Principal Asset Management℠

Advancing food security in a connected climate crisis: Implications and actions for global investors

In the face of worsening climate change, how can global investors help mitigate against the impact of greater food insecurity on economic output, labor productivity, and inflation? Analysis from Principal Asset Management℠ assesses the impact of different climate change scenarios on economic performance, in association with the Centre for Economics and Business Research (Cebr).

Introduction

KAMAL BHATIA
Global head of investments
Principal Asset Management℠

As a company focused on building a more financially inclusive and resilient society, we recognize the significant and complex challenges that climate change creates for individuals, communities, and governments globally. Rising temperatures and greater weather volatility impact how we live, eat, and work—and most aspects of our connected global economy.

One of the most pressing challenges is the significant impact of climate change on agriculture and the world's ability to feed and sustain itself. And we recognize this as a critical area of focus for investment to develop more sustainable and climate-resilient systems. Managing food security is critical given its historical linkages to social unrest, conflict, and warfare globally.

While much has been written on the impact of rising food insecurity, this research focuses on one specific aspect of the issue—namely, how different climate change scenarios, and the resultant impact on global food production, could affect economic performance.

In partnership with the Centre for Economics and Business Research (Cebr), we have leveraged publicly available literature and research to explore and extrapolate the potential impacts of rising global temperatures on agricultural yields, and considered how this could affect economic output, labor productivity, and inflation, for 121 markets across the world.

Rising temperatures mean lower human productivity and a higher cost of living for many.

The findings, whilst not surprising, are still shocking. The greater the extent by which the world misses the Paris Agreement targets of 1.5 degrees Celsius by 2050, the more expensive the cost of living and the less productive global economies become.

As global warming increases, we see that agricultural yields fall exponentially. These falling crop yields have a profound impact on food security which, in turn, has significant implications for global productivity (measured in terms of gross domestic product (GDP) per capita and labor productivity) and on inflation—both in food prices and at a headline level.

Leading to increased food insecurity in an interconnected world.

Climate change affects agriculture and food production in a variety of ways. It impacts food production directly, by altering agro-ecological conditions, and indirectly, by influencing the growth and distribution of incomes, consequently affecting the demand for agricultural products.

Equally, climate change leads to higher temperatures, increased concentrations of carbon dioxide in the atmosphere, and shifts in regional precipitation patterns. Collectively, these agro-ecological factors directly affect crop yields and agriculture productivity, thereby having considerable knock-on effects for food production of key staples and commodities.

The effects of climate change on the food system go far beyond agricultural yields.

This report's baseline analysis concentrates on only a small portion of the impact of rising temperatures on the food system. When potential second order effects are taken into consideration, the impact of climate change on economic resilience may be further compounded. These effects could include higher agricultural input costs, water availability, reskilling workforces, disrupted supply chains, squeezed labor markets, civil unrest, and mass migration. All of which would be further detrimental to productivity and the cost of living for local populations, especially in the most densely populated areas of the world.

Lower emitting, developing markets appear to bear greater burden of this key climate dynamic.

While assessing the economic impacts of climate change is a nuanced exercise with multiple variables around both the degree of future global warming and its subsequent impact on global activity, there will be costs as the planet warms with the effects seeming to disproportionally fall on developing nations.

The research shows that countries most affected by rising prices tend to be in the lowest emitting markets in the global south. Notably, regions in the Northern Hemisphere and regions with a larger concentration of developed economies (predominantly Europe and North America) see relatively smaller impacts compared to regions in the Southern Hemisphere and regions with higher concentrations of developing economies (Africa and Latin America).

Greater food insecurity increases the risk of political unrest and increased migration of resources.

If history is any indicator, it is important to be mindful of how increased food scarcity can impact the political stability of countries with less economic means, and in turn, neighboring countries and regions.

Lower agricultural output and higher food prices may drive more people to migrate away from rural areas to towns and cities – building on a trend of urbanization that is already common across many emerging markets. As these impacts become more pronounced over time, this could lead to the migration of populations to different countries altogether as they seek more consistent access to a stable food supply.

The impact on developed markets.

While this analysis indicates that emerging markets will be disproportionately impacted, the effects of climate change are likely to be far-reaching beyond their borders. Globalization, complex supply chains, and mobile populations mean that a failure to improve financial and economic conditions in those economies most impacted by rising temperatures can have dramatic effects in developed markets.

