Energy&Climate
INTELLIGENCE UNIT

CLIMATE, FOSSIL FUELS AND UK FOOD PRICES

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About

The Energy & Climate Intelligence Unit (ECIU) is a non-profit organisation supporting informed debate on energy and climate change issues in the UK. Britain faces important choices on energy and on responding to climate change, and we believe it is vital that debates on these issues are underpinned by evidence and set in their proper context.

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Executive summary

The global food sector has been hit by a 'perfect storm'. Following in the wake of the Covid pandemic, agricultural and food supplies have been hit by extreme temperatures, drought and flooding and faced the consequences of the Russian invasion of Ukraine.

The latter has increased energy prices globally; not just oil but also the prices of natural gas and fertiliser. These rising energy costs not only affect the costs at the farm-gate but also throughout the rest of the food supply chain.

The combination has resulted in prices (both nominal and real) of food and agricultural commodities on world markets reaching levels not experienced since the major oil and commodity crisis of 1972-74.

The UK imports around 40% of its food and agricultural needs from world markets and is therefore particularly prone to these global events. Although much media attention has been paid recently to rising fuel bills for households, food inflation is also a major concern. As of July 2022, food inflation was recorded at 12.7% and is second only to fuel bills in the rising cost of living faced currently by UK households.

There are many factors that can determine food prices for consumers including exchange rates, labour costs and sector specific supply shocks.

In this report, we focus on the role played potentially by climate change, as reflected in global temperatures and the increasing cost of fossil fuels.

The interaction between these effects is complex: climate change affects both the price of non-oil (agricultural) and oil prices on world markets via its effects on production and economic activity; fossil fuel prices have an impact in multiple ways (through the cost of fertiliser, storage, refrigeration and transportation) throughout food supply chains.

We show that in 2022, climate change and fossil fuel prices could cause food inflation to be around 11%. This translates into an increase in average household monthly spending of £33.90, £14.23 of which is estimated to be due to the effects of climate change and £19.66 due to energy prices, suggesting that the majority of the current increase in food inflation arises from fossil fuel price shocks on world markets. In context, these factors could increase household shopping bills in 2022 by more than £400 per year and the total annual UK food shopping bill by around £11.4 billion.

Looking beyond the current crisis experienced on world markets, both fossil fuels and climate change will continue to be important for UK food prices.

This report highlights these two factors as key drivers of food prices. In compiling this report, we draw on recent scientific and economic research to provide insights into their potential importance.

Of course, we recognise that other factors that we have not explicitly accounted for directly in these estimates, including responses of stakeholders in the food chain, may reinforce or offset these effects. Nevertheless, and bearing this caveat in mind, our findings suggest strongly that climate and fossil fuels are currently dominant factors in determining the costs of food for UK households.

Introduction

Against the backdrop of rising prices for agricultural commodities and fossil fuels on world markets, prices that UK consumers pay for food and energy have increased significantly since the middle of 2021.

This has been reflected in a cost-of-living crisis with demands for government action. The historically high rates of domestic inflation have brought increased attention to the impact that global events can have on UK households.

The high prices on world commodity markets reflects a multitude of factors (most immediately, the Russian invasion of Ukraine) but the extreme temperatures, drought and flooding experienced by many countries in recent months has highlighted the impact of extreme weather conditions on food prices.

When the current price spikes on world markets subside, the interaction between climate, fossil fuels and food prices will be an on-going concern for many governments. Climate change will be reflected in more frequent and more severe extreme weather; policies targeted towards reducing reliance on fossil fuels will be on the agenda of many governments, including the UK, with commitments towards Net zero by 2050. Agriculture - as a major source of greenhouse gas emissions globally - will have to prioritise adaptation and mitigation as part of the package of fulfilling climate conditions and against a background of increasing demands on agriculture to feed a rising global population. The role of OPEC+ too in controlling the supply of oil in the face of rising oil and gas prices will also be a significant factor in global markets. All of this will have implications for food prices in the UK and the cost of shopping baskets that households pay for food.

The links between climate, fossil fuels and food prices are complex: fossil fuel prices do not only affect the cost of agricultural output but also activities throughout the food chain such as processing and distribution; climate change and extreme weather not only have a direct impact on world agricultural markets, but also indirectly via their effect on oil markets; the extent of these changes on world markets and at the farm-gate on consumers will depend on the extent to which these prices are 'passed through' to supermarket prices i.e. the extent to which changes in prices of commodities traded on world and domestic markets are reflected in changes in prices of food on supermarket shelves. In some cases, farmers and firms in the food chain may absorb a significant proportion of these costs.

The overall aim of this report is to provide insights into the links between climate change, fossil fuels and the price of food for UK consumers. There are four main aspects:

1. We draw on recent research on the links between climate change and world commodity prices;
2. We highlight the ways in which fossil fuels affect world agricultural commodity markets and activities in the food chain;
3. We refer to recent research on how these changes in the food and agricultural sectors are 'passed through' to consumers;
4. Using recent research on the drivers of UK food prices, we calculate the potential extent to which UK food prices are influenced by climate change and fossil fuel price shocks.

Although focusing on the UK, the principles outlined here should be applicable to other contexts. We outline the main mechanisms via which climate, fossil fuels and food prices are linked. Our calculations are, by nature, subject to uncertainty and can vary across contexts but they show that climate and fossil fuel issues are important drivers of what UK consumers will pay for their shopping basket.

We start with summarising the current experience with UK inflation and developments on world markets.

Current context

Food and Energy Inflation in the UK

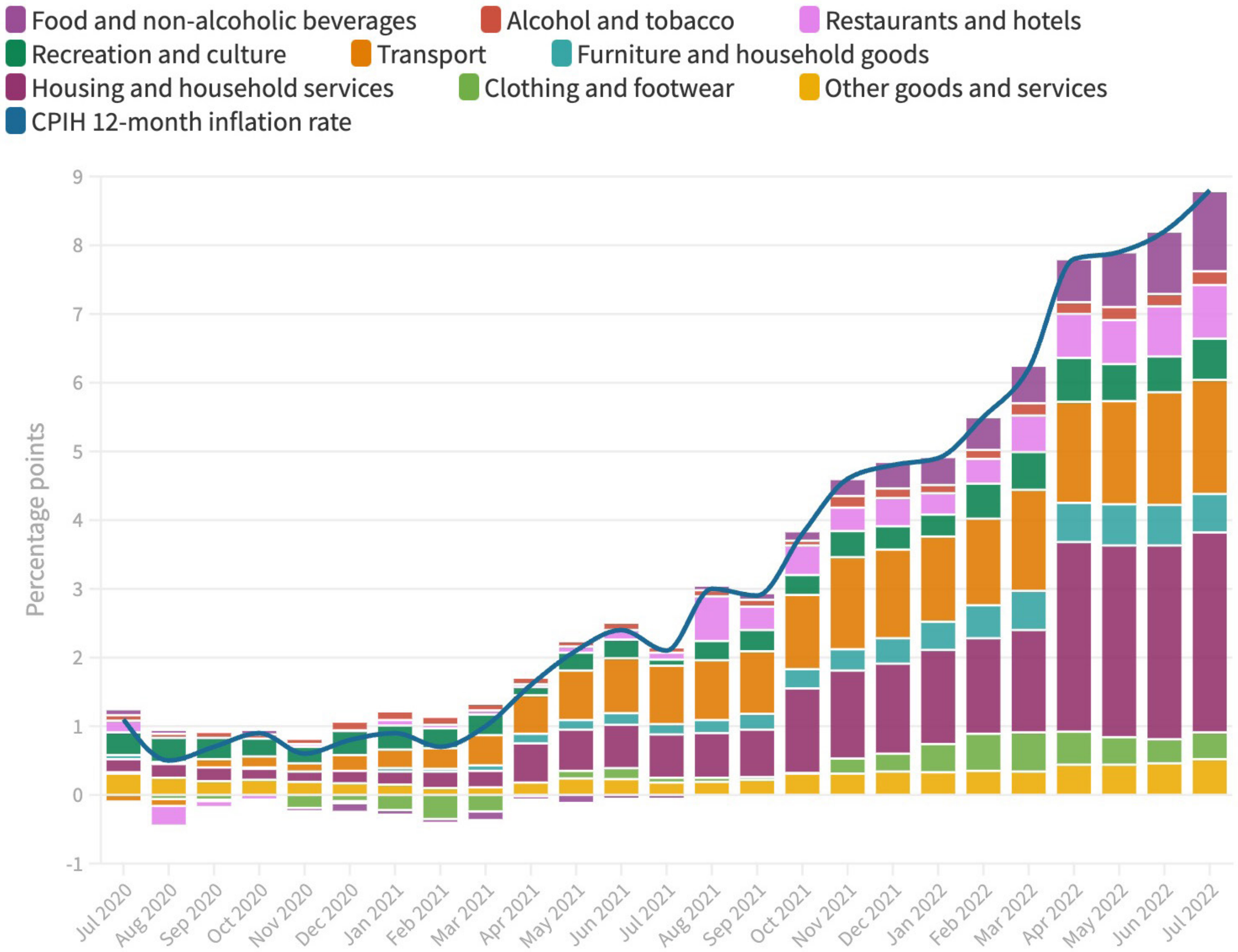
Global commodity markets and national food chains have been hit by a 'perfect storm' over the last two years.

A range of factors have been responsible for the current turmoil (recovery from the coronavirus pandemic; labour shortages; the Russian invasion of Ukraine; extreme weather in specific localities) all of which have been reflected in rising domestic inflation across many countries in both food and energy markets.

As an open economy where energy prices are determined by world market factors and with the UK importing more than 40% of its food and agricultural commodity requirements, it is of no surprise that much attention is currently being paid to the rising cost of living of UK households and the role that international factors play in it.

Figure 1 highlights the significance of energy and food for recent inflation in the UK. The figure shows the contribution of each of the 12 categories in the CPI to headline inflation over the last two years (2020 and 2021). While growth is noticeable in all categories of the consumer spending, it is particularly marked in the three categories 'food and non-alcoholic beverages', 'housing and household services' (primarily, electricity and gas) and 'transport' (primarily fuel prices), which combined account for around two-thirds of the headline inflation in July 2020.

Figure 1: Contribution to the Headline Rate of inflation (July 2020 to July 2022)



Source: Office for National Statistics (2022)

The data in Figure 1 suggests that the rise in food inflation is a separate issue from the rise in energy prices. However, there are potentially significant linkages between the two, most obviously on food prices due to the reliance of the global food and agricultural sectors on energy and fossil fuels more generally. The linkages are complex and involve direct and indirect linkages between climate, world agricultural and fossil fuel prices and the energy intensity of modern food supply chains. All these factors combine to be important drivers of the cost of shopping baskets for UK consumers.

In this report, we address the economic issues that underpin these linkages. The issues not only matter for addressing the current context of high inflation in the UK; they also matter for understanding future pressures on food prices in the UK. With government targets aimed at Net zero by 2050, increased pressure will be placed on limiting the use of fossil fuels. With agriculture being a major source of greenhouse gas emissions, there will be particular focus on adaptation and mitigation by UK agriculture. And, with global temperatures rising, extreme weather (high temperatures, drought and flooding) both nationally and globally will be an increasingly important driver of changes in world agricultural and domestic food prices. As noted in the recent National Food Strategy (2021) report:

> "The next big shock to our food supply will almost certainly be caused by climate change in the form of extreme weather events and catastrophic harvest failures".
>
> National Food Strategy Part 2 p. 10

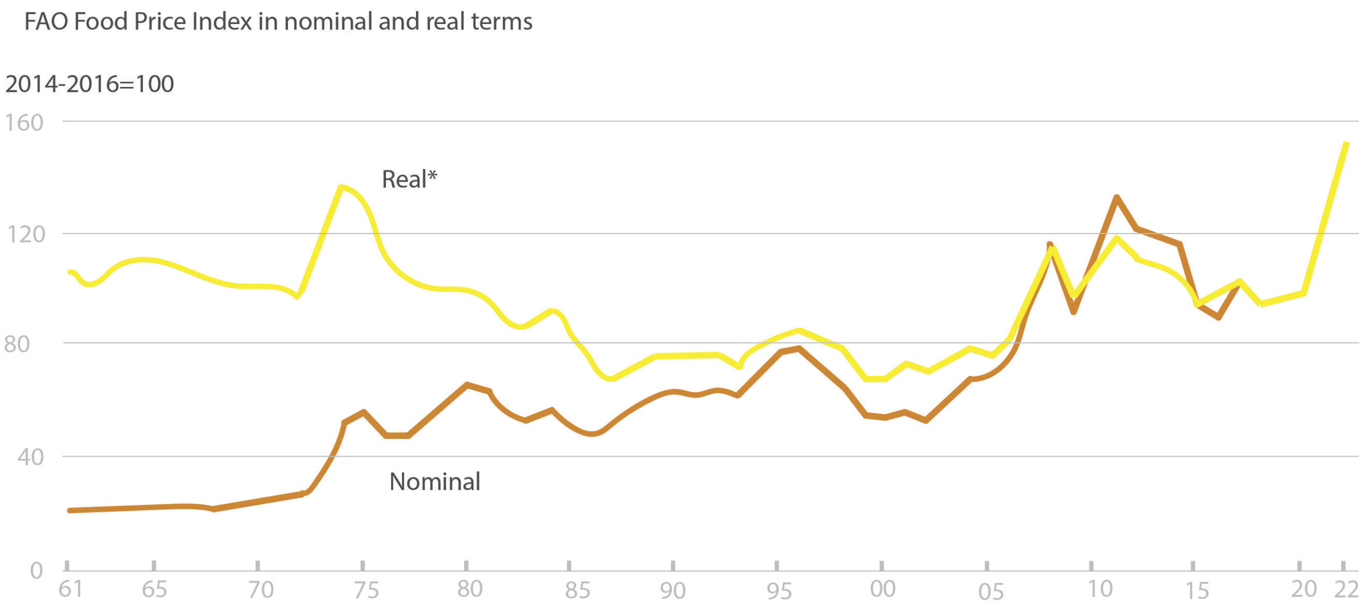
The UK and World Markets

Underpinning the rise in food and energy inflation in the UK are global events which have been reflected in world non-oil commodity prices and the price of energy on world markets. Figure 2 (on the following page) highlights the rise in prices on world agricultural markets.

