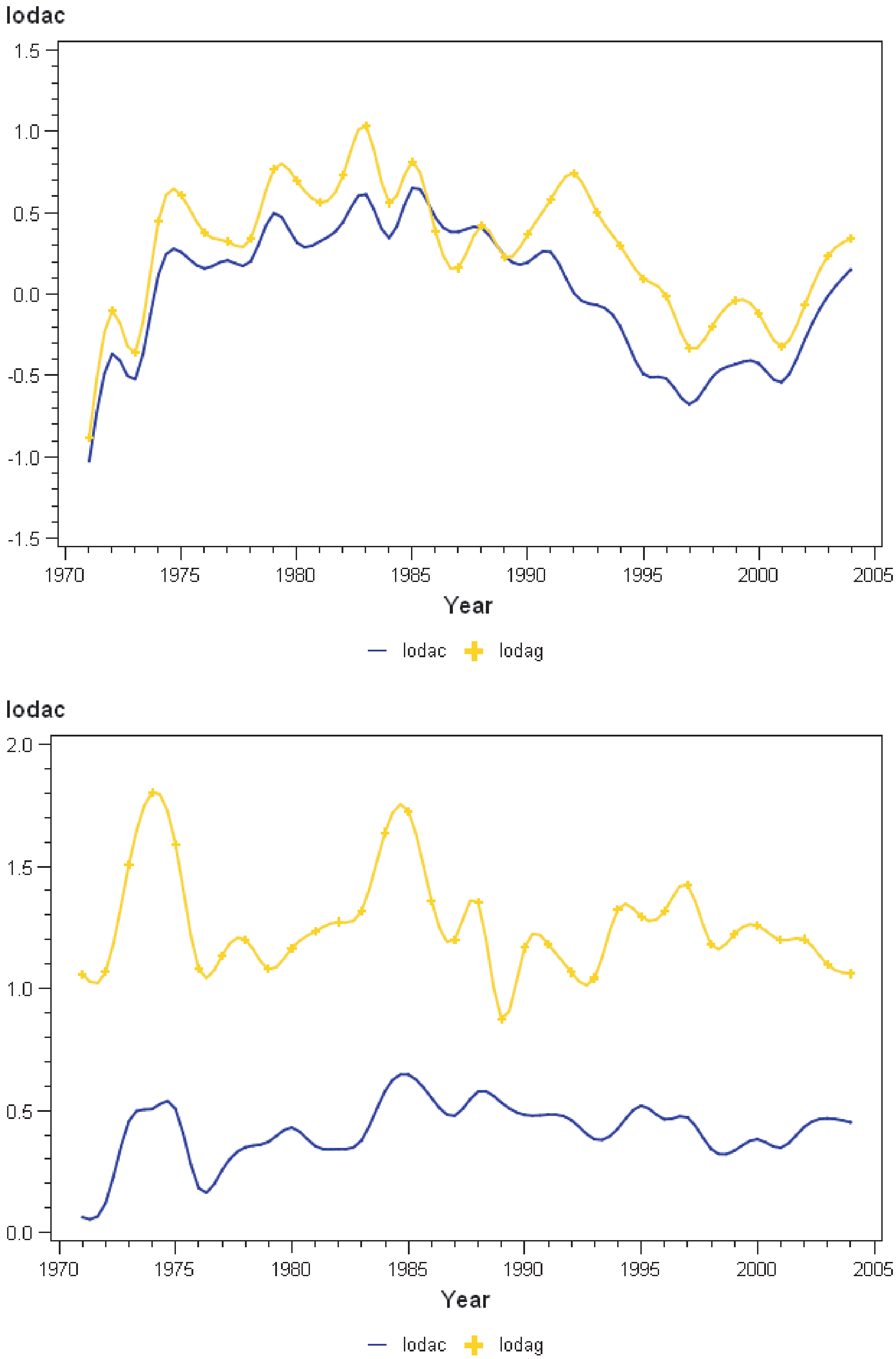


Figure 4.4: Official development assistance indicators from 1971 to 2004 for Sudan (top) and Mali (bottom). Plotted values have been standardised after taking their logarithm and may contain imputed values.

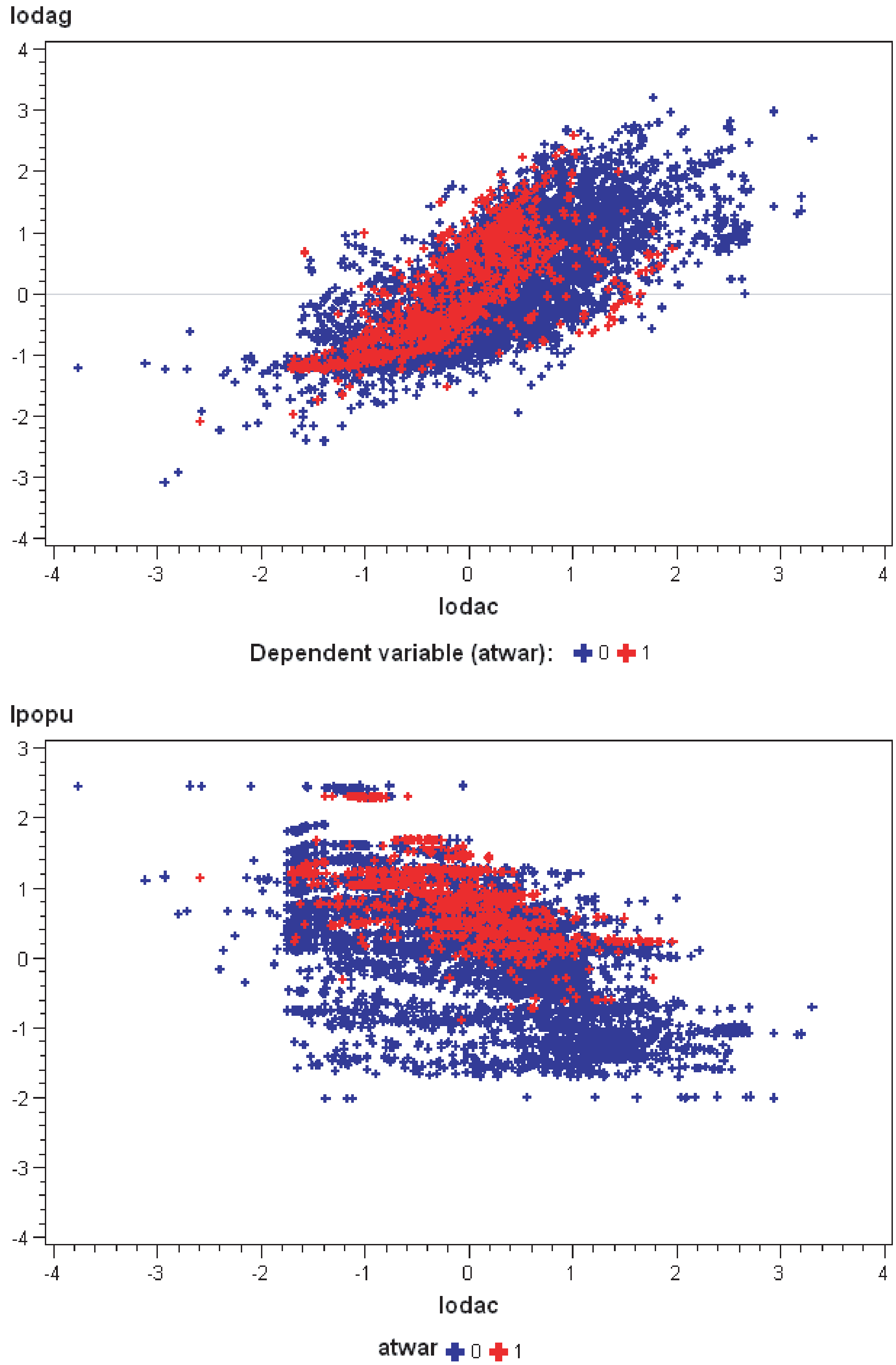


Figure 4.5: Official development assistance as percent of the GDP (*lodag*), and population size (*lpopu*), vs. official development assistance per capita (*lodac*) for conflict (1) and no-conflict (0) cases. Plotted values have been standardised after taking their logarithm.

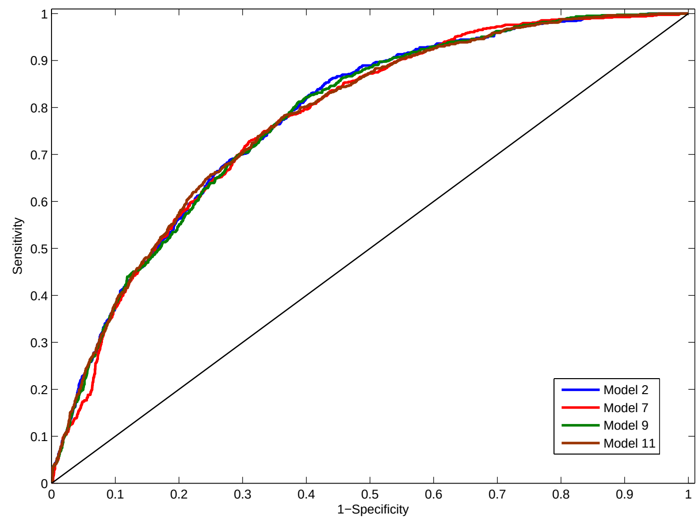


Figure 4.6: ROC curves of models that are most promising. The under-curve area is almost similar for the four curves (0.77).

curve plots the *sensitivity* as a function of *1-specificity* (false positive rate) as the predicted probability threshold is varied. It is used to represent on a ROC graph the *line of random guess* (line of no-discrimination) which lies on the diagonal line. The ROC curve is normally convex and the area under it measures the overall classification accuracy that the model could provide. More the ROC curve is far from the diagonal, better is the model. The ROC curve can also be used to decide the cutpoint value in the predicted probability if one is interested in a binary response output. The cutpoint will be a tradeoff between sensitivity and specificity. High sensitivity will be related to higher risk of false positives (higher risk of predicting erroneously a conflict) whereas low sensitivity raises the risk of false negatives (higher risk of missing to predict a conflict which occurred).

