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A Panel Threshold Regression (PTR) Approach

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Food Security, Prices and Geopolitical Risk: A Panel Threshold Regression (PTR) Approach

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Abstract:

Food security is a critical global issue that has gained increased attention since the onset of the Covid-19 pandemic and its disruption of the world's food supply and agri-food value chains. This article aims to assess the threshold of geopolitical risk at which food security becomes a significant concern for the international community. By analyzing data from a panel of 40 countries, including advanced and emerging economies, over the period from 2012 to 2021, the study examines the relationship between food security and geopolitical tensions. The Food Security Index (FSI) and its four pillars serve as the dependent variables, while the Geopolitical Risk Index (GPRI) acts as the threshold variable. Additionally, factors such as the Covid-19 pandemic, agricultural land area, urban population percentage, inflation, and GDP per capita are considered.

The analysis, conducted using a panel threshold regression model (PTR), reveals that geopolitical risk has an inflationary impact. The study identifies a threshold of 0.0261 for geopolitical risk, indicating that beyond this level, global food security is significantly reduced as inflation rises. The findings suggest that geopolitical risks contribute to price spikes in various commodities, including food, fertilizers, and oil, exacerbating inflationary pressures driven by fiscal responses to geopolitical events. Moreover, higher geopolitical risks increase uncertainty regarding inflation outlook, posing greater risks to tradeoffs between fiscal and monetary policies.

Keys word: food security, geopolitical risks, global food supply, Covid-19, PTR model.

Jel Classification: C23, E31, F40, Q17, Q18.

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1- Introduction

Interdependencies regarding raw materials and food have known a remarkable growth in this globalized world in recent years. Some of the reasons that can be quoted are: (1) the rate by which the worldwide population is growing, (2) the democratization of values, such as, the prosperity right for human beings and also (3) the evolving consumption patterns. In fact, an aspect that is considered as the most important one in influencing and shaping the security of the above-mentioned strategic goods is geopolitics. Since almost all the countries in the world are dependent on the importation of raw materials, fertilizers, food … etc, to satisfy their populations' needs, make them vulnerable to market volatility, armed and political conflicts …etc, in other words to geopolitical developments.

We can easily notice that at each event of geopolitical nature, we record impacts at different levels threatening the world stability. The most obvious geopolitical shock has been the Russia-Ukraine war and just before that the world health crisis provoked by Covid-19. As reported in a policy brief published by the United Nations[6] (UN) in 2020, Covid-19 caused impending global food emergency and food insecurity passed from 23.3% in 2014 to 26.4% in 2018 (Ma et al., 2021). Other remarkable data are from the United Kingdom (UK), where the use of the Food Bank recorded an increase from 41,000 people in 2009 and 2010 to three million people between 2018 and 2019 (Barker and Russel, 2020). This overall situation, in addition to the break that hit the world logistics chain (UNICEF, 2021), caused a sharp rise in food demand accelerating then food prices to unprecedented levels (Erokhin and Gao, 2020). The repercussion of the previous created a come-back to old economic policies based on protectionism (Egger et al., 2023), favorizing then new alliances in the world. The Russia-Ukraine war can be registered as the war that is about to shape this new world or in a more precise words marking the transition to a multipolar world, shifting from a world order in most of the 20th century dominated by three powers at their top the United Stated to multiple emerging powers represented by BRICS countries lead by China (De Ridder et al., 2013).

Given the fact that both Russia and Ukraine account for 33% of worldwide wheat trade, 17% of maize trade and 75% of sunflower oil trade[7], it is obvious by now that this war has profoundly destabilized agricultural products market, which has been emphasized through the data of the

[6] https://unsdg.un.org/sites/default/files/2020-06/SG-Policy-Brief-on-COVID-Impact-on-Food-Security.pdf

[7] https://www.csis.org/analysis/russia-ukraine-and-global-food-security-one-year-assessment

FAO Food Price Index[8] by recording an all-time high level in February and March 2022. This war was qualified by different international institutions[9] as *"an unprecedented shock to the global food system, with the most vulnerable hit the hardest.",* especially that Low-and middle-income, food-importing countries like African countries, countries of the Middle East, and Asia are dependent on the Black Sea for their imports (Magnan, 2017).

Since Covid-19, the world has been witnessing a destabilization and disruption in the global supply chains. The Russia-Ukraine war and the western sanctions have come to amplify the crisis into which the global food system has been going through. Production capacities and logistics are always the first to be affected in any event of geopolitical nature. Given the degree of globalization of food supply chain, its complexity has increased and become vulnerable to such geopolitical shocks.

From academicians, think tanks to different international organizations, passing by the intelligence society, they all acknowledge that in this globalized world, geopolitics and its risks are the corner stone to understanding the worldwide key events and the functioning of the world (Suárez-de Vivero and Rodríguez Mateos, 2017). Among these organizations, we find the World Economic Forum (WEF), that publishes every year the "Global Risk Report". In this report, the WEF covers five categories of large-scale risks, namely, technological risk, societal risk, environmental risk, economic risk and geopolitical risk. In their 2023 report, the WEF note that the geopolitical risk represented by geographic hotspots has great influence and impact on the functioning of the global financial and economic system, in particular in the region of Asia-Pacific, in which the concern is growing. Moreover, the report states for the future that "*Intensive geoeconomic weaponization will highlight security vulnerabilities posed by trade, financial and technological interdependence between globally integrated economies, risking an escalating cycle of distrust and decoupling. As geopolitics trumps economics, a longer-term rise in inefficient production and rising prices becomes more likely."*

Our paper makes three contributions. First, we examine empirically the relationship between geopolitical risk and food security using the most recent data, especially of "Food Security Index (FSI)" and "Geopolitical Risks Index (GPRI)". Second, our findings add to the previous and few conclusions on the influence of geopolitical events on food security and the main

[8] https://www.fao.org/worldfoodsituation/foodpricesindex/en/

[9] FAO, WFP, IMF, World Bank Group and WTO. https://www.imf.org/en/News/Articles/2023/02/08/pr2335-joint-statement-by-the-fad-imf-wbg-wfp-and-wto-on-food-and-nutrition-security-crisis

macroeconomic indicators (Caldara et al., 2023, Behnassi and Mahdjoub, 2022; Saboori et al., 2022; McMichael, 2009; Friedma and McMichael, 1989). Third, this is the first time in the literature that a threshold for "Geopolitical Risk Index (GPRI)" is estimated from which, food security and the main economic indicators are seriously threatened, especially inflation using a Panel Threshold Regression (PTR) model.

In the next section, we pass through the literature dealing with both geopolitical risk and food security with a special focus on their measurements and we present what has already been written on the impact of geopolitics on food security. Section 3 provides a description of the adopted methodology and the data we used. In section 4, we present our results and we discuss them, and the final section concludes and present the implications on the policy level.

2- Literature review

Geopolitical risk: measurement and impacts

Geopolitical risk has gained more interest of many scholars who have been trying to assess its impact especially since December 2019, the beginning of the spread of Covid-19 and February 24, 2022, the date of the beginning of the Russia-Ukraine war (Antonakakis et al., 2017; Umar et al., 2022; Zaremba et al., 2022). Many definitions of geopolitical risk emerge, some of them consider it as "*the exposure of one or more countries to political actions in other countries*" (Engle and Campos-Martins, 2020). In the beginnings, geopolitical risk's assessment tools were qualitative and has progressively turned to quantitative (Jiyoun et al., 2018; Wu et al., 2022). For instance, we find the risk attention, the economic quality index, the political system index and the global risks awareness. The models used for geopolitical risk assessment ranged from gravity models, nonlinear autoregression model to system analysis models (Costola et al. 2022; Faruk et al. 2022). We record also other forms of geopolitical risk assessment tools, such as, maps to a better visualization (The Economist Intelligence Unit, 2015) and technological tools based on communication and information technologies (CIT) like, geo-setting situational awareness and global news event tracking technology for monitoring and predicting geopolitical risk (Marsh, 2018). Indeed, the literature regarding the measurement of geopolitical risk has been growing, but, remains a challenging task for scholars. The difficulties in finding a good proxy for geopolitical risk, stems from its uniqueness (Bremmer and Keat, 2010). Many researchers opted for different approaches based on intuition or on macroeconomic data, yet, the results were qualified as subjective (Pyo, 2012). However, in 2018, Caldara and Iacoviello came up with a proxy as a measure of geopolitical risk.

