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Article

Quantitative Assessment of Political Fragility Indices and Food Prices as Indicators of Food Riots in Countries

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Abstract: The impact of resources on social unrest is of increasing interest to political leaders, business and civil society. Recent events have highlighted that (lack of) access to critical resources, including food, energy and water, can, in certain circumstances, lead to violent demonstrations. In this paper, we assess a number of political fragility indices to see whether they are good indicators of propensity to food riots. We found that the most accurate is the Political Instability and Absence of Violence Indicator of the Worldwide Governance Indicators by the World Bank. We compute a likelihood of experiencing a food riot for each quartile of this index. We found that the self-sufficiency of food does not seem to affect the likelihood of the occurrence of food riots, but that the level of political stability of a country does have a role. In addition, we identify a monthly and annual threshold for the Food and Agriculture Organisation Food Price Index, above which food riots in fragile states are more likely to occur.

Keywords: food riots; national fragility; food price threshold; state weakness; political fragility; resource conflict

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1. Introduction

After the events of the Arab Spring in 2008–2011, a growing body of research has been dedicated to understanding the origin of national political instability and what constitutes a fragile state. After the Cold War, the focus of political analysis switched from inter- to intra-state conflicts [1,2], and recently, much of the violent events that have occurred throughout the world took place in the so-called fragile states [1]. The importance of studying weak states are two-fold: (i) to understand the possible requirement for future aid or military assistance; and (ii) fragility often leads to conflict and spill-over effects among neighbouring countries [3,4]. However, there is a lack of agreement on a common definition of fragile states. As listed in Cament, Prest and Samy [1], some call these countries weak states [5], anaemic, phantom, captured, aborted and anarchic states [6], anocracies [7,8], illiberal democracies [9], delegate democracies [10], narco-states, dysfunctional states, criminal states and people's democracies [11], neo-trusteeships [12], outlaw states and troubled societies [13], rogue states [14], difficult partners [15], difficult environments [16], poor performers [17], weak performers [18], countries at risk of instability [19], Low Income Countries Under Stress [20], vulnerable and/or non-resilient states [21], quasi-states [22], failing and failed states [23] and collapsed states [24]. In this paper, all of these terms will be used as synonyms, apart from "collapsed states". We argue that the use of this term is completely inappropriate in this context, and we support the definition of collapse given by [25] that relates this concept to the collapse of a society, its decline and not to the political fragility of a country. Many of these definitions are used to produce global rankings of countries according to their state weakness. The definitions of state weakness differ as they were developed to highlight different aspects of fragility, but the rankings they produce are highly correlated [26,27].

In general, we can summarise the main pillars of political stability as four key government responsibilities [28]:

- To provide a national setting that can lead to sustainable and equitable economic growth;
- To set up and maintain legitimate, transparent and accountable political institutions;
- To keep their populations safe from violent conflict and controlling their territory;
- To meet the basic human needs of their populations.

When the government fails to provide one or more of these functions, a response from the general population could be triggered. However, the idea that state fragility is a spectrum and that every country is fragile to a certain extent is becoming more popular in the literature [3].

As listed in Cament, Prest and Samy [1], state fragility has mainly been studied by students from the perspective of the state [5], international security [29], international relations [22], critical theory [30], conflict and inequality [31], democratisation [9,32], political economics [33] and development economics [4,34]. Environmental and resource access as causes of state fragility have been neglected from the recent literature.

Two main methodologies have been implemented to better understand what constitutes political fragility: qualitative [35–37] and quantitative approaches (see below). For instance, the qualitative framework put together by Gaub [35] to analyse the recent and on-going regional instability that spread in North Africa and Middle East (*i.e.*, the Arab Spring) focuses on the importance and interplay between three main elements: (i) root causes or conditions for conflict; (ii) catalysts of conflict; and (iii) triggers of conflict. Gaub [35] argues that the presence of structural conditions for instability (e.g., scarcity of natural resources, unequal income distribution or large population growth) is not sufficient to produce conflict. Indeed, the main argument is that the identification and analysis of what he calls "catalysts of instability" is key to understanding conflict potential. These can be seen as sudden changes in the above-mentioned conditions (e.g., a rapid increase in the unemployment rate of a country or spikes in food prices). Once a situation has reached conflict potential by adding a catalyst to one or more root causes, there is still the need for a trigger to boost the conflict likelihood. These could be natural disasters, new elections or, as in the case of the Arab Spring, an isolated event of social distress, like the episode that is commonly known as the starting point of the Arab Spring, when Mohamed Bouazizi set himself on fire as a protest for too high prices of food. This type of analysis is becoming mainstream as other authors define climate change, resource scarcity, a rapidly increasing population and volatility in prices as "stressors" or "stress multipliers" [3,38,39]. Moreover, the presence of thresholds and tipping-points in the fragility spectrum has increasingly been acknowledged in the recent literature [3].

Among the quantitative research, we find different approaches to measuring political fragility: dynamic (e.g., econometric models), structural (e.g., indices of political fragility) and a combination between these [40]. This growing body of research has evidenced a link between the natural environment and instability [35] and an increase in the occurrence and intensity of intra-state conflict. In particular, climate change [41–45], resource scarcity [3,46–54] and prices of food [3,45,55–61] have been highlighted as stressors or catalysts for conflict or, more generally, as a threat for a country's national security.

In the set of Arab Spring-like events, such analyses become pivotal for the understanding of why this kind of situation exacerbates conflict. Although one of the main catalysts of the uprisings connected to the Arab Spring and similar events has widely been acknowledged to be high prices of food [35,38,55], the cause of the spikes in food prices themselves is still an open debate. In particular, the literature seems to be divided into two main streams: authors that believe that the reason behind food price spikes lays in a disruption to the supply chain (*i.e.*, a decrease in global supply of food) [38,62,63] and those that hold responsible the financial sector and the production of biofuels [55]. In general, the increase in food prices has been widely discussed by researchers, analysts and international organisations [60,61,64–68]. To demonstrate this link, Figure 1 plots the monthly data for the Food and Agriculture Organisation Food Price Index (FAO FPI) [69] and the number of violent demonstrations that were associated with food during each month. The plot clearly shows a link between the price of food and the occurrence of food riots, which is in line with the findings from Lagi, Bertrand and Bar-Yam [55], Bellemare [61] and Berazneva and Lee [70].