The graphics of figure 4.6 show ROC curves of four candidate models, Models 2, 7, 8 and 9. The four models are quite similar, with slightly higher sensitivity of Models 2 and 9 in the zone of best compromise between sensitivity and specificity. The differences are however too tight so that we can consider them equivalent on the ground of the ROC curves.

From these model assessment, we can conclude that the best alternative model to the full model (Model 2) is Model 9 which is obtained by selecting variables that have most explanatory power. This model has the advantage on Model 2 of parsimony and therefore it should be less affected by missing values because it is based on less variables. The question now is to know if we can build the predictive model based on selected variables only for further works. In other words, is the set of selected variables robust enough or just driven by data? We can partially answer the question based on theoretical considerations.

The variables that are retained in this model can be grouped into 5 categories: (i) economic indicators that measure the economic development level (thus state capacity to control growing conflicts); (ii) trade indicators that measure the openness and the inter-dependency of economies of different countries; (iii) indicators of development assistance that measure the dependency of economy to foreign aid and therefore its weakness and vulnerability to other countries willing; (iv) indicators of social fractionalisation; and (v) indicator of level of democracy which is an evaluation by experts of the political capacity of a state to handle internal problems. The indicator of level of democracy constitutes a way to take into account subjective assessment of political situation which can not be quantitatively measured. Its score depends heavily on the history of the country and on several past events that had not necessary affected significantly other indicators. It can be subject to serious bias however, if the experts involved in the assessment are not really independent. The link of these factors to the risk of armed conflict has been largely reported in previous studies, even though the relations were not systematically found robust. This is specially the case for the social fractionalisation indicators whom the effect has been discussed heavily by scholars.

4.2.3 Risk predictions based on structural indicators

We postulate that the process of conflict genesis and resolution takes more or less long time (at least five years) so that we can use data collected some years ago. We consider that results of the model fitted on data covering the period up to 2004 should hold for the period of the following five-year period, i.e. 2005-2010. We report hereafter results obtained mainly with the Model 9, and sometimes with the full model (Model 2) for comparison. We estimated the probability of armed conflict for the country-year observations without missing data for all the variables in the model. This is an important limitations because the estimates of countries that have not reported data to the international organisations (due to total collapse of the state or due to economic and diplomatic sanctions) are not reliable at all. Some of such countries are Afghanistan, Iraq, Libya, North Korea, Cuba, Somalia and the former Yugoslavia. Estimated probabilities for selected periods are mapped

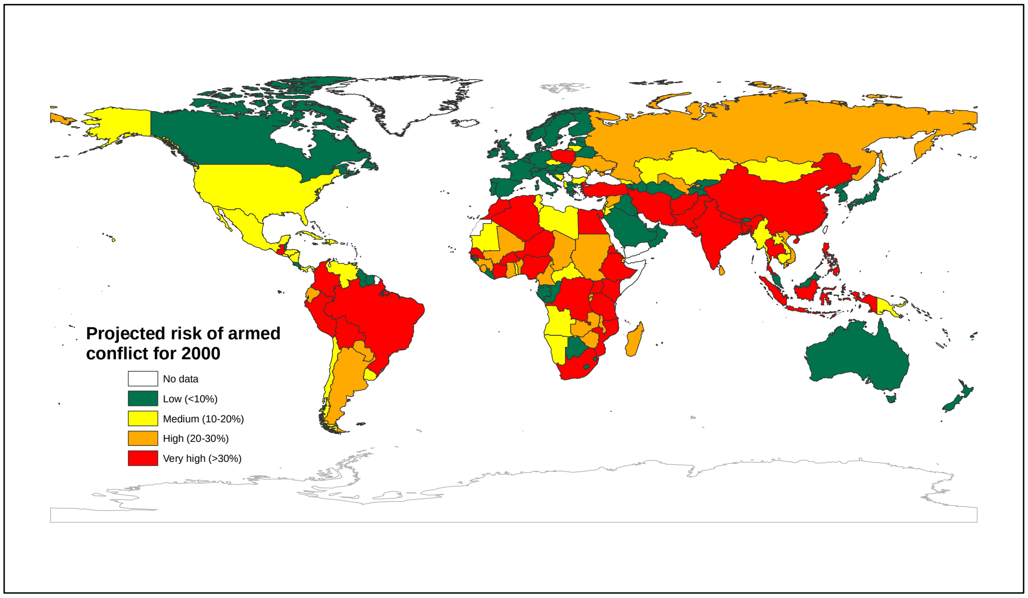


Figure 4.7: Risk of armed conflict in 2000 estimated with Model 9 (see text for details on the model).

on figures 4.7, 4.8 and 4.9. With these periods, we can assess the consistency of our model through time for the recent past. In fact, we present results for 2004 because it is the last year for which data are available. We compare them to those of 2003 and of 2000 only for the sake of brevity, but the main conclusions should not have changed if we had chosen other periods. Similarly, we present estimated probability time series for some countries.

To help reading these maps, we list in table 4.6 the top 20 countries with high estimated probability for armed conflict occurrence. There are 15 countries that are in the top 20 for the three reported years. This show that the model is consistent over time. These maps show a number of things that can appear strange on the first view. One could ask why countries like China, India, Brazil, Turkey and South-Africa are reported to have high risk of armed conflict whereas they are usually seen as stable. In fact, all these countries, along with Indonesia and Nigeria have large populations and relatively low GDP per capita and have experienced at least one armed conflict –according to the definition we adopted in this study– in the recent past. For instance Turkey has been on war for several years against the PKK (Kurdistan Worker's Party) rebellion; several "small" conflicts have been active up to now in India; Indonesia and Nigeria also have their domestic rebellions still active. The estimated high risk for China and Brazil is obviously due to

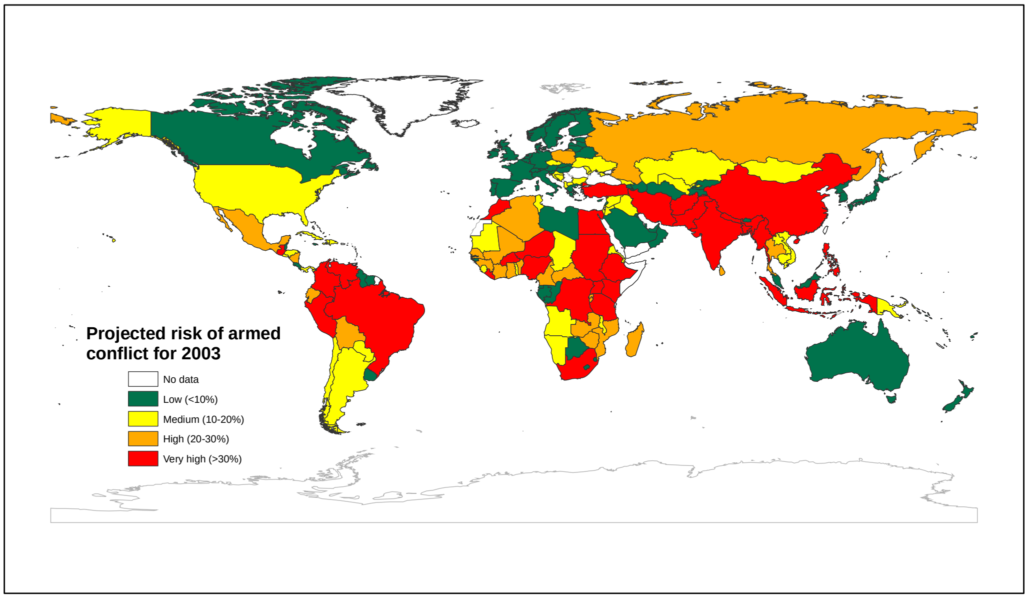


Figure 4.8: Risk of armed conflict in 2003 estimated with Model 9 (see text for details on the model).