CONSIDERATIONS FOR GLOBAL INVESTORS

Debt capital markets may require higher risk premia for providing sustainable capital

- Any +2- degree scenario—where temperatures rise, agricultural crop yields decline, inflation rises and GDP falls—could have significant impact on markets and economies, particularly regarding the nominal cost of borrowing.
- Under higher climatic conditions, we would expect to see increased bond issuance from both sovereign and corporate entities across the most impacted markets, as governments and companies are required to raise capital to fund investment into adaptation technologies and infrastructure. However, lower productivity and higher costs come with increased risk to investors in the form of higher downgrade and default risk.
- As such, this could lead to financial markets pricing in wider spreads and therefore a higher cost of funding—and therefore higher yields—for those markets in warmer climates looking to raise capital by issuing debt.

Global investors are able to influence not only the pace of global warming, but also to help mitigate its effects on food production.

- One way to help alleviate the negative impacts of climate change on food security is through investment in innovative solutions and technologies which help agricultural production to be more resilient in the face of a rising temperatures.
- A key component of this involves increasing the flow of capital from north to south by investing to combat climate change, particularly in the most vulnerable regions of the world.
- For global investors, companies that can generate value from helping solve the world's sustainability challenges, including helping to mitigate the GDP impact of falling food security, and should be considered for their long-term investment prospects.
- This will be a large and long-term trend towards 2050 as, globally, we must work out how we can feed 10 billion people with a lower environmental impact.

Executive summary

Our research suggests that, on a global scale, the transition from moderate to extreme climate scenarios[1], exhibits a progressive decline in GDP and non-agricultural labor productivity, while simultaneously exhibiting a gradual increase in food price inflation and headline inflation. Degrees below are measured in Celsius.

GDP impacts

In a scenario whereby global temperatures rise by two degrees Celsius compared to the +1.5-degree target, we estimate that global GDP per capita declines by -0.8%. In a +3-degree rise scenario, it declines by 1.6%.

- In Latin America, GDP per capita is expected to fall by -14.9% in a +2-degree scenario, and -23.7% in a +3-degree scenario, with Mexico the worst impacted economy out of those analyzed.
- In Africa, it is expected to fall by -12.3% in a +2-degree scenario, and by nearly -20% in a +3-degree scenario, with Ethiopia the worst affected economy out of those analyzed.

Labor productivity

The decline in labor productivity mirrors the decline in GDP per capita. At a global level, non-agricultural labor productivity falls by -0.5% and -1% under +2- and +3- degree scenarios respectively.

- Africa and Latin America face the most significant challenges, with non-agricultural labor productivity dropping by -7.8% and -9.5%, respectively under a +2-degree scenario, and -12.6% and -15.1% if temperatures rise by three degrees.
- Again, Mexico and Ethiopia are the most negatively affected economies under both temperature scenarios out of the markets analyzed.

+3-DEGREE SCENARIO:

- **1.6%** decline in global GDP per capita
- **1%** decline in global labor productivity
- **$72 USD** increase in price of food costing $1,000 USD today in Latin America

Inflation

In a scenario where temperatures rise by two degrees, global headline inflation is expected to be +0.03 percentage points higher than current 2050 estimates—reaching 4.33% rather than current baseline expectations of 4.3%. In a +3-degree scenario, it is expected to be 4.36%.

- Food price inflation globally is estimated to be 6.17% and 6.31%, rather than current 2050 expectations of 6%, under a +2- and +3-degree scenario respectively.
- To put these climate change-related inflationary increases into context, a basket of goods in Latin America that would cost $1,000 USD in a world which does not experience further global warming would cost $1,010 in a scenario where global warming rises by two degrees, and $1,018 in a scenario where global warming rises by three degrees.
- In the same region, food that would cost $1,000 USD in a world which does not experience further global warming would cost $1,039 in a scenario where global warming rises by two degrees, and $1,072 in a scenario where global warming rises by three degrees.

[1] On a global scale, the transition from moderate to extreme scenarios is exemplified by a global temperature increase from 1°C to 5°C, across 1-degree increments.

The impact of heightened food insecurity on economic output

The greater the extent by which the world misses the Paris climate targets of 1.5 degrees Celsius, the more global crop yields are predicted to decline. Such a fall has a notable knock-on effect on GDP according to Cebr analysis. The hit to economic output is not felt equally across the globe—markets in warmer climates see significantly greater declines than those in cooler climates.