However, research to date is partial in that it has been mainly qualitative, and the quantitative approaches that have been implemented (*i.e.*, statistical and econometrical models) have proven to be reliable only when analysing specific case studies [71]. Previous studies, like those of Berazneva and Lee [70] and Bellemare [61], have found a clear connection between the increase in food prices and the increase in food riots, with the second author being able to prove a causality relationship. In this paper, we provide an original quantitative framework that can be used to compute the likelihood of food riot occurrence according to the fragility of the countries as calculated by an index of political fragility and a threshold on the price of food as calculated by the FAO FPI. To do this, we start by reviewing several aggregated indices of political fragility to assess which one is better able to account for food riots. This research is intended to inform larger frameworks and political work streams, such as the recently established U.K.-U.S. Taskforce on Extreme Weather impact on Food Resilience, to assess national political fragility and the potential of the scarcity of different natural resources to act as an additional driver. This is the reason why we used only aggregated indices, because we wanted to assess the usefulness of a simple first step, which is readily accessible to senior decision makers, in identifying potential risk areas to then justify further detailed analysis. In this paper, we use the definition of food riot given by a recently published report by the Food Price Watch: "a food riot here is defined as: a violent, collective unrest leading to a loss of control, bodily harm or damage to property, essentially motivated by a lack of food availability, accessibility or affordability, as reported by the international and local media, and which may include other underlying causes of discontent" [39].

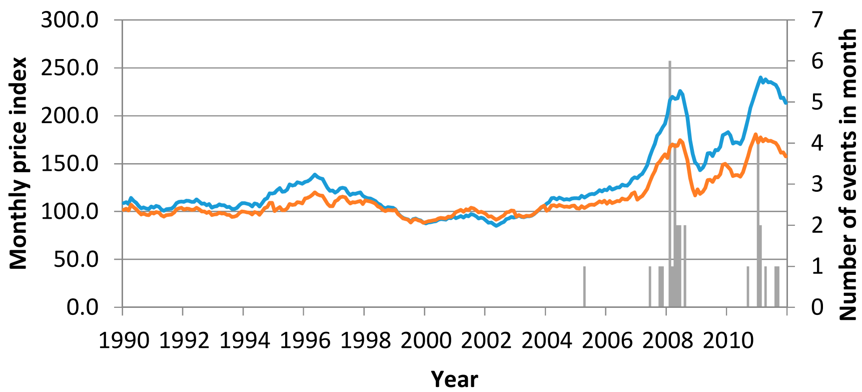

Figure 1. The FAO monthly price index (nominal prices in blue and deflated in red) for food between 1990 and 2011 compared to the number of violent demonstrations that were associated with food over that month (shown in green).

Since food riot events are (fortunately) infrequent, the data available is sparse and, therefore, violates the assumptions of the most common statistical and econometric techniques; we followed the example of Headey [68] using back-of-the-envelope calculations for some of the analyses. We then backed these calculations up with more reliable statistical tests and models where appropriate using R [72].

The aim of this paper is hence to: (i) identify the index (indices) of state weakness that best accounts for (predicts) food riots; (ii) test the hypothesis that countries that are not self-sufficient in food are more likely to experience food riots; (iii) compute a probability of the occurrence of food riots for countries; and (iv) test the hypothesis that there is a food price threshold above which food riots are more likely to occur and calculate it if possible.

This paper provides in the second section a brief description of the indices of state weakness that we have selected for our comparison. Section 3 details the methodology used to compare the indices of political fragility and the food riots, and Section 4 presents the results of our analysis. In Section 5, we compute a measure of likelihood of food riots in countries with/without food, and in the sixth section, we compute a threshold for the FAO FPI beyond which food riots are more likely to occur. Finally, we provide the concluding remarks and possible next steps.

2. Mapping the Field of the Indices of State Fragility

During the last decade, the efforts to measure what constitutes political fragility and fragile states have multiplied. One of the many approaches comprises the development of indices: this collapses different measures that are believed to have an impact on the fragility of a country into a single "number". This approach is particularly used when a practical method for ranking countries according to their risk of failure is required.

The United Nations Development Programme (UNDP) reviewed some of the freely available indices of state fragility and provides a clear and comprehensive overview of the methodology they use [27].

In Table 1 is a list of the indices that have been chosen for our analysis.

Table 1. Summary of the indices used in this study with time series available and the number of countries covered.

Index	Producer	No. of Countries Covered	Years Available
Bertelsmann Transformation Index State Fragility Index (BTI-SFI) [73]	Bertelsmann Stiftung	119 (2006)–128 (2012)	2006, 2008, 2010, 2012
Fragility Index of the Country Indicator for Foreign Policy project (CIFP) [74]	Carleton University	30 (2008)–197 (2010)	2006–2008, 2010
Failed States Index (FSI) [75]	Fund for Peace	76 (2005)–177 (2012)	2005–2012
Global Peace Index (GPI) [76]	Institute for Economics and Peace	120 (2007)–158 (2012)	2007–2012
Index of state weakness in the developing countries (ISW) [28]	Brookings Institute	141	2008
Peace and Conflict Instability Ledger (PCIL) [77]	University of Maryland	162 (2008)–163 (2012)	2008–2012
Political Instability Index (PII) [78]	The Economist Group	165	2007–2010
State Fragility Index (global reports) (SFI global) [79]	George Mason University	159 (2006)–164 (2010)	2006–2008, 2010
State Fragility Index (excel file) (SFI xls) [80]	George Mason University	164 (2004)–167 (2012)	2004–2012
Worldwide Governance Indicators: Political Instability and Absence of Violence (WGI) [81]	The World Bank	207 (2004)–212 (2012)	2004–2012