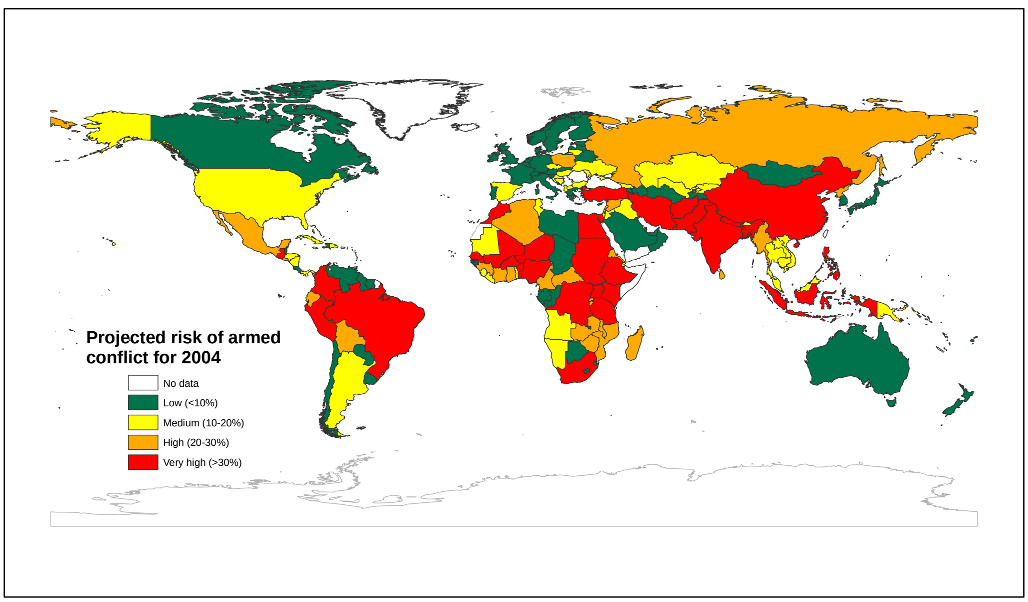


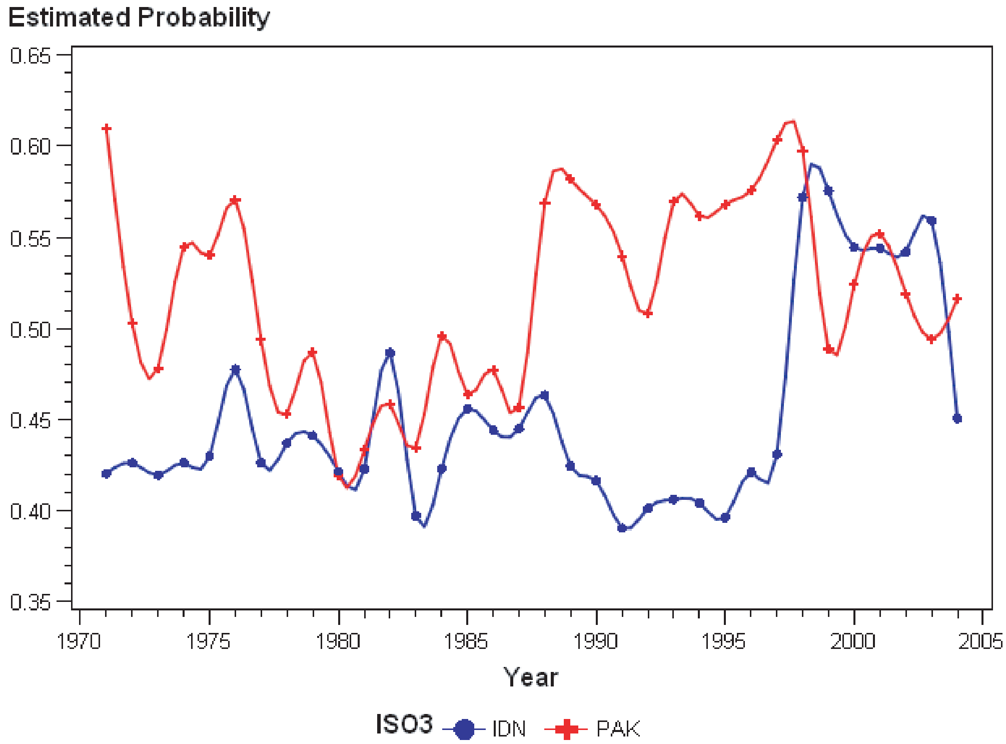
Figure 4.9: Risk of armed conflict in 2004 estimated with Model 9 (see text for details on the model).

Table 4.6: Top 20 countries ranked according to the projected risk (π_{ij}) of internal armed conflicts in 2000, 2003 and 2004

2000		2003		2004	
Country	π_{ij}	Country	π_{ij}	Country	π_{ij}
India	0.79	India	0.70	India	0.71
Afghanistan	0.58	Afghanistan	0.64	Pakistan	0.52
Indonesia	0.54	Indonesia	0.56	Morocco	0.49
Congo, Dem Rep	0.53	Ethiopia	0.56	Indonesia	0.45
Pakistan	0.52	Pakistan	0.49	Colombia	0.45
Turkey	0.47	Colombia	0.44	Nigeria	0.43
Ethiopia	0.47	Brazil	0.42	Niger	0.43
Morocco	0.46	Kenya	0.42	Kenya	0.43
Brazil	0.44	Bangladesh	0.40	Bangladesh	0.41
China	0.43	Peru	0.40	Congo, Dem Rep	0.40
Tanzania	0.41	Morocco	0.39	Peru	0.40
Bangladesh	0.41	Liberia	0.38	Nepal	0.39
Egypt	0.41	Turkey	0.38	Brazil	0.38
Nigeria	0.40	Egypt	0.36	Turkey	0.37
Colombia	0.40	Nepal	0.36	Mali	0.37
Nepal	0.39	Myanmar	0.35	Burkina Faso	0.36
Kenya	0.38	Congo, Dem Rep	0.35	Guatemala	0.36
Niger	0.37	South Africa	0.34	Tanzania	0.36
Thailand	0.37	Guatemala	0.34	Egypt	0.36
Peru	0.37	Tanzania	0.33	Ethiopia	0.34

their large populations because they did not experience any internal armed conflict since 1971, whereas the high risk for Tanzania is obviously due to its very poor economic performance.

Another interesting information that can be derived from the results of this model is to analyze the trend of the risk of armed conflict for a country over years. Such time series plots are shown on figures 4.10–4.12. We took examples of large asian countries, countries rich in mineral and fossil resources, countries that are recovering from severe wars (Angola and Mozambique) and countries that did not experience internal armed conflict while their neighbours, with which they share many characteristics, have been heavily affected (Kenya and Tanzania).



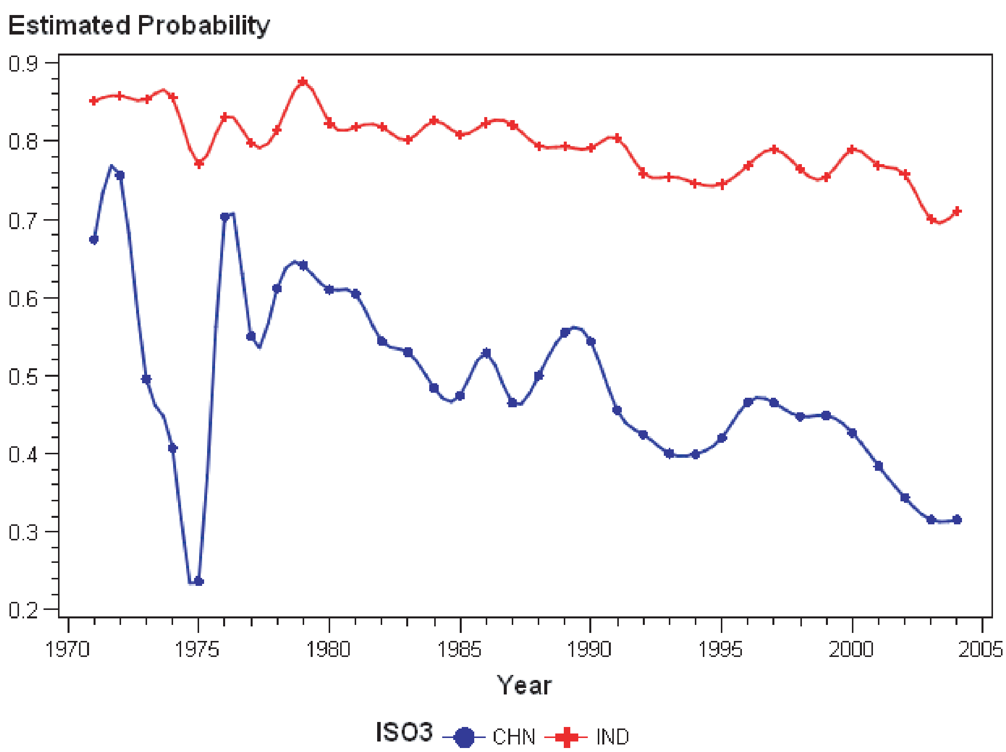


Figure 4.10: Evolution of the risk of internal armed conflict from 1971 to 2004 for some countries. The ISO codes are as follows: IDN for Indonesia, PAK for Pakistan, CHN for China and IND for India.