The factors that determine prices on world commodity markets are varied and typically involve the interaction between a range of drivers. In the ongoing crisis, we have had the immediate impact of the invasion of Ukraine which reinforced the rising trend in commodity prices as part of the recovery from the global pandemic. There has also been an increase in protectionism across many countries in order to protect domestic consumers from events on world markets.

The importance of showing the data in real terms is that it takes into account the underlying increase in general price levels (inflation), facilitating comparison over long periods of time. So, in real terms, agricultural commodity prices on world markets exceeded the levels of 1972-74, which was the most significant commodity crisis in the post-war period. In real terms, agricultural commodity prices on world markets have also exceeded the levels associated with more recent food crises in 2008 and 2011.

Figure 2: World Prices for Agricultural Commodities 1961-2022

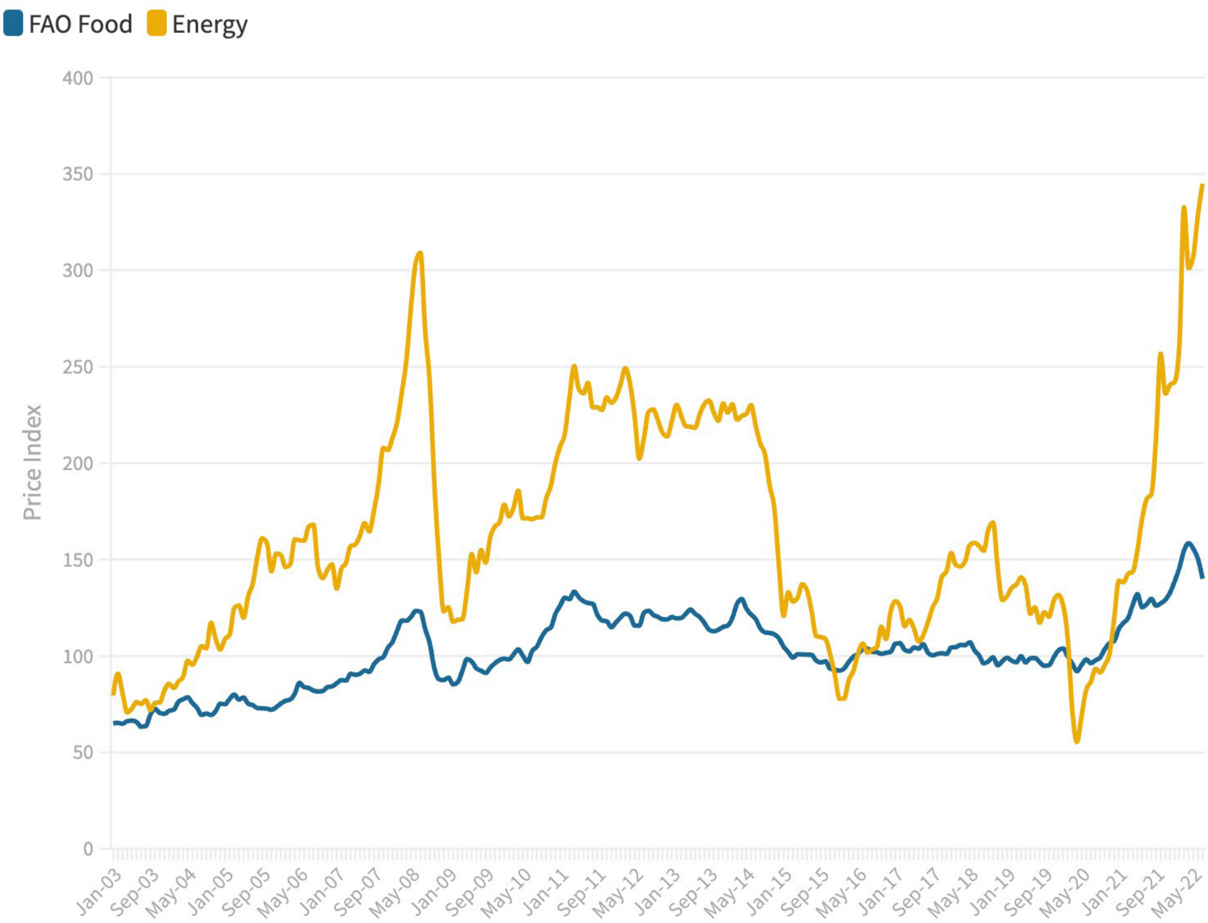


* the real price index is the nominal price index deflated by the World Bank Manufactures Unit Value Index (MUV)

Source: Food and agriculture Organisation (2022)

The recent spike in world agricultural commodity markets is related to prices in world energy markets. Reflecting the importance of Russia as a supplier of fossil fuels, the price of energy on world markets has increased dramatically since the early part of 2022. This is clear from Figure 3 (on the following page) where we present data (in nominal terms) on world food commodity prices (as in Figure 2) with the world price of energy (which includes world oil and natural gas prices). Energy prices tend to be more volatile than food prices and the recent spike in world energy markets is clear from this figure.

Figure 3: World Energy and Food Prices (2015=100)



Source:: FAO and IMF

As we note later, food and agricultural activities are energy intensive. High oil and natural gas prices drive up costs throughout food chains. Associated with the price of energy, the price of fertiliser has also increased significantly: this has an obvious impact on production at the farm level and is the source of an additional link between energy and commodity and food markets. In the remainder of this Report, we look at how climate and fossil fuels affect food prices in the UK.

Key Points

- Inflation in the UK has been rising; food and energy being the main sources of this recent rise
- World prices for agricultural commodities have risen substantially since 2020
- The increase in agricultural prices has been exceeded by the rise in world energy prices
- Agricultural and food prices are related to developments on fossil fuel markets
- The UK imports more than 40% of its food and agricultural commodity requirements. Therefore, developments on world markets can impact on the UK as can be seen by the recent experience of UK inflation

Climate change and food prices: uncovering the links

We focus on the transmission pathways from climate change to consumer food prices in five parts:

1. recent climate change metrics
2. climate change and global agriculture
3. agriculture's contribution to climate change
4. climate change and commodity prices
5. commodities and the food chain.

The research relating to these pathways forms the basis for the focus on UK consumer food prices in the subsequent section.

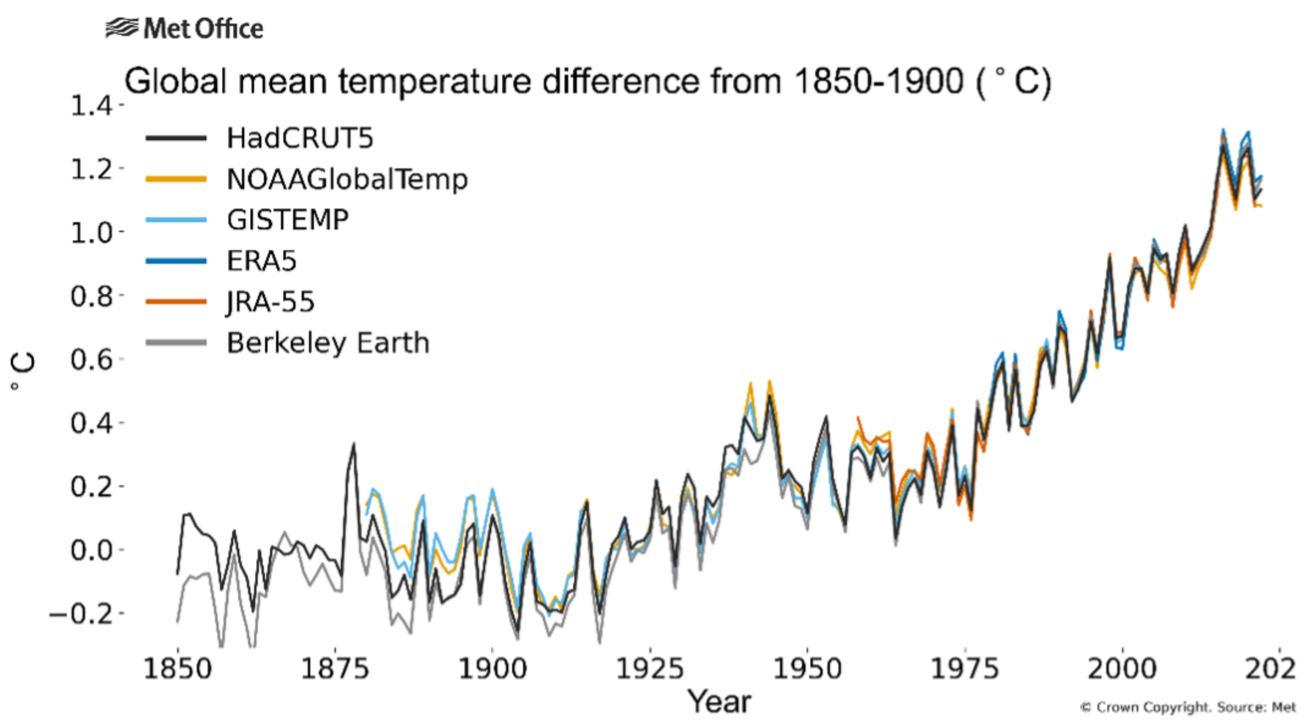
Climate change: global warming and extreme weather

Climate change refers to a change on a timescale of at least several decades in global or regional climate patterns, including temperatures, precipitation, and wind. These shifts have in the Earth's history been natural; but according to the IPCC (2022, p123) it is "unequivocal" that human activities are now the main driver of climate change, primarily due to burning fossil fuels like coal, oil and gas.

In broad terms, the main underlying driver of climate change is the extra heat trapped in the Earth's system, which leads to a rise in the average global temperature. Progressive changes also include sea level rise, ice melt, etc., which also have an impact on weather.
Analysis of data suggests that since the Industrial Revolution, the world has become 1.1oC warmer.

Analysis of data suggests that since the industrial revolution, the world has become 1.1oC warmer (World Meteorological Organisation, 2022) with a rate of increase that is both accelerating and heterogeneous across the globe. Figure 4 shows the rise in global temperatures; despite the variation in temperatures, it is the underlying upward trend that is the most notable feature of the data presented in the figure. The steep rise in global temperatures since the 1950s is notable; between 2011-2022, global temperature was 1.1o higher than the 1850-1900 average.

