War in Ukraine: The Rationale ”Wait-and-See” Mode of Global Food Markets *

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Abstract

Russia's invasion of Ukraine is a major shock at the heart of the breadbasket of Europe at a time when global stocks are running short. With inelastic supply and demand for such basic goods and lack of inventories to cushion the shock, the basic economics of storage arbitrage explain the commodity price spikes needed to ration the war-related supply shortage. In this paper, I show that to make sense of the chaotic price fluctuations requires a consistent empirical tool such as the storage model with rational expectations. Empirical analysis of the unfolding commodity shock using a storage model lens suggests that the global food market is currently in a "wait-and-see" mode, with price movements reflecting a loss in the size of the global share of caloric production from Ukraine. I show also that the supply and demand outlook for the next two years is aligned to the price expectations of market participants and send the signal that the world should prepare for a period of scarcer supply and high and volatile food prices, for as long as the conflict lasts. Sound policymaking in this context could rely on this normative device to ease the suffering of the most vulnerable populations who are at risk of hunger and malnourishment.

Keywords: Storage, volatility, food security, commodity price dynamics.

JEL classification: Q02, B41, Q11.

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1 Introduction

The supply-chain disruptions and labor shortages caused by the Covid-19 pandemic combined with poor weather conditions made more frequent and extreme by climate change have strained global food markets, and the eruption of the war between Russia and Ukraine on February 24, 2022 sent already rising global commodity prices soaring further. The Russia-Ukraine conflict is causing uncertainties over world food supplies and is generating strong price volatility and the risk that even more people will suffer from malnutrition, hunger and poverty. The commodity crisis could trigger riots and social unrests in developing countries reliant on commodity imports and where a significant portion of household incomes is spent on food.[1] Global food security has become a burning issue and is at the top of policymaking agendas around the world. Thus, to organize policy discussions and calibrate and evaluate political actions requires a good empirical model which provides a common architecture.

In the commodity price literature, the standard model for empirical analysis of commodity price volatility is the competitive storage model with rational expectations that was proposed by Gustafson (1958). This is a basic supply and demand dynamic equilibrium model in which storage plays a central role. It shows how production, consumption and commodity prices are connected in the forward-looking storage decisions of speculators that are ruled by the logic "buy low, sell high". Many of the model's theoretical predictions are supported by the actual behavior of commodity prices which show occasional upward peaks and clustering of volatility.[2]

In this paper, I show how this normative tool can be used to address some of the following policy-relevant questions. How much in aggregate and commodity-by-commodity do market operators believe that the world has lost access to? Could prices go even higher? Are economic agents receiving a "good" price signal that reflects both current and expected scarcity levels, and if so how long will these inflated global food prices persist? I focus on three of the main human food staples: wheat, corn and soybeans which are those most directly affected by the war in Ukraine.[3]

[1] In some sub-Saharan countries this portion is 40%.

[2] See Williams and Wright (1991) for an extensive overview of the theory underlying the storage model, the numerical considerations involved in the model's resolution, and the subsequent variants developed in the literature.

[3] The exclusion of rice is not to suggest that it is not important but rather because its production is affected less directly by the conflict in Ukraine. Also, the high levels of substitution in production and consumption among all these crops means that movements in maize, soybean and wheat quantities capture the dynamics of rice prices.

I adopt a three step approach. First, to put into context the surge in commodity prices three months after Russia's invasion of Ukraine I present some of the main stylized facts related to commodity price dynamics. The empirical evidence and data on prices and quantities show that recent price spikes are typical of cyclical booms in commodity prices (Wright, 2011, 2014). Second, I describe the storage model and highlight the intuition underlying the crucial role of inventories in the asymmetric responses of current and futures prices to shifts in market fundamentals. I conduct an empirical analysis of the negative supply shock caused by the Russian's invasion of Ukraine building upon the work of Roberts and Schlenker (2009, 2013) which was extended by Gouel and Legrand (2022). Specifically, I show how the economics of storage behavior helps to explain the recent movements in global commodity prices not only qualitatively but also quantitatively. I emphasize the rational response of global prices to reflect the market balancing among supply, storage and demand for immediate consumption.

Third, I review and discuss the main supply and demand market forces at work and how well they match the expectations of futures market operators to try to predict food prices in the coming two years. I assume that these factors will be critical for policymakers trying to navigate the uncertainties related to a drawn out war.[4]

2 The empirical facts

2.1 Turmoil in Europe's breadbasket

Let's start by putting the commodity-price crisis in perspective. The war between Russia and Ukraine–often described as the breadbasket of Europe–has hit at the heart of the global food system. Figure 1 helps set the stage of the magnitude of this food supply shock.

The graph depicts global production and the export shares of the world top ten exporters of maize, wheat and soybeans. The numbers are averaged over the past five years to smooth annual production fluctuations which occur mainly as a result of weather hazards. In the case of wheat and especially winter wheat,

[4] Since this is a continuously evolving situation, interested readers should consult the daily articles on the farmdoc daily website `https://farmdocdaily.illinois.edu/` which provides updated and insightful analyses of these key market indicators, and latest developments in agricultural markets more generally. Other useful sources are the articles published on `https://asmith.ucdavis.edu/news` and the International Food Policy Research Institute (IFPRI) blog `https://www.ifpri.org/landing/blog`.

Figure 1: Major exporters of Corn, Wheat and Soybeans

Russia and Ukraine are respectively the world's first and fifth biggest exporters.[5] Both countries are also significant players in the corn market, and account for 4% of world corn production which represents 17% of global exports.[6] Therefore, between them Russia and Ukraine account for about 12% of the calories traded worldwide, and more than 10% of the vegetable oil market. Also, Russia is the world's second-largest exporter of oil and natural gas, which implies that this food crisis is being compounded by an oil shock which will further increase food production costs. In addition, since Russia is also a major supplier of fertilizers, there will be an indirect effect on agriculture and global food production which will result in sustained elevated prices of food commodities. Overall, the range of the commodities directly affected by the war in Ukraine is causing one of the biggest shocks to commodity markets since the 1973 oil shock.

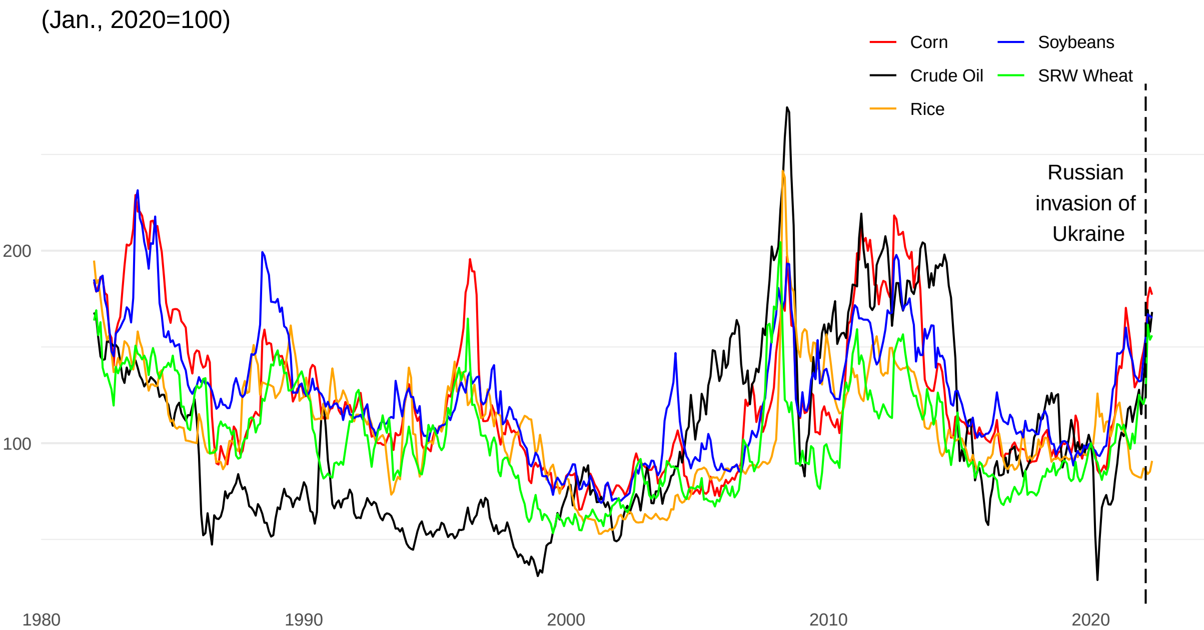
[5]Specifically, 70% of Russian and more than 90% of Ukrainian is winter wheat. For the current 2021-2022 marketing year, this refers to wheat planted in fall 2021 which should be harvested and marketed in summer and fall 2022.

[6]They account also for 29% of the barley and 75% of the sunflower oil traded internationally.