In their paper, Caldara and Iacoviello (2018) propose an approach to measure the geopolitical risk by counting the number of journal articles dealing with events of geopolitical risk nature. They produced an index on a monthly and daily basis by following up newspapers in the United States of America (USA), Canada and the United Kingdom (UK). The index is available online[10] with two versions, the first from 1985 and the second called "Historical" is from 1900 (using at that time 3 newspapers in the USA). By having a close look at the historical geopolitical risk (GPR) index, we observe a significant peak during the two world wars (WW I, WW II), in addition to other major geopolitical shocks, such as, the collapse of the Soviet Union, the US-Iraq war, the 9/11 terrorist attack on world trade center in New York, the Gulf war and the various terrorist attacks on different European countries. However, the index still an issue of debate and criticism, especially that the index did not capture the 2008 financial crisis. In its construction, the authors distinguished between the GPR act index and the GPR threat index, where in the first the focus is on the direct impact of geopolitical events and in the second, they focus on the impact of geopolitical risk. The GPR index was normalized since 2000 with an average value of 100 and covers 43 countries.

In an update of methodological order, Caldara and Iacoviello (2022) adopt a dictionary-based method. The last consist of identifying and counting words used by journalists and related to geopolitical risk (events and threats). This approach is based on a wider definition of geopolitical risk by including influential actors and parties, such as, governments, supranational and international institutions (Rice and Zegart 2018) and taking into consideration the evolution of languages to best capture the terminology related to geopolitical events.

Food security: measurement and determinants

If, formerly, the food availability was the major determinant of wealth for empires and civilisations. Over time, other pillars added to this determinant, such as, affordability, and sustainability, which makes talking about food security more complicated.

Nowadays, measurement is critical for assessing and monitoring food security (Manikas and Sundarakani, 2023). The need for assessing the individual, household, and national food security led researchers and international organizations (WB, FAO, WFP) to construct indicators reflecting the field reality. The complexity of food security concept makes it difficult to build composite indexes and involves multiple choices that influence the outcome

[10] https://www.matteoiacoviello.com/gpr.htm

(Santeramo, 2015a), whether at a micro level (household) or at a national level or the frequency of appearance (daily, monthly, or annually). According to the FAO declaration: "*Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (World Food Summit, 1996). Following this framework, many indicators have been added to the literature by academia, think tanks, and international agencies (Global Food Security, Index (GFSI), the Global Hunger Index (GHI), and the Poverty and Hunger Index (PHI)).

The concept of food security has known a remarkable evolution and this evolution has been followed by a growing number of contributions aiming at better measuring and assessing it (Webb, 2006; Barret, 2010; Coates, 2013), from exploring environment and food production's relationship (Chen et al., 2021; Kidane and Kejela, 2021) passing by dietary (Lamarache, 2021; Gupta and Freedman, 2021) to arrive at proposing new strategies of dealing with food security (Aryee et al., 2021; Anghinoni et al., 2021) and we can say that the literature in this regard is large (Cooper, 2020).

In the beginning, the research was concentrated on the problems of food supply, such as, the basic foodstuffs availability and the stability of prices on both the national and the international level. Then, the interest in analyzing food security switched to individuals and households (Ihab et al., 2015; Xie et al., 2021). Yet, still the focus was on a single factor and at a low geographical level (Cai, 2020). Reaching a good measure of food security requires understanding and taking into consideration the development of drivers of food security through space and time, which will be useful for decision-makers (Van Meijil et al. 2020).

It should be noted in this regard that, based on the definition of food security adopted during the 1996 World Food Summit mentioned earlier in this subsection, an ideal food security index must reflect or take into consideration four axioms (Upton et al., 2016), which are:

(1) Scale axiom: in the definition "all people" means that, both individuals and households are concerned at a different scale of aggregation geographically and jurisdically;
(2) Time axiom: "all time" in the definition means that, over time, predictable and unpredictable variability of food security are captured and defined as the dimension of "stability";
(3) Access axiom: it reflects the accessibility or availability of food to all people;
(4) Outcomes axiom: called also the "utilization" dimension, that measures what is needed to have a healthy life.

Upton et al. (2016) reckon that, none of the available food security indexes in the literature satisfy the axioms they presented in their paper. What is also noticeable in the literature that, there is no consensus among researchers about the "best" food security index (Carletto et al., 2013; Caccavale and Giuffrida, 2020). A closer look at this variety of indexes shows that, the majority of them are interested in measuring accessibility to food at a household level. A few of them managed to measure besides the availability and the access dimension, the utilization dimension at both individual and national levels. The other dimension "stability", can be captured by following the estimation of food security indexes through time. In that matter, we find three composite indexes that can, in addition to measuring the "stability" dimension, measure at the national level the other three dimensions, namely, "access", "availability" and "utilization". These indexes are: the "Global Food Security Index (GFSI)" (Economist Intelligence Unit, 2021), "Suite of Food Security" (FAO, 2013) and "Proteus Composite Index (PCI)" (Caccavale and Giuffrida, 2020).

There is clearly a trade-off to be made between these indexes. Since our paper in concerned with the issue of food security in the light of geopolitical developments in the world, we will focus on the assessment of food security at the national level. As we recall the above discussion, the choice should be on an index that captures the four dimensions and close to the axioms described by Upton et al. (2016). We have at our disposal three indexes, namely, Global Food Security Index (GFSI), Suite of Food Security and Proteus Composite Index (PCI). Table 1 below addresses the strengths and weaknesses of these indexes:

Table 1. Food security indexes at the National Level

Index	Description/Method	Level of analysis	Dimension covered	Possible purpose	Strengths and Weaknesses
Suite of Food Security index	Composite index (0–100) covering all the four dimensions of Food Security. The multiple dimensions and indicators are normalised, and then aggregated using a set of weights, for example based on PCA	National	Four	*Estimate prevalence of Food Insecurity *Monitor trends in Food Security at national and global levels	*The index accounts for all the FS dimensions and components, provides insight into levels & trends of Food Insecurity; facilitate global and regional Food Security governance, availability of data from FAO. *No normalization weighting and normalization methods

Global Food Security Index (GFSI)	Composite index (0–100) by aggregating multiple indicators, using expert weights, or weighting methods: DEA and PCA	National	Four	*Analysing the factors influencing food security *Monitoring Food Security at global level	*The index provides insights into the vulnerability of a nation's food system by attributing to the causes. *The index focuses on analysis of Food Security determinants, and do not measure Food Security outcomes
Proteus Composite Index (PCI)	PCI is constructed from 21 indicators: availability (2 indicators), access (7 indicators), 8ormalizati (2 indicators), and stability (10 indicators)	National	Four	Monitor the food security progresses of countries by comparing within (over time) and between countries.	*The index addresses the shortcomings of other composite indicators in terms of weighting, normalization, and sensitivity. *Eleven of these indicators were adopted from FAO's Suite of food security Index

Source : Manikas et al. (2023)

After reading carefully table 1, we can say that the safe choice is the one for the "Global Food Security Index (GFSI)", despite its shortcomings in terms of food security outcomes. Combining FS inputs and outcomes, researchers have realized a division based on the final goal:

- The inputs regroup all variables serving the food availability with determinants of nutriments and micro-nutriments; physical access based on the food transportation (roads, rail-lines); economic access based on price levels; and finally, the access to improved water sources and sanitation facilities.
- The outcomes of all efforts from individual, household, and public authorities can be measured by sub-indicators regarding the pillar: for the availability: the inequity of access, and food composition. The utilization is measured by the percentage of children and adults with abnormal weight (signs of undernourishment); the vulnerability and stability are measured by price volatility, local food production variability especially cereals, foreign food trade, and political stability.