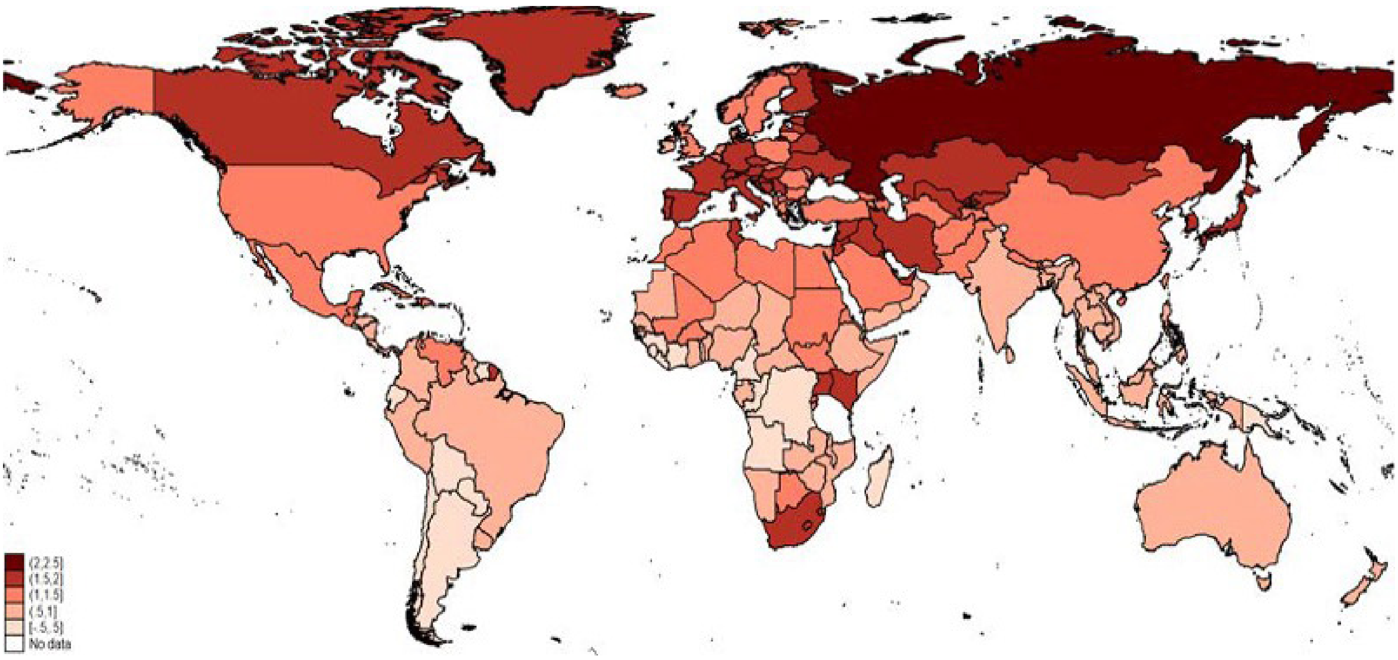
Figure 4: The Rise in Global Temperatures



Source: The Met Office

However, the distribution of rising temperatures varies geographically. Figure 5 shows the average temperature difference in the first twenty years of the 20th and 21st centuries. The darker red-shaded areas correspond to greater changes in temperature. The figure indicates that increased temperature trends have been most pronounced in the Northern hemisphere and in mid-latitudes.[1]

Figure 5: The Change in Average Temperatures over the Last Century



Source: Faccia et al., (2021)

Extreme weather events also matter for domestic and global sources of agricultural output and there has been increased attention paid to the potential macroeconomic consequences associated with them (see, for example, Acevedo et al. (2020), Batten (2018) and Faccia et al., (2021)). Between 1970 and 2019 alone there was a five-fold increase in weather related disasters and while higher temperatures can lead to heatwaves and droughts, warmer air holds more moisture, so precipitation can be both more frequent and intense.

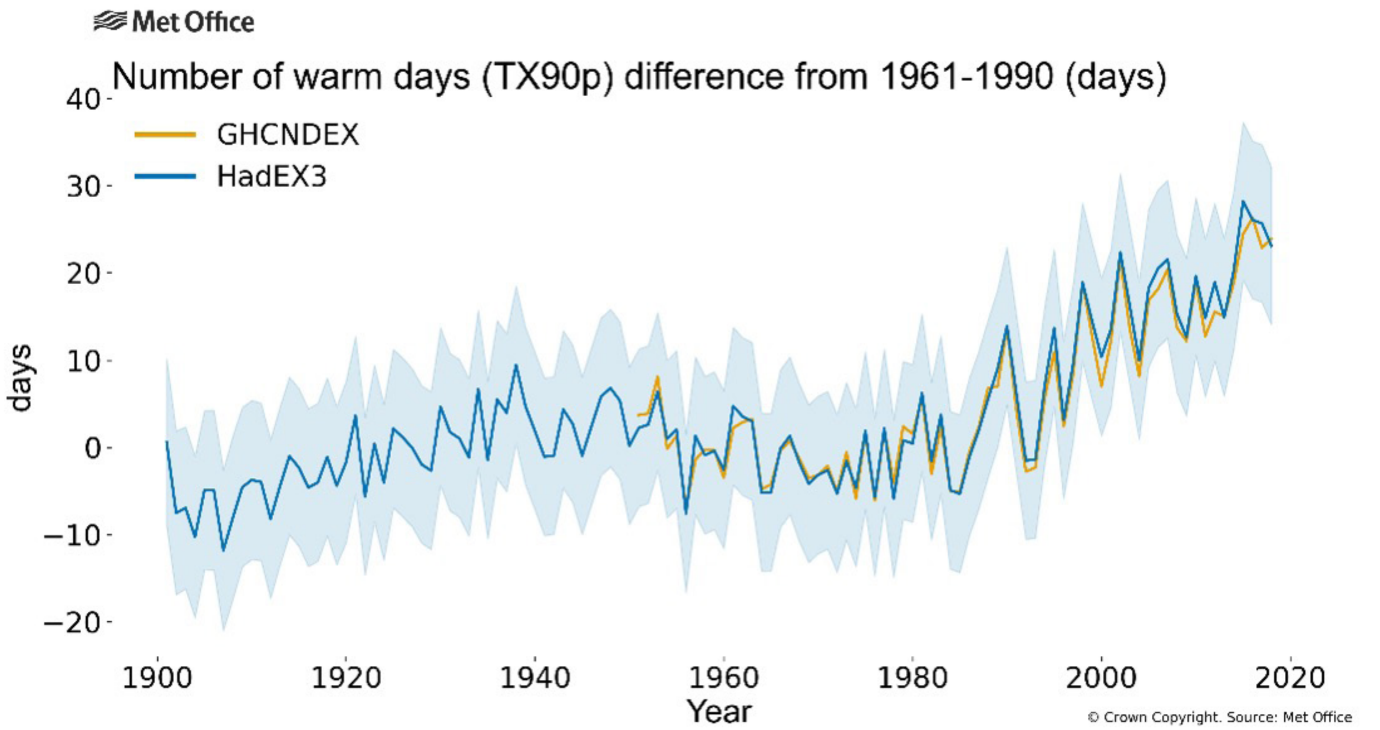
Recent scientific developments mean it is now possible to analyse individual extreme weather events to see if they were shaped by climate change (see, for example, Clarke et al., 2022) while the World Meteorological Organisation has also reported on the attribution of extreme

1 A rising global temperature expands the oceans and increases the rate of glacier melt leading to a rise in sea levels causing land loss and salination of coastal plains. The Artic is now known to have heated four times faster than the global average since 1979 when satellite measurements began, accelerating sea level rises as the Greenland icesheet melts. In 2022, the Antarctic Sea ice extent also reached its lowest value for July in the 44-year satellite data record, well below the previous record.

weather and climate change (World Meteorological Organisation, 2022). Of the 504 extreme weather events studied in over 400 peer-reviewed scientific papers published over the last twenty years, 71% were found to have been made more likely or more severe by anthropogenic (human caused) climate change, particularly those that were heat related (Carbon Brief, 2022).

Data on extreme temperatures is consistent with the global rise in temperatures shown in Figure 6. The evidence presented in Figure 6 - which records the number of warm days in each year (i.e. when the temperature exceeds the 90th percentile of the distribution for the 1960-1990 period) - clearly indicates the rise in temperature extremes.

Figure 6: Increase days of extreme temperatures



Source: The Met Office

Key Points:

- Climate change manifests as an underlying warming in global temperatures (global warming).
- Extreme weather events (temperatures, floods and drought) are also increasingly frequent and more intense.
- Research attributing climate change to extreme weather has highlighted the potential links between them.

Climate change's impact on global agriculture

The recent IPCC 6th Assessment Report (2022) has highlighted the various dimensions via which climate and extreme weather affects agricultural production. It points to the impact of climate change on current food production and the increasing numbers of people globally facing food insecurity, particularly in poorer and politically fragile states.

Most of our food comes from crops, livestock and fisheries. While global food supply increased dramatically in the last century, climate change has begun to slow that growth, reducing the gains that would have been expected without climate change. Regionally, negative effects are apparent in regions closer to the Equator, with some positive effects further north and south, although the impact varies significantly by food type and location (IPCC Assessment Report, 2022). This diversity of the impact across regions and crops is also noted by Brenton et al. (2022).

The effects of climate and extreme weather have both short and longer-term impacts on agricultural production. Acevedo et al. (2020) confirm the generally negative effects of temperature (and precipitation) on agricultural output more broadly in both the short and medium term, although the precise effect varies geographically; higher temperatures affect hotter countries more acutely than cooler ones. Given the strong negative correlation between a country's level of development and its average temperature, poor countries are more affected by climate shocks than richer countries.

Ortiz-Bobea et al. (2021) offer a different perspective on the effects of climate change on global agriculture. They move attention away from the focus on yields to productivity in the agricultural sector more broadly (what is technically referred to as total factor productivity). This provides a wider perspective than the focus on yields as farmers can use different combinations of inputs in response to climate change. Nevertheless, even with this wider perspective, the impact on global agriculture is substantive. Using data for 172 countries between 1961 and 2015, climate change is estimated to have reduced agricultural productivity by 21%. These country-level impacts are greater in warmer regions with reductions in productivity between 26% and 34%.

Notably, the impact of climate change has been a more recent phenomenon. Between 1961 and 1988, Ortiz-Bobea et al. (2021) estimate no apparent effect on agricultural productivity. With higher temperatures in particular being the cause, most of the decline in productivity has been recorded in the 1988-2015 period. In short, the risks and consequences of climate change and extreme weather having an impact on agricultural production have been increasing.
To capture global aspects of changing climate, researchers have often relied on data relating

to the El Niño Southern Oscillation (ENSO). This phenomenon sees climatic conditions across the Pacific Ocean vary between two phases –El Niño, which results in a net warming of the atmosphere, and La Niña, which brings a net cooling. Both phases cause changes in weather conditions that affect production in many parts of the world's most productive farmland and fisheries (Iizumu et al., 2014). Data relating to the El Niño phases where temperatures are warmer have therefore been used to reflect climate change. In particular, as we report below, the anomalies associated the El Niño phases have been used by economists to gauge its impact on world commodity prices.

Extreme weather events have been identified as a principal source of the increased frequency of food production shocks, acutely reducing supplies on land and in the oceans. As Cottrell et al. (2019) quantify, trends in food production shocks have risen in all sectors. They report that, for global crop production, over half of all shocks related to climate (mainly drought); extreme weather was also responsible for over 20% of the shocks affecting the global livestock sector.[2]

More broadly, climate change and extreme weather can affect all levels of the food chain. The post farm-gate sectors (food processing, distribution, storage and retailing) are equally vulnerable to the trends and shocks that have disrupted yields, particularly in nutrient-rich foods (e.g. vegetable, fish meat and dairy) that are perishable and hence reliant on transport infrastructure and cold storage to ensure food availability. The IPCC (2002) report identify three key aspects that have contributed to elevated rates of food loss and food waste as agricultural products move though the food chain in warmer, more humid conditions: threats to food safety (e.g. fungal infestations, microbial activity); greater reliance on and costs of cold storage for perishable products (e.g. electricity) and disruptions to transport and distribution infrastructure (e.g. flooding).

Key points

- Evidence shows that long-term climate change and shorter-term extreme weather variation has had significant effects on global agriculture.
- Agricultural yields have declined significantly, as has agricultural productivity more generally as a result of climate change.
- These impacts vary by crop and geography.
- Climate change and extreme weather can impact on the food chain at all levels, increasing costs.

2 Other sources of shocks included conflict and geopolitical events though climate events may also be a driver of conflict.

Agriculture's impact on climate

Climate change has an impact on agriculture; but agriculture is a major source of climate damage too, albeit less than the contribution of industry to global greenhouse gas emissions (IPCC, 2022). As has been well-documented, the major source of emissions related to agriculture is the animal and livestock sector. Ahmed et al., (2020) estimate that the greenhouse gas emissions directly associated with the global livestock sector are equivalent to the emissions from the United States (8%) and exceed that of India (3%) and Brazil (2%).