Since the aim of this paper involves a cross-country and inter-temporal comparison, we were looking for indices with a high coverage both of years and countries ranked. This meant we left out of our analysis five indices of political fragility: (i) the Country Policy and Institutional Assessment (CPIA)/International Development Association (IDA) Resource Allocation Index (IRAI) developed by the World Bank [82]; (ii) the Harvard Kennedy School Index of African Governance developed by the

Harvard Kennedy School [83]; (iii) the Political Risk Atlas developed by Maplecroft [84]; (iv) the Political Risk Map developed by AON [85]; and (v) the Political Risk Index developed by the Political Risk Services [86]. The first two indices have been excluded because of their low country coverage, whereas the last three are not freely available to the public and do not provide access to time series. As for the BTI, the index as produced by the Bertelsmann Stiftung is actually made of two different indices: the Status Index and the Management Index, which rely on further indicators [73]. The 2009 UNDP User's Guide on Measuring Fragility [27] extracted two indicators from the index built by the Bertelsmann Stiftung and rearranged them in a new fragility index called the State Fragility Index (BTI-SFI) for the year 2008. The two measures selected by the UNDP team are: (i) monopoly on the use of force; and (ii) basic administration (*i.e.*, security area and political area). The information provided about this index refers to the BTI-SFI and not to the index as developed by its producer. Since the UNDP report provided the BTI-SFI for only the year 2008, the index relative to the other years has been computed by the authors of this paper.

3. Methodology

Our analysis focuses on comparing whether these indices of state fragility captured the food riots that occurred during the period 2005–2011. In particular, we carried out a simple cross-index comparison computing the extent to which each index either predicted, described and post-described the food riots.

Our analysis took into account the years 2004 and 2012, because the indices had different purposes: some aimed at being only descriptors of the "current" situation, whereas others had a predictive purpose (*i.e.*, claim to be able to forecast situations of fragility or unrest), and still others claimed to be able to do both. Moreover, most of the indices carry a disclaimer saying that they should not be used to make decisions about, for instance, in which country to invest funds or where to implement a particular policy. Despite this recommendation, all of the indices are commonly used in the policy-making process, even if that is not their purpose. For all of these reasons, we decided to include in our analysis the year 2004 in order to check whether the indices were able to predict the food riots from 2005 onwards. The year 2012 has been included to test whether all of the indices (*i.e.*, predictive and descriptive) suffer from a one-year (or more) time lag in the data for the indicators on which they rely. For example, the food riot that occurred in Burundi in 2005 may only be captured in the scores for that country one or more years later.

For the purposes of our analysis, we first identified the countries that experienced food riots during the period 2005–2011, which covers the Arab Spring, by carrying out a simple keyword search to find newspaper articles in English that clearly stated the occurrence of violent demonstrations in response to the increase of the price of food or its scarcity (*i.e.*, food riots) in African, Middle-Eastern and Asian countries. The following are the countries resulting from this research with the year(s) during which violence associated with food riots occurred within their borders in brackets: Burundi (2005) [87], Somalia (2007; 2008; 2011) [88–90], India (2007; 2008) [91,92], Mauritania (2007) [93], Cameroon (2008) [94], Burkina Faso (2008) [94], Ethiopia (2008) [94], Côte d'Ivoire (2008) [95], Morocco (2008) [96], Egypt (2008; 2011) [97,98], Haiti (2008) [99], Senegal (2008) [94], Yemen (2008) [96], Tunisia (2008, 2011) [100,101], Sudan (2008; 2011) [102,103], Lebanon (2008) [96], Kenya

(2008) [104], Bangladesh (2008) [105], Guinea (2008) [100], Mozambique (2010) [106], Algeria (2011) [107], Oman (2011) [108], Uganda (2011) [109], Iraq (2011) [110] and Syria (2011) [111]. Each year therefore experienced the following number of food riots: 2005 (1), 2007 (3), 2008 (17), 2010 (1), 2011 (9). As can be seen, years 2008 and 2011 were the years that experienced more food riots.

It is noteworthy that our list of countries differs from that of Lagi, Bertrand and Bar-Yam [55]. In particular, we excluded the following countries because of either a lack of a clear connection with food riots or violence: Mozambique (2008), Libya (2011), Mauritania (2011), Saudi Arabia (2011), Yemen (2011), Morocco (2011) and Bahrain (2011); but, we included the following countries that were not captured by Lagi, Bertrand and Bar-Yam [55]: Somalia (2011), Kenya (2008), Bangladesh (2008) and Guinea (2008).

Using the above list of countries that experienced violent demonstrations as a reference, we computed the ability of each index to act as a predictor. To test their accuracy, we first needed to identify those countries defined by the various indices as weak. Unfortunately, there was not one commonly used definition of a weak state across the indices as: (i) the indices carried a different categorisation between years; (ii) the different indices used different categorisation; (ii) different scoring techniques have been applied to the different indices and to different versions of the same indices (e.g., the SFI as computed in the excel spreadsheet downloaded from the George Mason University website and as computed for the Centre for Systemic Peace Global Reports). In addition, the time series provided by the developers of the indices did not cover the whole period of time that we were analysing, and some indices did not have data for all of the countries, with some very important missing countries (e.g., Somalia in the Political Instability Index). For instance, the CIFP for 2006 and 2008 provides only the top 30/40 most at-risk countries and only the ranking of the countries (and not the scores) for the year 2010. This and other similar examples made the cross-index comparison difficult. To partially overcome these problems, we decided to test the accuracy of the indices in accounting for food riots by selecting the most at-risk countries for each of the indices. To determine the number of countries to test, we first examined those indices that had defined categories. In particular, the categories that we took into account for the indices examined are: (i) very high alert, high alert and alert for the FSI; (ii) failed states, very fragile states and fragile states for the BTI-SFI; (iii) top 30/40 for the CIFP; (iv) top 20% less at peace for the GPI; (v) failed states, critically weak states and weak states for the ISW; (vi) top 15 countries for the PCIL; (vii) very high risk and high risk for the PII; and (viii) extreme fragility and high fragility for the SFI.