Furthermore, this analysis only assesses the hit to GDP as a result of changes to crop yields. The impact of increasing temperatures and declining agricultural crop yields on metrics such as GDP will likely only be magnified once second order effects are taken into consideration. These knock-on effects across the agricultural sector would be negative for global activity overall.

The research suggests that the damage to crop yields becomes progressively worse with each successive rise in the average temperature.

In a scenario whereby global temperatures rise by two degrees compared to the 1.5-degree target, we estimate that global GDP per capita declines by -0.8%. In a +3-degree scenario, it declines by -1.6%.

The impact of declining crop yields on economic output due to rising temperatures is not experienced equally across the globe. Regional discrepancies are large, and a clear north-south divide emerges.

Regionally, the most extreme negative impact is felt in Latin America. GDP per capita in this region is expected to fall by -14.9% in a +2-degree scenario, and -23.7% in a +3-degree scenario.

In this region, out of all markets analyzed, the most negatively impacted market is Mexico which experiences an estimated -23.5% and -37.5% fall under a +2- and +3-degree scenario respectively.

Similarly, output across Africa is expected to fall by -12.3% in a +2-degree scenario, and by almost -20% in a +3-degree scenario.

In this region, out of all markets analyzed, the most negatively impacted market is Ethiopia which experiences an estimated -18.5% and -30.4% fall under a +2- and +3-degree scenario respectively.

Regions with cooler climates today could initially see an increase in crop yields, and in associated economic output, as temperatures begin to rise.

In Europe, North America, and parts of Asia, the initial increase is attributable to the fact that most of these economies are in the Northern Hemisphere. Warmer temperatures in these regions have the potential to prolong growing seasons and enhance crop diversity.

Notably, these areas exhibit a higher concentration of developed economies in comparison to other regions. While this does not inherently make them less susceptible to climate change, their substantial resources and subsequently enhanced adaptive capabilities enable greater investment in climate-resilient agriculture. This is likely another reason as to why we see an estimated increase in GDP per capita ranging from +0.4% to +0.8% across the +2- and +3-degree scenarios for these regions.

Even within these regions, which appear to show positive output trends, notable discrepancies emerge on a market-by-market basis.

Europe's average GDP per capita increase of +0.4% under a +2-degree scenario is dragged upwards by large rises in crop yields in countries such as Finland (+1.2%), Norway (+0.8%), and Sweden (+0.7%), which have historically not had a climate conducive to an agricultural economy.

By contrast, markets in Southern Europe in particular, which are some of the biggest food and beverage producers across the continent, would experience much steeper declines in crop yield and productivity under hotter climates.

For example, Turkey (-3.2%), Greece (-1.9%), Spain (-1.2%) and Italy (-1.0%) are predicted to experience some of the largest GDP falls of all markets analyzed under a +2-degree scenario. Under a +3-degree scenario, the impact is even greater.

Key insight

KAMAL BHATIA
Global head of investments
Principal Asset Management℠

"It is important to note that our analysis highlights a clear baseline relationship between higher temperatures and wider economic metrics. The estimated GDP per capita declines or increases outlined in this research are attributable only to the change in anticipated crop yields under various climate scenarios. It would be reasonable to expect that, under increasing temperatures, there would be significant knock-on effects which would create perpetual negative global activity feedback vortex.

For example, even if warmer temperatures enabled greater crop yields in Scandinavia, being able to take advantage of this and reap the potential benefits would require reskilling the workforce, establishing the supply chain, and investing to effectively establish an entirely new industrial infrastructure with limited population flexibility.

Therefore GDP per capita growth connected to higher agricultural output is likely to be a 'false positive'; when various impacts of higher temperatures on economic output are assessed in aggregate—of which crop yields are only one—the overall impact on economic output across the globe would be much more extreme and far more negative than we highlight here."