Agriculture's significant contribution to climate change poses significant challenges for the future. These challenges are multi-faceted and relate to adaptation and mitigation strategies as well as potentially fundamental changes in the global food system including technological improvements, diets and food waste.

Key Points

- Agriculture is also a main source of climate change, where greenhouse gas emissions from the animal and livestock sectors are significant.
- Addressing agriculture as a source of climate change will pose significant challenges to policymakers, farmers, businesses and consumers.

The implications for world commodity prices

The heterogeneous impact of climate and extreme weather across different regions of the world will be reflected in the price changes of agricultural commodities in global markets. As noted above, there are several dimensions to climate change and extreme events. To date, the focus of much published research assesses the impact of climate on commodity prices using data relating to the El Niño phase of ENSO. Though the data do not capture all dimensions of climate change and extreme weather, their ready availability and global reach makes them useful in studies of the impact of climatic events on world commodity markets. Research has highlighted the impact of temperature anomalies on economic activity. De Winne and Peersman (2021) focus on the effect of global temperatures on the macro-economy as feeding through world commodity markets (though they do not report specific commodity price effects which is our focus here).[3]

Researchers have noted the diverse ways in which global climatic events can affect world commodity markets. Most directly, El Niño can have an impact on yields that directly affects agricultural production though, as noted above, the effects can be geographically heterogeneous. Second, El Niño can have an impact on energy markets. For example, the lower power output from hydroelectric sources during El Niño phases necessitates the burning of more coal and oil.

Since El Niño also affects the macro-economy more generally (and where some countries and regions experience increased economic growth), energy demand increases by this channel too. As a consequence, El Niño can directly increase world agricultural prices by affecting output; but it also affects these markets by driving up input costs due to the increase in energy prices.

Cashin et al. (2017) estimate that given the underlying data patterns, a typical El Niño shock increases non-oil world commodity prices by around 5.3%. Since El Niño can also have an impact on economic activity more generally, it will also lead to an increase in world oil prices, the impact on oil prices being greater than non-oil world commodity prices (the estimated increase being around 14%).

Focussing on the world wheat market, Gutierrez (2017) assesses the effect of weather variability (using the ENSO anomaly measure) on production and hence export prices across countries,

3 The impact of higher temperatures on the macro-economy has become a recent focus of research with the results suggesting that higher temperatures could reduce economic activity particularly in developed countries. Aside from the effects coming through world commodity markets, higher temperatures work through additional mechanisms such as reducing labour productivity (see Brunner (2002) and Peersman (2021)).

with the impacts being more strongly associated with La Niña rather than the El Niño phase of the cycle. Estimates suggest that La Niña increases export prices in the US by around 8% and in Australia by 10%, once the lags in response are accounted for.

An assessment of individual commodity prices traded on world markets, covering 43 agricultural and non-agricultural commodities is provided by Ubilava (2018). His estimates indicate that a typical El Niño shock increases world prices of oilseeds by as much as 10%. For other agricultural commodities, world prices would rise by around 3%. Effects are strongest for commodities grown in tropical areas. Ubilava's analysis corroborates other results that show important non-linearities (as temperatures rise, the effects get even stronger), in that the same shock has greater impact during the El Niño phases of ENSO than the La Niña phases, underscoring that the warmer the climate becomes the greater the effect of any shock will be.

The research reported above highlights the extent to which increasing climate variability will affect world prices. As we expand on below, this will be a source of consumer food price inflation though the precise way these changes will work through the food system are both complex and uncertain, not least because agriculture's contribution to climate change and thus in food prices will be affected by the extent of adaptation and mitigation that is adopted. But climate variability will not be the only driver of world commodity and domestic food prices over the long-run. Technological improvements in production and distribution, changes in diets, population growth and government policies will all have an impact on the future trends and variability of agricultural prices. These issues create considerable uncertainty in determining the longer-term aspects of climate change on food prices.

Key Points

- Economists have provided estimates of the impact of climatic events on world commodity prices.
- Estimates suggest an increase in world prices with the effect varying by commodity.
- While climatic events lead to an increase in prices, the increased frequency of extreme weather events will also increase the volatility (i.e. the magnitude of changes) of world prices.
- Over the longer-run, adaptation and mitigation of agriculture's contribution to climate change will also impact on the price of food but the effect will depend on other drivers of change in the global food system.

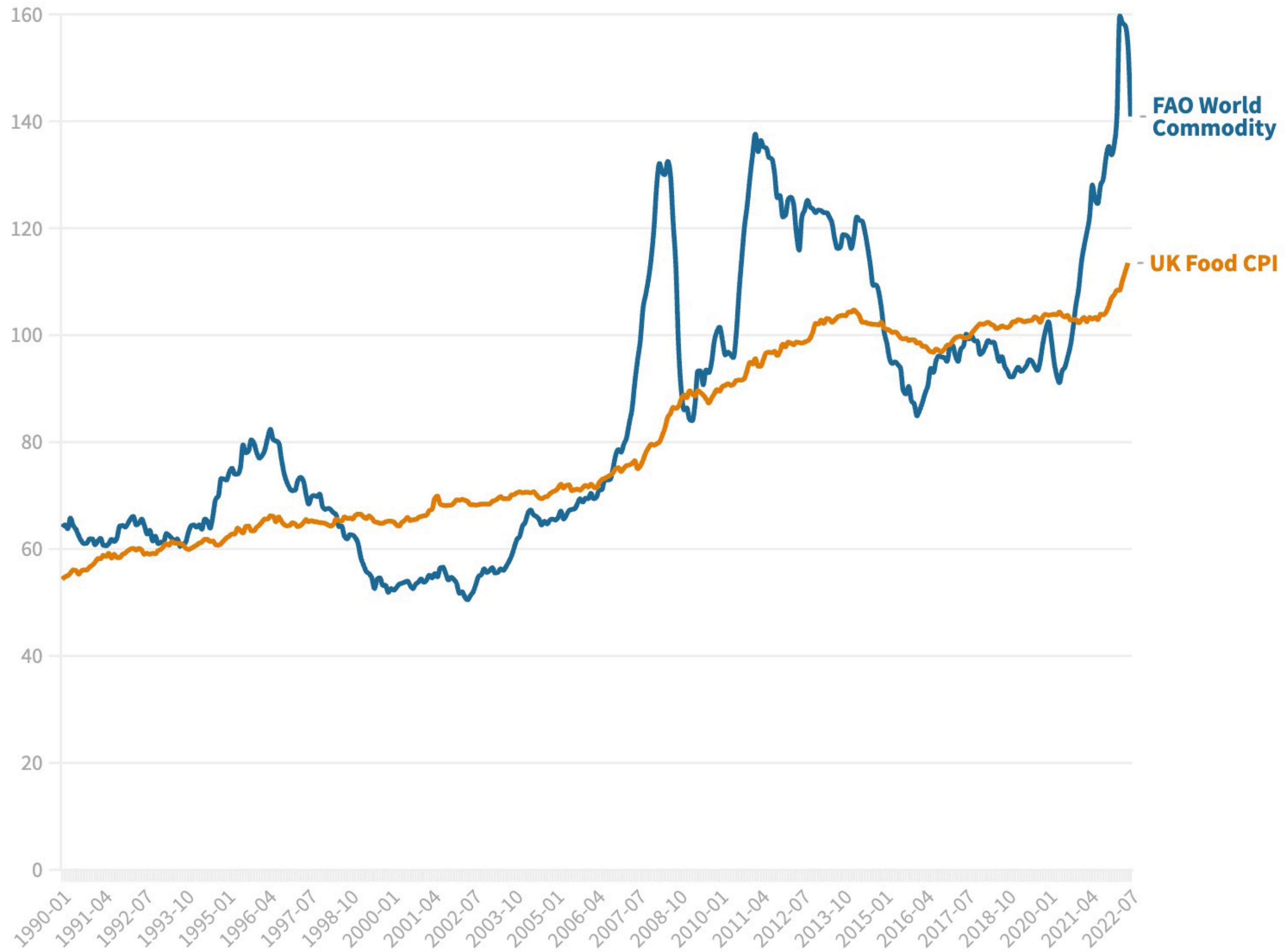
Commodities and the food chain

The foregoing review highlights the different dimensions of climate change and the potential impacts on global agriculture and world market prices. However, world market prices are distinct from the prices that consumers pay for food in supermarkets. Clearly, commodities traded on world markets are used as inputs that are combined with many others to produce the food products that consumers purchase. For example, wheat constitutes around 10-15% of the total value of the price of bread. Indeed, though the cost shares vary across food products, unprocessed agricultural commodities typically account for a relatively small share of the final processed products bought by consumers (25–30% for the US, Hobijn, 2008; 15–30% in the EU, Bukeviciute et al., 2009). Even for commodities traded on world markets that are not subject to processing (e.g. bananas or pineapples), they still pass through the supply chain, adding value at each successive stage, such that the prices at retail can behave very differently from world market prices.

Food products purchased in a supermarket not only reflect the prices of other ingredients such as packaging but also a host of services such as processing, manufacturing distribution and marketing in which labour, energy and capital costs predominate. As a result, the price of food purchased in shops only bears a passing resemblance to the price of commodities grown in the UK or traded internationally.

To illustrate this point, compare the Food and Agriculture Organisation's commodity price index with the ('All Items') index of food calculated by the UK's Office of National Statistics as shown in Figure 7. Not only do the cycles in commodity and retail food prices differ but commodity prices are inherently more volatile. In the data presented in the figure, commodity prices are over 3.5 times more variable than the retail prices of food, owing primarily that the food in the shopping baskets contains many other components whose prices are more stable.

Figure 7: Commodity Prices and the Price of Food in the UK (2015=100)



Source: Food and Agriculture Organisation (2022), Office for National Statistics (2022)

There are two factors that, in broad terms, determine how events on world markets affect the consumer prices for food. The first is the extent to which the UK is linked to world markets. With the UK importing over 40% of food and agricultural products, this suggests that events on world markets will be reflected in domestic UK food and agricultural prices. But the second factor is the extent to which these changes are passed through to consumers where 'pass-through' (or, interchangeably, 'price transmission') reflects the activities and behaviours of firms as agricultural products move through the food chain.

Key Points

- World commodity and domestic agricultural prices are related, but not synonymous with consumer prices for food in the retail sector.
- 'Pass-through' refers to the extent to which shocks originating on world or domestic markets are reflected in retail food prices.

Fossil fuels and food

Until now, the emphasis in this report has been on the impact of climate change and the increasing frequency of extreme weather on global agriculture and how this will have an impact on the food sector and, by extension, consumers. But linking climate-related issues to the food sector cannot ignore the importance of fossil fuels in the production of food. As we discuss below, the linkages between climate, energy and food are multi-dimensional.

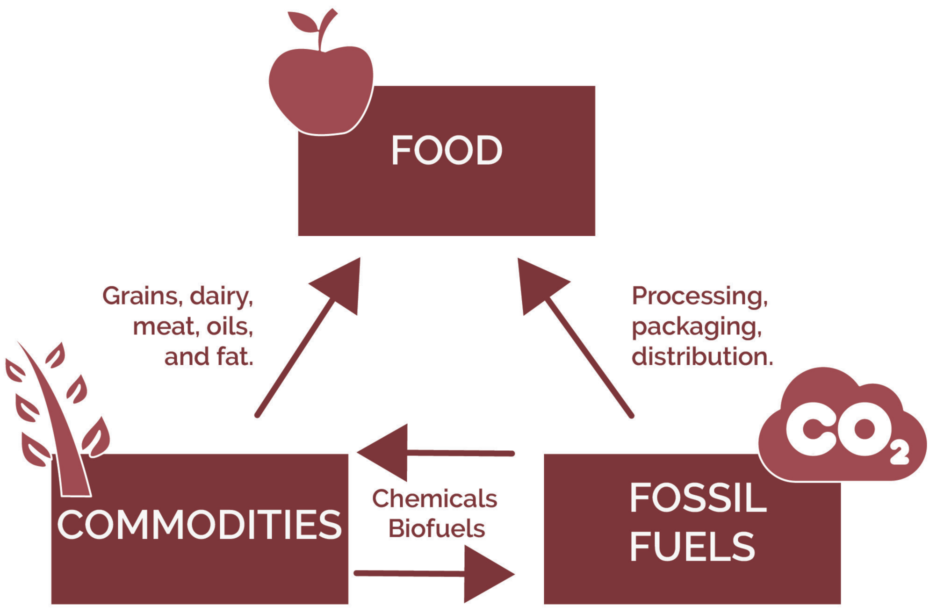
Linkages between fossil fuels, agriculture and food

Figure 8 presents an outline of these linkages. Fossil fuels are a vital component in agricultural production in terms of agrochemicals and fuel for machinery. They are also essential to the food industry as a source of raw materials (primarily plastic packaging) and energy (for distribution and storage, for example). In addition, some key agricultural commodities can be grown for food or fuel.