Once selected, we checked how many countries were included for each index across these categories. The average number of countries in these categories across the indices was 31. Therefore, the most fragile 30 countries as classified by each index were used to analyse the accuracy of each index. We also assessed the most fragile 40 countries to see if this changed our conclusions.

This analysis is an assessment of whether the various measures of fragility are accurately able to capture violent demonstrations due to a food-related catalyst. It does not measure the overall accuracy of the index as related to other catalysts or triggers for violent events (or state failure events).

4. Evaluation of the Indices of State Weakness

As outlined in the previous section, for every year in our list, we checked:

(1) Which one captures the highest number of countries that experienced food riots relative to the other countries throughout all of the years;
(2) Which index is better at representing the food riots that occurred in the same year;
(3) Which index is better at representing the food riots that occurred in the following year;
(4) Which index is better at capturing the food riots that occurred in the previous year.

4.1. Accuracy of the Indices

As mentioned in the previous section, the first step of our analysis was to evaluate which index better predicted/described/post-described the violent demonstrations associated with food that occurred in 2005–2011, including those events associated with the Arab Spring. Each index of state weakness comprises a number of indicators collapsed into a single value by computing weighted or rank averages. Two common indicators used by the indices are the countries' gross domestic product (GDP) and the gross domestic product per capita (GDP pc). To test whether by adding further information to the indices (*i.e.*, including other indicators, such as those associated with inequity levels or measures of corruption and governance), the indices provide a better assessment of state weakness than by using GDP pc or GDP alone, we also included two versions of GDP pc (current $ and 2005 constant $ versions). The data source for the two versions of the GDP was the World Bank's indicators website [112,113]. The data presented some gaps across the years that were filled using simple interpolation and are part of a larger database held and kept up-to-date by the Global Sustainability Institute (GSI) [114].

In Table 2, we provide as an example the results for the year 2008 (the year for which we found the highest number of food riots). The accuracy is measured as the number of countries that experienced food riots within the year to be assessed, identified in the top 30 or 40 most at-risk countries according to each index in the year prior, same year and year post. For example, a measure of 50% in the top 30 means that half of the countries that experienced food riots were categorised as within the 30 most "weak" states in a particular index.

Table 2. Example of accuracy test carried out on the indices for the food riots occurring in 2008 (best data coverage: food riots recorded in 15 countries).

Name of the Index	2007 Year Prior		2008 Same Year		2009 Year Post	
Descriptive Indices:	**Top 30**	**Top 40**	**Top 30**	**Top 40**	**Top 30**	**Top 40**
SFI xls	41%	47%	41%	59%	47%	59%
SFI global	41%	53%	47%	53%	NA	NA
GPI	35%	47%	35%	53%	47%	53%
ISW	NA	NA	47%	47%	NA	NA
BTI	NA	NA	47%	53%	NA	NA
WGI	**65%**	**65%**	59%	65%	59%	65%
Descriptive and predictive indices:						
CIFP	53%	59%	47%	NA	NA	NA

Table 2. *Cont.*

Name of the Index	2007 Year Prior		2008 Same Year		2009 Year Post	
FSI	53%	77%	**59%**	**77%**	**65%**	**71%**
Predictive indices:						
PCIL	NA	NA	41%	65%	41%	65%
PII	41%	41%	NA	NA	41%	47%
GDP per capita:						
GDP pc (current $)	35%	41%	35%	47%	35%	41%
GDP pc (2005 const $)	29%	35%	35%	41%	35%	41%

Notes: The bold cells refer to the indices that had the highest accuracy score.

For each year of food riots, the highest number of countries that experienced food riots categorised as weak for each index was captured. Table 3 lists the indices with the highest accuracy for each year of food riots, both as predictors (index from the previous year), descriptors (index for the same year) and post-descriptors (index from the following year). 2008 and 2011 saw the highest number of food riots and are therefore considered as more important for this analysis.

Table 3. Best indices divided by year for food riots.

Purpose of the Index	Year of Food Riots				
	2005	2007	2008	2010	2011
Predictor	WGI, SFI xls, GDP pc (current $), GDP pc (2005 constant $)	SFI xls, CIFP	WGI	PCIL, GDP pc (current $), GDP pc (2005 constant $)	WGI, SFI xls
Descriptor	WGI, SFI xls, FSI, GDP pc (current $), GDP pc (2005 constant $)	WGI, SFI xls, CIFP	FSI	PCIL, GDP pc (current $), GDP pc (2005 constant $)	WGI
Post-descriptor	WGI, SFI xls, FSI, CIFP, SFI global, BTI, GDP pc (current $), GDP pc (2005 constant $)	GPI, PII	FSI	PCIL, GDP pc (current $), GDP pc (2005 constant $)	WGI

In general, the index that was most accurate was the WGI, which correctly categorised as highly fragile the highest number of countries that effectively experienced food riots for three out of five years, both as a predictor and descriptor, and two out of five years as a post-descriptor. The second most accurate was the SFI xls, which scored three out of five years as predictor, two out of five years as a descriptor and one out of five years as a post-descriptor. The FSI was third, with two years out of five as both descriptor and post-descriptor, along with both versions of the GDP pc (current $ and 2005 constant $), which scored two out of five years in all three categories. Therefore, the other indicators can be considered as no better than general GDP measures as a tool for food riot analysis.

Since the two years with the most observations are 2008 and 2011 (*i.e.*, 17 and nine, respectively), we can conclude that our analysis suggests WGI as the best predictor of food riots, even if its purpose was only descriptive. The best descriptors and post-descriptors are the WGI and the FSI. Only two out of four indices that claim to be predictive actually scored first for at least one year in our accuracy test: the CIFP and the PCIL. Perhaps surprisingly, these indices scored first only one year out of five.

For the other two predictive indices, the FSI was shown to be a good descriptor, but not as good a predictor, whereas the PII did not perform well in either category.

4.2. Time-Lag in the Data

To investigate the presence of possible time lags in the data underlying the indices, we plotted the scores of the indices for the countries that experienced food riots, grouping them by the year in which the food riot occurred. For each index, we computed the simple average score for every year for those countries. This was done only for the countries that experienced food riots in 2008 and 2011 because of the larger number of observations (*i.e.*, food riots) during these years.