2.2 Commodity price traits

Despite the above, by historical standards the current commodity price spikes in real terms are not as high as those reached in the food and energy crises in 2007-2008 and 2011-2012. However, the simultaneous involvement in price surges of energy, industrial metals and agricultural goods is less frequent although it was a feature of the 2008 crisis. Figure 2 shows monthly price variations over the past 40 years for the four main food staples and oil.[7]

Figure 2: Real monthly indices based on April 2022 prices



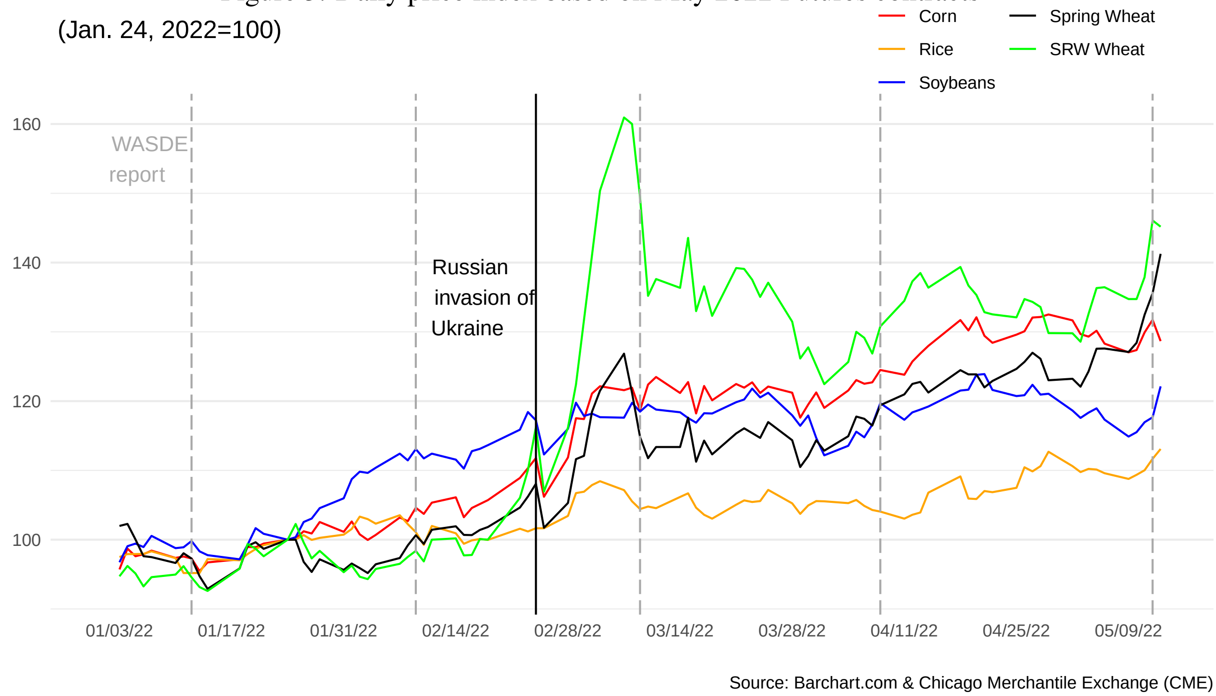
Source: World Bank Pink Sheets. Prices are deflated by the U.S. CPI (Bureau of Labor Statistics).

What is striking in the present case is the degree of price volatility, with prices doubling and even trebling in the space of a few months. Swings of this magnitude suggest that already high prices could rise even further. Figure 2 provides a good illustration of the main stylized facts regarding commodity prices behavior. Specifically, the dynamics of commodity prices are characterized by long periods of low and stable prices interrupted by sharp price peaks which tend to be followed by prolonged periods of high and more volatile prices. Note also that cycles are asymmetric with price peaks not matched by equally sharp troughs. As I will

[7] Nominal prices are taken from the World Bank monthly Pink Sheets deflated by the U.S. Consumer Price Index computed by the U.S. Bureau of Labor Statistics and expressed as an index with respect to the price January 2020 price.

show below, one of the structural forces driving all these movements is storage. Figure 3 depicts the period related to the Russian invasion.

Figure 3: Daily price index based on May 2022 Futures contracts



It shows the daily prices of these crops for the May 2022 futures contracts which were the closest to delivery at the time of the Russian invasion, since the beginning of 2022. All prices are expressed relative to their January 24 levels i.e. one month before the Russian invasion. Note first that all prices were trending upward even before the start of the conflict. This can be attributed in part to supply-chain disruptions and to inflation due to the pandemic, partly to droughts and poor harvests in key producing areas, and partly to fears related to the looming conflict and its expected consequences for agricultural commodity markets. The prospect of a war driving up prices is further evidence of the role played by market expectations in price dynamics. In other words, part of the likely supply disruption had been anticipated and included in prices before it was actually realized.

Second, note the gradient in the price reaction depending on the product considered. In this case, basic supply and demand economics are at play. For example, since most of Ukrainian and Russian wheat is winter wheat and thus had been sown before the Russian invasion, a much higher price is needed to ration a rather fixed supply suddenly reduced by the conflict. This means that the huge jump in the price of winter wheat following the outbreak of the war should come as no surprise. Likewise, greater flexibility in the supply of yet to be planted spring wheat, corn and soybeans–at both the intensive and extensive margins–combined with the lower shares of Russia and Ukraine in the global production and trade of these crops, explain the more muted responses of their respective prices. Hence, the second-largest price spikes are for spring wheat, followed by corn, soybeans and finally rice whose supply is not threatened directly by the war, and which is barely used for the production of biofuels and whose supply and demand tend to be quite concentrated, mainly in Southeast Asia.[8]

Third, note the sensitivity of prices to the arrival of news, from information on the surface planted, growing conditions and yield prospects to inventory levels and trade restrictions, ect. An important source of public information on agricultural commodity markets is the monthly World Agricultural Supply and Demand Estimates (WASDE) reports published by the USDA (Adjemian, 2012; Lehecka et al., 2014; Gouel, 2020; Adjemian and Irwin, 2018; Karali et al., 2020). The WASDE report release dates are indicated by the gray vertical dashed lines and it is striking to see that they had an impact on prices, more or less long-lived and varying in extent depending on the information provided. For instance, the March report, issued two weeks after Russia invaded Ukraine, seems to have been pivotal in calming markets by re-anchoring prices to levels more in line with what the market collectively believed at the time were the prevailing supply and demand conditions. This applies particularly to soft red winter wheat whose price began to rocket in a kind of market panic due perhaps to the lack of publicly available information.[9] However, while the prices of these five staples had begun rising in the days preceding the invasion, neither the January nor February reports mentioned impending war as a potential threat to global food supplies. This indicates that other information including privately collected intelligence, matter for the pricing of commodities.

2.3 The caloric approach

The very high levels of correlation among the prices of these four crops show that they are close substitutes for both production and consumption. The markets for these staple foods are also subject to frequent policy

[8]According to United States Department of Agriculture (USDA) figures, since 2016 only 9% of the rice produced globally crosses borders, compared to 15% of corn, 25% of wheat and almost 45% of soybeans.

[9]The wave of export bans imposed on wheat in the days following the outbreak of the war may have fueled the huge surge in wheat prices recorded at that time.

interventions especially in developing countries (Gouel, 2014), and this is likely to affect the relationship between global and domestic prices. For these reasons and to ignore other issues related to product heterogeneity and spatial variation, it is helpful to study world agricultural markets "in aggregate". One option is to follow Roberts and Schlenker (2009, 2013) and make an aggregation based on the caloric content. Using the same methodology including the modification proposed by Hendricks et al. (2015), Gouel and Legrand (2022) updated the dataset used by Roberts and Schlenker (2013) to cover the period 1961-2017. This means that the prices of these four commodities are expressed in dollars per calorie using the conversion ratios in Williamson and Williamson (1942), and then are aggregated into a single caloric index, weighted by the respective share of each crop in global calorie production.[10] However, unlike the above analyses which use FAOSTAT data, the empirical analysis in this paper uses USDA Production, Supply and Distribution (PSD) data (USDA, 2020). In terms of the price series considered, I follow Gouel and Legrand (2022) who use the December 2022 futures contracts for corn and wheat, and the November 2022 futures prices for rice and soybeans.[11]

Table 1 presents the correlations among daily prices and the correlations with the aggregate "grains" index . The table shows that crop prices are strongly correlated, and all show a correlation with the grains

Table 1: Correlation coefficients of daily prices based on December and November 2022 Futures contracts

Commodity	Grains	Maize	Rice	Soybeans
Grains				
Maize	0.99			
Rice	0.98	0.97		
Soybeans	0.91	0.90	0.91	
Wheat	0.98	0.97	0.96	0.85

Notes: The correlation are computed over the lifetime of the contracts namely from September 14, 2021 to May 27, 2022.

index that is greater than 0.9. These high correlation levels confirm that these food commodities are highly substitutable. Note also that each of the individual prices is correlated more strongly to the grain index than to the price of any other crop. This supports the decision to study the state of the global food market based on an aggregate caloric index for these four crops.