These crops, called 'biofuels', strengthen the links between agricultural food and fossil fuels. The two most common types of biofuels are bioethanol (derived from maize and sugarcane) and biodiesel (derived from animal fats and vegetable oils such as sunflower and palm oil). Production of these crops can thus be diverted away from food and into fuel as market prices fluctuate.

While biofuels often receive government support as an alternative to petrol or diesel, many scientists, environmental experts and groups have raised concerns about their use, particularly crop-based biofuels which they have cautioned are often not low-carbon due to the associated land use change emissions (Searchinger et al., 2008). The relationships are complicated: an increase in the price of fossil fuels not only raises input costs to farmers and the food industry in general but also diverts land for food production into land for fuel, putting pressure on food prices in the process. In this way, the price of fossil fuels has a potential double effect on the prices of agricultural commodity prices and can amplify prices changes in world markets. Given the relative size of oil and agricultural commodity markets, oil price shocks can contribute to spikes in agricultural commodity markets.

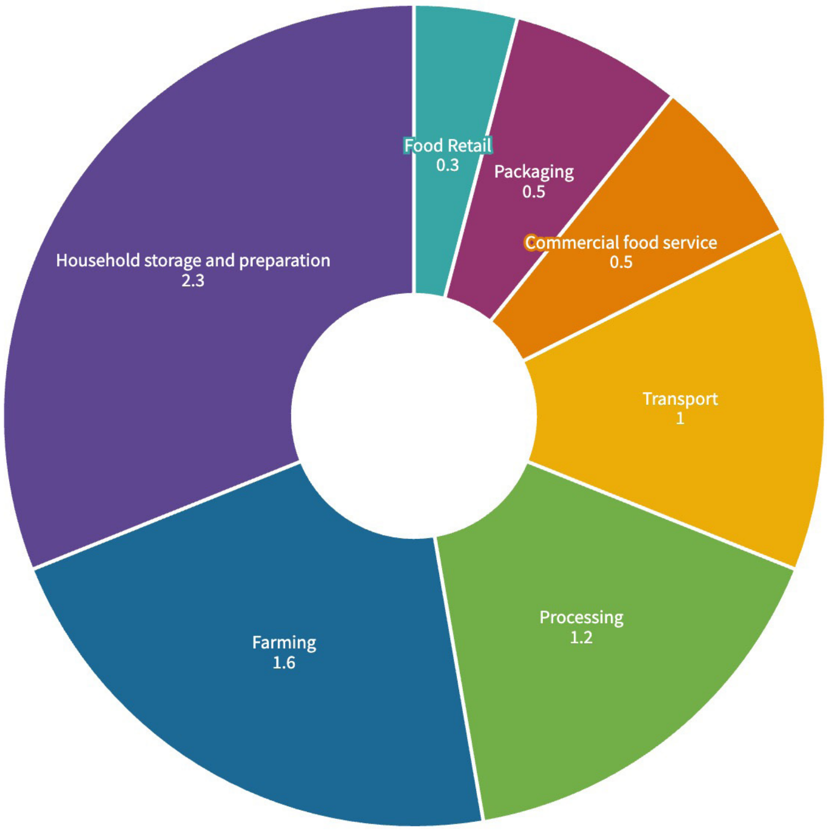
Figure 8: Linkages between fossil fuels, agricultural commodities and food



Energy intensity of the food and agricultural sector

Agriculture and food are energy intensive. It is estimated that around 30% of the world's energy is used by the agricultural and food sectors (Choose Energy, 2019). The energy intensity of the food and agricultural sector is illustrated in Figure 9. For every calorie of food consumed in rich countries over 7 calories of energy is required to produce it. While farming itself is fossil fuel intensive (fertilizers and fuel) nearly 80% of the energy required to produce food is consumed elsewhere in the food chain (Heinberg and Romford, 2009).

Figure 9: Energy Intensity of Food and Agriculture



Source: Heinberg and Bomford (2009)

Fossil fuels have an impact on food and agriculture in a number of ways. Apart from the diesel oil required to power machinery, agriculture relies on fertiliser, itself produced from or using fossil fuels.

The industrial processing of food is also highly energy intensive. It is estimated that 1.8% of the world's energy is used for this single purpose, creating 1.8% of world greenhouse emissions (The Royal Society, 2020). Transportation and freight also rely on oil, natural gas is required for refrigeration and carbon dioxide produced from natural gas has a wide range of uses in the food industry from carbonating fizzy drinks to stunning animals before slaughter. Most of the processing and manufacturing of food, such as washing, cooking/baking and drying require vast amounts of natural gas and electricity. In the UK for example, 58% of energy demand from food processing derived from natural gas; 32% from electricity (Ladha-Sabur et al., 2019). As the figure shows, by far the most energy intensive part of food production occurs within the home, primarily refrigerated storage and cooking.

Biofuels, oil and commodity markets

As has been alluded to above, there are two main channels by which oil prices exert an impact on food prices. On the one hand, there is a direct impact; in many parts of the world commercial agriculture is energy-intensive. On the other hand, there is an indirect channel arising from the demand for widely traded agricultural commodities (principally maize, soybeans, wheat and sugar) as biofuels (see, Harri et al., 2009; Zhang et al., 2010; Du et al., 2011).

Biofuel demand, particularly in times of high oil prices, has been significant. OECD-FAO (2011) report that during 2007-09, biofuels accounted for some 20% of the global consumption of sugar cane and 9% of vegetable oil consumption. Furthermore, the adoption of biofuel mandates (mandatory obligations to blend fixed proportions of biofuels with fossil fuels) in both the US and European Union is widely thought to have hardened the inelasticity of demand that gives rise to agricultural price volatility in the first place. In countries where biofuel mandates were most aggressive, effects were stronger, Hertel and Beckman (2011) reporting that in 2010 about 40% of maize production in the US ended-up in biofuels. A recent discussion of the links between biofuels and agricultural commodity markets is provided by de Gorter et al. (2015).

How strong is the relationship between fuel and agricultural and food prices?

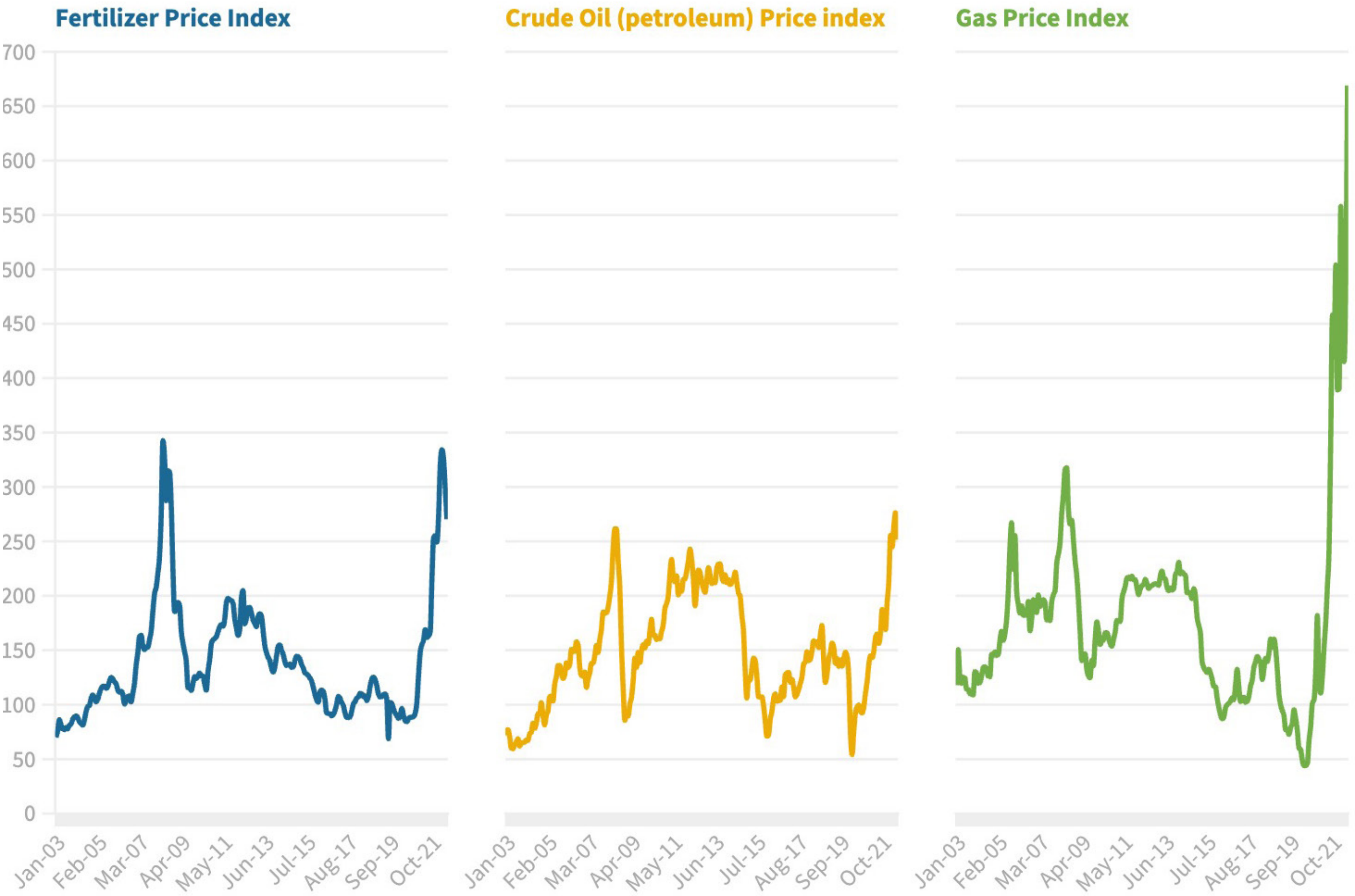
Quantifying the strength of the links between fuel (principally oil) and agricultural and food prices has been subject to much recent research, and considerable controversy. Themes that have been addressed on this issue relate to, inter alia, the source of the oil price shock (Wang et al., 2014); the role of the linkage between biofuels, oil and food prices (Baumeister and Kilian, 2014); and whether the link between oil and agricultural prices is permanent or a more recent relation (Peersman et al., 2021 and Gilbert, 2010). Research to date indicates that the link between oil and food prices can vary over time, sometimes being particularly strong (most obviously, when oil prices spike) but at other times considerably weaker.

Recent events in energy markets

Recent events in the global economy have highlighted the impact that fossil fuels can have on agriculture and food chains. Although Russia and Ukraine are important sources of agricultural commodities to world markets, Russia is also an important source of fossil fuels and the Russian invasion of Ukraine has seen the prices of oil, natural gas and fertiliser jump significantly over the first half of 2022.

Figure 10 highlights these price developments. A comparison of the figures shows that the world oil price is generally more volatile than the prices of natural gas and fertiliser. However, prices for all three fossil fuels increased significantly in 2022. Since the summer of 2021, world oil prices have increased five-fold; natural gas by a factor of 3.5; and fertiliser by a factor of around 3. The rise in the price of fossil fuels has therefore been a major contributor to the increase in the prices of agricultural commodities in world markets detailed in Figure 2.

Figure 10: Prices in World Oil, Fertilizer and Natural Gas Markets



Notes: Natural Gas Price Index, 2016 = 100, includes European, Japanese, and American Natural Gas Price Indices. | Fertilizer Index, 2016 = 100, includes DAP, Potash, UREA. | Crude Oil (petroleum), Price index, 2016 = 100, simple average of three spot prices; Dated Brent, West Texas Intermediate, and the Dubai Fateh

Source: International Monetary Fund (2022)

As we have noted in the previous section, events on world markets and domestic agricultural markets matter for food prices for consumers; but how much they matter will depend on the extent of 'pass- through' of shocks emanating on world markets through the food system and ultimately consumers.

Key Points

- Both agricultural production and the food chain are fossil fuel intensive.
- Fossil fuels have an impact on the cost of food at all levels of the food chain.
- There is an additional complexity involving the interaction between biofuels, oil and non-oil commodity prices which can exacerbate price spikes on world markets.
- World prices (agricultural commodity, oil and natural gas) are more volatile than retail food prices.