This assessment was done for both indices with the highest accuracy score. The WGI and FSI averages are provided in Figures 2 and 3, respectively. Note that to draw these plots and to carry out the other tests included in this paper, the scoring scale of the WGI has been inverted from "low-score = bad" and "high-score = good" to "low-score = good" and "high-score = bad".

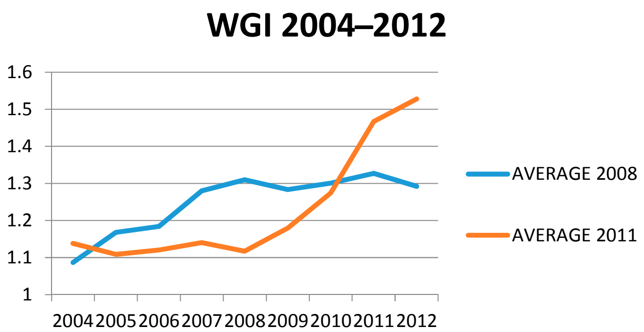

Figure 2. Plot of the WGI average scores each year from 2004 until 2012 for the countries that experienced food riots in 2008 (blue line) and those that experienced food riots in 2011 (red line).

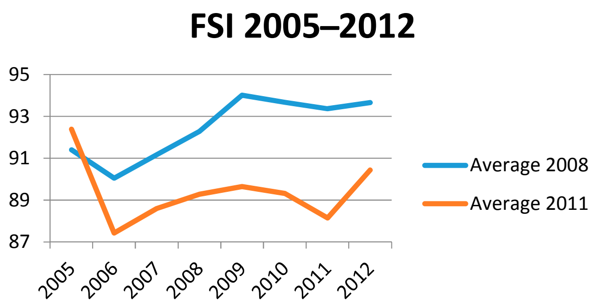

Figure 3. Plot of the FSI average scores each year from 2004 until 2012 for the countries that experienced food riots in 2008 (blue line) and those that experienced food riots in 2011 (red line).

If each index were able to accurately capture food riots as a risk, we would expect to see a peak in the average fragility/risk in the years 2008 and 2011 for each set of countries (peak in 2008 for the blue 2008 country line and a peak in 2011 for the red 2011 country line) if the index has a descriptive purpose and a peak in the average fragility/risk in the years 2007 and 2010 for each set of countries if the index has a predictive purpose. The WGI (Figure 2) shows a peak in 2008 with no delay, whereas it continues to rise into 2012 after the 2011 food riots, which could indicate a delay or that other factors could be associated with this increase, and further analysis would be needed when a subsequent year's analysis is available. For the FSI (Figure 3), instead, we find a one-year delay in capturing the food riots for 2008, and again, the 2011 food riots show a higher risk in 2012. This further shows the inability of the FSI to fulfil its aim as a predictor, at least in the case of food riots. Given this analysis, we propose that the WGI is the most accurate index to use, as it best captures the underlying "conditions" [35] for food riots. The remainder of the paper will use the WGI for subsequent analysis.

5. Towards a Likelihood of Failure for the Categories of the WGI

We now wish to use the WGI, so that in the future, it could be used as a tool to assess the condition of a country relative to its probability to experience a food riot and to test whether food self-sufficiency and global food price are good proxies for "catalysts" [35]. We assume that a "trigger" is still required, and this measure of probability could be seen, given all other things being equal, as a likelihood of such a trigger event occurring in these countries in any given year. Again, as outlined by Headey [68], we use a simple approach initially to test this hypothesis given the scarcity and the structure of our data. However, we then present in Section 6 a more statistically robust analysis to confirm our findings.

We now use the full WGI index including all countries: we divided the countries into quartiles according to their score, and we further divided the countries in two categories, according to their net food production throughout the years: (i) countries with positive net production of food (self-sufficient); and (ii) countries with negative net production of food (not self-sufficient). To calculate the countries' net food production, we used data from the Food and Agriculture Organization of the United Nations Statistical Database [115] on national production and consumption of food. The data presented some gaps, which have been filled as described in GSI [114]. However, the following countries had scores for the WGI, but did not have enough data for food production/consumption and have thus been excluded from the analysis: French Guiana, Réunion, Martinique, Taiwan (China), Nauru, Netherland Antilles and Anguilla.

Unlike the measure of accuracy computed in Section 4.1, the likelihood of food riots is measured as the number of countries experiencing a food riot compared to the number of countries in each quartile of the WGI. We computed the likelihood of food riots for each WGI quartile for both categories of food availability (*i.e.*, food available/lack of food), for every year when there was a food riot (*i.e.*, 2004, 2006, 2007, 2009, 2010 when we use the index as a predictor and 2005, 2007, 2008, 2010, 2011 when we use it as a descriptor). An example of this can be found in Table 4. For instance, a measure of 50% in the first quartile of the WGI for countries without food means that of the countries without food included in the first quartile of the WGI (*i.e.*, most fragile), 50% of them experienced a food riot in that year.

Table 4. Likelihood of food riots for the quartiles of the WGI in 2008.

WGI Probability of Food Riots in 2008				
Quartiles	**1st**	**2nd**	**3rd**	**4th**
WGI as predictor				
Countries without food	67%	21%	13%	0%
Countries with food	40%	24%	5%	0%
WGI as descriptor				
Countries without food	50%	27%	13%	0%
Countries with food	33%	29%	4%	0%

To generalise our findings, we have averaged the results of the likelihoods across years, and the results are presented in Table 5, also computing the standard deviation between years.

Table 5. Average likelihood of food riots for the quartiles of the WGI.