It should be noted that in the methodology of the GFSI, each pillar contributes to the overall index according its weight, which are: affordability 30%, availability 25%, quality and safety 22,5% and sustainability & adaptation 22,5%[11].

[11] https://impact.economist.com/sustainability/project/food-security-index/methodology

Geopolitical risks and food security

The impact of geopolitical events has been for a long time a concern for scholars. For that, the literature has been registering contributions that have been dealing with the impact of geopolitical risks on different areas and sectors, such as, financial markets (Yang et al., 2021; Hoque and Zaidi, 2020; Rupeika-Apoga and Wendt, 2022), banking (Phan et al., 2022), tourism (Balli et al., 2019) and agriculture (Micallef et al., 2023; Saâdaoui et al., 2022). However, empirical contributions dealing with the impact of geopolitical risk on the agricultural commodity market are the most popular, but, remains limited (Tiwari et al. 2021). The last researchers investigated the relationship between the agriculture sector and geopolitical events. In this regard, given the influence of the energy sector, Tiwari et al. (2021) shed light on the relationship of this sector and agricultural markets and explored geopolitical risks' implications on oil and agricultural commodities, for instance, wheat, oats, soybean and corn. This investigation was done using a copula approach for a period of 28 years. The paper concluded that, an increase in geopolitical risk leads to a strong movement between energy markets and the agricultural commodities we mentioned earlier, which is in line with the results of Cunado et al. (2020).

In fact, the interest in food as security[12] or food security dates back to 1974, the year of the global food crisis. The concern at that time was about scarcity, availability in terms of food provision at the international level and this crossed with the debate regarding overpopulation (Club of Rome 1972; Ehrlich 1968). Being aware of considering food as a geopolitical weapon was in the heart of the literature in the United States (Rothschild, 1976; Paarlberg, 1978), about which, a special issue of "International Organization" was published under the title "The Global Political Economy of Food" (Puchala et al., 1978). Other scholars have embarked on the exploration of this issue, among them we find Wallensteen in 1976 and 1986, who stated that "*the power over food production and distribution is of great importance, perhaps exceeded in significance only by access to military power"* and added that this, is a matter of national security. Orme (1998) and then Clapp (2017) went in line with the conclusions of Wallensteen and reckon that food security is a zero-sum game between states.

The global food crisis in 2007-2008 and then 2011-2012 have revived the issue of food security. These spikes were behind the riots that hit the most import-dependent countries, as a

[12] "Food as security" is a concept used in the early literature on international relations and security studies (Zhou, 2022).

consequence, most of the international organizations in addition to governments, civil society and the private sector started rethinking the governance landscape for food security to better deal with the issue of hunger (Zhou et al., 2020). However, the tensions between world powers (USA, Russia and China) are rising and are jeopardizing the functioning of different world institutions (World Health Organization (WHO), World Trade Organization (WTO) and United Nations (UN) security council … etc) making the issue of food politicized through some measures, such as, the sanctions imposed by Russia on Western food products in 2014, the sanctions on US soya beans exports to China as a result of the trade war between the two countries.

Besides, the Global Risks Report 2019 published by the World Economic Forum (WEF) emphasizes that international conflicts increase the risk of '*geopolitically motivated food-supply disruptions'*. This competition of geopolitical nature is obstructing all international efforts to promote dialogue and cooperation to reach the goal of getting it over with hunger. This competition can take different forms, one of them are related to agricultural resources which impact populations and food security. The recent food crisis unveiled the necessity of ensuring or securing agricultural resources, especially for countries experiencing deficits of water, nutrients and productive land. These deficits have pushed countries to invest abroad in agricultural resources, such as, acquiring arable lands (Woertz, 2013; Lisk, 2013). As a resource closely related to the agriculture sector, water resources consumption in agriculture represents 70% of the global consumption (Wolf, 2007), and with its scarceness it can constitute a reason for a war and can have an impact on social stability (Dell'Angelo et al., 2018a; Dell'Angelo et al, 2018b).

Another essential element in food production is "phosphorus", this resource can guarantee the fertility of the soil and so the production. Any disruption in the provisioning of this product will surely have consequence on food production (Cordell and Neset, 2014; Cordell and White, 2015; Nanda et al., 2019). The use of this resource is divided in general between "production of food" and "as a mineral fertilizer" (Cordell et al., 2016) and can be found in Western Sahara and Morocco (72% of the global reserves)[13]. On the other hand, Europe and India are the most import-dependent countries and the most vulnerable to any geopolitical events that might influence fertilizers' supplies.

[13] This estimation is according to the US Geological Survey (USGS). Mineral Commodity Summaries (USGS: Reston, VA, Jan. 2020),

In general, geopolitical events are in most cases transformed into armed conflicts, which are the main drivers threatening food security and are responsible for the deterioration of food security since 2014 (the first Russia-Ukraine conflict). Data from the FAO and the different agencies of the United Nations (UN) of 2016 confirm that most of the undernourished populations lived in countries characterized by war or armed conflicts (Pettersson, and Öberg, 2020), and this situation has a potential to pass-through into the economic development of the country.

In order to gain some geopolitical advantages, some countries resort to armed conflicts by using starvation of populations as a war tactic. In this regard, a number of resolutions[14] have been adopted by the United Nations (UN) Security Council in countries like, South Sudan, Syria, Yemen and Somalia (Conley and de Waal, 2019). These kinds of tactics have implications on food security directly and indirectly, it causes damages to all the food chain from production, logistics to impact the access of populations to food (Brück and d'Errico, 2019). Melander et al. (2016) consider that these conflicts are mostly between states or interstates and are becoming more and more internationalized, and add that geopolitical issues have great impact of this conflict-food security relationship.

By going through the literature, we notice that there is a shortage in terms of empirical contributions studying the relationship between geopolitical risk and food security. As a result, a gap is identified because most academic studies focus on the causality relationship between geopolitical risk and the two most researched commodity markets, namely, precious metals and energy. Hence, the gap has to do with agricultural commodity markets and the food regime within a worldwide geopolitical context.

3- Data and Methodology

Data

Given the insufficiency of some statistical data related to macro variables, we consider it appropriate to resort to panel data models with a threshold effect. This method will allow us to study a sample composed of 40 countries (Table 2), 17 among them are advanced economies and 23 are emerging market economies for a period spanning from 2012 to 2021.

Table 2. Countries of the sample

Argentina	Danemark	Israel	Philippines	Sweden
Australia	Egypt	Italy	Poland	Switzerland

[14] UN Security Council Resolution 2417, S/RES/2018/2417, of May 24th, 2018.

Belgium	Finland	Japan	Portugal	Thailand
Brazil	France	Malaysia	Russia	Tunisia
Canada	Germany	Mexico	Saudi Arabia	Turkey
Chile	Hungary	Netherlands	South Africa	Ukraine
China	India	Norway	South Korea	United Kingdom
Colombia	Indonesia	Peru	Spain	United States

Source : established by the authors.

In our model, we distinguish two categories of explanatory variables. The first relates to the threshold variable (Geopolitical Risk Index). The last is used to determine the existence of an asymmetric threshold effect. The second category includes control variables. These are, in fact, GDP per capita, the inflation rate, the agricultural land and the urban population (Table 3).