Why does food inflation matter?

UK Retail Food Prices and Food Inflation

The average prices of goods and services consumed in the UK are monitored by the Office for National Statistics and measured by the Consumer Prices Index (CPI).

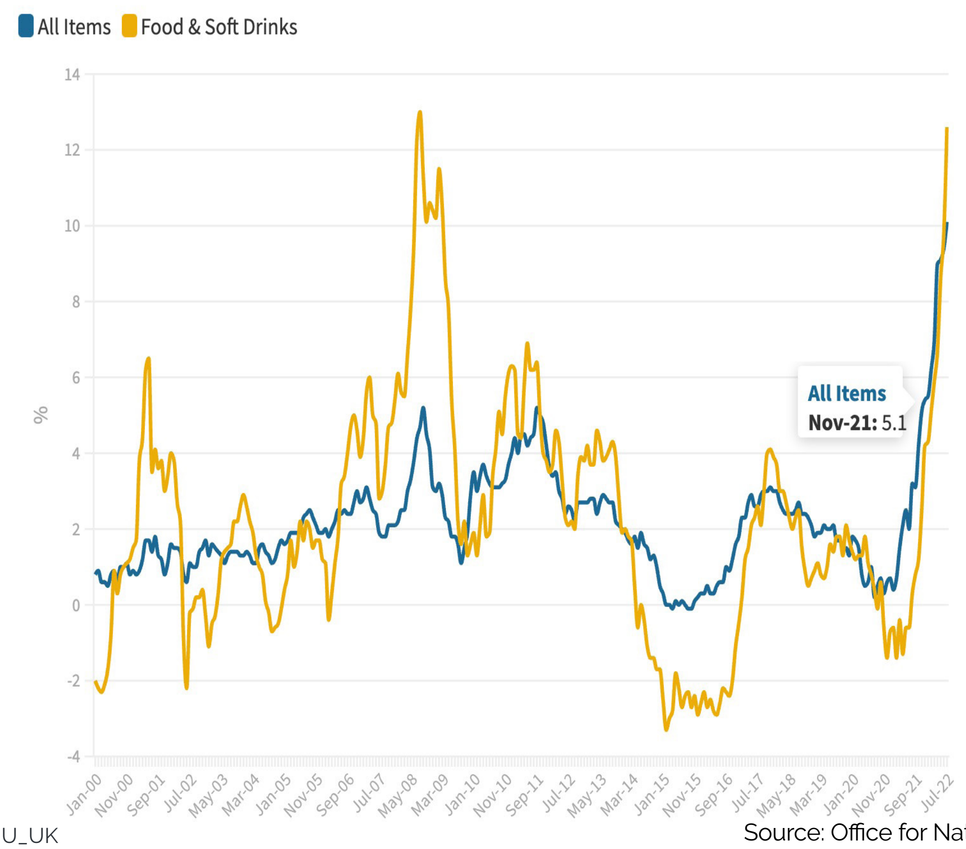
This index is a representative 'basket' of around 700 goods and services purchased by consumers in around 140 locations across the UK. This is the All Items (or headline) index that contains 12 broad categories covering spending on 'Food & non-alcoholic beverages', 'Housing, water, electricity and gas' and 'Transport', and is broken down further into 85 classes, for example, bread and cereals, electricity, new cars and fuel. In all, around 180,000 prices are collected every month to calculate the CPI. As a result, the CPI measures the level of prices at monthly intervals.

Given the broad nature of spending that it covers, the CPI is often used to measure the cost of living of a typical household in the UK. Food and non-alcoholic beverages (in shops and on the internet) is one of the principal categories of spending in the CPI, occupying about 12% of the overall index, whereas eating out has a weight of 7%, fuel (diesel and petrol) for cars and electricity and gas used in the home each represent about 3% of the index. Food and energy thus represent just less than a quarter of the index.

To gauge fluctuations in the CPI better (i.e. the speed at which prices are rising or falling), analysts measure the rate of inflation, which is the change in prices (as measured by the CPI) over a 12 month period, say between July this year and July last year. The headline inflation figure reported in the media is the All Items measure, although rates of inflation for its component parts are also widely reported. Figure 11 shows the headline rate of inflation along with 'food and non-alcoholic beverages' in the UK since 2000.

Reflecting to some extent the volatile nature of world commodity prices, food inflation is more volatile than the headline rate of inflation. For example, during the commodity crisis of 2008-9 food price inflation in the UK peaked at 12.3% in July 2008, while headline inflation (which includes the price of all commonly purchased goods and services), rose by only 4.4%. Note that inflation rates have also been negative (most notably in 2015-16) implying that consumer food prices were falling.

Figure 11: Rates of General and Food Inflation in the UK January 2000 to June 2022

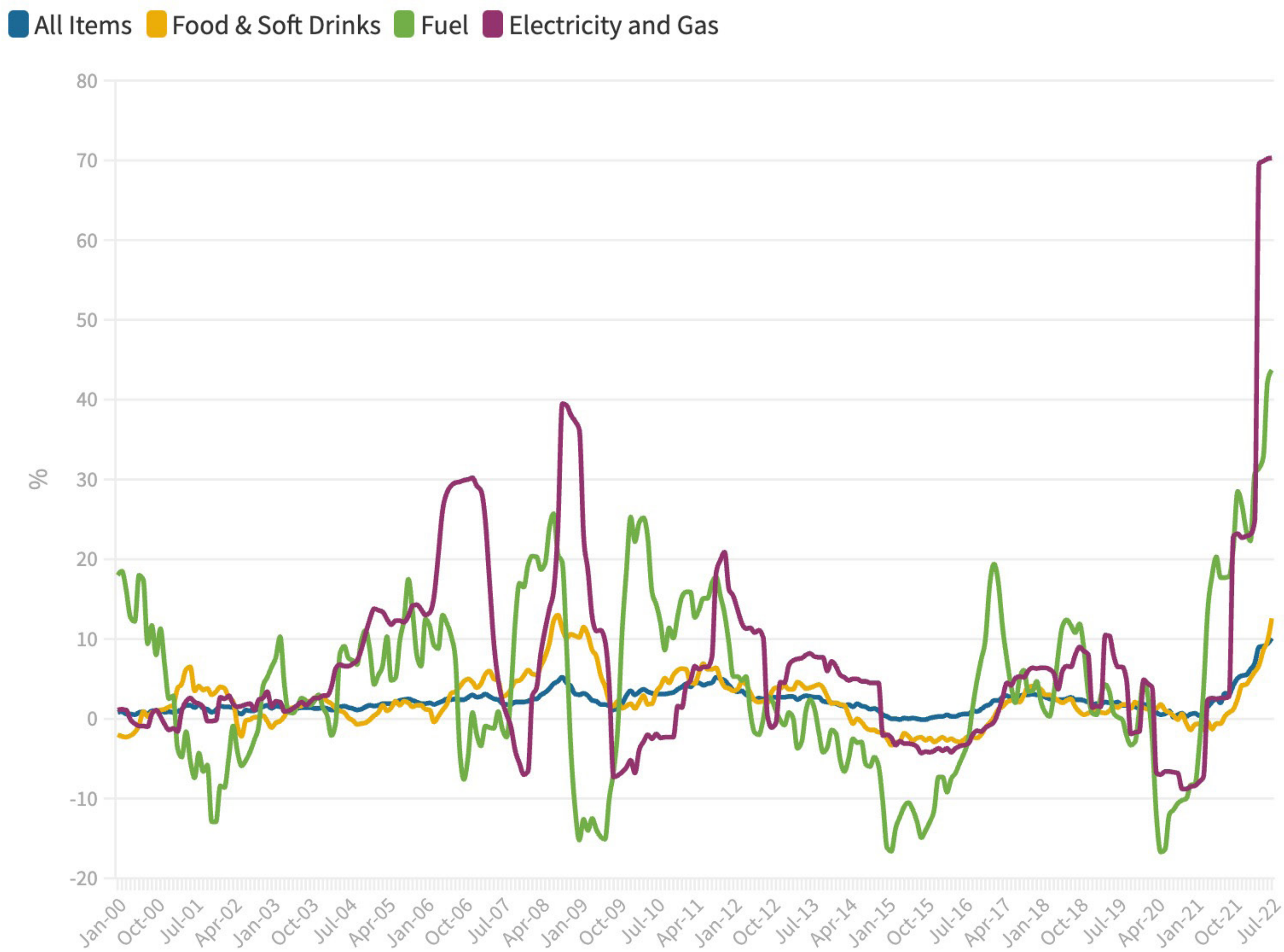


Source: Office for National Statistics

While food prices typically fluctuate more than prices in general, fuel and household energy prices are historically among the most volatile. Figure 12 augments Figure 11 with rates of inflation for vehicle fuel (petrol and diesel) and household energy (electricity and gas). Inflation rates for energy dwarf even those for food and soft drinks. Whereas food and drink inflation is typically twice as variable as headline inflation, rates for fuels and energy have a variability that is eight times the headline figure.

As the Figure shows, energy and fuels are rising at unprecedented rates: the 12 months to July 2022 electricity and gas prices rose 70%, petrol and diesel by 42%. The introduction of the Domestic Gas and Electricity (Tariff Cap) Bill in 2018, which curbs the frequency and extent of energy providers to change prices, in part is a response to this volatility.

Figure 12: Rates of General and Food Inflation in the UK January 2000 to June 2022



Source: Office for National Statistics (2022)

The consequences of food inflation

Inflation erodes what you can buy with the money in your pocket. If annual inflation is running at 10% then goods that might have cost £10 one year ago will require £11 to buy today. Because inflation reduces what you can buy from one year to the next with the same amount of money, it acts like a tax on consumers.

Taxes that affect low-income consumers more than high-income ones are known as regressive taxes. Because we all need food to eat even when food prices rise, it is difficult to avoid food inflation. In essence, you need to pay more to obtain the same amount of food. If your income is rising less than the price of food, you will have to buy fewer other goods to maintain the same diet. While for high income groups the impact of rising food prices may be negligible, for those on low incomes this is not the case. Furthermore, high income households, who are likely to be buying premium version of the products can 'trade down' and buy cheaper versions (supermarket own labels instead of branded products). Those on a low income are likely to be purchasing the cheapest goods already and thus find it more difficult to avoid food inflation.

But the consequences of high food prices and increasing food inflation are not limited solely to the prices paid at the check-out. There can also be consequences for health. As highlighted by the recent National Food Strategy (2021), the health consequences of eating highly processed food are significant and healthier food is more expensive than highly-processed and convenience food. As such, one of the potential impacts of high and rising food prices, is that consumers might choose less healthy food over healthier options

Key Points

- Food Inflation is more variable than general inflation.
- Given the importance of agriculture and food imports in the UK, food inflation is more responsive to climate, world commodity and fossil fuel prices than general inflation.
- Food inflation is regressive, impacting on the poorest households disproportionately.
- Food inflation also has implications for food choice (healthy diets etc).

Linking climate and fossil fuels to UK food prices

A wide variety of factors affect retail food prices in the UK. Some of these reflect events and circumstances domestically (such as wage rates, and the cost of other inputs sourced locally) and others are more international in origin, such as the prices of commodities on international markets which are themselves traded in US dollars. In this section, we shine a spotlight on the effects of climate change (specifically, the difference in global temperature from a 1951-80 base) and fossil fuels on the price of food in Britain.

Consistent with the media attention that has been given to the high summer temperatures in 2022, in combination with the Russian invasion of Ukraine and the supply disruption caused by the pandemic, UK food inflation has been particularly high in recent months. In July 2022, prices of food and drink were rising at a rate of 12.7% year on year compared to the historical average (since 2000) of 2.3%. For comparison, All Items inflation was 10.1% and 2.2% respectively. Food prices actually fell in the first seven months of 2021 and averaged only 0.28% over the year, so it is well to bear in mind that the high rates of food inflation we are currently witnessing are a very recent phenomenon. This is just an illustration of the volatility of food inflation noted in Figure 11.

Retail food prices in the UK tend to lag developments further up the food chain by around 6-12 months (Davidson et al. 2016) reflecting factors such as the growing season of key crops, the length of contracts and the behaviour of firms to the inherent variability of agricultural input prices. This has two noteworthy implications: first, current inflation (at the time of writing, autumn 2022) largely reflects developments on input markets in the spring of 2022; second, the current high rates of inflation are likely to be persistent for some time. Specifically, the dry weather conditions over the last year and the ongoing crisis in world energy markets will affect production and planting decisions and hence agricultural prices in both 2022 and 2023.