WGI Average Probability of Food Riots				
Quartiles	**1st**	**2nd**	**3rd**	**4th**
WGI as predictor				
Countries without food	20%	9%	4%	0%
Standard deviation	24%	10%	5%	0%
Countries with food	16%	7%	1%	0%
Standard deviation	14%	11%	2%	0%
WGI as descriptor				
Countries without food	20%	9%	4%	0%
Standard deviation	24%	10%	5%	0%
Countries with food	16%	7%	1%	0%
Standard deviation	14%	11%	2%	0%

Two main findings should be noted from the table above: (i) the standard deviations of the percentages for every quartile are rather high and indicate an extreme variability in the occurrence of food riots over the time period considered in our analysis (this is due to the stochastic nature of food riots, and in certain years, only one food riot was seen); and (ii) while the figures for the likelihood of food riots are slightly higher in those countries that lack food, they are not sufficiently different to support the hypothesis. This means that the annual availability of food only has a marginal effect on the occurrence of food riots. This may be due to a number of different factors, including a higher degree of corruption, seasonal variation in the availability of food or lack of infrastructure existing in those fragile countries (see, for example, [37]), leading to inadequate distribution of food within countries, even if there is enough available over a given year. We therefore conclude that annual food availability within a country is not a catalyst for food riots alongside the condition of being an existing fragile state.

6. Calculating a Threshold of Fragility

We now wish to test our second hypothesis: that there is a threshold in the international price of food beyond which food riots are more likely to happen. Therefore, we analyse the global price of food as reported by the FAO FPI at the time of the food riots to try and find a threshold above which food prices will act as a catalyst for food riots. We present here our analysis, which again is initially based on a simple mathematical approach as suggested by Headey [68] and then a more robust statistical test to confirm our findings, on both the deflated and the nominal version of the FAO FPI to control whether inflation has an impact on our analysis.

Figure 4 shows the distribution of food riots (number of events) in each year compared with the nominal price of food during that year. A normal distribution that closely follows the data is also shown. We used a least square difference to best match the normal distribution (allowing the mean and standard deviation to vary, but constraining the maximum number of events in any year to be 17, the maximum observed). From this, we can see that the mean of the best fit normal distribution is at a price of 212 for the nominal FAO FPI with a standard deviation of 15. Therefore, if the impact of food price on violent events is normally distributed, then 95% of violent events will occur between an average yearly price of 182 and 242. This is comparable to the threshold calculated by Lagi, Bertrand and Bar-Yam [55], who found it to be set at 210.

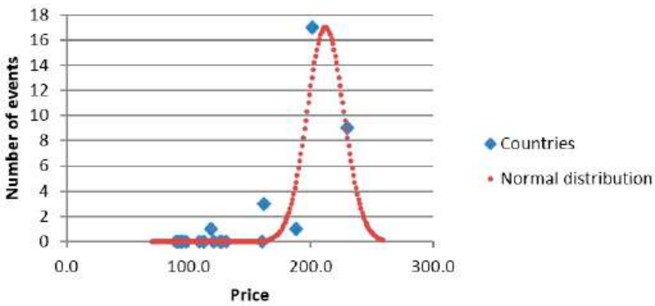

Figure 4. Number of countries experiencing a violent event at a given price (FAO nominal annual food price index) compared with a normal distribution.

However, we wish to calculate the likelihood of a food riot event occurring once the price is above a threshold. Therefore, we look at the number of events compared to the amount of time the price was actually above the threshold. Figure 5 shows this distribution using monthly data. Here, two distinct distributions of prices (red line) can be seen. To demonstrate statistical significance, we selected monthly food prices for the deflated FAO FPI for 2005–2011 (the period of food riots) and separated the binned data into two series associated with months that do experience a violent event and those that do not (this represents two series of deflated prices). We used a t-test assuming unequal variance between samples, and the distributions are shown as significantly different below the 1% confidence level ($p = 0.009$, one tailed). Therefore, our observation of two distinct distributions is confirmed. Over the period of time assessed (1990 until 2011), a "normal" distribution of prices in a typical month is seen (the peak centred around 90–100). Therefore, we would expect the deflated FAO FPI to vary between 80 and 120 in a "normal" month with little impact on food riots. However, a second (fat tail) distribution of prices above 130 is seen when monthly prices are above the "normal". In this distribution, food riots have an increased likelihood of occurring.

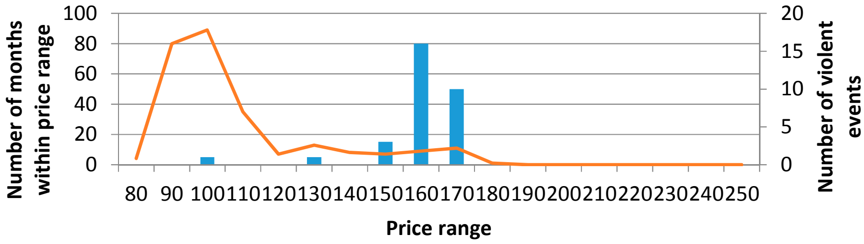

Figure 5. Number of months (red line) that the deflated FAO FPI is within a given range (the first "bin" corresponds to a range of 80 to 90, the second 90 to 100, and so forth) for data from 1990 until the end of 2011. The blue columns represent the monthly price range at which violent events occurred.

Now, exploring the price fluctuations on an annual basis, Figures 6 and 7 clearly show two regimes: a "normal" regime when food riots are rare and an extreme regime where food riots are more likely. The normal distribution in Figure 4 is calculated using data contained within the fat tail of Figure 6. The FAO FPI (nominal) ranges from 80 to 140 for a "normal" year (for the deflated prices index, the range is 80 to 120). In times of heightened food insecurity, average annual food price (nominal) is above 160 (120 for deflated prices). However, we note that there are outlier events that may impact our ability to predict a threshold. In particular, food riots at the low nominal price index range 100–120 occurred in one country (Burundi). Four countries experienced food riots at ranges of 160–200 (*i.e.*, Somalia, India, Mauritania and Mozambique), and all others experienced food riots above 200. It should be noted that three of the four food riots in the 160–200 range occurred the year prior to the peaks in violent food-related events and, therefore, could be influenced by the perception of future high prices. Therefore, to calculate a threshold, we use the major food riots (in blue in Figures 6 and 7) to suggest an annual FAO FPI threshold of 200 (nominal price) or 140 (deflated) as a level above which there is higher risk of violent food events in certain countries.