Effect of change in agricultural crop yield on GDP per capita under different climate change scenarios

	Change in GDP per capita				
	+1°C	+2°C	+3°C	+4°C	+5°C
World	-0.2%	-0.8%	-1.6%	-2.8%	-4.4%
Africa	-5.7%	-12.3%	-19.8%	-28.1%	-37.3%
Asia	0.7%	0.5%	-0.1%	-1.3%	-3.2%
Europe	0.2%	0.4%	0.6%	0.3%	0.1%
North America	0.2%	0.5%	0.8%	1.2%	1.6%
Latin America	-7.0%	-14.9%	-23.7%	-33.4%	-44.5%
Oceania	-0.5%	-1.0%	-2.8%	-4.1%	-5.5%
Caribbean	-2.1%	-4.3%	-6.7%	-9.3%	-12.1%

Effect of change in agricultural crop yield on GDP per capita, top 10 negatively impacted economies

Economy	Impact on GDP under a +2-degree climate scenario	Impact on GDP under a +3-degree climate scenario
Mexico	-23.5%	-37.5%
Peru	-21.9%	-35.0%
Colombia	-19.8%	-30.9%
Indonesia	-19.6%	-30.4%
Dominican Republic	-18.9%	-29.5%
Ethiopia	-18.5%	-30.4%
Egypt	-16.5%	-26.0%
Kenya	-16.5%	-25.7%
Costa Rica	-16.2%	-25.1%

The impact of heightened food insecurity on labor productivity

Changing agricultural crop yields because of rising temperatures also impacts non-agricultural labor productivity, particularly the impact of heat stress arising from elevated temperature and humidity. This stress encompasses more frequent work pauses, interruptions, reduced pace, and an elevated risk of injuries, consequently decreasing productivity.

As seen in the GDP per capita analysis, the effects become more pronounced as temperature levels increase, with developing economies in warmer climates disproportionately impacted.

- The decline in labor productivity mirrors the decline in GDP per capita. At a global level, non-agricultural labor productivity falls by -0.5% and -1.0% under +2- and +3- degree scenarios respectively.
- As with GDP, developing economies in warmer climates are disproportionately impacted. Africa and Latin America face the most significant challenges, with non-agricultural labor productivity dropping by -7.8% and -9.5%, respectively under a +2-degree scenario, and -12.6% and -15.1% if temperatures rise by three degrees. By contrast, regions such as Europe and North America experience relatively milder declines.
- Mexico (-14.9% under a +2-degree increase and -23.9% under a +3-degree increase) and Ethiopia (-11.8% under a +2-degree increase and -19.4% under a +3-degree increase) are the most negatively affected economies in their respective regions under both temperature scenarios.
- Even in Europe which, on a regional basis, experiences minor increases in labor productivity under each climate scenario analyzed, sees notable discrepancies on a market-by-market basis. Large European economies such as Spain and Italy see declines of -0.8% and -0.6% respectively if temperatures rise two degrees, and -1.2% and -1.0% for a +3-degree increase.

Key insight

PUSHPIN SINGH
Senior economist at the Centre for Economic and Business Research

"These findings underscore the urgent need for climate mitigation and adaptation strategies, especially in vulnerable regions, to safeguard both agricultural and non-agricultural sectors from the adverse impacts of climate change. Given the consequences highlighted in our analysis, the need for action is indisputable. Co-ordinated measures by the world's largest carbon emitters are crucial to meet climate targets. The public and private sectors will play an instrumental role in accelerating climate action to remain below a 2°C temperature increase."

Effect of change in agricultural crop yield on non-agricultural labor productivity under different climate change scenarios, by region

	Change in non-agricultural labor productivity per capita				
	+1°C	+2°C	+3°C	+4°C	+5°C
World	-0.1%	-0.5%	-1.0%	-1.8%	-2.8%
Africa	-3.6%	-7.8%	-12.6%	-17.9%	-23.8%
Asia	0.4%	0.3%	-0.1%	-0.8%	-2.0%
Europe	0.1%	0.2%	0.4%	0.2%	0.1%
North America	0.1%	0.3%	0.5%	0.8%	1.0%
Latin America	-4.5%	-9.5%	-15.1%	-21.2%	-28.3%
Oceania	-0.3%	-0.6%	-1.8%	-2.6%	-3.5%
Caribbean	-1.3%	-2.7%	-4.3%	-5.9%	-7.7%

Effect of change in agricultural crop yield on non-agricultural labor productivity, top 10 negatively impacted economies

Economy	Impact on non-agricultural labor productivity under a +2-degree climate scenario	Impact on non-agricultural labor productivity under a +3-degree climate scenario
Mexico	-14.9%	-23.9%
Peru	-14.0%	-22.2%
Colombia	-12.6%	-19.7%
Indonesia	-12.5%	-19.4%
Dominican Republic	-12.1%	-18.8%
Ethiopia	-11.8%	-19.4%
Egypt	-10.5%	-16.5%
Kenya	-10.5%	-16.4%
Costa Rica	-10.3%	-16.0%
Honduras	-10.0%	-15.6%

The impact of heightened food insecurity on inflation

The impact of higher temperatures on agricultural yields is inflationary across the globe, according to this analysis. The greater the extent by which the Paris climate targets are missed, the greater the extent to which the cost of goods and services rises, with the most pronounced increases felt in food prices.