Calculating the Effects of Climate Change and Energy Price Shocks on UK Food Prices

Our aim is to assess the joint impact of climate change and energy price shocks on UK food prices. To do this, we augment the food price inflation model used by Defra (Davidson et al., 2021) with estimates drawn from recent international research reported above to assess the impact of climate change and global fossil fuel shocks on UK food prices and consumer expenditure on food under a number of different scenarios. The results from the calculations we undertake should be interpreted as a useful guide to the likely effects based on the best available data rather than the outcome of a formal decomposition exercise. Details of the methodology and the assumptions underpinning the estimates below is outlined in the Appendix.

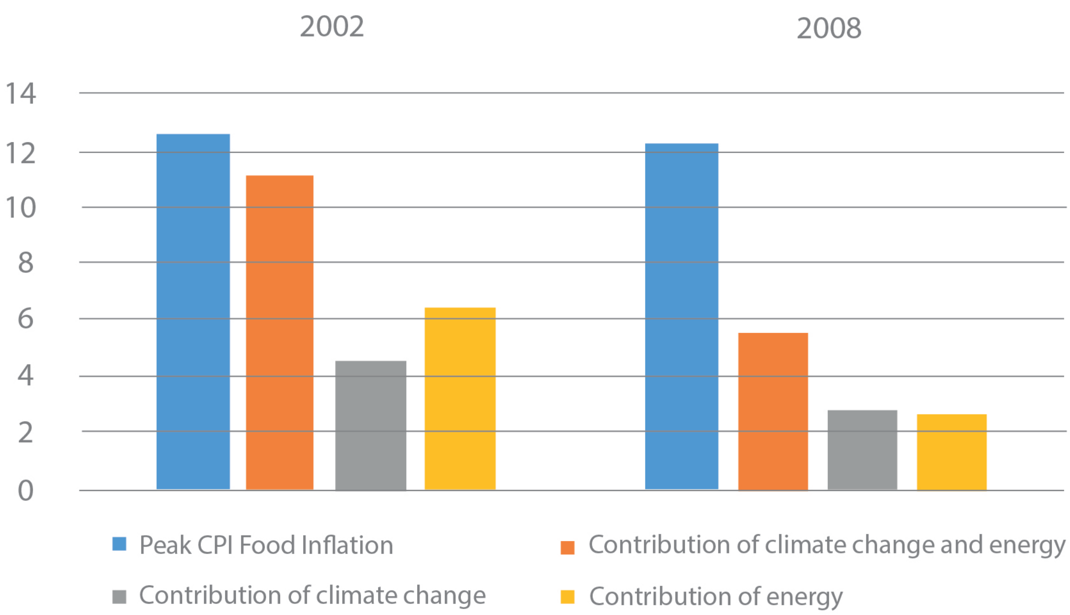
We find that the combined effects of the recent spike in energy prices and high global temperatures could have increased the retail price of food by as much as 11.2% in 2022, translating into an additional £33.90 increase in the cost of the average household food spending per month (equivalent to a rise of £406.82 during the year). This will add an estimated £11.4 billion to the annual food bill in 2022 that stood at £118 bn in 2021.
CPI food inflation began 2022 at 4.4% and had reached 12.7% by July with an average rate for the first six months of 7.6%. The 11.2% rate of increase we calculate from climate change and energy costs for the whole of 2022 suggests that the current elevated rates of food inflation are likely to persist for the remainder of 2022 as pressure that has built up in the food chain passes through to consumer prices. Our calculations suggest that the lion's share (11.2/12.7=88%) of

the 12.7% food inflation experienced in July 2022 is associated with the impact of the energy price shock and climate change.

We can also assess the individual contributions of climate change and energy price shocks to the 11.2% food inflation that has been calculated. The figures imply that climate change accounted for 42% of the 11.2% increase and energy prices 58%. This translates into increases in household monthly spending of £14.24 and £19.66 per month respectively. This breakdown is reported in Figure 13.

For comparison, we present the impact of these factors for 2008, the year in which a recent world food price crisis occurred; this is also reported in Figure 13. The comparison is apposite since the 2008 crisis saw food price inflation peak at 12.1%, a level comparable to the current peak of 12.7%. Two features stand out from this comparison. First, the effects of both climate change and energy prices have increased substantially since 2008, reflecting the higher levels of warming and energy price inflation we now observe. Second, while each factor had a similar effect in 2008, the current food price spike is dominated by the influence of fossil fuels.

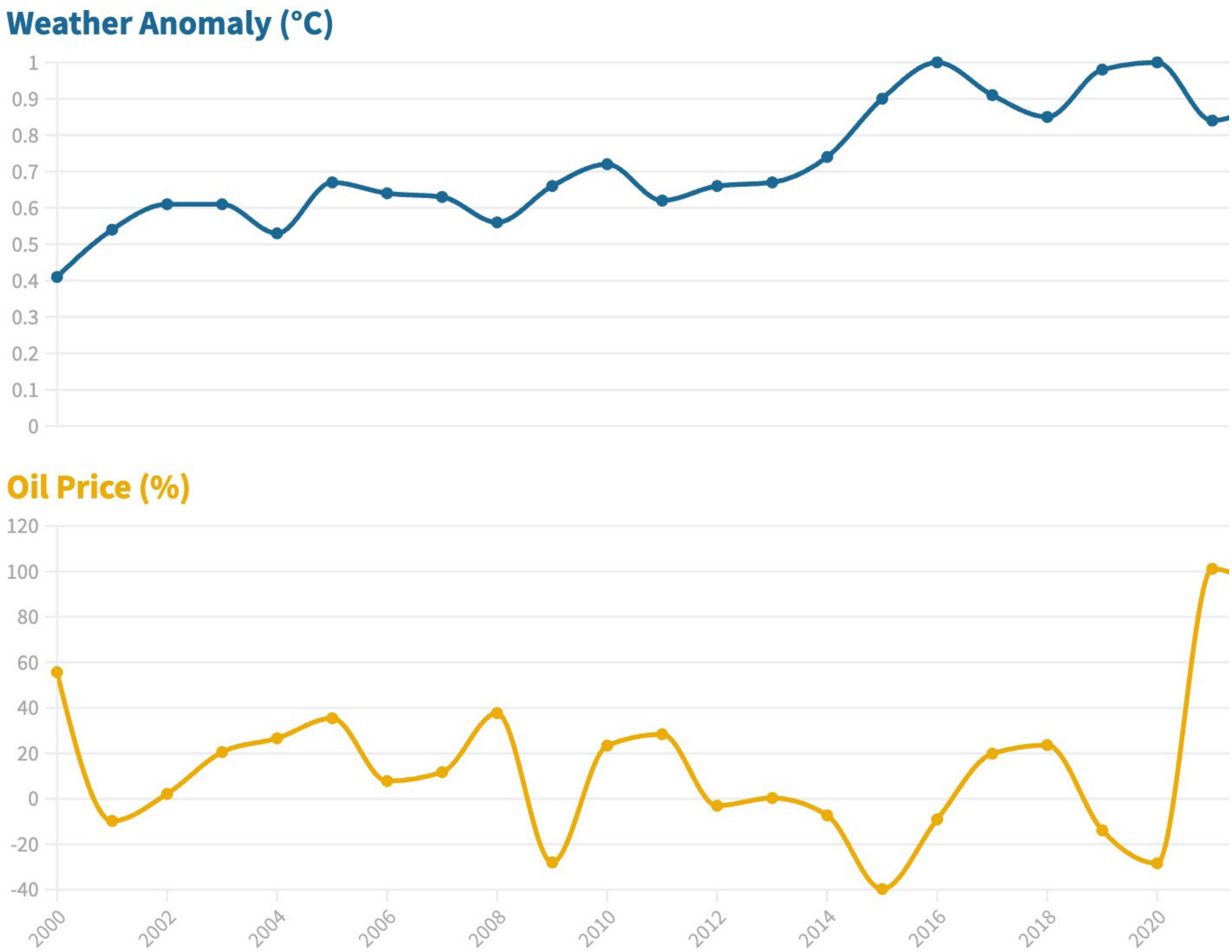
Figure 13: Calculated Contributions to Peak Food Inflation from Climate Change and Energy Prices in 2022 and 2008



Source: Authors' calculations

As is clear from the comparison of the food price spikes in 2008 and 2022, the relative importance of climate change and the cost of energy on food inflation varies from one crisis to the next - and indeed, one year to the next. By means of illustration, consider Figure 14 below which plots the data on climate change and energy price inflation used in the calculations. The climate change data, produced by the National Oceanic and Atmospheric Administration in the US, measures the difference in global temperatures from a (1951-80) baseline; energy price inflation is based on the index of oil and gas prices produced by the International Monetary Fund. Whereas the climate change data is seen to fluctuate around a rising trend, energy price inflation is simply characterised by variability, the shock in 2022 being exceptional. It is important to recognise that these features impart specific effects on the food price inflation experienced by UK households: climate change typically leads to higher prices as the trend rises through time; energy prices boost or depress food prices, depending on whether they are rising or falling.

Figure 14: Global Temperatures and Oil Price Inflation (2000-2022)



Source: National Oceanic and Atmospheric Administration, (2022), International Monetary Fund (2022)

The data show that food prices are rising at virtually unprecedented rates. The assessment presented here suggests that this is largely due to the current combination of climate and energy-related factors. Given the inherent variability of energy prices we may ask what would the rate of food inflation have been in 2022 in the absence of the energy price shock? Results suggest the rate of food inflation might be expected to be over 6.6% lower than it currently is, somewhere around 6.1%.

In this scenario, household spending on food might be expected to rise by an additional £14.08 per month in 2022 rather than the estimated £33.90 including the energy price shock. In sum, climate change clearly has a material effect on the cost-of-living crisis and is made all the worse due to the potential indirect effects relating to the impact of energy prices in the food chain.

A further implication of the findings presented here is that the effects of climate change on food price inflation and the cost-of-living are likely to grow every year. As such, we could expect food prices to rise in the longer term in the absence of mitigation or adaptation, estimates suggesting that climate change will add some 0.12 percentage points to food inflation every year, increasing the UK's food bill by some £114 million annually.

Key Points

- Climate change and spikes in fossil fuel prices account for the majority of the current high levels of food inflation in the UK.
- The contribution of these factors is more significant compared to the spikes in food prices and UK food price inflation in 2008.
- At some point, the spikes in fossil fuel prices on world markets will subside; but the scientific evidence suggests that global temperatures will continue to increase, underpinning the importance of climate change to UK food prices in the future.

Conclusion

UK households currently face a squeeze on the cost-of-living with most of the attention from the media and politicians focussed around energy bills. However, the cost of food in household shopping baskets has also risen significantly. This issue is not separate from the current price spikes on world energy markets, which are themselves largely reflective of the Russian invasion of Ukraine.

Fossil fuels are an important cost factor in the price of food with fossil fuel prices affecting all stages of the food chain. It is, however, not the only driver of food prices. Macroeconomic factors matter too as indeed does climate change. With extreme temperatures, drought and floods affecting national and global food supplies, awareness of the potential impact of climate change on food prices has increased. Once the current spike in the prices of fossil fuels passes, the rise in global temperatures will - in the absence of global action - continue to increase, as will the frequency and intensity of extreme weather.

We have reviewed the recent scientific and economic research that addresses the linkages between fossil fuels and climate change on food prices in the UK. This is a particularly pertinent issue for policymakers and stakeholders in the UK given the importance of imports in the UK's food supplies and, therefore, the potential exposure to world markets. We have aimed to quantify the potential effects on food prices and shopping bills. Of course, other factors may ameliorate and exacerbate the magnitude of the impacts we report here, but it is unlikely to defuse the impact of the insights that arise from the research by the scientific and economics research communities: climate change and fossil fuels are potentially important in determining the price of food in UK supermarkets.

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Appendix: Underlying Model and Methodology

Key to understanding the impact of climate change and energy price shocks on consumer food prices is the mechanism and extent to which price shocks are passed through to consumers. In this appendix, we sketch the transmission pathways through which climate shocks and fossil fuel prices affect consumer prices of food in the UK.

Our focus is on calculating the joint impact of these pass-through effects directly on UK food prices. Recent international research reported in the main text provides estimates of specific links in the overall chain. By combining these separate pass-through effects, we are able to assess the potential impact of climate change and global fossil fuel shocks on UK food prices and consumer expenditure on food, which we do so under a number of different scenarios. While this provides a tractable framework for analysis, the transmission pathways we identify do not represent a complete description of all the effects and interactions, and these limitations need to be borne in mind.