Table 3. Data description

Variable			Description
Dependent variable		*fsi*	The Food Security Index
	Regime dependent variable	*agri_land*	The agricultural land (% of land area).
		urb_pop	The urbanization rate (% of total population).
		inf	The inflation rate (annual %)
		lgdppc	Log of the real Gross Domestic Product per capita
	Regime independent variable	*dcovid*	The dummy variable that assumes a value of 0 for the pre-coronavirus period (2012–2018) and 1 for the coronavirus period (2019–2020)
Threshold variable		*gpri*	The Geopolitical Risks Index

Source : established by the authors.

It should be noted that the choice of the sample consists of the availability of statistical data. The FSI data were extracted from the Global Food Security Index database. GPRI was constructed by Dario Caldara and Matteo Iacoviello, it is a measure of adverse geopolitical events and associated risks based on tally of newspapers' articles covering geopolitical tensions, and examine its evolution and economic effects since 1900. The other explanatory variables were extracted from WDI database and the World Bank websites.

Methodology

The literature reckons, that one of the major advantages of using panel data analysis is their ability to capture the heterogeneity associated with the nature of the data via individual effects

(random or fixed) and time effects between individuals. Thus, the estimated coefficients of the observed predictors will be identical across all the observations (individuals and time). However, in many applications, the hypothesis of slops poolability may be infringed. The latter warrants the adoption of techniques that might support better the heterogeneous nature of the sample.

Therefore, we suggest a threshold regression model proposed by Hansen (1999) and developed by Wang (2015) for panel data. The latter defines the structural character of rupture or tipping point in the relationship between two variables. This model has found wide applicability in the capture of many economic phenomena, in particular, to treat heterogeneity problems within the framework of non-linear panel data, where each individual varies, and the structural relationships can also vary from one individual to another. Seleteng et al. (2013) notes that the PTR model is a fixed-effect model in which the coefficients of the regressors can vary from one individual to another and also over time.

Thus, we write the regression model of the threshold effect panel data with two regimes, as follows :

$$\begin{cases} \boldsymbol{FSI_{it} = \alpha_i + \beta_1 X_{it} + \beta_2 GPRI_{it} + \varepsilon_{it}} & \boldsymbol{1(GPRI_{it} \leq c)} \\ \boldsymbol{FSI_{it} = \alpha_i + \beta_1 X_{it} + \beta_3 GPRI_{it} + \varepsilon_{it}} & \boldsymbol{1(GPRI_{it} > c)} \end{cases} \text{.....(1)}$$

$$\text{with } \boldsymbol{i = \overline{1 \ldots . 40}} \qquad \boldsymbol{t = \overline{2012 \ldots . 2021}}$$

The matrix writing of (1) is given as follows :

$$\boldsymbol{FSI = \alpha + X\beta'_1 + GPRI\ \beta'(c) + \varepsilon} \ldots . . (\mathbf{2})$$

$$\text{with } \boldsymbol{\beta = (\beta_2, \beta_3)}$$

where $\boldsymbol{\alpha_i}$represents unobserved and time-invariant fixed country-specific effects. FSI_i is the Food Security Index, $\boldsymbol{X_{it}}$denotes the matrix which comprises control variables, $GPRI_i$ is the Geopolitical Risks Index and consists of the threshold variable and $\boldsymbol{c}$ the threshold value.

The threshold variable divides the sample into two regimes. The first represents a part of the sample, where the threshold variable $GPRI_i$ takes values lower than the threshold value, and the second represents the remaining part of the sample, or the threshold variable $GPRI_i$ takes values higher than the threshold $\boldsymbol{c}$.

The econometric relationship in each regime is linear and is characterized by different coefficients (β_1 *and* β_2). These coefficients are estimated using the ordinary least squares (OLS)

method. The estimation of the model as a whole requires the determination of the value of the threshold $\boldsymbol{c}$.

The value of the threshold $\hat{\boldsymbol{c}}$ is determined according to the methodology presented by Hansen (1999), where $\hat{\boldsymbol{c}}$ takes its value among the values of the threshold variable $GPRI_i$.

To determine the optimal value of the threshold, (Chan, 1993; Hansen, 1999) recommend the estimation of $\hat{\boldsymbol{c}}$ by minimizing the residuals squares sum S(c).

In order to prevent the number of observations in each regime from being insufficient to estimate the equations of each regime, the value of the threshold $\hat{\boldsymbol{c}}$ has been determined by restricting S(c) while ensuring that a minimum of 10% (40 obs) of the observations are in one of the regimes.

$$\hat{\boldsymbol{c}} = \boldsymbol{argmin}\, \boldsymbol{S}(\boldsymbol{c}) \ldots\ldots (\boldsymbol{3})$$

With $\boldsymbol{S}(\boldsymbol{c}) = (\boldsymbol{FSI} - \hat{\boldsymbol{\alpha}} + \boldsymbol{X}\widehat{\boldsymbol{\beta}}'_{\boldsymbol{1}} + \boldsymbol{GPRI}\,\widehat{\boldsymbol{\beta}}'(\boldsymbol{c}))'\,(\boldsymbol{FSI} - \hat{\boldsymbol{\alpha}} + \boldsymbol{X}\widehat{\boldsymbol{\beta}}'_{\boldsymbol{1}} + \boldsymbol{GPRI}\,\widehat{\boldsymbol{\beta}}'(\boldsymbol{c}))$

Unlike traditional approaches that determine the existence of a threshold effect between variables in an exogenous way, the endogenous approach is based on an empirical model. The latter will allow us to construct a confidence interval for the threshold value (Hansen, 2000).

It is essential to establish a confidence interval to test the statistical significance of the estimated threshold value.

The null hypothesis of non-linearity against the alternative hypothesis of the existence of a threshold are presented as follows:

$$\begin{cases} H_0: \ \beta_2 = \beta_3 \\ H_1: \beta_2 \neq \beta_3 \end{cases}$$

The determination of the asymptotic distribution of the likelihood ratio test is based on the application of the bootstrap method proposed by Hansen (2000).

4- Results and Discussion

Preleminary analysis

Table 4 below provides descriptions and summary statistics of the key variables used in the analysis. We focus on food security index (FSI) as a dependent variable and geopolitical risk index (GPRI) as the threshold variable.

Table 4. Descriptive Statistics

Variable	*Obs*	*Mean*	*Std. dev.*	*Min*	*Max*
gpr_1985	*400*	*.2281101*	*.3873347*	*.005639*	*2.62763*
fsi	*400*	*69.89325*	*7.931377*	*49.5*	*84.3*
fsi_aff	*400*	*82.20625*	*9.487508*	*51.4*	*94.2*
fsi_ava	*400*	*62.74825*	*8.200489*	*36*	*81.7*
fsi_qsa	*400*	*76.21925*	*9.889923*	*46.7*	*89.5*
fsi_sus	*400*	*55.0885*	*11.74566*	*28.1*	*87.4*
inf	*400*	*3.662688*	*6.125772*	*-2.093333*	*53.55*
lgdppc	*400*	*9.70311*	*1.052648*	*7.198539*	*11.37756*
agri_land	*400*	*75.03021*	*14.54258*	*31.634*	*98.117*
urb_pop	*400*	*40.3301*	*21.03795*	*2.693886*	*80.77304*

Source : established by the authors.

The data presented in the table above cover the period from 2012 to 2021. The average value of the variable geopolitical risk index for the countries of the sample is 1,32% and the maximum is 2,63%. The table also shows the other values of the control variables.

Results of the threshold estimation and the PTR model

Before estimating the threshold model, we test the non-linearity relationship and the existence of a possible threshold effect between food security and geopolitical risk. We reject the null hypothesis of absence of effects of the threshold of the model using the p-values of the bootstrap method, as proposed by Hansen (1999). To obtain the approximations of the F-statistic and then to calculate the p-values, the bootstrap procedure is repeated 5000 times for each of the threshold tests of the panel.