[10]See Gouel and Legrand (2022) for a detailed description of the methodology employed.

[11]These data are those used to estimate the demand elasticities I will use thereafter.

3 The rationale for the commodity price behavior

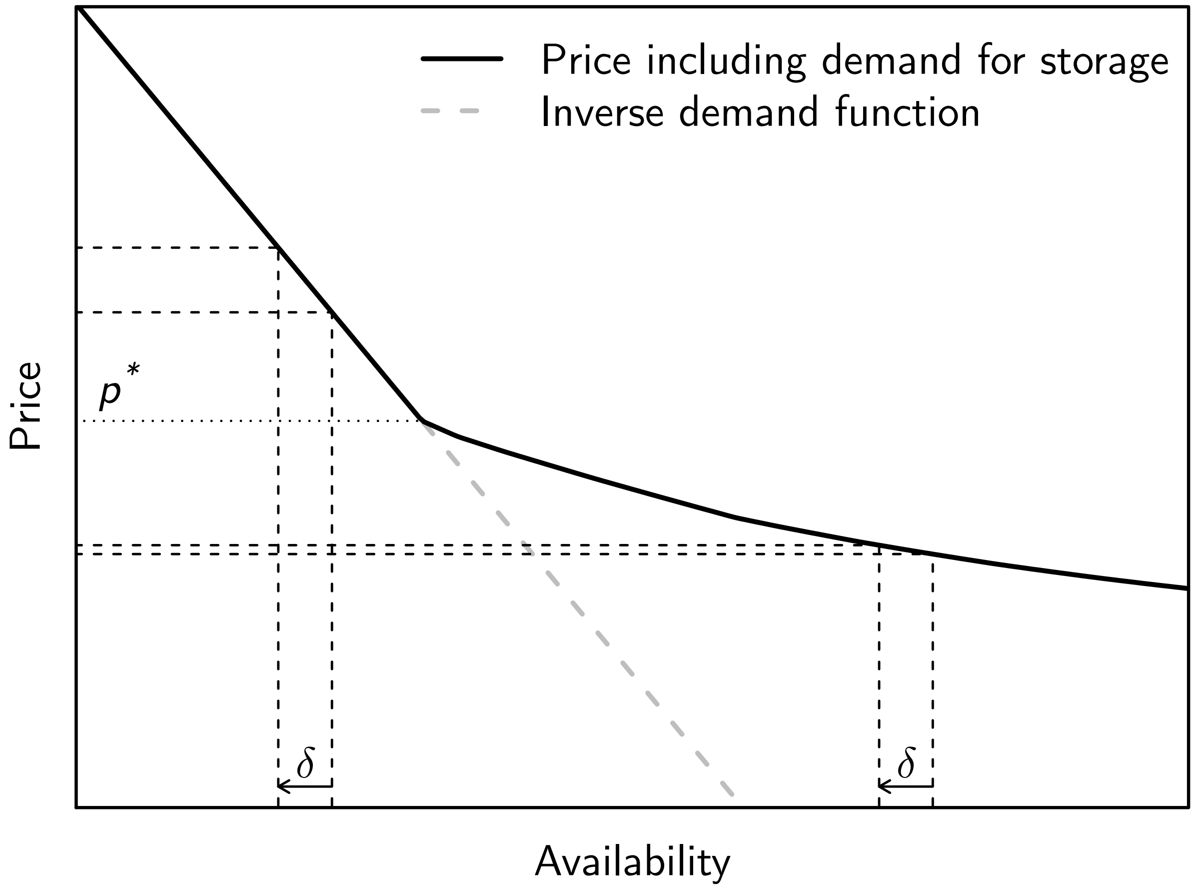
3.1 The storage mechanism

To guide policy and economic decisions in the present volatile environment with its chaotic fluctuations requires a consistent analytical framework for the analyzes of the commodity price behavior. In the context of commodities, it is recognized that intertemporal transfer of inventories is a crucial mechanism in the formation of commodity price fluctuations. The model employed is the competitive storage model with rational expectations which builds on well-established theory related to commodity markets. More precisely, in between producers and final consumers, there are forward-looking speculators who maximize their profit by storing a commodity at a cost. Their arbitrage decision is dictated by the difference between the expected and the current price. It is important to note also that because storage cannot be negative–i.e. commodities cannot be consumed before being produced–there is a non-negativity constraint on storage. This zero lower bound on storage introduces an essential nonlinearity which then translates into nonlinearity of the predicted commodity price series. Intuitively, when stocks exist prices tend to be low and stable. Without inventories that can be carried forward, prices are higher and more volatile. In addition, demand for storage sets a price floor which prevents a price collapse but if stocks are empty prices can peak.[12] Finally, by buying low and selling high, speculators are linking current and expected prices which automatically induces price persistence. Figure 4 is a graphical representation of market demand which provides an intuitive explanation for the smoothing effect of storage.

In this model, market demand consists of demand for immediate consumption, and speculative demand for storage from speculators who can buy and store the commodity at a cost in the expectation of making a profit by selling the product later. By making total market demand more elastic, this forward-looking demand for storage is crucial to explain overall commodity price behavior. Specifically, to the right of the kink in the curve, supply is relatively abundant so there are inventories which can be released to buffer against the impact on prices of a given production shortfall, denoted "δ" on the graph. In contrast, when prices are high and stocks are empty, market demand equals consumption demand, which is very inelastic for staple products. It seems that a much bigger change in the price is required for consumption to absorb the full impact of a

[12] This is at the heart of the observed asymmetric distribution of prices (i.e. positive skewness) and fat right tails (i.e. excess kurtosis).

Figure 4: Relationship between market price and availability



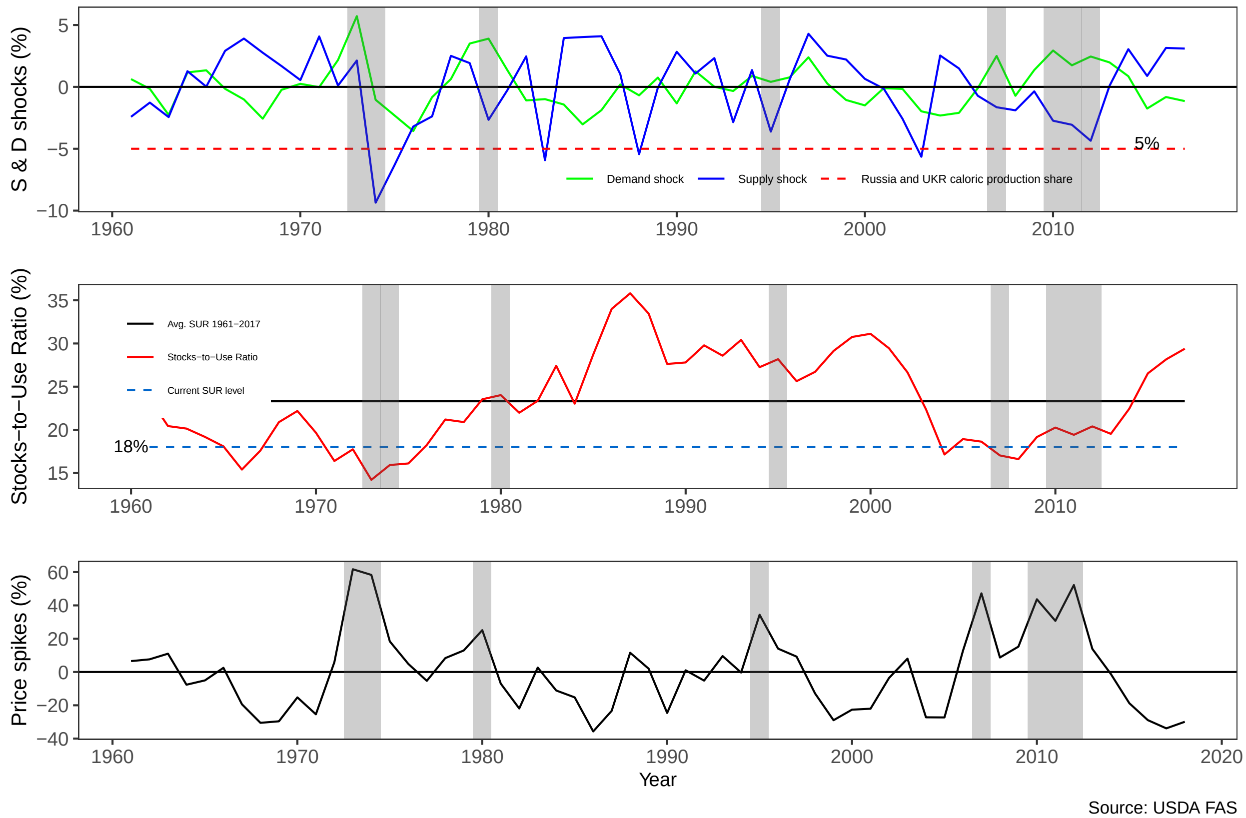
similar sized supply shock "δ". Indeed, only such high prices will induce people to shift resources from the consumption of other basic good such as gasoline or health care to satisfy the most vital need for food. This hits the poorest first and hardest and sometimes induces a lowering of their daily calorie intake.