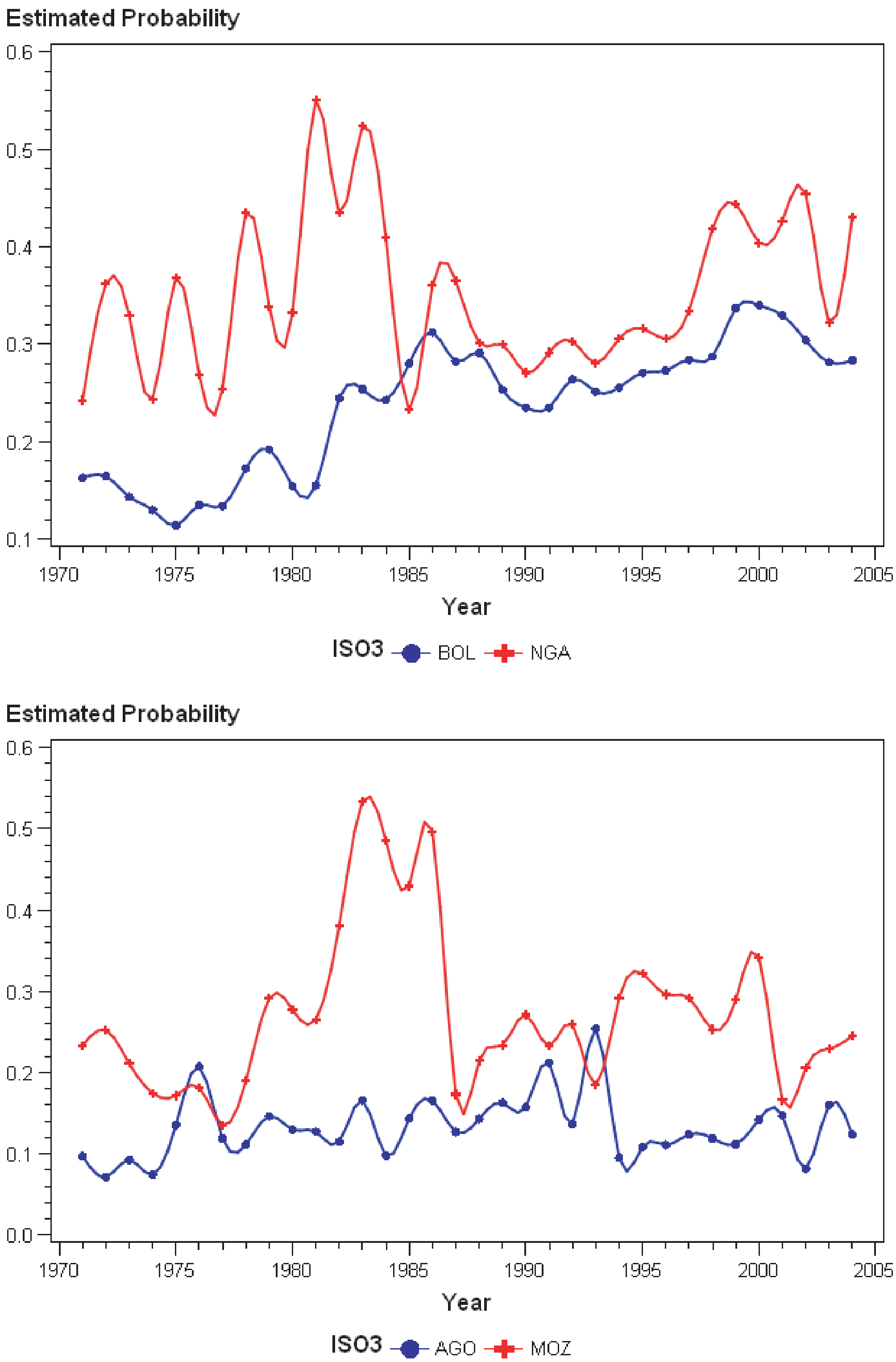


Figure 4.11: Evolution of the risk of internal armed conflict from 1971 to 2004 for some countries. The ISO codes are as follows: BOL for Bolivia, NGA for Nigeria, AGO for Angola and MOZ for Mozambique.

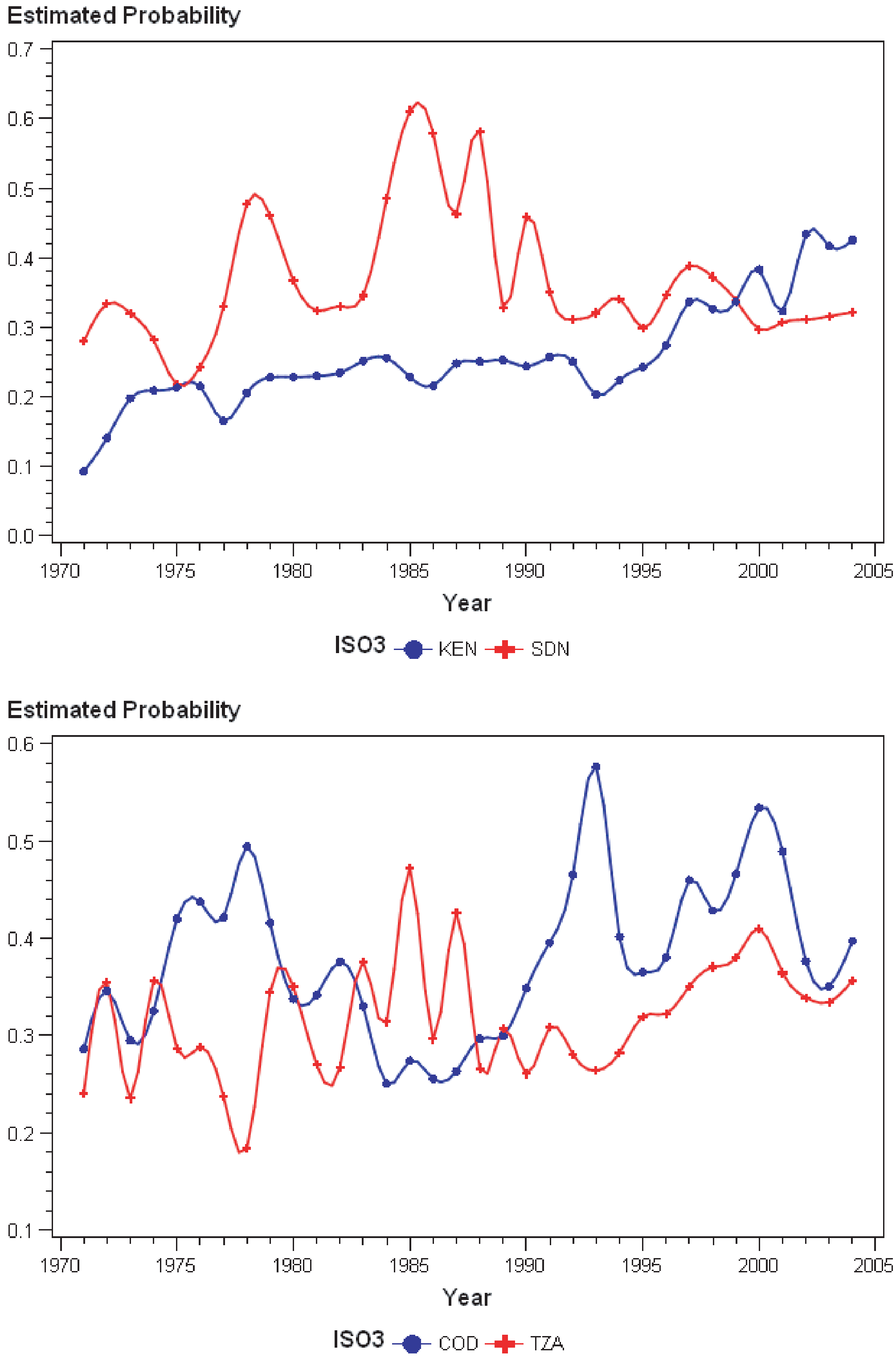


Figure 4.12: Evolution of the risk of internal armed conflict from 1971 to 2004 for some countries. The ISO codes are as follows: KEN for Kenya, SDN for Sudan, COD for Democratic Republic of the Congo and TZA for Tanzania.

4.3 Risk related to previous conflicts

The probability that an armed conflict occurs in a country (for the period 1971-2004) was estimated on the basis of occurrences of conflict previously observed. As explained in section As it can be seen on figure 4.13, this probability was almost constant for different years during the cold war period (until 1991), diminished a little bit around 1995 and became raising again in early 2000s'. This means that on the global level, the probability to observe an armed conflict has been almost constant for several years, with a mean value of 0.73 and a mode of 0.78 (most likely value). Another interesting thing to observe on this figure is that the end of the cold war period is marked by a pick in the number of countries at war (s_i) and in the potential number of countries prone to armed conflict ($\hat{S}_i$) whereas the probability $\hat{p}_i$ of risk related to previous conflict is on the minimum. This means that this period marked a change in the pattern of armed conflicts. If we examine the different components of the number of countries at war each year (figure 4.14), we can note that in that period there are more new armed conflicts than other years while the number of resolved conflict in the same period is relatively low. Moreover, in the following years, we observe less new conflicts and more resolved conflicts. It is important to understand that what we put in the category of resolved conflicts the countries that were at war during the year under consideration and that have not yet returned to war at the end of the studied period, i.e. 2004. The probability $\hat{p}_i$ takes into account this and does not necessary follow the trend of s_i, the number countries at war. A number of countries that resolved their conflicts between 1990 and 1995 did not return to conflict afterward.

For each country and for each year, we estimated α_{ij} the probability of conflict due to the conflict history by applying formula 3.13. The values of p_i at the first and last years (1971 and 2004) could not be directly estimated. They were replaced by the mode value. We finally took the average value between the probability estimated with Model 9 (structural factors) and that related to the history of conflicts. This can be regarded as the overall risk of armed conflict given the socio-economic situation of the country in the recent past. Figures 4.15 to 4.17 show average probabilities for some countries as comparison with figures 4.10 to 4.12. We can note that the effect of previous conflicts is well marked for countries like Angola, RDC and Sudan for which the probabilities calculated form the structural indicators model were relatively low. Similarly, the overall risk for China becomes much lower than for India because the latter has had armed conflicts for almost all the period under consideration.