We show in table 5 the results of the single threshold test with bootstrap p-values. The test statistic for a single threshold is significant (p=0.092) when using the global food security index (FSI). For the pillars of food security, namely, affordability (fsi_aff), availability (fsi _ava), quality and safety (fsi _qsa) and sustainability and adaptation (fsi _sus), the significance levels are close to each other, p=0,040, p=0,088, p=0,036 and p=0,040 respectively. It is therefore possible to note the presence of a single threshold in the estimation of the model; consequently, the analyses are carried out using a single significant threshold, the reason why we did not test for the presence of 2 or 3 thresholds is justified by small number of observation (N=400).

Table 5. Estimation of the threshold

	Threshold estimator (level = 95)			Threshold effect test (bootstrap = 5000)						
	Threshold	Lower	Upper	RSS	MSE	F-stat	Prob	Crit10	Crit5	Crit1
fsi	0.0261	0.0154	0.0347	1343.5501	3.4450	20.68	0.0740	19.4544	22.4540	29.8853
fsi_aff	0.2721	0.2208	0.3251	3680.2821	9.4366	28.86	0.0483	23.9976	28.6697	36.7634
fsi_ava	0.0247	0.0229	0.0267	4338.4077	11.1241	22.17	0.0917	21.5807	24.9558	32.7163
fsi_qsa	0.2208	0.1656	0.2289	3505.3770	8.9881	30.81	0.0363	25.1135	29.0443	36.0992
fsi_sus	0.1184	0.1036	0.1222	4453.7193	11.4198	36.16	0.0567	32.2174	37.3017	49.4874

Source : established by the authors.

After confirming the existence of a single threshold, we proceed to the estimation of the value of the threshold. The above table (left side) indicates the value of the threshold for the variable global food security index, which is estimated at 0.0261 and which lies between the two lower (0.0154) and upper (0.0347) limits under a confidence level of 10%. The estimation of the threshold for the pillars of food security index, gave the following results: 0,2721 (fsi_aff), 0,0223 (fsi_ava), 0,1782 (fsi_qsa) and 0,0504 (fsi_sus) under the respectively significance levels 5%, 10%, 5% and 5% and between the following lower and upper bounds: L: 0,2531 & U: 0,3251, L: 0,008 & U: 0,0343, L: 0,0694 & U: 0,5512 and L: 0,027& U: 0,0775 respectively.

In the light of the threshold value that has just been estimated, it is now possible to divide the sample into two groups according to the two regimes. In this sense, the classification includes observations below and above the threshold. For FSI, the percentage of values in this scheme is 18,5 % over the 10-year period. The second group includes observations greater than the threshold, representing 81,5%. The percentages for FSI pillars are as follows:

- fsi_aff : 78,5% below and 21,5% above;
- fsi_ava : 17% below and 83% above;
- fsi_qsa : 74% below and 26% above ;
- fsi_sus : 57,25% below and 42,75% above.

The results of the two regimes in table 6 indicate the significance and dynamic effects of geopolitical risk on inflation and GDPPC. Thus, to determine the characteristics of relationships.

Table 6. Estimation results of the PTR model

VARIABLES		fsi	fsi_aff	fsi_ava	fsi_qsa	fsi_sus
Threshold value		0,0261**	0,2721**	0,0247**	0,2208**	0,1184**
Obs below threshold		74	314	68	296	229
Obs above threshold		326	86	332	104	171
	dcovid	0.579	0.0980	-0.769	1.241*	2.438***
		(0.411)	(0.654)	(0.737)	(0.644)	(0.720)
Below the threshold	**urb_pop**	0.00752	0.120	-0.228	0.306	-0.306
		(0.121)	(0.203)	(0.217)	(0.195)	(0.225)
	inf	0.0721	-0.466***	0.316***	0.248***	0.0578
		(0.0449)	(0.0578)	(0.0807)	(0.0566)	(0.0634)
	agri_land	0.742***	0.00672	0.607***	0.683***	2.344***
		(0.130)	(0.205)	(0.229)	(0.199)	(0.226)
	lgdppc	11.12***	14.96***	10.70***	5.538	10.40***
		(2.202)	(3.481)	(3.911)	(3.450)	(3.830)
Above the threshold	**urb_pop**	-0.0109	0.199	0.239	0.329*	-0.318
		(0.119)	(0.203)	(0.213)	(0.196)	(0.224)
	inf	-0.0900***	-0.293***	0.00426	-0.0417	0.131
		(0.0312)	(0.0738)	(0.0560)	(0.0713)	(0.0829)
	agri_land	0.825***	0.0482	0.845***	0.528**	1.457***
		(0.123)	(0.231)	(0.221)	(0.213)	(0.252)
	lgdppc	10.70***	14.47***	9.091**	7.059**	17.89***
		(2.139)	(3.643)	(3.827)	(3.549)	(3.977)
Constant		-95.26***	-67.19**	-79.54***	-43.61	-212.3***
		(17.04)	(27.49)	(30.49)	(27.29)	(30.23)
Observations		400	400	400	400	400
R-squared		0.391	0.295	0.173	0.175	0.447
Number of country		40	40	40	40	40

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

Source : established by the authors.

The results of our model show the effects of independent variables and regime-dependent variables on food security. This allowed us to distinguish which are the variables that contribute negatively or positively to food security.

For all the regressions from 1 to 5, we notice that under and above the threshold, meaning, with a high or low level of geopolitical risk, the coefficients of GDP per capita contribute positively to the global food security as well as its pillars except for food security "quality and safety" when it is below the threshold is insignificant. The contribution is almost the same when it comes to the global food security index and its pillar "availability" and "sustainability and adaptation" with coefficients estimated at 11,12 / 10,70 and 10,40 respectively (under the threshold), while the contribution to food security "affordability" is the highest and estimated at 14,96. Above the threshold, the contribution of GDP per capita is always positive as mentioned earlier, with a slight decrease compared to the previous estimates under the threshold. As for the global food security, food security "affordability" and "availability" the coefficients are estimated at 10,70 / 14,47 and 9,091. Food security "sustainability and adaptation" registered the highest coefficient (17,89) with a big increase compared to the coefficient under the threshold.

The results for the variable "inflation", are controversial. Under the threshold (low level of geopolitical risk), "inflation is only significant for the regressions 2, 3 and 4, meaning for the pillars "affordability", "availability" and "quality and safety". However, only the contribution to food security "affordability" is negative and estimated at -0,466, which means that inflation reduces food security "affordability" by 0,46 points, while for food security "availability" and "quality and safety" the contribution is positive and estimated at 0,316 and 0,248 respectively. These positive signs can be acceptable when the geopolitical risk is low or under the threshold, yet, remains difficult to interpret. When we are above the threshold (high level of geopolitical risk), "inflation" is significant for only the global food security and food security "affordability" and the contribution is negative, estimated at -0,09 and -0,293 respectively, meaning that inflation reduces food security and food security "affordability" and by 0,09 and 0,29 points. These negative signs are in line with the literature and the theory (Saboori et al. 2022; Caldara et al., 2023). Caldara et al. (2023) showed that a high level of geopolitical risk lead to uncertainty, which makes economic activity gets lower and lower and if the world or the region are facing military conflicts, this will make military spending increasing and in turn will push public debt to increase and trade decline.

The variable agricultural land (% of land area) was found to be positive and significant under and above the threshold, except for food security "affordability". It means a larger percentage of agricultural land contribute positively to food security whether in high or low geopolitical situation.

Another controversial result is the one of "Urban population", this variable is only significant where the geopolitical risk is high (above the threshold) in explaining food security "quality and safety". It means that an increase in urban population (as a % of total population) will improve food security "quality and safety" by 0.329 points. This variable was expected to be significant and positive in all the regressions, yet the variable was only significant in one regression.