3.2 Current market tightness

Figure 5 empirically illustrates the mechanisms through which shifts in the market fundamentals induce prices to fluctuate.

The top panel depicts the supply and demand shocks measured as the log deviations from the quantity trends. The same trend modeling is used to compute the cyclical fluctuation of prices plotted in the bottom panel. Shaded areas denote price spike events defined as log deviations from the trend which are larger

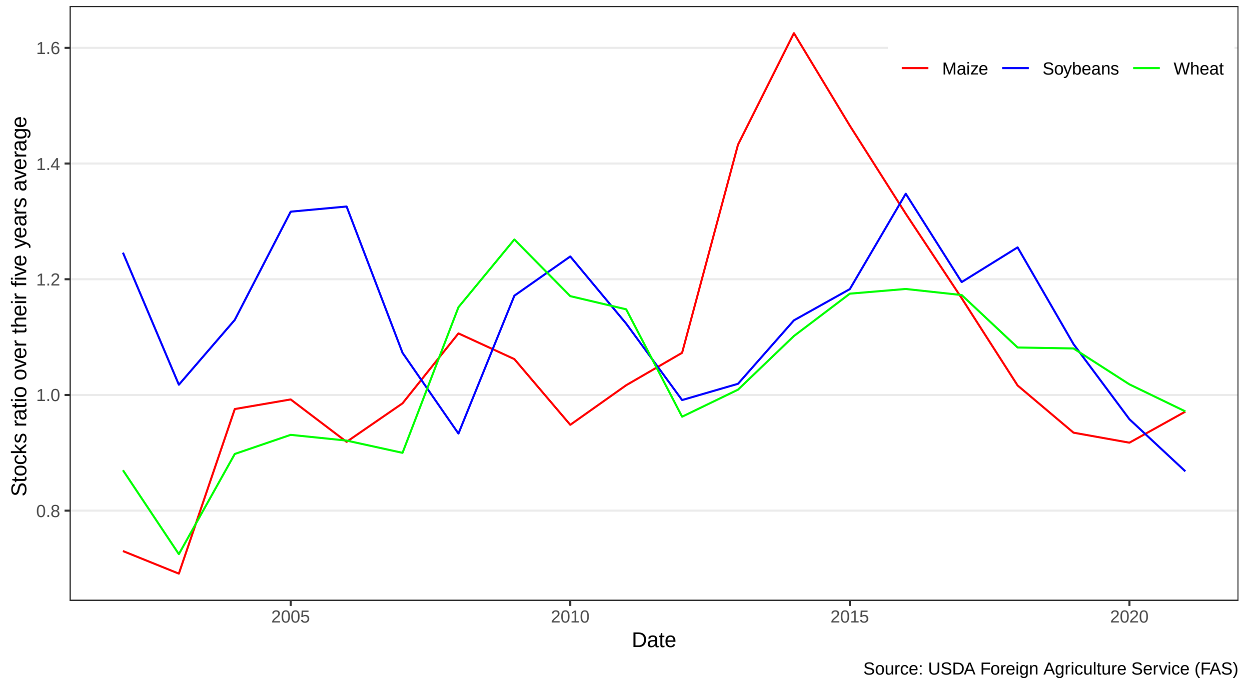
Figure 5: Historical shocks, inventory levels and price reactions



than one standard deviation (i.e. 24%). The middle panel shows the levels of the world stock-to-use ratio which is a proxy often used to assess the degree of availability tightness in the market. This decomposition helps to explain the market movements through a storage model lens: supply disturbances are larger than demand disturbances. However, all price spikes are associated with large demand shocks. In addition, with the exception of the 1995/1996 price peak, all the spikes occur when the stock-to-use ratio falls below about 20%. Moreover, there are seven years when total supply shocks are at least one standard deviation below the mean (i.e. 3.3%) but only 1974 and 2012 correspond to price spikes. In the other five years, prices remain close to their trends. This further demonstrates the importance of storage to buffer against supply shortfalls. Without inventories, a -2.5% supply shock would lead to a 28% price increase because the inelastic demand for consumption would have to match the corresponding shift in supply. Finally, the dotted horizontal line in the middle panel indicates that at 18% the current stock-to-use ratio is close to its 2008 level and to levels where historically spikes have been observed.

As figure 6 shows, this is further confirmed by another common metric used by analysts and traders in commodity markets which is the inventory levels divided by the five-year average.

Figure 6: Tighter global inventories



It is clear that for the three major crops considered, inventory levels are below their five-year average and are at or even below levels recorded during the 2007/2008 and 2011/2012 food price crises. The main takeaway from figures 4, 5 and 6 is that a good understanding of commodity price movements relies on close monitoring of the supply and demand market fundamentals including speculative demand for inventories. Specifically, given the ongoing tightness in availability of global supplies, it can be assumed that total availability at the start of 2022 was below the level at which the price kink in figure 4 occurs. This is the critical level below which the market becomes particularly sensitive to any supply or demand disturbances.

3.3 A supply shock assessment

3.3.1 In aggregate

As already explained, the formation and dynamics of global commodity prices are described well by the basic storage model which features a competitive price clearing a market comprised of final consumers and risk-neutral speculators who hold inventories in anticipation of achieving a profit over the incurred storage cost. Using the storage model as a consistent empirical tool, it is possible to assess how much grain the market collectively believes will be lost in 2022. Put another way, how much of a reduction in available quantities has the market priced in? The sensitivity of prices to variations in quantities can be estimated statistically and is represented by the slope of the inverse demand curve in figure 4. That is we can assess the global supply reduction "δ" (figure 4) currently priced in the market based on the observed price variations before and after the Russian invasion. Figure 7 shows that between February 18 and March 11, the price of calories rose by 12%, and then climbed to 19% on April 22 and 23% on May 24–respectively two and three months after the beginning of the war.

Figure 7: Daily caloric price index based on November or December 2022 Futures contracts

Using the elasticity value of -0.089 estimated by Gouel and Legrand (2022, table A10) using USDA FAS data, price variations of these magnitudes correspond to a reduction of 1.07% gradually increasing to 1.7% and then 2.1% three months after the war. To put these figures in perspective, over the past five years Ukraine produced 2.3% of world calories on average. This implies that three months after Russia invaded Ukraine, market participants were recognizing that in 2022 the world would have to cope with the loss of Ukraine's entire production of maize, wheat and soybeans. This is evidence also of the gradual response of agricultural markets to the unfolding crisis, and the price discovery process happening virtually in real-time to incorporate new information about prevailing global supply and demand conditions.

3.3.2 Commodity by commodity

Working with a combined caloric index might mask disparities across the different crops included in the aggregate index. This suggests the need to disaggregate this spike in the price of calories to try to assess how much of a reduction in each product is actually incorporated in their individual prices. Is the market sending the right price signals? For a while, the market can err on the upside or the downside but ultimately, prices will revert to the fundamentals dictated by the physical quantities available. The econometric strategy suggested in Gouel and Legrand (2022) allows estimation of significant elasticity for each of the staples individually.[13] Table 2 summarizes the results.

As expected, the biggest reduction in available calories is from wheat with a loss of nearly 5.7% three months after the start of the conflict. This equals about 80% of the combined shares of Russian and Ukrainian global calories of wheat traded. The results are similar for soybeans with anticipated shortfalls of 0.6% but less so for corn with a shortage of 2.8% i.e. only 40% of the combined shares of Russia and Ukraine in the corn calories traded internationally.[14]

In sum, the staggered price jumps following Russia's invasion of Ukraine reflect a world food market behaving as if agricultural production from that region is simply too uncertain to be relied upon at this stage. However, the fact that the higher prices correspond almost exactly to the loss of the Ukrainian production

[13]See Gouel and Legrand (2022, table A13).

[14]These are ballpark estimates in the sense that other relevant choices regarding futures contracts or the specific dates used to compute the price variations might produce different results. It is possible also that individual elasticity values might be overestimated given the risk of mixing own-price and cross-price elasticities when running estimations on the separate crops. Hence, the estimated crop-by-crop losses are less reliable than the reductions obtained "in aggregate".