As with productivity and labor activity, the inflationary impact of climate change is felt most acutely in warmer climates and especially in the world's most food-insecure regions, where higher prices for goods, services and food could increase the already high number of people living below the international poverty line.

In a scenario where temperatures rise by two degrees, global headline inflation is expected to be +0.03 percentage points higher than current 2050 estimates—reaching 4.33% rather than current baseline expectations of 4.3%.

- In a +3-degree scenario, it is expected to be 4.36%.
- Food price inflation is estimated to be 6.17% and 6.31%, rather than current 2050 expectations of 6%, under a +2- and +3-degree scenario respectively.

Across developed markets, the impact of climate change on food inflation, though lesser than in developing markets, is still stark.

- Under a +3-degree scenario, $1,000 of food would cost $1,020 in the United Kingdom, $1,026 in Germany, and $1,021 in France.

As with productivity and labor activity, the inflationary impact of climate change is felt unequally across the world. Latin America is one of the most impacted regions.

- A +2-degree increase in headline inflation is anticipated to add +0.07 percentage points on top of a baseline expectation of 6.6% and add +0.12 percentage points in a +3-degree scenario.
- Food price inflation would be +0.54 percentage points higher (to 14.2%) or +0.98 percentage points higher (to 14.7%) under a +2- and +3-degree scenario respectively.
- To put these climate change-related inflationary increases into context, a basket of goods in Latin America that would cost $1,000 USD in a world which does not experience further global warming would cost $1,010 in a scenario where global warming rises by two degrees, and $1,018 in a scenario where global warming rises by three degrees.
- In the same region, food that would cost $1,000 USD in a world which does not experience further global warming would cost $1,039 in a scenario where global warming rises by two degrees, and $1,072 in a scenario where global warming rises by three degrees.

A similar pattern emerges in Africa.

- In a +2-degree scenario, headline inflation is expected to be +0.07 percentage points higher due to climate change—reaching 5.47% rather than current baseline inflation estimations of 5.4%.
- Under a +3-degree scenario, headline inflation in the region is poised to rise by +0.13 percentage points from current estimations to 5.53%.
- Food price inflation is expected to increase by +0.23 and +0.43 percentage points under a +2 and +3-degree scenario respectively. This would take food price inflation to 6.83% and 7.03%, up from current estimations of 6.6%.
- In context, the model shows that a basket of goods in Africa worth $1,000 USD in a world which does not experience further global warming would cost $1,013 in a scenario where global warming rises by two degrees, and $1,023 in a scenario where global warming rises by three degrees.
- In the same region, food worth $1,000 USD in a world which does not experience further global warming would cost $1,035 in a scenario where global warming rises by two degrees, and $1,065 in a scenario where global warming rises by three degrees.

The economies which see the highest increase in food prices from a $1,000 USD level today under a +2-degree scenario are all in Africa.

- They are: Central African Republic ($1,180), Kenya ($1,096), South Africa ($1,086), Cameroon ($1,073), and Côte D'Ivoire ($1,052).
- In Latin America, the economies which see the highest increase in food prices from a $1,000 level today under a +2-degree scenario are Bolivia ($1,046), Venezuela ($1,045), Argentina ($1,044), Chile ($1,042) and Brazil ($1,040).

To provide some sense of the impact of higher food costs, note that, in Latin America and the Caribbean today, 4.3% of the population—or 28 million people—live below the international poverty line of $2.15 per day. In Sub-Saharan Africa, this rises to 34.9%—or 391 million people.[2]

Additionally, Latin America and the Caribbean will account for 25% of global agricultural and fishery exports by 2028, highlighting how climate-related food price inflation will have a significant impact on international food prices, according to the Food and Agriculture Organization.[3]

The analysis highlights the relationship between food insecurity and economic resilience, and these findings are consistent with wider research. African countries populate the bottom order of the Notre Dame Global Adaptation Index rankings for food vulnerability, underscoring the disproportionately larger exposure to changes in agricultural yield due to climate change amongst these economies.[4]

Key insight

SEEMA SHAH
Chief global strategist
Principal Asset Management℠

"The repercussions stemming from decreased food supplies, attributed to the effects of climate change and rising temperatures, extend beyond drops in output and productivity. As populations contend for food resources that are expected to become relatively scarcer amidst rising temperatures, price rises ensue, subsequently exacerbating inflationary pressures.