The dummy variable Covid-19 was found to be significant only in two cases, food security "quality and safety" and "sustainability and adaptation".

The constant in our model reflects the initial situation of food security and it is clear that the situation is negative and significant even when we isolate the influence of the other variables and that is true for food security and its pillars.

Discussion

In summary, our empirical results show that the dummy variable "dcovid" representing Covid-19 is only significant for the case of the FSI pillars "quality and safety" and "sustainability and adaptation". As explained in the section of literature review "Food Security: Measurements and Determinants", FSI "quality and safety" is interested in measuring the nutritional quality and variety of average diets, in addition to the food safety. On the other hand, FSI "sustainability and adaptation", evaluates the exposure of countries to natural resource risks, climate change and their adaptations to these risks. Having the dummy variable of Covid-19 significant only when it comes to these two pillars indicates the importance given to these two dimensions of food security when facing a crisis. In other words, in times of a pandemic like Covid-19, at a governance level and a consumption level, the priority is given to the quality and safety of food and the way households and governments adapt their policies to face or cohabitate with such a crisis (Daoudi and Bouzid, 2020).

The harmful effects of inflation on the structure of the economy are not to be demonstrated. A rich theoretical and empirical literature has emerged to demonstrate how inflation is transmitted to the economy and which sectors are the most affected by this phenomenon (Espinoza et al.,

2012). For the first regression (global food security), starting from a threshold of geopolitical risk (GPR) estimated at 0,0261, as the geopolitical risk increases inflation becomes a burden for all the governments of the countries of our sample and start reducing food security by 0,09 points. Theoretically speaking, there is no proof to which extent such an impact of geopolitical risks could be of that harm, because traditionally, this is a result of negative supply or/and demand shocks. In that respect, the mechanisms of the propagation of these negative shocks are well known in the literature. For instance, investment and so GDP could be affected negatively, which will in turn move to inflation and vice versa. When we analyze the relationship between geopolitical risks and inflation from a supply standpoint, it is obvious that any war (geopolitical event) and all the risks coming with, have a devastating damage to both physical and human capital, could disrupt international trade and hence food and raw materials supply, which will create a shortage and then a price increase (Glick and Taylor, 2010). The last would cause reduction in the ability of countries to afford food products, which is in line with the significance and the sign of the coefficient of inflation in the second regression (FSI_affordability). The last reduces food security (affordability) by 0,293 points, yet, this impact is valid starting from a threshold of geopolitical risk (GPR) of 0,2721. Besides, any war could also divert capital flows and make the use of resources less efficient due to the shift of their allocation. On the other side, the uncertainty created by the war or even a political conflict regarding the future of economic activity in any country, could affect the demand side in many forms, such as, curbing companies from investing or hiring and affecting the consumers' demand decision. On the macroeconomic level, times of wars push governments to face the negative consequences on the "demand" by increasing public spending (including military spending), financed by debt in order to boost the demand (Hall and Sargent, 2022). At the end, high or low inflation would be defined on the basis of the extent of the war and its lasting as well as the measures taken to face it.

Whether the country is developed, emerging or developing, they all share and agree on the necessity of disposing great areas of land devoted to agriculture activities to guarantee its food security. For that matter, our results proved this point of view. We notice from table 6 above that the coefficient of the variable "agri_land" increased from 0,742 when the geopolitical risk is low to 0,825 in the second regime (high geopolitical risk (> 0,0261)), meaning that the area devoted to agriculture activities becomes more important as long as the geopolitical risk increases, which will in the end increases global food security. The same can be said when it comes to food security (availability), this pillar of food security measures the level of

production and the available capabilities, the probability of any supply disruption and the capability of the country to support the efforts of enhancing agricultural output. In the first regime (low geopolitical risk (<= 0,0247)), the coefficient was found to be 0,607 and becomes 0,845 in the second regime (high geopolitical risk > 0,0247). However, the variable "agri_land" is less important in the second regime of the 4th and 5th regressions (from 0,683 to 0,528 and from 2,344 to 1,457 respectively) with a geopolitical risk greater than 0,2208 and 0,1184 for FSI_quality and safety and FSI_sustainability and adaptation, respectively. These results show the order of priority given to these pillars of food security in times of a high geopolitical risk (>0,2208 and >0,1184) like wars, when governments and households are less concerned with food safety and quality as well as the adaptation of governments and households with the consequences of wars, since the supply chain is disrupted.

Events of geopolitical nature (wars, political instability … etc) have the characteristics of impacting revenues for both the importers and the exporters. This impact could be big if the target of the war or a conflict is one of the main chokepoints in the world for instance (Figure 1). These chokepoints could be: (1) Maritime chokepoints, (2) Coastal chokepoints or (3) Inland chokepoints.

The figure 1 below indicates the maritime, coastal and inland chokepoints and also the main shipping routes in the world. Here some facts about the worldwide trade (Bailey and Wellesly, 2017):

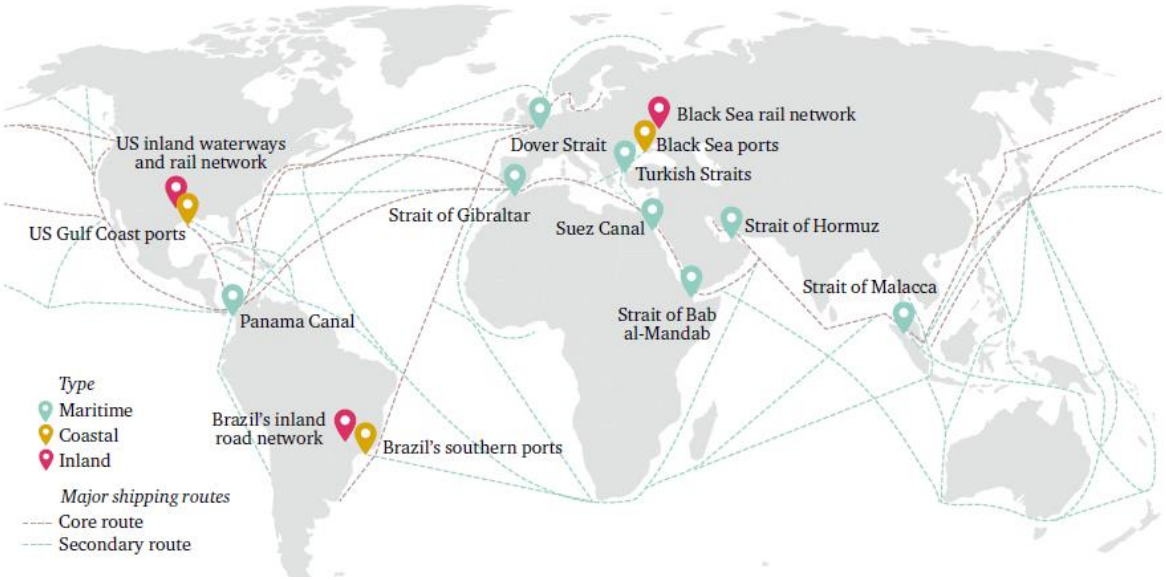
- More than 50% of maize, rice, wheat and soybean trade are transited through the most important coastal and inland chokepoints in the Brazil, the United States and the Black Sea[15]. More than 25% of the exports of Soybean make their road through the Strait of Malacca
- 60% of the maize, rice, wheat and soybean United States exports[16]are transited through inland waterways;
- 25% of the global soybean exports are transited through the southern ports;
- 60% of wheat exports coming from Russia and Ukraine are transported through the rail to reach the Black Sea ports;

[15] This strait links the Mediterranean sea to the Black Sea. The last is called also the "Breadbasket". This Trait represents around 33% of wheat trade.

[16] It represents 13% of worldwide exports.