Table 2: Supply reductions reflected in prices

Crop	Date	α_D	Price Variation (%)	δ (%)
Grains	03-11	-0.09	11.89	-1.06
	04-22		18.76	-1.68
	05-24		23.32	-2.09
Maize	03-11	-0.13	9.62	-1.26
	04-22		21.20	-2.77
	05-24		21.33	-2.79
Soybeans	03-11	-0.17	1.86	-0.31
	04-22		2.84	-0.48
	05-24		3.67	-0.62
Wheat	03-11	-0.13	25.69	-3.24
	04-22		32.60	-4.11
	05-24		45.03	-5.67

Notes: The price variations are computed based on the closing price on Friday, February 18, 2022 (i.e. the week before the Russian invasion). α_D are the values of demand elasticity obtained by Gouel and Legrand (2022).

does not mean no Ukrainian crops entering the market. Commodities by definition are quite homogeneous, and so some of the anticipated supply reductions might come from other disturbances such as bad weather, lower yields globally and export restrictions. On the other hand, these other negative supply shocks can partly be balanced by the reachable share of Ukrainian grains. It is the case that despite the war and the blockading of Black Sea ports, some Ukrainian farmers have been able to plant, harvest and even sell at least part of their crop although train transport imposes limits on capacity, and is costlier and cumbersome. It is estimated that some 20 to 25 million metric tons of corn and wheat are currently trapped in Ukraine, i.e. approximately half of average Ukrainian exports of corn, soybeans and wheat combined. In addition, Russian agricultural exports have not been targeted by international sanctions so can still be brought to the market.

Therefore, how much grain from that particular Black Sea region will reach the market is subject to constant reassessment. However, what ultimately matters is that producers and consumers receive the right price signals i.e. dictated by the true market fundamentals. It would seem that the world will have to endure a period of scarce supply curtailed even more by the conflict, and that the size of this additional loss roughly matches predicted Ukrainian production for the 2021/2022 marketing year. This raises the question which I address below of how long the market believes this negative shock on food supplies will last.

3.4 Term structure analysis

In view of the structural role of the expectations of commodity market participants in shaping both current and future price paths through the channel of inventories, we can obtain insights into how long the market expects the negative supply shock to persist. This can be achieved by analyzing the term structure of futures prices based on the curve formed by the prices of futures contracts on a given date over different expiry months. In a "contango" market, supplies are relatively abundant and the futures curve slopes upward which provides an incentive to carry inventories forward following the classic speculation strategy of buying low and selling high. In the case where supplies are running short the futures curve moves in "backwardation", i.e. price of nearby futures contracts trade at a premium above those with later maturities, leading speculators to clear their inventories and ease the current shortage.

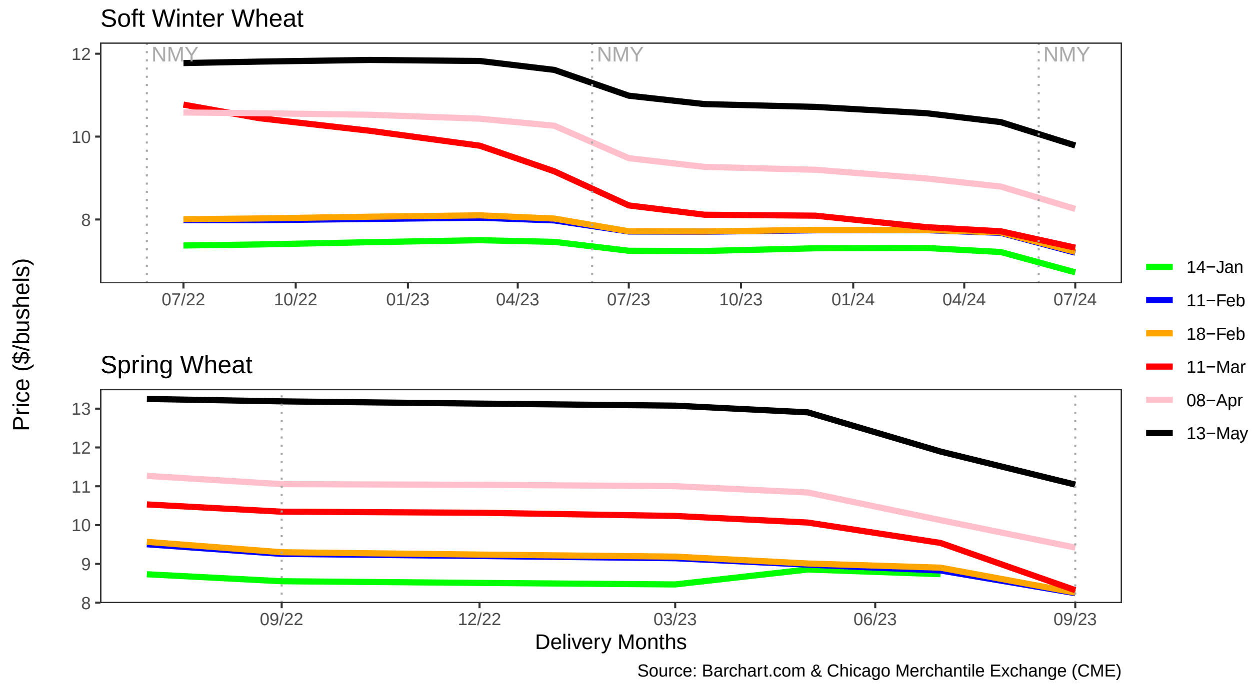
Figure 8 depicts the futures curves for all the traded contracts for soft winter wheat (SRW) up to July 2024 and spring wheat (HRS) up to September 2023 at six different dates during the crisis: January 14, February 11, February 18, March 11, April 8 and May 13.[15]

In January 2022, the fact that most curves are either flat or downward sloping indicates that wheat markets were already tight before the war. Only spring wheat prices for delivery after March 2023 were in a slight contango. This is in line not only with the observed low inventory levels (figure 6) but also to growing fears about the consequences of the tensions between Russia and Ukraine on future winter wheat supplies.[16] From mid-January to a week before the war (i.e. February 18), the whole winter curve shifts upward reflecting market expectations of a coming shortage as conflict loomed. Two weeks after the invasion (i.e. on March 11), in contrast to the prices of contracts with an expiry date after July 2023 the prices of nearby winter wheat futures contracts jumped. The result is a forward curve moving in a steep backwardation. However, a month later, the forward curve flattens with a marked increase in prices at the back end of the curve and stable prices at the front end of the curve. This might suggest a recognition among traders that part of the Black Sea wheat was still accessible but that lingering conflict would weight heavily on future crops from Ukraine and risk affecting world wheat production beyond 2023. On May 13 the shape of the curve had hardly changed but

[15] In a calendar year there are 5 futures contracts for both SRW and HRS wheat. With the exception of February 18, all the selected dates correspond to the Fridays immediately following WASDE report releases.

[16] Recall that the vast majority of the wheat produced by Russia and Ukraine is winter wheat that is planted in the fall and harvested starting in June. As a result, most of the global quantity of winter wheat available in 2022 was fixed when the war started. However, production of spring wheat, corn and soybeans could be increased by increasing the planted acreage.

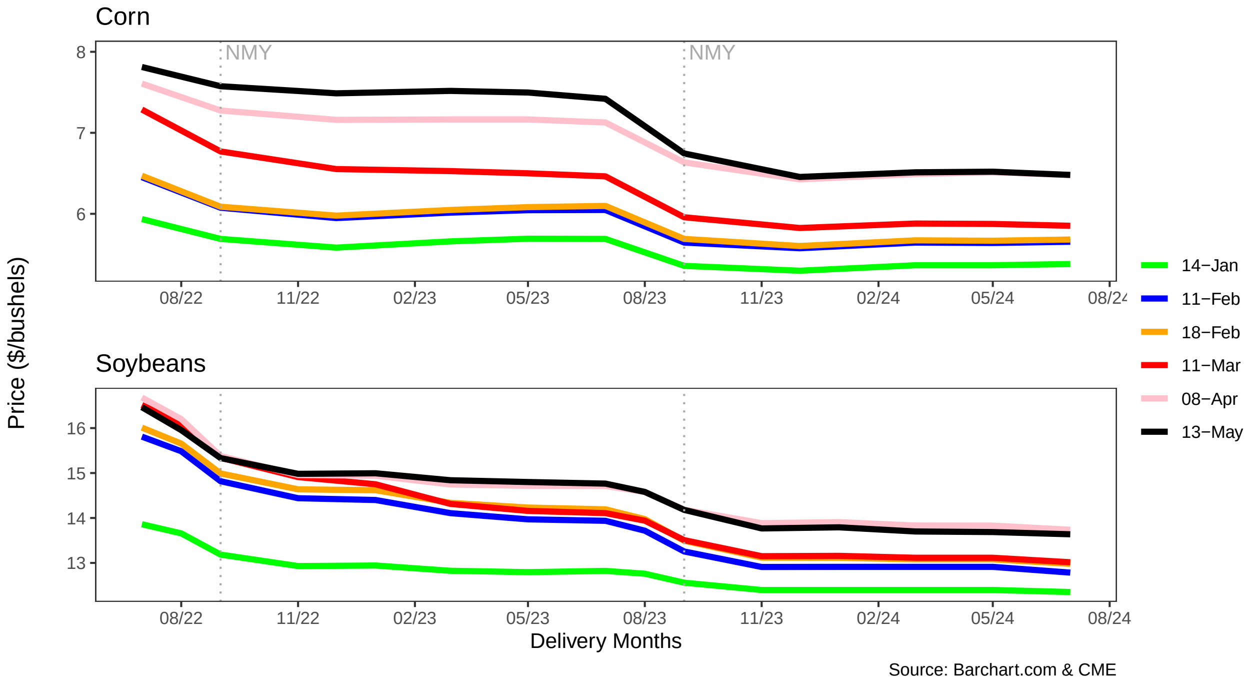
Figure 8: Forward curves for Wheat futures prices



had moved slightly upward, indicating that the supply shock on wheat supplies is likely to be long-lived (i.e. extending after July, 2024). The lower shares of Russia and Ukraine in the corn and soybean world markets means that the chronology of the movements in the term structure of futures prices for corn and soybeans is slightly different (see figure 9).