A similar phenomenon was seen with energy commodities in the wake of the Russian invasion of Ukraine, leading to a surge in energy prices and thereby placing significant upward pressure on headline inflation globally. The impact of climate change on food prices, and subsequently inflation, has also become increasingly evident in recent years.

Furthermore, while these aggregated inflation numbers are arresting enough by themselves, the inevitable year-on-year fluctuations in crop yields are likely to send frequent shocks through the global food system. This is likely to be particularly pertinent in Africa where smaller farmers are often fully dependent upon natural rainfall for their crops. In any severe climate scenario, natural rainfall becomes more unpredictable, as warmer air holds more water, which in turn means that rain falls less frequently, but it comes with greater force and thus higher risk of flooding. In our view, food inflation will not be linear but could be subject to unpredictable swings."

Anticipated increase in headline inflation under various climate scenarios

	Headline Inflation: Percentage point increase from current estimations				
	+1°C	+2°C	+3°C	+4°C	+5°C
World	0.01	0.03	0.06	0.10	0.14
Africa	0.03	0.07	0.13	0.20	0.28
Asia	0.01	0.02	0.03	0.05	0.07
Europe	0.00	0.01	0.02	0.04	0.05
North America	0.00	0.00	0.01	0.01	0.02
Latin America	0.03	0.07	0.12	0.19	0.28
Oceania	0.00	0.01	0.01	0.02	0.03
Caribbean	0.00	0.01	0.02	0.04	0.05

	Headline cost increase based on $1,000 basket of goods				
	+1°C	+2°C	+3°C	+4°C	+5°C
World	$1,003	$1,008	$1,014	$1,023	$1,033
Africa	$1,005	$1,013	$1,023	$1,037	$1,053
Asia	$1,002	$1,004	$1,008	$1,012	$1,018
Europe	$1,001	$1,004	$1,007	$1,011	$1,016
North America	$1,001	$1,002	$1,004	$1,006	$1,009
Latin America	$1,004	$1,010	$1,018	$1,029	$1,042
Oceania	$1,001	$1,003	$1,005	$1,008	$1,011
Caribbean	$1,002	$1,004	$1,008	$1,012	$1,018

[2] World Bank: March 2023 Update to the Poverty and Inequality Platform (PIP)
[3] Food and Agriculture Organization Regional Office for Latin America and the Caribbean
[4] Notre Dame Global Adaptation Initiative

Anticipated increase in food price inflation under various climate scenarios

Food price inflation: Percentage point increase from current estimations					
	+1°C	+2°C	+3°C	+4°C	+5°C
World	0.07	0.17	0.31	0.49	0.71
Africa	0.09	0.23	0.43	0.67	0.97
Asia	0.02	0.06	0.11	0.17	0.25
Europe	0.02	0.05	0.09	0.14	0.20
North America	0.02	0.06	0.10	0.16	0.24
Latin America	0.21	0.54	0.98	1.55	2.24
Oceania	0.03	0.07	0.12	0.19	0.28
Caribbean	0.04	0.11	0.20	0.32	0.46

Food cost increase based on $1,000					
	+1°C	+2°C	+3°C	+4°C	+5°C
World	$1,011	$1,028	$1,052	$1,082	$1,118
Africa	$1,014	$1,035	$1,065	$1,102	$1,148
Asia	$1,005	$1,013	$1,024	$1,038	$1,055
Europe	$1,006	$1,015	$1,027	$1,043	$1,061
North America	$1,009	$1,024	$1,043	$1,068	$1,099
Latin America	$1,015	$1,039	$1,072	$1,114	$1,164
Oceania	$1,008	$1,020	$1,036	$1,057	$1,082
Caribbean	$1,005	$1,014	$1,025	$1,040	$1,057

Analyzing the effects of declining crop yield on agricultural economies

Extreme climatic conditions pose higher threats to global food security in agricultural economies which are net-exporters of crops. Reduction in agricultural productivity as a result of higher temperatures not only disrupts the food supply chain, and therefore food security, of these economies, but also has a ripple effect onto those countries to which they export food commodities.