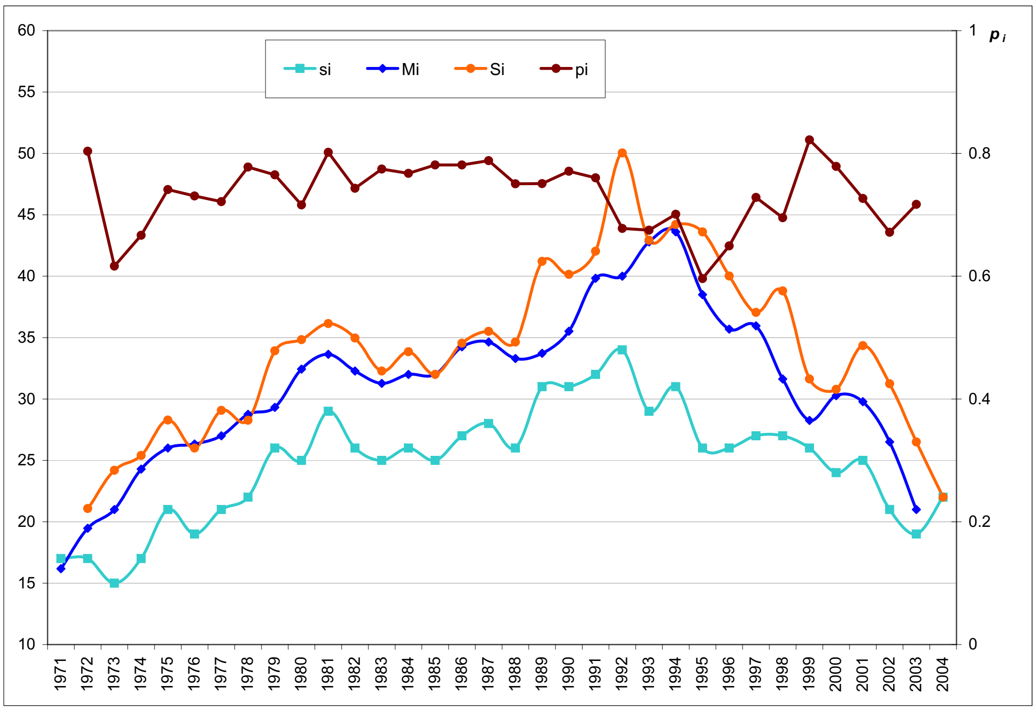


Figure 4.13: Evolution of the probability of armed conflict based on the history of conflicts ($\hat{p}_i$), the frequency of armed conflicts (s_i), estimate of the number of countries prone to armed conflicts ($\hat{S}_i$), and estimate of the number of countries that are prone to two or more episodes of armed conflict ($\hat{M}_i$).

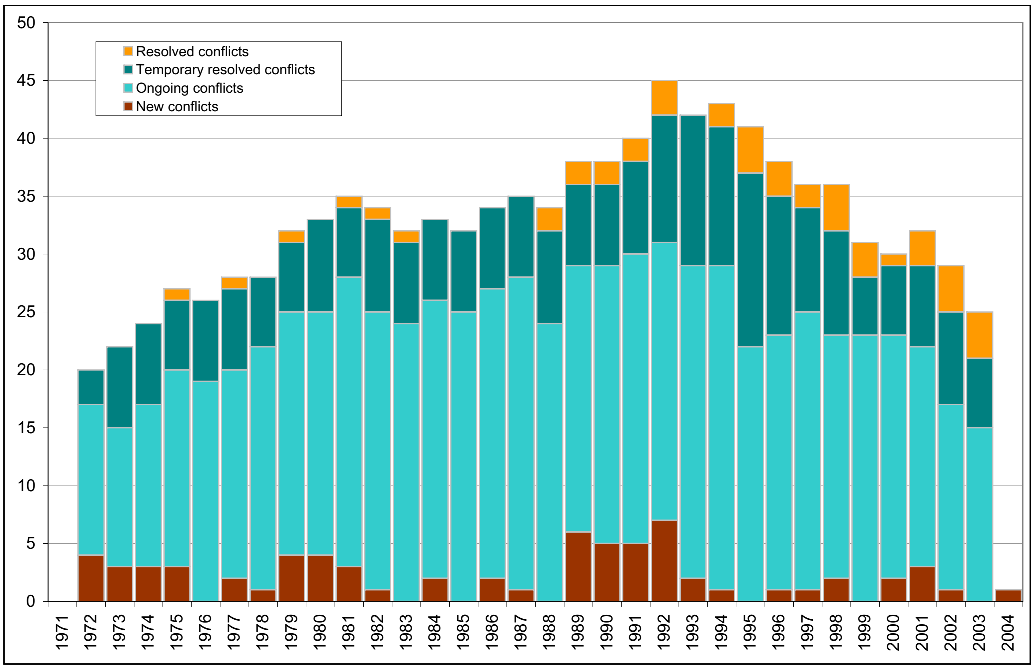


Figure 4.14: Evolution of the total number of countries involved in or are prone to an armed conflict each year with a breakdown into different categories (new, resolved, temporary resolved and ongoing conflicts). Note that some categories can not be calculated for the first and last years (1971 and 2004, respectively). For instance, it is not possible to calculate the number of new conflicts in the first year of the period under consideration, and the number of resolved conflicts for the last year.

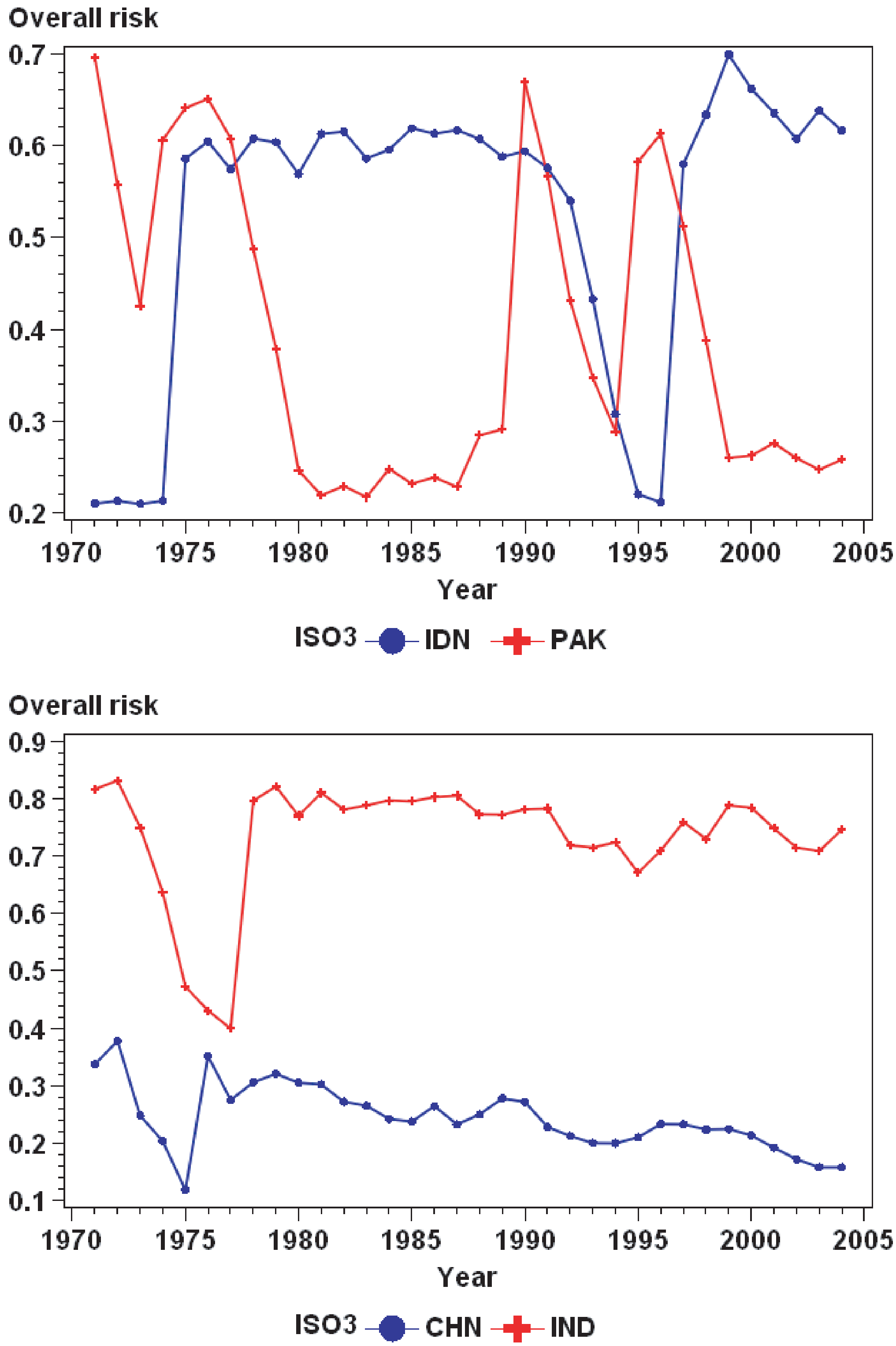


Figure 4.15: Evolution of the risk of internal armed conflict from 1971 to 2004 for some countries. The ISO codes are as follows: IDN for Indonesia, PAK for Pakistan, CHN for China and IND for India.