On January 14 the corn futures market was in a more normal state with upward sloping futures curves for most of the 2022/2023 and 2023/2024 marketing years. In other words, on that date the market operators believed that although scarce, the expected supplies of corn would be sufficient to make storage profitable at the start of each of these marketing years to alleviate the later relative scarcity in those years until the arrival of the next crop. This thinking seemed to hold up to February 18 differing only in the upward shift of the whole curve suggesting that the worsening situation in the Black Sea region would likely have a more direct effect on the wheat market and that the shock on food supplies would be short-lived. Following the Russian invasion, the forward curve for corn moved into backwardation though with a flatter slope than observed for winter wheat. This is further support for the idea that the biggest impact is expected to be on winter wheat. The moves of the forward curve over the succeeding two months are similar to those observed for

Figure 9: Forward curves for futures prices of Corn and Soybeans



winter wheat, with a flattening but upward shifting curve. Then, market participants again expect tighter corn supplies in 2022/2023 and even tighter in 2023/2024 as shown by the fact that from April 8 to May 13, only futures prices for contracts expiring in 2023 increase.

It is interesting that, before the Ukraine war the forward curve for soybeans seemed more sensitive to reported supply and demand conditions in South America where nearly half of world soybean production is located. For instance, the largest inversion in the slope from nearly flat to downward sloping occurred between mid-January and February 11, immediately following the release of a WASDE report which referred to lower global soybean production in 2021/2022 following droughts in the South American region. The very scarce inventories explain why from the start of 2022 the term structure of soybeans futures prices was flat. Initially, the war in Ukraine somewhat steepened the curve with modest price increases occurring only at the front-end of the curve. Note the gradation in the price responses of each crop, depending on the respective shares of Ukraine in their global production.

In summary, as the conflict drags on with no sign of a peace, it seems that the market is adjusting gradually to the new reality of a world which will have to do without Ukrainian food supply for the next two years at least, and for as long as the conflict lasts. In many ways, the conflict is weighing on future supply of Ukrainian crops, due to damage to crop fields and the communication infrastructure, grain stuck in Ukraine's ports and disruption to the planting season. This is a direct consequence of the seasonality in agricultural production where missing a key stage such as planting reduces the harvest a few months later. The confluence of these factors might explain why within a given marketing year forward curves are mostly flat, reducing slightly from one year to the next. This results in a scenario of higher prices for long periods and tight global supply and demand conditions with scarce inventories.

4 The supply and demand outlook

Having shown that the dynamics of global commodity prices is determined consistently by the market fundamentals of supply, demand and inventories, we need to look at supply and demand to get a better picture of expected short and medium run future food market developments. I explore each of these factors in turn. On the supply side, there are two major channels through which production is affected randomly: yield and the cost of inputs.

4.1 Limited supply

With current global food supplies relatively tight, and with loss of access to most Ukraine's crops, one of the main driver of agricultural prices in the months ahead will be the expected size of production from other major world exporting areas to make up the shortfall. In the case of agricultural products, a major source of yield variations is weather.

Yields prospects There are growing concerns about yield effects of climate change due to the multiplication of devastating droughts and floods in exporting countries such as those that contributed to the bad harvests and low inventory levels observed at the end of 2021. These extreme weather conditions are fueled by a worldwide weather-making phenomenon called "El Niño Southern Oscillation" (ENSO) (Handler and Handler, 1983; Iizumi et al., 2014; Hsiang and Meng, 2015; Ubilava, 2018), which global warming might make more frequent and extreme in the future (Timmermann et al., 1999).[17]. In the fall 2021, the National

[17]Depending on the tropical Pacific ocean surface temperatures and the winds, ENSO is classified as: La Niña (cool phase), Neutral or El Niño (warm phase).

Oceanic and Atmospheric Administration (NOAA) declared that a "moderate" La Niña episode had developed for the second year in a row.[18] Conditional on such a moderate La Niña event, should and how expectations of trend yield deviations be modified? To explore this question, I examine the history of yield deviations in years of La Niña events. According to the Oceanic Niño Index (ONI) used by the NOAA, 13 moderate or strong La Niña Episodes have been recorded between 1960 and 2021. Figure 10 shows the trend yield deviations and the corresponding average corn, soybean and wheat yields under moderate or strong la Niña conditions for each of the three major global exporters of these crops.

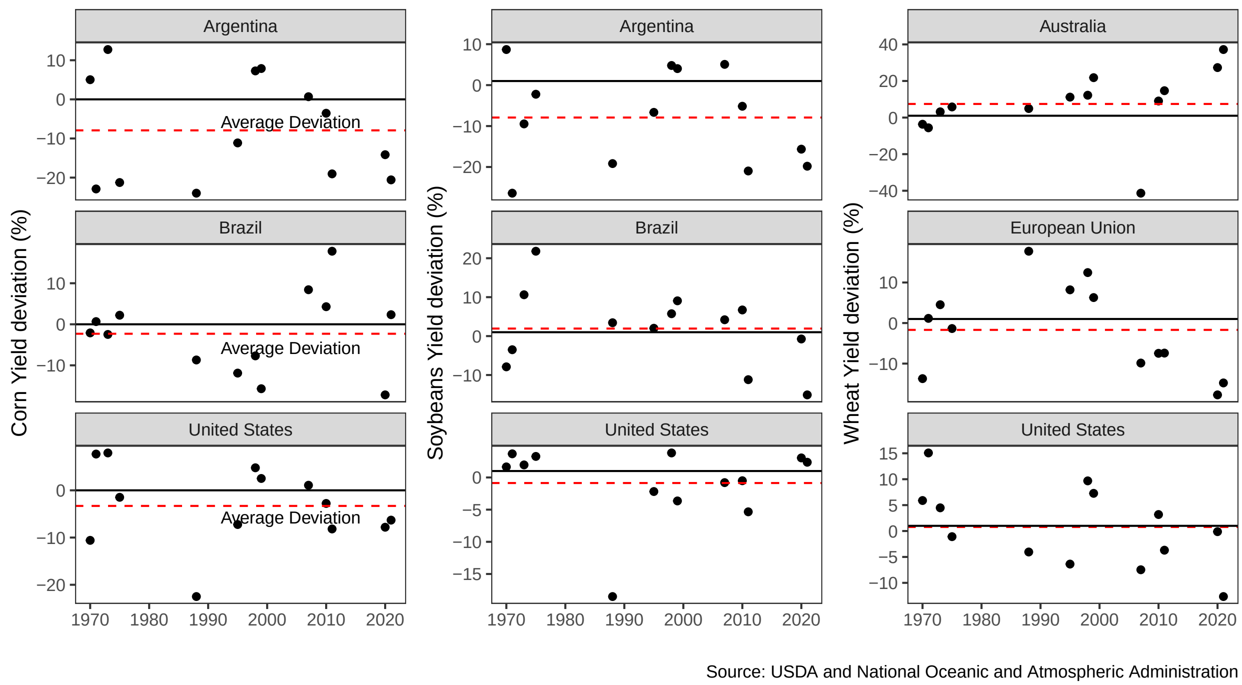


Figure 10: Historical Corn, Soybeans, Wheat yield deviations under moderate La Niña events (1960-2021)

Only the negative average values of yield deviations observed for corn and soybeans in Argentina are statistically significant. Although not significant, agricultural production by most of the major exporting countries in moderate to strong La Niña years are on average associated with below trend yields.[19] This is