Below we outline how select agricultural economies have responded to the impact of heightened food insecurity.

India and protectionism

According to the Food and Agriculture Organization of the United Nations, India exported $9.62 billion of rice in 2020.[5] However, recent events have highlighted the risk that food security issues, led by climate change, can lead to greater protectionism, which is, in turn, inflationary.

India's 2023 rice export bans saw rice prices in other exporting countries including Thailand and Vietnam increase by around 20%.[6] Protectionism forces impacted Asian countries to secure more food supply to help ensure social stability, which further exacerbates geopolitical tensions.

Our data suggests:

- In a scenario where global temperatures rise by two degrees, we estimate that India's GDP per capita declines by -9.8%. In a +3-degree rise scenario, it declines by -15.3%.
- Under a +2-degree scenario, labor productivity in India declines by -6.2% and by -9.8% under a +3-degree scenario, according to the model.
- In terms of food price inflation, a basket of food in India worth $1,000 USD in a world which does not experience further global warming would cost $1,020 in a scenario where global warming rises by two degrees, and $1,037 in a scenario where global warming rises by three degrees.

Malaysia and fiscal impacts

Asian agricultural economies whose governments intervene in the food markets are also exposed to inflationary risks and fiscal impacts under higher temperature scenarios. For example, Malaysia maintains one of the most regulated rice markets in the world and has subsidies to help reduce inflationary impact of rising food prices. The government is expected to roll back some of these subsidies which could have an impact on weaker growth and higher inflation.

Additionally, weaker growth and higher inflation is likely to have a compound effect in those markets that are already experiencing a lot of fiscal stress coming out of the pandemic.

Our data suggests:

- In a scenario where global temperatures rise by two degrees, we estimate that Malaysia's GDP per capita declines by -11.5%. In a +3-degree scenario, it declines by -17.9%.
- Under a +2-degree scenario, labor productivity in Malaysia declines by -7.3% and by -11.4% under a +3-degree scenario, according to our model.
- In terms of food price inflation, a basket of food in Malaysia which would cost $1,000 USD in a world which does not experience further global warming would cost $1,017 in a scenario where global warming rises by two degrees, and $1,032 in a scenario where global warming rises by three degrees.

[5] Food and Agriculture Organization of the United Nations - Major Commodities Exporters
[6] Reuters: Global rice supplies tighten after India's July export ban (August 31st, 2023)

Brazil, public policy, and development of financial instruments

By contrast, in recent years Brazil has set out a number of policies that seek to reconcile environmental conservation and sustainable agricultural production, such as the 2012 Brazilian Forest Code.

In 2020, the Ministry of Agriculture, Livestock and Food Supply (MAPA) has outlined its three-year plan, which aimed to make Brazilian agriculture more sustainable, efficient, and competitive. This included, amongst other measures, "advancing research and dissemination of tropical agriculture technologies that ensure agricultural productivity increases that are aligned with environmental preservation" and "structuring new financial instruments that maximize funds to finance sustainable production models and improve alignment among existing public policies."[7]

It could be said that the culmination of these policies and commitments came in May 2023, when Brazil's President Lula signed a joint declaration on food security at the G7 summit.

As such, Brazil may be better positioned than many other Latin American economies, not least because of the strength of its agricultural technology and renewable energy industries which have already attracted significant investment.

Our data suggests:

- In a scenario where global temperatures rise by two degrees, we estimate that Brazil's GDP per capita declines by -14.7%. In a +3-degree scenario, it declines by -22.8%.
- Under a +2-degree scenario, labor productivity in Brazil declines by -9.3% and by -14.5% under a +3-degree scenario, according to our model.
- In terms of food price inflation, a basket of food in Brazil which would cost $1,000 USD in a world which does not experience further global warming would cost $1,040 in a scenario where global warming rises by two degrees, and $1,074 in a scenario where global warming rises by three degrees.

[7] Guidelines for the sustainable development of Brazilian agriculture - MAPA (January 2020)

Implications and actions for global investors

Global allocators of capital need to invest now to help mitigate these challenges. We see this as a critical moment for action, without which investors may face the value of their investments eroded over time due to higher costs, lower output, and exponentially exogenous risks.

From an investor perspective, allocating capital to globalized companies whose business interests—either through near-shoring or global operations—are clearly aligned to helping emerging markets develop climate mitigation solutions is an important consideration.