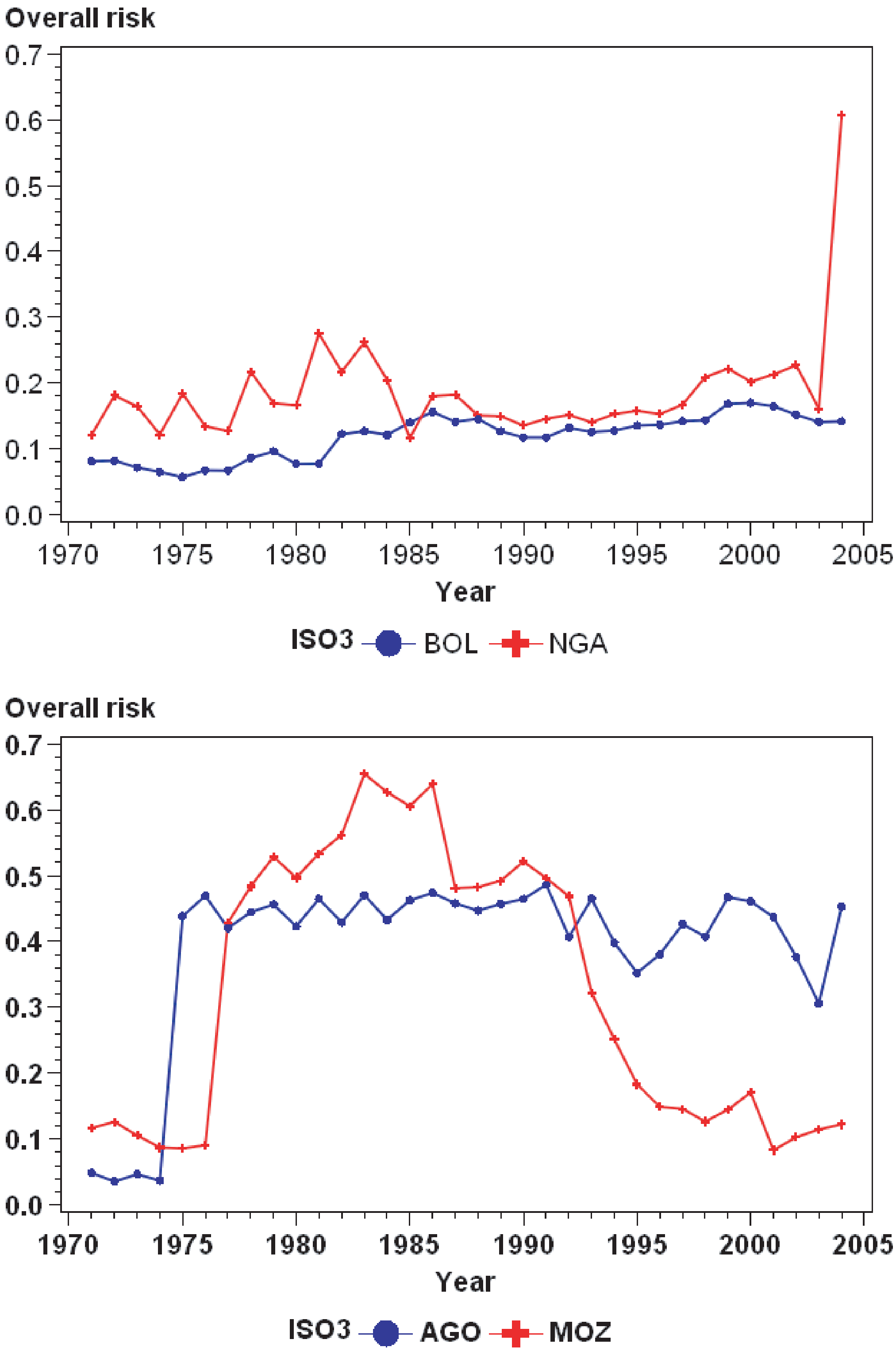


Figure 4.16: Evolution of the risk of internal armed conflict from 1971 to 2004 for some countries. The ISO codes are as follows: BOL for Bolivia, NGA for Nigeria, AGO for Angola and MOZ for Mozambique.

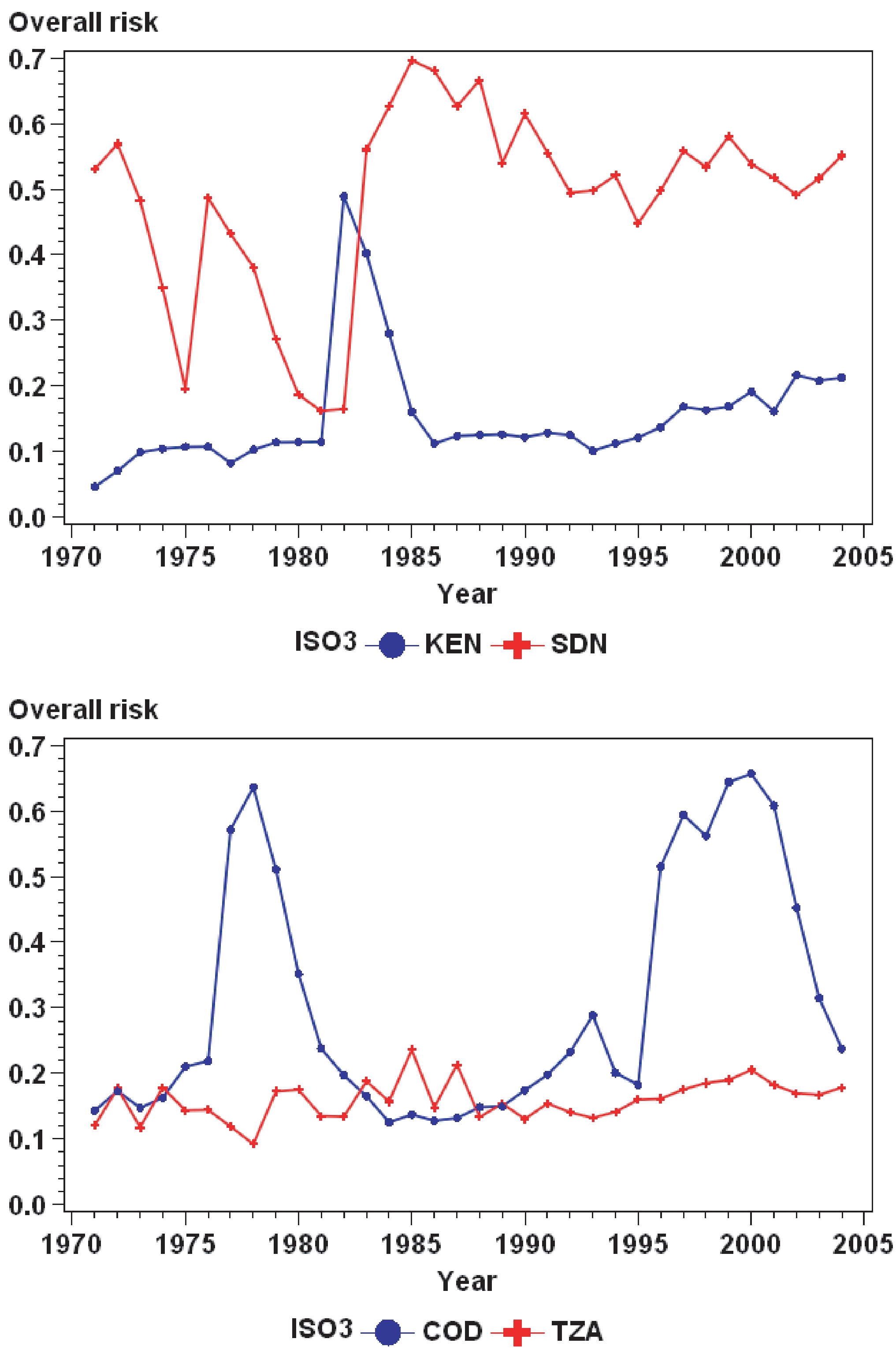


Figure 4.17: Evolution of the risk of internal armed conflict from 1971 to 2004 for some countries. The ISO codes are as follows: KEN for Kenya, SDN for Sudan, COD for Democratic Republic of the Congo and TZA for Tanzania.

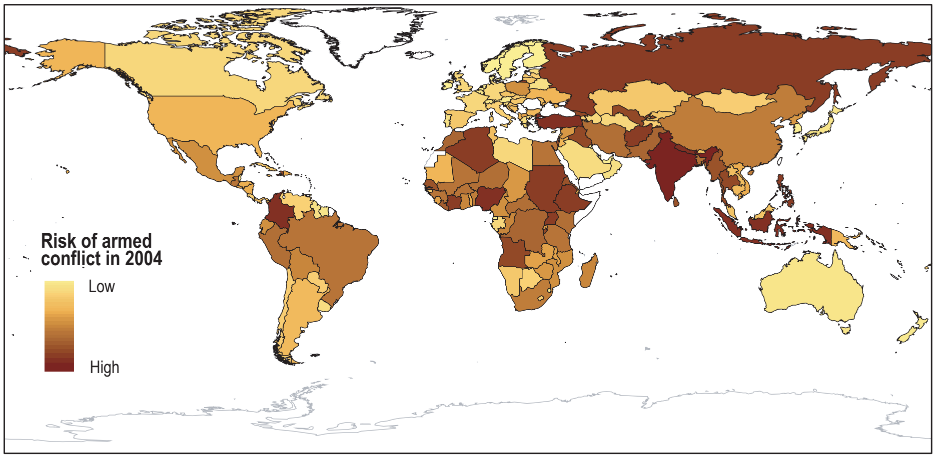


Figure 4.18: Risk of armed conflict in 2004 as estimated with Model 9 (see text for details on the model) and adjusted for the effect of previous conflicts.