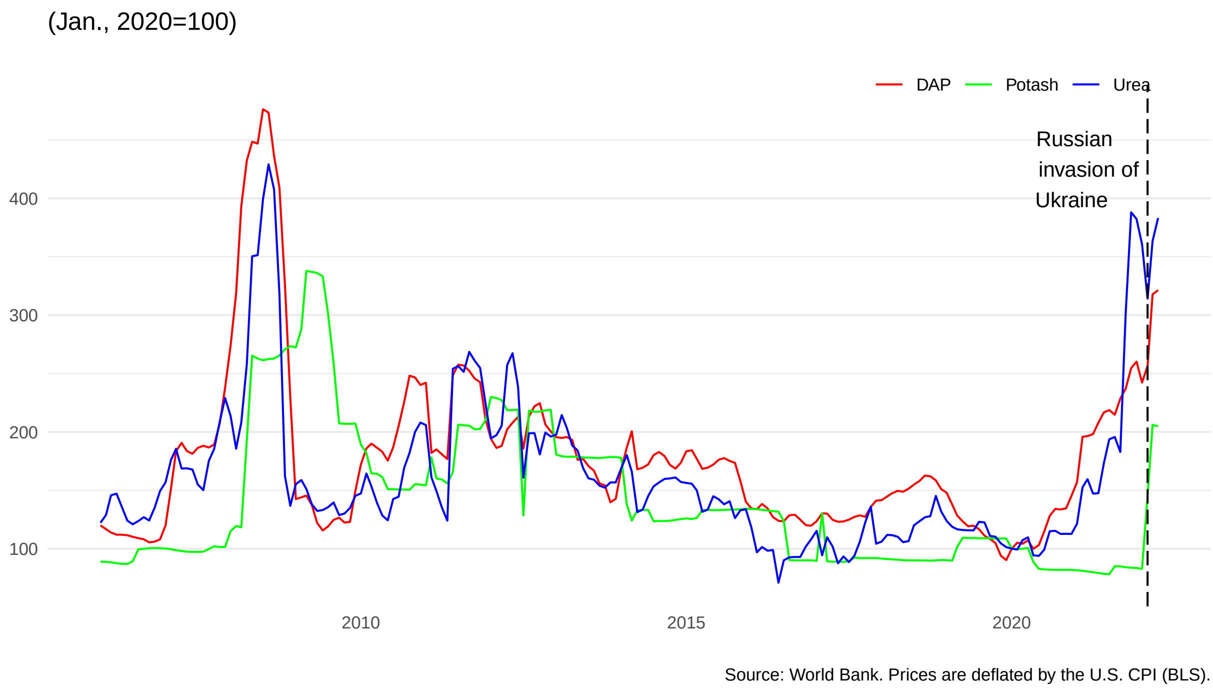
[18]Given that all ENSO episodes vary in intensity, each event can be further classified from weak to strong depending on the magnitude of the temperature anomalies as measured by the NOAA's Oceanic Niño Index (ONI). See https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php for monthly data published by the NOAA and https://ggweather.com/enso/oni.htm for the specific years selected in this study based on the classification provided by Jan Null.

[19]This result is in line with Iizumi et al. (2014) who find that *"the global mean yields of maize, rice, wheat and soybean during La Niña years tend to be below normal"*. The decrease in global yields is further exacerbated if farmers decide to extend planting to less fertile lands.

not to say that in "moderate" La Niña weather conditions exceptional crops are unattainable in these key producing areas, while further offsetting positive yield shocks might come also from other less important producing countries. However, historically La Niña years are more often associated with poor harvests in the main exporting countries, stresses on global supplies and inventory drawdowns.

Production costs In addition to weather-related shocks, production cost shocks are a source of supply disturbances. There are two channels through which higher input costs can weigh on supply: lower planted acreage and reduced yields. Figure 11 depicts the monthly price series for the three most widely used fertilizers providing the main nutrients for the crops: diammonium phosphate (DAP), muriate of potash (MOP) and urea (nitrogen).

Figure 11: Fertilizer prices



Since January 2020, the price of these nutrients has doubled or even trebled to reach levels close to the very high levels seen in 2008. Strong demand sustained in part by the higher agricultural prices has combined with supply chain bottlenecks, surging energy prices, export restrictions and international sanctions to explain the steep rise in fertilizer prices observed since the beginning of 2020. The war in Ukraine fueled a further 30% price rise.[20] The impact will be spread unevenly across countries and crops. In some of the richer countries where farmers often apply more fertilizer than is needed (Smith, 2022), the latest rise in fertilizer prices following the Russian invasion might encourage a rethinking of agricultural practices, from precision farming to experimentation with new management systems and crop rotation in order to reduce fertilizer use. This would produce both savings and environmental benefits in the short-run.[21] Additionally, profit-maximizing farmers might decide to cultivate crops such as soybean which require less fertilizer, thereby lowering the production of wheat and corn for example. This partly explains the forecast that U.S. farmers will grow around 4% more soybeans than in 2021 based on planted acreage projections published by the USDA.[22] However, in many developing countries where fertilizers make agricultural production viable, the rise in fertilizer prices is likely to affect both the acreage grown and the resulting yield leading to lower global food production.

4.2 Robust and inelastic demand

Since it seems that the potential for increasing global food supplies will be limited in the immediate future, bringing prices down and closer to their long-run trends could be achieved by lowering demand. This can be achieved either through a change along the demand curve, or through an inward shift of the curve akin to a negative demand shock (e.g. the great recession of 2008). Given the role of the U.S. as a major agricultural powerhouse, and for reasons related mostly to reliable and timely publication of data, the focus is on developments in the demand for U.S. food staples. These fall into three main categories: exports, biofuels production, food and animal feed.

Exports sales Since a substantial share of U.S. agricultural production is exported,[23] a crucial factor in the formation and dynamics of prices moving forward is foreign demand. Indeed, very high prices might cool demand in other more price-sensitive countries. The usual indicator for this is the weekly pace of U.S. export sales of corn, soybeans and wheat depicted in figure 12.

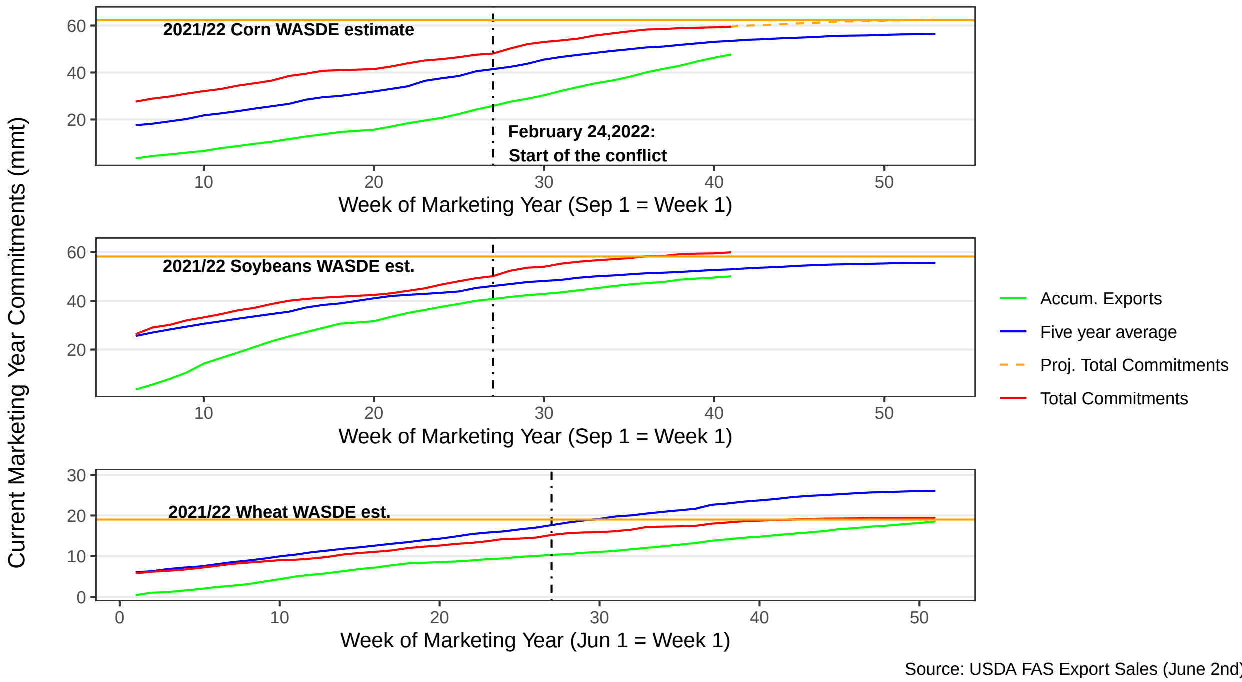
[20] According to FAOSTAT figures, in 2019 Russia accounted for 9% of the DAP, 15% of the urea and 25% of the MOP used throughout the world.

[21] In the longer run, persistently higher input prices may even spur technological innovations to achieve more sustainable and less input-intensive farming.

[22] Since soybeans are usually planted in rotation with corn, a similar reduction in corn acreage is expected.