Specifically, there are, of course, other factors that can drive the price of food (such as wages, exchange rates and marketing strategies) and these factors may offset or reinforce the effects of fossil fuels and climate change and have not been controlled for in the calculations produced in this report. At certain periods of time, they could potentially be the dominant driver of retail prices. Furthermore, we assume that climate change primarily has an impact on the supply of food rather than demand. Demand responses are likely to mollify the supply side shocks, as consumers hunt for bargains more actively and generally trade down (i.e. purchase lower price versions of the same product).

Moreover, the impact of fossil fuel costs and climate change works through the food system over time. Given that the estimates produced here draw on models that were based on data prior to recent events, the timing and magnitude of the effects through the food chain may differ. We do not specifically measure the effect of supply shocks in specific markets such as the decline in exports from Ukraine as a result of the Russian invasion. In addition, since we are employing a world price index that relates to a basket of agricultural commodities, the "Russia-Ukraine" effect comes via the link between global energy and fertiliser prices that will have an impact on this world agricultural commodity price index. As a result, the calculations we provide should be interpreted as a useful guide to the likely effects based on the best available data rather than the outcome of a formal econometric exercise. These issues are of course an avenue for future research.

Global Temperature Shocks

Drawing on recent international research, we identify three channels of transmission through which climate change has an impact on consumer food prices:

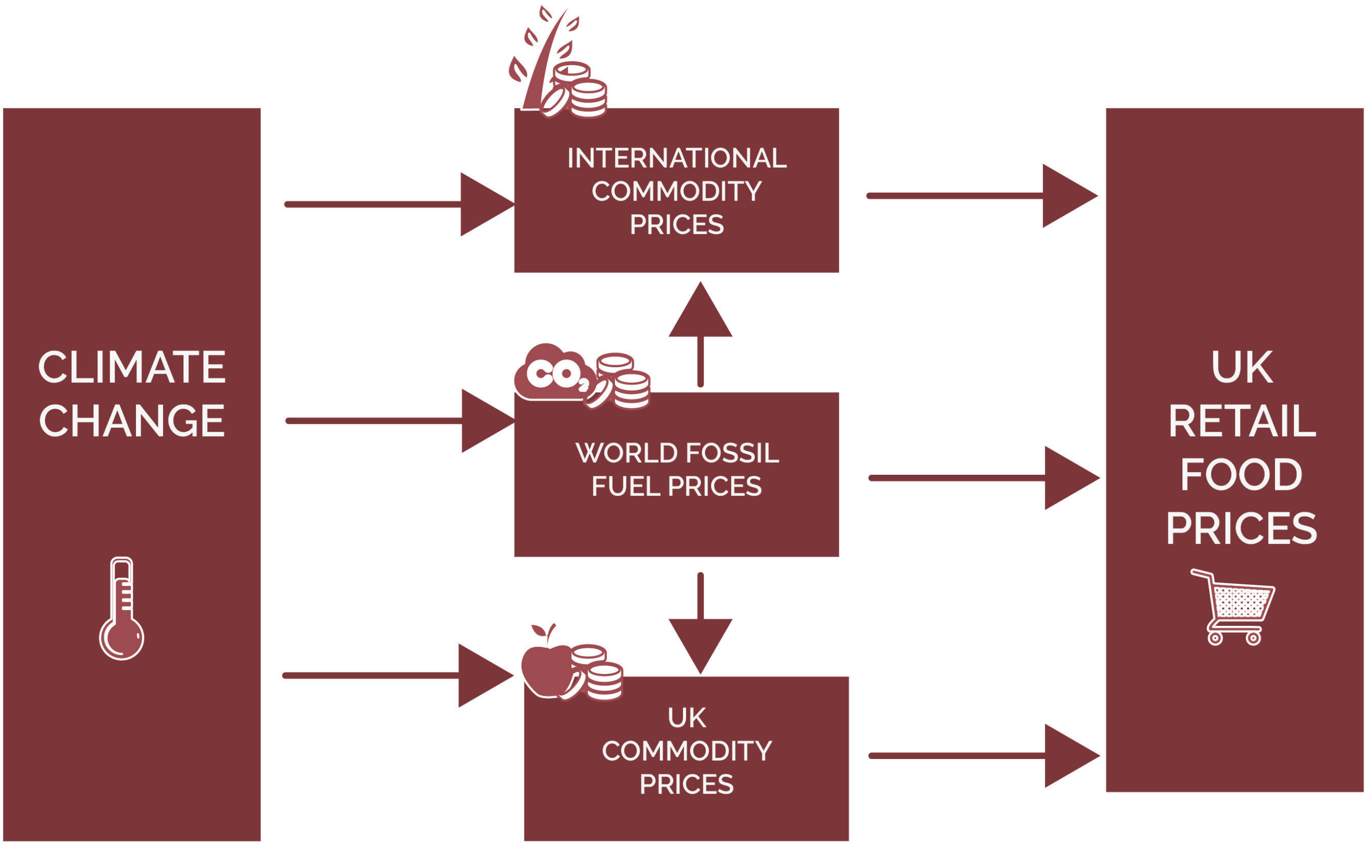
- international commodity prices
- domestic prices of farm products and
- the price of energy.

The transmission pathways are sketched in Figure A1. Each of the arrows represents a path of transmission. The mechanisms underlying the quantitative impacts are briefly set out below.

To begin, we use the global land-ocean temperature index produced by the National Oceanic and Atmospheric Administration in the US, as our global indicator of climate change. These data measure the difference in annual average global temperatures from a (1951-80) baseline and thus capture both the rising trend in global temperature and annual anomalies (i.e. extremes of temperature).

As discussed in the main text, global warming and the extreme weather events that are associated with it, cause supply disruption, yield variability and thus higher prices on both world and domestic agricultural markets (Faccia et al., 2021). In turn, these higher commodity prices feed into the price of retail food as shown by the horizontal arrows in the figure. Applying these temperature shocks to the El Niño estimates of Cashin et al. (2017) delivers the effects of climate shocks on world and domestic prices; we have assumed these shocks are the same. Cashin et al., 2017 also finds a statistically significant link between climate change and the demand for energy as, for example, farmers increase their use of irrigation and mechanisation, while at the same time more refrigeration and air conditioning is needed. The effects compound the demand for fossil fuels to replace hydroelectricity. To reflect this additional channel of transmission, there are arrows leading from climate change to fossil fuel prices.

Appendix Figure A1: The Transmission of Global Weather Shocks on UK Retail Food Prices



To assess the effect of these factors on UK retail food prices, we employ the coefficients provided in Davidson et al. (2021) which measure the effects of world commodity prices, domestic commodity prices and manufacturing input costs. Three features are noteworthy here. First, international prices are adjusted to reflect UK dependency on imports; Second; international price shocks are fully reflected in domestic prices; third energy prices are adjusted to reflect their importance in manufacturing input costs using estimates reported in Green and Zhang (2013).

Combining the effects, we find that for every 0.2˚C increase in annual average global temperature, UK consumer retail prices increase by one percentage point, approximately 80% of which is due to changes in agricultural (world and national) prices, and 20% due to the indirect effect of higher energy prices.

Energy Shocks

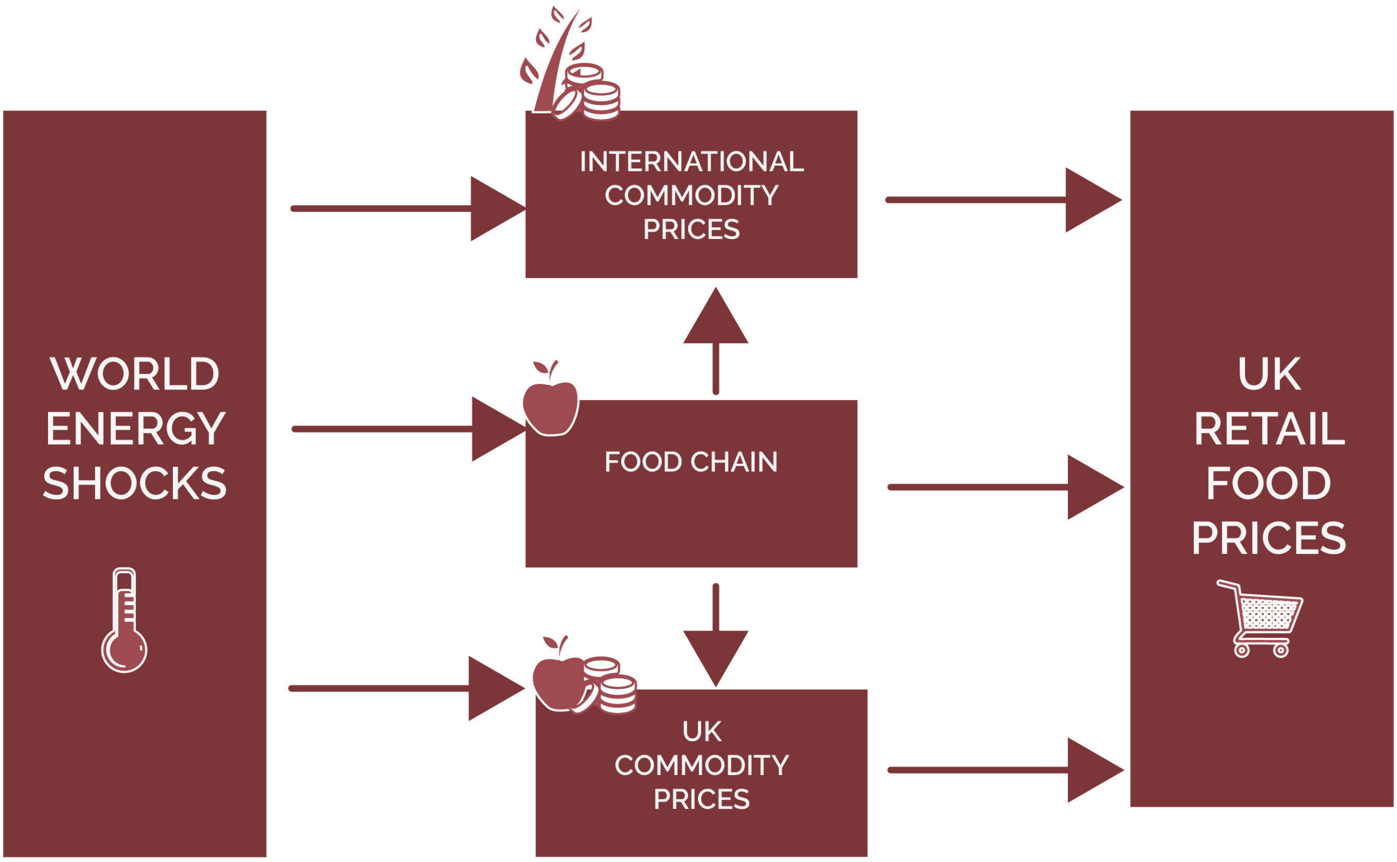
We use the Energy Price Index produced by the International Monetary Fund, as our measure of energy shocks. This index is broadly based, including the price of crude oil, coal and propane gas traded on world markets.

Being an important input into agricultural production for fuel and fertiliser, the price of oil and gas affects the prices of all commercially grown commodities as well as affecting costs throughout the food chain, owing to the energy intensive nature of activities such as processing, distribution and retailing of food (Baffes, 2009). High oil prices may also divert biofuel feedstocks from food supply adding upward pressure to food prices (Taghizadeh-Hesary et al., 2019) and strengthening the link between food and fuel markets.

As set out in Figure A2, the transmission channels for international energy shocks into UK food prices are via:

- international commodity markets
- food chain (processing, distribution and retailing)
- UK agricultural sector

Appendix Figure A2: The Transmission of Global Weather Shocks on UK Retail Food Prices



To quantify the effect of energy price shocks on UK food prices we first assess the impact of energy prices on agricultural prices. To do this we use the World Bank estimate calculated by Baffes (2007) which we apply to both international and UK commodity prices. These effects are then fed into the coefficients estimated by Davidson et al. (2021) reported above to quantify the effect of energy shocks arising from agriculture on consumer food prices.

As energy is an important cost in the food chain, which itself affects the price of food purchased by consumers, we apply the IMF energy prices changes to the coefficient estimated by Davidson et al. (2021) taking into account the importance of energy in manufacturing costs (Green and Zhang 2013).

Combining these effects, we find that a 10% increase in world fossil fuel prices is associated with a 0.7 percentage point increase in retail food prices, approximately 80% of which is due to the effects in agriculture, via competition with biofuels and higher input costs and the remaining 20% due to higher food chain costs.