We present on figures 4.18 and 4.19 maps of risk of armed conflict in 2004 as estimated in this study. We recall that the estimates for some countries must be interpreted with caution as they socio-economic data were actually sparse. This is especially the case for Iraq and Afghanistan. The model can be updated easily as new data become available. The first map depict the risk on a continuous scale whereas the second shows countries classified into four groups with breakpoints defined as follows: low risk ($< 10\%$), medium risk ($10-20\%$), high risk ($20-30\%$) and very high risk ($> 30\%$). In the context of armed conflicts, we are talking about rare events (the cases represent 7% of the observations), and probabilities greater than 20% can be ragarded as already high (King and Zeng, 2001a). We used this

On the basis of these results, we can note that the ten countries with highest risk are in the order India, Indonesia, Colombia, Nigeria, Nepal, Turkey, Ethiopia, Uganda, Sudan and Philippines. All these countries have indeed strong central governments that have been challenged for a long time by different kind of rebellions. They will perhaps never explode into total war and collapse, but they remain in somehow fragile. We think however that the model overestimate the risk for India and Turkey. Their estimates are systematically high for the last 20 years, even 30 years for India. In the same time they showed a remarkable economic development. These countries

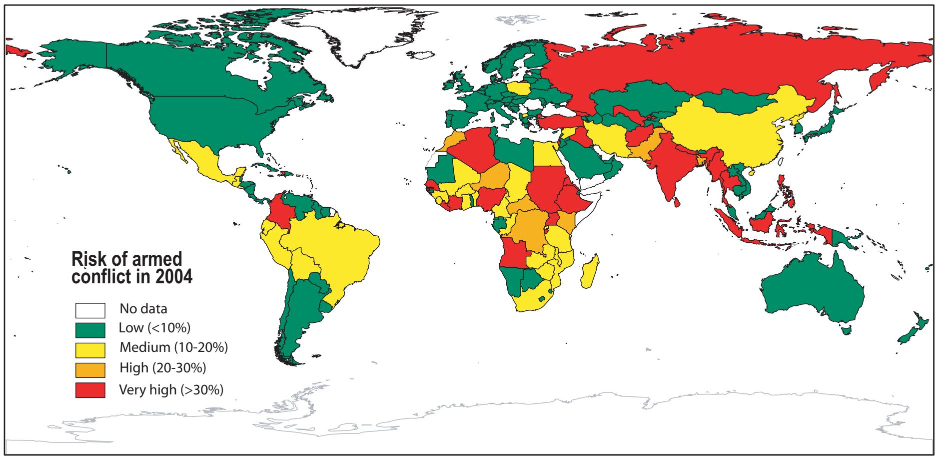


Figure 4.19: Risk of armed conflict in 2004 as estimated with Model 9 (see text for details on the model) and adjusted for the effect of previous conflicts.

succeeded in keeping at low level the influence of their rebellions and concentrating to development economic rather than trying to resolve all conflict cases before moving ahead for economic activities.

4.4 Comparison with the World Bank composite indicator of political stability

Studies on conflict risk modelling are usually conducted as isolated cases in that sense they rarely try to compare their results with those produced with different approaches. The World Bank produces the Worldwide Governance Indicators (WGI) that cover 212 countries for 1996, 1998, 2000, and every year since 2002. These indicators could be compared for example with the CIFP index which aims also to provide a risk assessment measure, and vice-versa.

We have chosen the political stability indicator of WGI as an alternative measure of risk of conflict with which we can compare our risk index. We found that the correlation between both indices, as measured by the Spearman correlation coefficient, was highly significant ($r = -0.77, p < 0.01$ in 2004, and $r = -0.74, p < 0.01$ in 2003). This means that both indices agree globally as it can be seen on figure 4.20. These figures plot the logit of our overall risk index as function of the WB political stability indicator for 2003 and 2004. We used the logit scale because we can expect a linear relationship between the logit of the estimated probability and the WB indicator which is based on the distribution of the aggregate of individual indicators. The WB

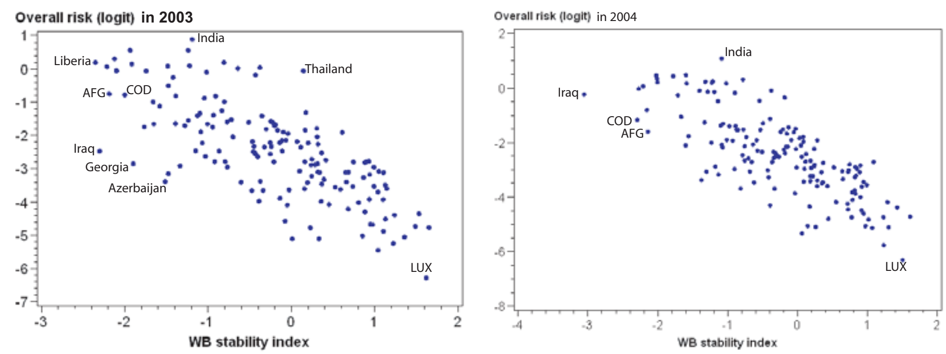


Figure 4.20: Comparison of the JRC's conflict risk index and the WB's political stability index in 2003 (left) and 2004 (right). Some extreme points are labeled with the country name or ISO code (COD for the Democratic Republic of the Congo, LUX for Luxembourg, and AFG for Afghanistan).

indicator is not a probability measure but a ranking indicator, standardised to mean 0 and variance 1 worldwide for each year. It is actually a linear combination of several individual structural indicators, and by consequence, it should be linearly more or less correlated to the exponent part of the logistic regression model (equation 3.2). We can observe indeed the expected linear relationship. The main disagreement cases are Iraq and India, and in some way the DRC and Afghanistan, for the 2004 data whereas for the 2003 data, the main disagreement cases are Iraq, Georgia, Azerbaijan, Thailand and India. Our model predicts high risk for India whereas the WB's index indicates low level of political instability. On one hand, the fact that India has been globally stable and experiences rapid economic growth since decades explains the good score on political instability index. On the other hand, India has been involved in armed conflicts, of minor intensity compared to its huge territory and population, but with so many fatalities that they meet the definition of armed conflict used in this study. As consequence, our model predicts logically high probability of armed conflicts. In the case of Iraq and Afghanistan, lack of data on structural indicators as opposed to high media coverage explains the aforementioned discrepancies. In the case of Georgia and Azerbaijan, our model predicts low risk, which corresponds indeed to structural indicators trend and to the fact that those countries had resolved their respective internal conflicts in 1993 and 1995. In the meantime, this countries continued to occupy an important place in the media up to now in the general context of the Caucasian region politics. This is probably the reason of the bad score on the WB's index because it is largely based on experts' opinion.

Chapter 5

Conclusion

Throughout this report we hypothesized that a number of widely used structural indicators might be strongly correlated with the risk of armed conflict in a country. We found that the regression model may be used to predict the probability of conflict outbreak and used operationally for warning about the risk of war in any country. However, while certain structural conditions may exacerbate already existing political tensions in a country, the mechanisms which then lead to conflict are not well understood and can be highly specific. The estimates for some countries must be interpreted with caution as their socioeconomic data were actually sparse. This is especially the case for Iraq and Afghanistan. However, the model can be updated easily as new data become available. The method outlined is operational; it can be used for estimation of conflict probability and for prediction of conflict for countries for which structural data exists; results are as good as any currently in use. Estimated probability time series show that our model is consistent over time.

For decision makers the output of a conflict prediction model should be the location, time frame, impacts of conflict and conflict response feedback effects. Models such as ours, using structural data cannot produce such outputs; they make a static assessment of country level performance, which can then be ranked for conflict risk.

Appendix 1. Kenya case study

This short note addresses the root causes of the current political violence in Kenya[1]. Since a number of studies on the link between armed conflict and socio-economic factors have shown some strong correlations between these phenomena, at-risk situations (in terms of large-scale politically motivated violence) can be identified and monitored accordingly (Figure 1).

A global model to estimate the risk of armed conflict was developed by the JRC with an emphasis on structural factors (hereafter referred to as structural indicators). The first focus was on armed conflicts because they are better monitored than other, less coordinated political crises, which are thought to have less impact (casualties and economic loss). It is worth noting however that in many cases, classical armed conflicts develop as a consequence or extension of civil unrest, particularly when the root causes are not properly addressed or the central government becomes unable to enforce order on all its territory.

The literature review and variable selection methods identified 9 factors as being the most influential on the prediction of the risk of armed conflict. These factors were: (i) indicators of economic activity (GDP per capita, GDP growth rate, merchandise exports, exports of goods and services as percent of the GDP), (ii) indicators of economic dependency on foreign aid (official development aid (ODA) per capita and ODA as percent of GDP), (iii) indicators of social fractionalization (religious fractionalization index and ethno-linguistic fractionalization index), (iv) population size, and (v) an indicator of regime type (index of democracy level). They were auto-selected from a set of 20 factors for their explanatory power.