- The most important grain flow in the world is transited through the Panama Canal and the Strait of Malacca[17]

Figure 1. Maritime, coastal and inland chokepoints



Source : Rodrigue et al. (2017)

To conclude about this point, any event that could disrupt the supply chain in these chokepoints will affect immediately the supply and the demand side as explained earlier. The first indicator to be impacted is inflation through spikes in the prices of agricultural products, raw materials … etc, which will in turn create a shock in demand and supply. The shock is translated in the supply side, through a shortage in provisioning, making then the revenues of the suppliers to be reduced and as a consequence the GDP per capita gets lower. The same mechanism will occur in the demand side, the spike in the prices will reduce the capability of the authorities and the households to access and afford their needs because of the reduction in their purchasing power. The overall impact makes the coefficient of GDP per capita much more important as the geopolitical risks increase. Our results are in line with the above explanation and mechanism. Beyond the following thresholds of geopolitical risk (high geopolitical risk): >0,2208 (FSI_quality and safety), >0,1184 (FSI_sustainability and adaptation), GDP per capita becomes much more important by 27,47% and 72,02% respectively. Nevertheless, in terms of importance, practically, no gain was registered for the case of global food security (for a geopolitical risk higher than 0,0261) and for FSI_ affordability (for a geopolitical risk higher than 0,2721), where the coefficients witnessed a small decrease estimated at 3,5% on average.

[17] This strait include also the Singapore strait that relies the Asian and the Western markets.

On the other hand, FSI_availability (for a geopolitical risk higher than 0,0247) recorded a decrease in terms of the importance of the coefficient (from 10,7 to 9,091, with decrease of 15,04%). The last could be interpreted by the fact that geopolitical events, as previously explained especially for the case of chokepoints, create a shock in supply, which affect the provisioning of different products, including food products, this reality makes governments and households give less importance to the dimension of availability due to their incapacity of influencing this pillar of food security.

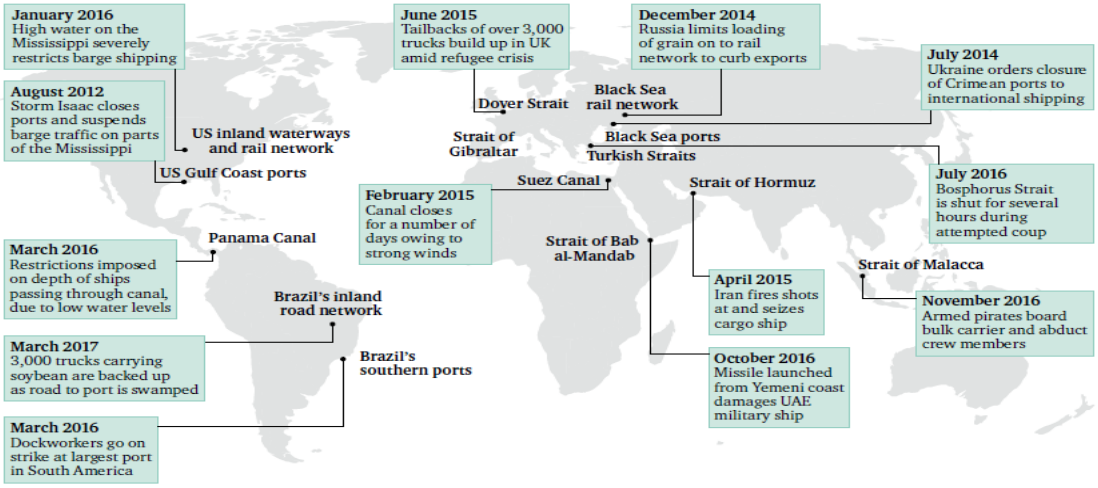
As mentioned in the beginning of this section, we faced in our paper some controversial results, especially in terms of the signs of some coefficients, such as, the ones of inflation for the regressions (3 and 4) (for FSI_availability and FSI_quality and safety respectively), where the signs were expected to be negative, and urban population for the regression 4 (for FSI_quality and safety), where the sign is positive instead of negative. The explanation we can give to these kinds of results is that, the presence of aberrant and influential values may considerably modify the magnitude of the regression coefficients and even the direction of the coefficient signs (Kennedy, 2002). Outliers have the potential to disproportionately impact estimated regression coefficients and distort the relationship between independent and dependent variables. In our case, we found a large variation in our regressors, namely inflation rate and urban population, with standard deviations of 6.12 and 21.03 (Table 4), respectively. However, another explanation can be advanced, which is related to the composition of our sample. Our sample is basically formed with 42,5% of developed economies, where in this kind of economies, a low level of geopolitical risk is generally associated with a low level of inflation (Caldara et al., 2023) and the growth rate by which the population is growing is low[18] (UN, 2022). The combination of these factors makes the coefficients of inflation and urban population less important in terms of a sign and magnitude in such a context.

The threshold of the variable geopolitical risk index (GPRI) we estimated earlier using the PTR model divided our sample into two regimes. We are now able to classify the countries of our sample on that basis, which gives us of course countries with a low level of geopolitical risk (Regime 1) and countries with a high level of geopolitical risk (Regime 2) and another group of countries swinging between the two regimes (under and above the geopolitical risk threshold).

[18] https://unctad.org/data-visualization/now-8-billion-and-counting-where-worlds-population-has-grown-most-and-why

The classification is available in table 7 below and since we cannot in this paper, deal with each country separately, we will just try to analyze the most relevant results.

Figure 2. The main chokepoints disruptions (2014-2017)



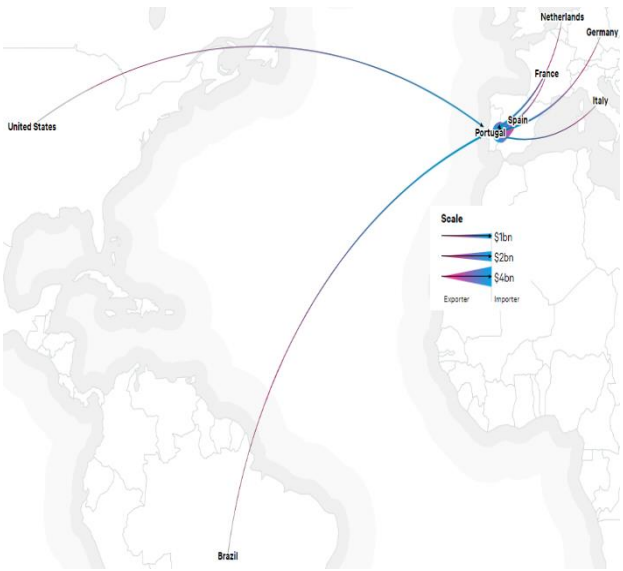
Source : Bailey and Wellesly (2017)

For instance, in table 7, for the variable FSI, we notice that only Portugal belongs to the group with a low level of geopolitical risk (Regime 1), this makes sense since Portugal is not a major actor in the region or in the world, in addition to the fact that the provisioning of Portugal from the different agricultural products and fertilizers is done away from the most vulnerable chokepoints (Figure 2 and Figure 3) to high levels of geopolitical tensions, which makes the probability of any perturbation in the provisioning very low, except for the dover strait that witnessed in 2014 an event over the refugee crisis in the United Kingdom (UK) (Bailey and Wellesly, 2017).