[23] About 15% of corn, more than 40% of wheat and almost half of soybean production.

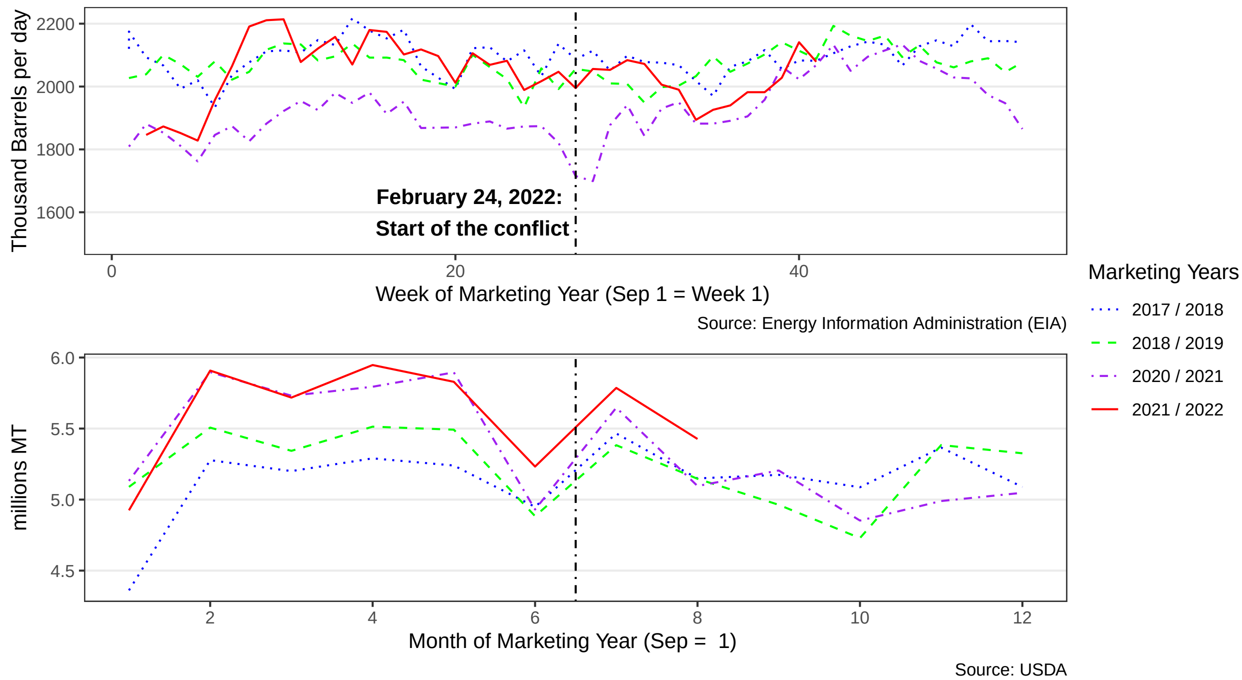
Figure 12: Weekly export sales of U.S. Corn, Soybean and Wheat



For each crop, the line labeled "total commitments" is the actual quantities shipped added to committed sales as recorded by the USDA Foreign Agricultural Service. The date of the Russian invasion is indicated by the vertical dashed line. Figure 12 shows that before and after the war the surge in prices seems not to have had an impact on U.S. shipments. Indeed, accumulated exports 100 days after the Russian invasion (i.e. week 41 of the marketing year for corn and soybeans and week 52 for wheat) were on track to meet or even exceed USDA WASDE projections for the current marketing year. For corn, the dashed extension of the line confirms that if the weekly pace of export sales to the end of the marketing year follows that observed over the past five years (the blue curve), then in line with WASDE estimates 62.25 million metric tons of U.S. corn will be shipped by the end of the ongoing marketing year. In the case of corn and soybean both pace and total export sale quantities were significantly higher than their five-year averages. Total wheat exports are below the levels observed in past years but this seems not to be related to the conflict in Ukraine and seems to be mainly the result of the long-term decline in U.S. wheat acreage combined with last year's drought-related declines in yields, and an overall lack of the U.S. competitiveness in wheat compared to corn and soybean (for a discussion see Schnitkey et al. (2022) and Langemeier and Zhou (2022).)

Biofuels production Another major use category for U.S. corn, and to a lower extent soybean, is production of biofuels (i.e. ethanol and biodiesel) which has been boosted mostly by European Union and U.S. mandates enacted in the early 2000's. The strength of demand for biofuels is frequently assessed based on weekly U.S. ethanol production and monthly U.S. soybeans crushed shown in figure 13.[24]

Figure 13: Weekly U.S. ethanol production and monthly U.S. Soybeans crushed



For comparison, in each panel the solid line represents production and crushing figures for the current 2021/2022 marketing year with the previous five marketing years (excluding the very unusual 2019/2020 marketing year which was affected by coronavirus-related restrictions) represented by the dotted and dashed lines. The graph in figure 13 shows that the war-induced oil shock has not dented oil consumption; ethanol production is at a level that compares with levels in recent years. For example, the rebound in demand for gasoline and ethanol in week 40 of the marketing year which is associated with the start of the driving season is the strongest in the five years.

[24] Production of soybeans that is not exported is mainly crushed to produce soybean meal (about 80%) used mostly around the world for animal feed, and to produce soybean oil, of which according to the Energy Information Administration about 30% goes to production of biodiesel.

Food, feed and industrial use The last main use category is food and animal feed. Around two-thirds of U.S. wheat per year is consumed domestically in the form of cereals and bakery products, and this share has remained quite stable across time. The demand for livestock feed is usually more elastic–if households start to eat less meat for example. However, such cut backs do not seem likely to happen soon if the pace of soybeans crushing (bottom panel of figure 13) is maintained in 2023 as WASDE projections predict.

Overall, at this stage all three types of demand for U.S. staple food products are steady. Caloric demand for food, feed and transport fuel is too inelastic in the short-run, and especially in developed countries such the U.S. There are also no signs so far of a "demand destruction". Indeed, the latest WASDE projections show that total export and domestic demand for U.S. grains and soybeans is expected to remain at or close to their already stronger 2021/2022 levels through 2023. In other words, the ongoing food and energy supply shocks are not expected to persist for long enough to force economic agents to change their production processes and consumption habits. Therefore, the anticipated robust demand for U.S. food staples will underpin prices in the short to medium run. This is consistent with the relatively flat shape of the term structure of futures prices described in the figures 8 and 9 above.

5 Conclusions

The war in Ukraine is a major shock to the global supply of grains at a time when global inventories are running at historical lows. Together, Russia and Ukraine account for almost 15% and 5% of the global production of wheat and corn respectively which is about 5% of the world calorie supply. What is worse, these countries account for a much larger share of traded calories, with nearly 12% of food calories consumed worldwide exported from this Black Sea region. Put differently, the war in Ukraine is a major shock that has occurred at the wrong time and in the wrong place.

In this paper, I have shown that a basic storage model with rational expectations framework can consistently rationalize commodity prices behavior. This is the structure commonly used to organize economic thinking and policy discussions about commodity price volatility. I used this model as a normative device, and revisited the negative supply shock triggered by Russia's invasion of Ukraine. Specifically, I show that the price movements reflect a shortfall in the size of the global share of caloric production from Ukraine, both in aggregate and commodity-by-commodity. This suggests that the market is in a "wait-and-see" mode, and is responding gradually to updated information about current and future fundamentals of world supply and demand, leaving room for sudden upward or downward movements depending on how the situation in Ukraine evolves. In that sense, the longer the conflict goes on, the worse will be the supply situation.[25]

Indeed, the war-related supply disruption is putting pressure on both current and future global food supplies, with yields at risk of suffering from elevated input costs. It will require a series of bumper harvests to replenish global stocks to levels sufficient to buffer future supply shortfalls. On the other side of the market balance, the main demand factors show no signs of easing–at least in the short run–which is why the world needs to prepare for a period of high and volatile food prices.

While policy prescriptions are beyond the scope of this article, lessons from past commodity-price crises teach that a prompt and coordinated world level policy response is needed to alleviate the pain inflicted on the most vulnerable populations, and avoid the understandable but counter-productive cascades of export restrictions that can make things worse even for the sanctioner country (Porteous, 2017). There is no spare production capacity and every ton of grains and soybean that is harvested needs to reach the market to ease the pending global food shortage. We need guaranteed timely and reliable information on the physical quantities available in order to reduce the uncertainty and economic burden of such a volatile environment (Bloom, 2009). In 2008, a deep global economic recession was required to stop the unfolding rallies in commodity prices–one can hope that this time things will be different.

[25] In contrast to crises such as the Covid-19 pandemic, wars i.e. the current conflict in Ukraine leave lasting political, social and economic scars whose effects are felt beyond the damage incurred to infrastructure and production capacities in the battered areas (Korovkin and Makarin, forthcoming).

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