In a separate analysis undertaken by the JRC, the model took also into account the effect of past conflicts (history of armed conflict in the country). The overall risk was obtained by combining both estimates for each country and each year. The database contains therefore estimates for 196 countries and for the years from 1971 to 2004. A trend curve of the estimates is

[1]This note has been written in January 2008 at the moment of the violent events that erupted after presidential elections of December 2007

Figure 1: Evolution of the risk of internal (armed) conflict from 1971 to 2004 in Kenya. Estimates are based on socio-economic factors and conflict history

an interesting source of information for early warning because it can show situations that have been worsening over time. This is important information for conflict prevention policy implementation. The Kenyan case is illustrative with this respect. It might be recalled that this model was been developed in early 2007, and did not take into account the current situation in the country. The overall risk trend curve shows that the risk of conflict in Kenya has been rising since 1994 and that the trend has been consistent since then (Figure 1). While ethnicity has been mentioned as contributing to risk of armed conflict, Kenya's high ethnic and religious fractionalization scores do not support this explanation. In fact, a high number of different groups increases the group coordination problems and, therefore, given a level of fractionalization, the probability of civil war may be smaller.

Kenya has had an enviable reputation for stability and economic performance among less developed countries. However it seems that this reputation concealed the real trend of its economic indicators within the context of the international system. In fact, Kenya's GDP per capita has been almost constant (around 420 constant 2000 USD/capita) since 1995 while the foreign development aid has continuously decreased (Figures 2 and 3, respectively). In the same period, the volume of imports and exports of merchandise increased denoting a dynamic economy (Figure 4). This is the picture of Kenya considered in isolation.

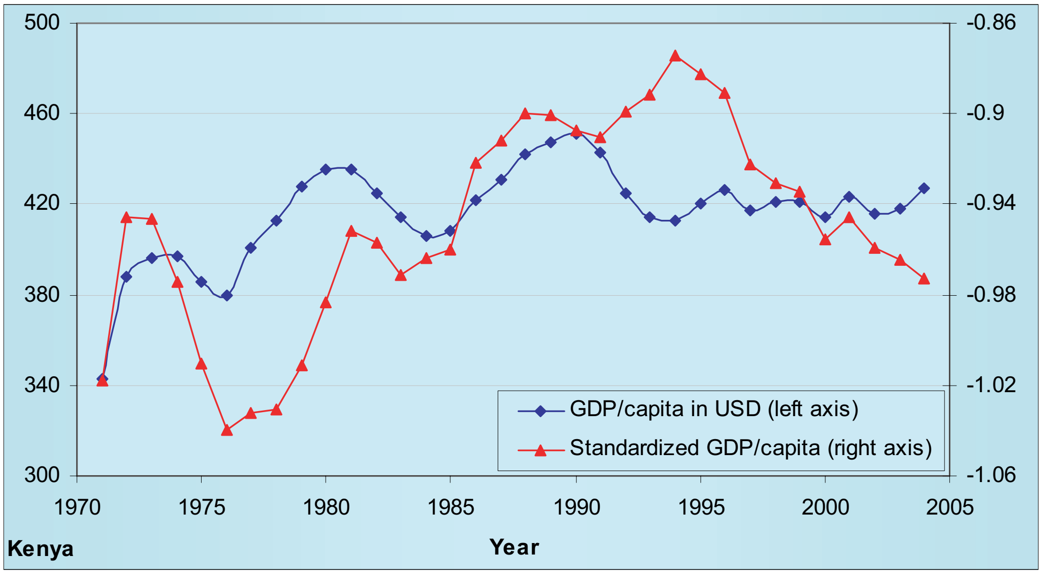


Figure 2: Kenya's GDP per capita trend in absolute values (constant 2000 USD) and relative to other economies (standardized values). Source: The World Bank, *2006 World Development Indicators*.

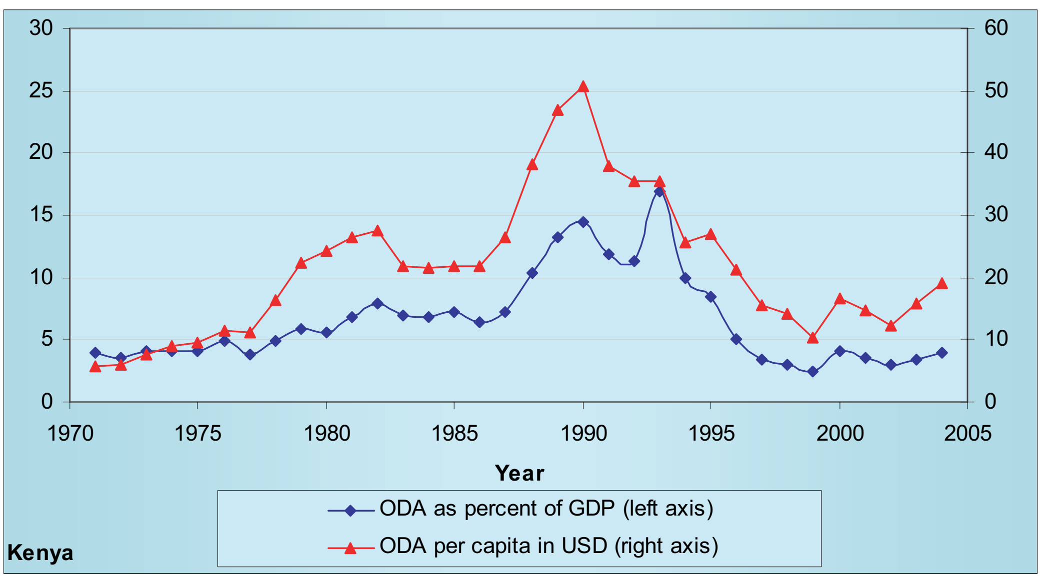


Figure 3: Trend in official development assistance (ODA) to Kenya. Source: The World Bank, *2006 World Development Indicators*.

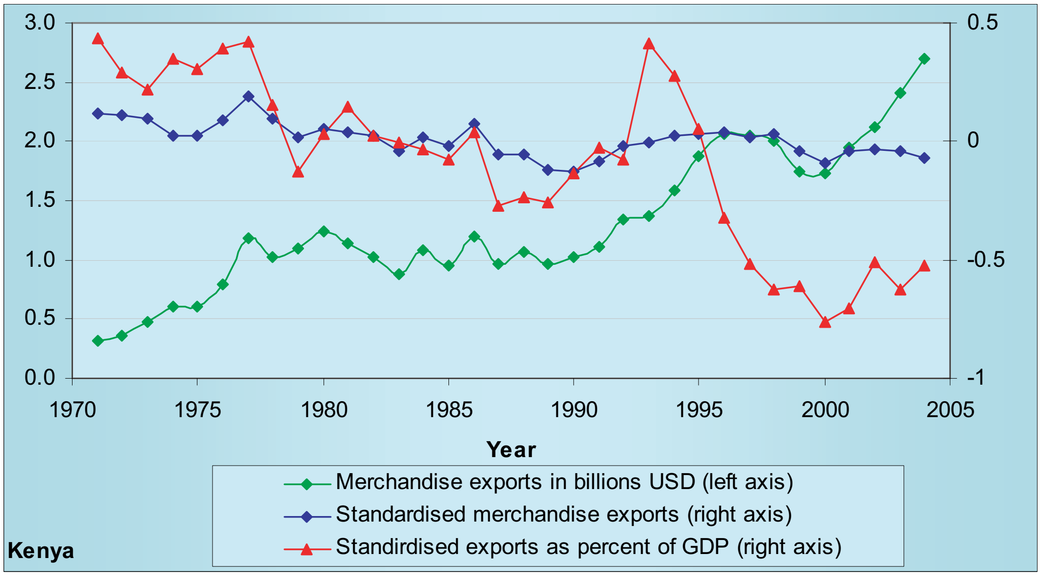


Figure 4: The trends in Kenya's export indicators show a contrasted picture: merchandise exports in absolute values show a consistent and rapid growth in the first half of the 1990s and since 2000, whereas exports share of GDP increases from 2000 after a sharp decrease in the 1990s. Source: The World Bank, *2006 World Development Indicators*.

If the figures are put in the context of the global economy, the situation is different. This has been done by looking at trends of standardized data for each year. In practice, the index is obtained by subtracting the mean value and dividing by the standard deviation. Both statistics (mean and standard deviation) are calculated on the global level and for each year. This indicator can be regarded as a ranking score to benchmark countries socio-economic situation. The trend of standardized GDP per capita shows that Kenya's score has decreased since 1995 (Figure 2).

Based on this analysis of structural trends, the model determines that it was possible to alert policymakers to the deteriorating Kenyan situation before the outbreak of recent violence.

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Abstract
Tools for automated quantitative analysis of information are more and more required in the framework of early warning systems, to support political decision makers in making timely evaluations of the risk of severe crises.
This report describes a scientifically sound approach to build a statistical model to assess quantitatively the risk of intra-state armed conflict in any country in the world. Our models are based on structural indicators, and they therefore make a static assessment of country level performance, which can then be ranked for conflict risk. The temporal trend provide additional information on the evolution of the situation. Attention is paid to operationalise this approach in early situation assessment.

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