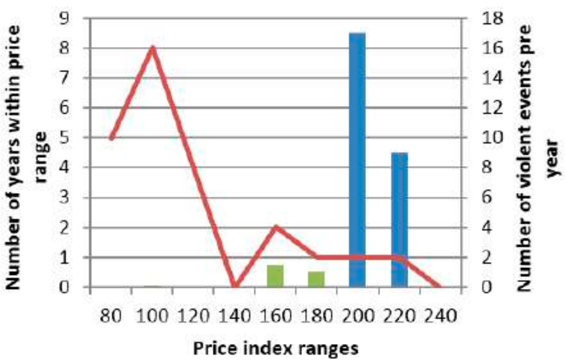

Figure 6. Number of years the FAO FPI (nominal value) was between certain values (red line) compared with the number of violent events per year associated with food insecurity (green and blue columns). The price index ranges are in blocks of 20 (for example, the first "bin" is for 80–100, the second is for 100–120, and so forth). The blue columns represent the years 2008 and 2011. The green columns represent all other years (2005, 2007, 2010).

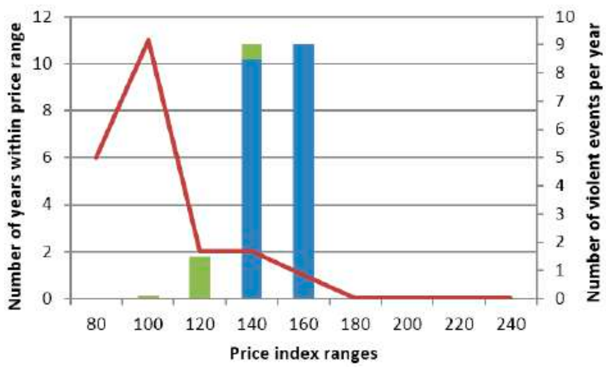

Figure 7. Number of years the FAO FPI (deflated value) was between certain values (red line) compared with the number of violent events per year associated with food insecurity (green and blue columns). The price index ranges are in blocks of 20 (for example, the first "bin" is for 80–100, the second is for 100–120, and so forth). The blue columns represent 2008 and 2011. The green columns represent all other years.

To further specify the value of the threshold for the deflated monthly FAO FPI, we estimated a logit model with random effects for country and time, with time expressed as the number of months since January 2005. Only the countries that actually experienced riots during the period under consideration were included in the analysis. The maximum likelihood estimations resulted in a highly significant positive coefficient for the deflated FAO FPI, supporting the idea of a direct causal relation between these two variables (Table 6). In addition, the estimated value of the threshold above which countries start to experience food riots with this method was 148. More precisely, the 148 threshold represents the deflated FAO FPI value above which the probability for a random country to experience a food riot is >1%.

Table 6. Random effects logit regression model estimates.

	Estimate	**SE**	***t*-value**	***p*-value**
(Intercept)	−14.434	2.165	−6.667	0.000
FAO FPI deflated	0.066	0.013	5.091	0.000
σ	0.000	0.294	0.000	1.000
Log-Likelihood	−138.114			
No.	2100			

To support our earlier conclusions that being a country identified as more fragile by WGI and our rejection of the hypothesis of being a net food importer increase the likelihood of experiencing food riots in that country, we implemented a hazard model using the above FAO FPI threshold. Hazard models or survival analyses are used to estimate the time it takes for an event to occur [116]. In our case, the events were the food riots, and we focused on the months during which the deflated FAO FPI was above the 148 monthly threshold as calculated in our random-effects model. In the 2005–2011 time frame considered for this study, there were 32 non-continuous months above the threshold, in particular the periods from September 2007–September 2008, November–December 2009 and August 2010–December 2011. Since the bulk of our food riots were concentrated in the first period (*i.e.*, 19 events from September 2007–September 2008), we decided to use that as our reference period for this analysis and right-censored data after that date. Furthermore, since a couple of countries experienced more than one food riot during that time frame, we only recorded the first one for those countries. As for the covariates used in the model, since the time frame selected was in between two years, we computed an average estimate for the WGI for each country, and we used data for 2008 to ascertain whether the country was a food exporter or importer. This last choice was due to inconsistencies in the data about food between the two years and that we wanted to test whether a country being a net importer in the particular year it experienced a food riot was significant or not.

Table 7 shows the results from the hazard model. The food availability in a country does not significantly impact the occurrence of food riots. Conversely, the relationship between WGI and food riots is highly significant: for every unit increase in the WGI estimate (*i.e.*, higher political fragility), the likelihood of experiencing a food riot increases on average by a factor of 2.75. These results confirm the findings from the previous sections of the paper.

Table 7. Hazard model on months from 2007 to 2008 when deflated FAO FPI was above the 148 threshold using whether the countries were net importers/exporters and WGI as covariates.

Covariates	Regression Coefficient	Exponentiated Coefficient	Standard Error (Coef)	Robust Standard ErrorE	z	*p*-value
Importer/exporter	−0.1286	0.8793	0.4807	0.4690	−0.274	0.784
WGI average 2007/2008	1.0103	2.7465	0.2066	0.1543	6.548	5.83e^{-}11 ***

Notes: $N = 202$; number of events = 18 (9 observations deleted because they were missing); concordance = 0.826 (se 0.069); R-squared = 0.114 (max possible = 0.609); likelihood ratio test = 24.44 on 2 df; $p = 4.92 \times 10^{-6}$; Wald test = 46.59 on 2 df; $p = 7.626 \times 10^{-7}$; score (log rank) test = 29.91 on 2 df; $p = 3.206 \times 10^{-7}$; robust = 12.77, $p = 0.001688$; Sig. codes: 0 "***"; 0.001 "**"; 0.01 "*"; 0.05 "."; 0.1 " ".

To further examine the effect of the WGI estimate for a country on the likelihood of that country to experience a food riot when the FAO FPI is above the 148 monthly threshold, we calculated the hazard ratios assuming the relationship between WGI and food riot as linear and plotted them in Figure 8.