Table 7. Classification of countries based on FSI

Regime 1	Régime 2		Régime 1 &2
Portugal	Australia	Norway	Argentina
	Belgium	Philippines	Chile
	Brazil	Russia	Colombia
	Canada	Saudi Arabia	Denmark
	China	South Africa	Finland
	Egypt	South Korea	Hungary
	France	Spain	Indonesia
	Germany	Sweden	Malaysia
	India	Switzerland	Peru
	Israel	United Kingdom	Poland
	Italy	United States	Thailand
	Japan		Tunisia
	Mexico		Ukraine
	Netherlands		

Figure 3. The main exporters of agricultural products and fertilizers to Portugal



Source : established by the authors. *Source : https://resourcetrade.earth/*

The classification of Argentina, Chile, Colombia, Indonesia, Peru and Thailand to both regimes, can be explained by the source of their importation in terms of agricultural products and fertilizers that need to pass by some chokepoints belonging to or influenced by countries representing high geopolitical risks like the straits of Malacca and the black sea (strait of Bosphorus). The swinging between the two regimes indicates the uncertainty turning around some straits, despite the fact that the shipping regulations in these straits are respected in most times, but the risks of any disruption is a possibility that is likely to occur. Poland and Hungary are more likely to be in regime 2 instead of swinging between the two regimes, because of their historical links to Russia and the continuous conflicting situation still prevailing between these countries.

5- Conclusion and policy implications

Conclusion

Food security in the world is a major issue that has been shed light on again since the Covid-19 pandemic following the disruption that hit the world food supply chain as well as the agri-food value chain. In addition to the other factors that affect food security, such as climate change, this problem will worsen in case of any major event of geopolitical nature.

We managed in our paper to estimate a threshold of geopolitical risk for a panel of 40 countries (17 advanced economies and 23 emerging economies) using a panel threshold regression. We found that geopolitical risk is inflationary due its responsibility for the spikes in the prices of different commodity prices (food supply, fertilizers, oil … etc) and with the inflationary effect of fiscal policy as a response to such a geopolitical event. With a lower consumer sentiment and tough financial conditions, higher geopolitical risks can enhance uncertainty around inflation outlook and bigger upside risks to inflation, thus aggravating the tradeoffs between fiscal and monetary policy.

Our results indicated also, the importance to governments and especially households of disposing revenues (GDP per capita) to face the consequences of geopolitical risk and this importance was reflected through an increase in the coefficients of GDP per capita compared to the first regime. The results for variable “area of land devoted to agriculture” confirmed what is already in the literature, that an increase in the surface destined to the agricultural activities

especially in tough times is an insurance that contributes to consolidate food security. On the opposite of our expectations, we found wrong sign and less significance of the variable "urban population" in the different regressions and the argument we gave was strictly technical related to aberrant observations that could influence the sign and the significance of a variable. At the end, Covid-19 was found also to be contributing to food security, but the focus in times of this health crisis was two dimensions of food security, namely, "quality and safety" and "sustainability and adaptation".

We demonstrated in this paper the central role chokepoints play in the process of international trade, they are the epicenter in today's geopolitics. Vulnerable to climate change and international political conflicts, any disruption in the functioning of these chokepoints (armed conflicts, military exercises, political tensions … etc) will make them the source of the spillovers to the world economy, which will have consequences on the main macroeconomic indicators, at its tops inflation, investment, unemployment and GDP.

Policy implications

The issue of food security is a serious concern for governments and international organizations especially since the 2008 food crisis (Mittal, 2009), the Arab Spring in 2011, Covid-19 in 2020 and the different armed conflicts around the world. Its implications were apparent through the spikes of food prices and the issue is dealt with in a framework of geopolitics (Lester, 2011). In fact, this is an old new problem having in common one reality, that the world has changed and is more globalized and more complex than before, and the Russia-Ukraine war is the geopolitical shock marking the transition to a multipolar world (De Ridder et al., 2013), threatening as a consequence food security around the world. The signs of this transition can be quoted as follows: a decrease in GDP growths, an increase in governments debts, a decrease in foreign exchange reserves, weak monetary unions and large depreciations of Euro and US dollars. This destabilized environment is undoubtly affecting food value chains and food supply chains because of the widespread use of protectionist policies (Egger et al., 2023) and both raw materials and food products are becoming now strategic goods or more precisely instruments.

The response of each government to such a geopolitical shock depends on whether the country is a producer, exporter, importer of raw materials and food or agricultural commodities. If we take it by product, India and China are the "prime deliverers" of rice; Argentina, USA and Brazil for soybeans; China, India, USA, Russia, Ukraine, France and Australia for wheat. On the other side of the market, we find Kingdom of Saudi Arabia (KSA), Iran and Philippines as the largest demanders of rice; Japan and China for soybeans; Italy, Brazil, China, Kingdom of Saudi Arabia

(KSA), the Netherlands and Egypt for wheat. Large producers adopt a behavior of keeping great stocks to meet their high domestic demand and they become net importers in extreme cases like in the times of Covid-19 health crisis. Hence, the quantities given for trade by large producers are small when it comes to a highly important agricultural commodities and these quantities are estimated at 5% for rice for example, at the opposite of small countries that provide international markets with large quantities like the Netherlands (De Ridder et al., 2013).

Prioritizing food security requires having a political-strategic view with an objective of meeting domestic demand. Exporting countries can recourse to production quotas and imposing restrictions on exportation, while importing countries have the possibility of opting for a vertical integration in the global food supply chain for their companies or adopting a proactive behavior consisting of leasing or purchasing agricultural land. For these countries, ensuring the consumers' right to access to a decent food supply at a country level is their main challenge to be achieved. To do that, their objective is:

- To reduce the impact of any disruption in food supply, keeping a country level self-sufficiency is the only bumpers available against a sudden food supply shock;
- Establishing strategic relationships with countries possessing key raw materials and agricultural commodities;
- New institutional governance arrangements need to be negotiated and implemented internationally and nationally to a better cooperation in the area of food and raw material trade between suppliers and demanders;
- Combining the three above points to ensure a sustainable international food system to prevent shocks of different nature including geopolitical shocks.

At a world level, keeping the worldwide chokepoints away from geopolitical conflicts is key to a large extent to protect supply chains. The risks these chokepoints could face can be divided into three categories of disruptive hazards (Bailey and Wellesly, 2017):

(1) Weather and Climate: Floods, storms, we can add natural disasters, such as, earthquakes. These events can harm the efficiency of key infrastructures and cause a temporarily shut down;
(2) Security and Conflict: terrorism, organized crimes, war, political instability and riots;
(3) Institutional: political or economic decision to shut down chokepoints or put some restrictions on them, which will cause for example food products flow to be reduced.

For example, in 2017, Gulf countries and Egypt decided an embargo on Qatar, causing 40% of their food imports to be canceled.

The risks we just mentioned are increasing and are determined by three trends:

(1) The growing dependency on chokepoints as a consequence of the growing volume of international trade;

(2) The evolution of climate change is making the chances of increasing the frequency of occurring of floods, storms, typhoons…etc, high, which will in turn have repercussion on chokepoints (ex. frequent closures). In addition, the rising levels of seas and oceans will also put coastal storages and ports out of operations;

(3) A permanent underinvestment making the available infrastructure under capacity and do not suit the growing volume of trade.

The Russia-Ukraine war has created enormous implications for the world, especially to the european and the african continent. This geopolitical shock has impacted through the mechanisms we described earlier in this paper food security in both continents. The strong connection of Europe and Africa to Russia, in terms of energy (gas) and food (wheat and sunflower) has emphasized the vulnerability of these two continents to such a shock of geopolitical nature, where the chokepoints in this region of the world were the bridge through which the shock has propagated. This situation pushed Turkey, the United Nations (UN) and the international community to intervene in order to face and limit the consequences of the war. The different parties at their top Russia and Ukraine reached an agreement in July 2022[19], in which they allow the export of grain and other agricultural products through the Black Sea rail networks and the Black Sea ports after months of blockade where the storage capacity reached its limits due to the non-export of most of the grains and oilseeds harvested in 2021 and part of them harvested in 2022. In addition to the consequences on food security, the war has impacted also energy security through the disruption in provisioning in gas to Europe because of the explosion that hit the pipelines “Nord Stream 1 & 2” in the Baltic Sea.

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