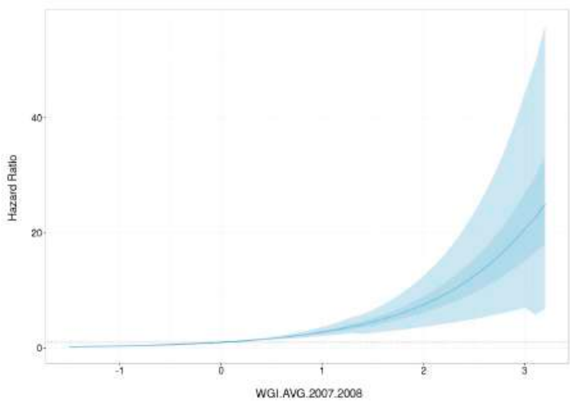

Figure 8. Plot of the hazard ratios for WGI, where the hazard ratios are plotted on the y-axis and WGI on the x-axis. The shaded areas represent the σ and 2σ probability intervals, respectively.

As Figure 8 shows, countries with higher WGI estimates are relatively more likely to experience food riots than those with lower WGI estimates. For instance, Somalia, who had an average WGI of 3.28 in the years 2007–2008, was around 21-times more likely to experience a food riot than Malawi, whose average WGI was 0.00.

7. Discussion

Data on the different dimensions of state weakness are by their nature static and represent only a snapshot of a country at a particular point in space and time. For this reason, indices of state weakness are fallible and should not be used to predict political fragility. However, they do supply valuable insights into the trends in the stability of a country and can support understanding of their near future conditions.

In our analysis, we tested two hypotheses: (i) food riots are more likely to happen in countries that are net food importers; and (ii) that there is a threshold in the international price of food above which food riots are more likely to happen. We reviewed several indices of political fragility to assess which one is better able to account for food riots, and our results show that the Political Stability and Absence of Violence indicator of the Worldwide Governance Indicators (WGI) developed by the World Bank is overall the best predictor, which also was the best descriptor along with the Failed States Index developed by the Fund for Peace. The analysis we presented was not a measure of the overall accuracy or usefulness of each index, as they may better measure non-food-related fragility.

We found that our first hypothesis only had marginal evidence to support it within the data analysis, and therefore, we reject that. Our second hypothesis was found to be significant, and we presented a threshold above which food riots are more likely to occur. Moreover, we found a positive significant relationship between the WGI estimates for the countries and the occurrence of food riots.

Therefore, a condition for an increased likelihood of food riots is that a country is classed with higher fragility (as measured by the WGI), and a catalyst for a food riot is the annual Food and Agriculture Organisation's Food Price Index (FAO FPI) being above 200 (nominal) or 140 (deflated). We recalculated the likelihoods presented in Table 4 to only include those years above those price thresholds and including all countries regardless of whether they had surplus food available or not, and this is presented in Table 8.

Table 8. Average likelihood of food riots to occur for the quartiles of the WGI when FAO FPI was above the threshold.

	WGI Average Probability of Food Riots			
Quartiles	**1st**	**2nd**	**3rd**	**4th**
Likelihood	36.67%	17.84%	5.02%	0.00%
Standard deviation	3.33%	10.29%	2.67%	0.00%

From the data presented in Table 4, a clearer trend in the likelihood of the occurrence of food riots within a given year when the global food price is above our calculated threshold is seen (this occurred in 2008 and 2011). Moreover, for the quartiles we have calculated using the WGI, the table shows that the likelihood of experiencing a food riot increases with the increase in fragility (more fragile countries in the first quartile have a 37% likelihood of a food riot event compared to 18% likelihood for the second quartile). However, it is worth noting that fragility is not confined to the first two quartiles of the WGI, but also, relatively stable countries that fall in the third quartile can still experience (with a 5% likelihood) violent events (when triggered and when global food prices are above the threshold). Therefore, for a given year with an average food price above our thresholds, countries classed within each quartile of the WGI will have a likelihood of experiencing a violent food riot as set out in Table 8, all other things being equal. This likelihood could be interpreted as the likelihood of experiencing a trigger event given the right conditions and catalysts for violent events.

As Table 8 shows, fragility is not confined to poor and developing countries; every country can be fragile to a certain extent. In addition, food riots have contributed to wider destabilisation of regions, such as seen during the Arab Spring, and are therefore likely to have wider impacts on the global economy. Therefore, further research to understand the links between fragile states and in particular their ability to respond to high global food prices when they occur is needed to better define the condition-catalyst interconnections. If this type of assessment is used, then in the future, it may be possible to proactively allocate development aid or to engage with those governments seen at higher risk to ensure that a trigger event does not then lead to violent conflict.

This paper explored only food-related violent events. Further research is required to explore other catalyst events, including those associated with global trends, such as energy security and resource availability. While further research is required to better understand why particular countries experience trigger events and to better define the role of food distribution within a country, this paper is a first step towards a quantified assessment of the likelihood of food riots.

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Author Contributions

All of the authors contributed equally to this work. In particular, Davide Natalini led the research activities and analysis around the evaluation of the indices of state weakness and the writing of the paper. Aled Jones led the research on calculating the food price threshold of fragility and supervised the whole research. Giangiacomo Bravo supported the statistical testing.

Abbreviations

BTI	Bertelsmann Transformation Index
BTI-SFI	Bertelsmann Transformation Index State Fragility Index
CIFP	Country Indicator for Foreign Policy Project
CPIA IDA IRAI	Country Policy and Institutional Assessment International Development Association Resource Allocation Index
FAO FPI	Food and Agriculture Organisation Food Price Index
FSI	Failed States Index
GDP	Gross Domestic Product

GDP pc	Gross Domestic Product Per Capita
GPI	Global Peace Index
ISW	Index of State Weakness in the Developing Countries
PCIL	Peace and Conflict Instability Ledger
PII	Political Instability Index
SFI global	State Fragility Index (Global Reports)
SFI xls	State Fragility Index (Excel file)
UNDP	United Nations Development Programme
WGI	Worldwide Governance Indicators: Political Instability and Absence of Violence

Conflicts of Interest

The authors declare no conflict of interest.

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