Equally, the companies that can deliver effective solutions to these climate challenges should be in an advantageous position to create value. We outline some examples below.

Digitalization of agriculture

We see opportunities in innovative solutions that enable increased food production with a lower environmental impact.

One of the most exciting prospects within sustainable agriculture is the application of technology to increase efficiency of farming practices. Agriculture remains one of the least digitalized industries, however, over the past decade, this has started to change with the application of cutting-edge technologies that enable much better-informed decisions and efficiency.

For example, vision technology, combined with artificial intelligence and machine learning, eliminates the need for broadcast herbicide spraying uniformly across an entire field by distinguishing within 200 milliseconds (or the blink of an eye) between a viable corn or soybean plant, for example, and a weed, and then only applying a precision application of herbicide to the intended target. The benefit to the farmer is a massive reduction in herbicide usage and input costs by up to 70 or 80%, while maintaining 100% weed control[8], which is good for profitability, yields and the environment.

Eliminating food waste

In order to feed the world sustainably, it is important to both conserve resources and practice sustainable methods of farming. Reducing food waste is an essential part of this process.

The food waste challenge is different in developed and developing countries. In developed countries, the challenge ultimately comes down to buying too much and throwing too much away.

However, in developing countries, much of the challenge stems from insufficient levels of refrigeration, minimal availability of farming technology, and poorer farmers being forced to harvest early due to lack of food and money. The opportunities from expanding the availability of farming technology and refrigeration to developing countries, are significant.

Artificial intelligence

Artificial intelligence (AI) and machine learning are already having an impact in sectors such as manufacturing and biotechnology, but they are yet to be adopted on a grand scale in agriculture. That dynamic is likely to change in the future, and as it does, the potential positive impact is immense.

For example, a promising opportunity is the use of drones to continuously monitor plants in the fields, including signs of disease or decay. In those cases, AI holds the potential to identify what may be wrong, and then suggest solutions from databases containing best practices from around the world.

Continuous monitoring means that the AI-enabled solutions can evaluate and learn from the effectiveness of the solutions provided to the problem and suggest alternative actions more quickly if needed, which can lead to higher yields and significantly reduced waste due to less spoiled crops.

Overall, the companies that deliver precision agriculture and digitalized solutions will be well positioned for the coming decades. Not only will there be high demand for these solutions that should enable significant revenue growth, but selling software enabled solutions with an outsized positive impact on yields and productivity can also expand financial margins and lower capital intensity.

The combination of higher growth, expanding margins and lower capital intensity positions the leading companies in the industry for decades of potential value creation, while mitigating the potentially catastrophic impact of heightened food insecurity on economic output, labor productivity and inflation.

[8] Ruigrok T, van Henten E, Booij J, van Boheemen K, Kootstra G. Application-specific evaluation of a weed-detection algorithm for plant-specific spraying. Sensors. 2020;20:7262. doi: 10.3390/s20247262.

About the Principal Global Sustainable Food Strategy

The Principal Global Sustainable Food strategy seeks to invest in the companies that deliver solutions and contribute to the transition to a sustainable agricultural and food sector.

The strategy does so, as it sees a large and long-term investment potential for decades to come.

Investment process

The strategy follows a fundamental investment process, grounded in the aim of investing in the companies that contribute to the transition to a sustainable food and agricultural sector.

The strategy operationalizes this through alignment with select UN Sustainable Development Goals (SDGs), and it will specifically focus on SDGs 2, 3, 6, and 12, as these are the ones that underpin a sustainable food transition.

UN Sustainable Development Goals aligned to sustainable food transition

The strategy is expected to utilize a proprietary quantitative SDG tool, that is based on text analytics. The text input for the tool, will include the 169 Targets that underpin the SDGs and the knowledge of the analysts and project managers of the Global Large Cap team, that have more than 20 years of experience on average.

As such, the SDG tool will propose which SDGs the companies have exposure to, which is then validated by the PMs and analysts as part of the investment process.

The strategy targets the most important elements of the transition to sustainable food systems, considering the entire path from farm to table.

Examples of these themes will include increased efficiency in food production, reduction of food waste across the supply food chain, nutrition and healthy living, agricultural science, and water irrigation.

Conclusion

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In the face of a climate crisis, the question of how to balance environmental conservation and sustainable agricultural production is extraordinarily complex.

We must acknowledge that food security and climate change have an intertwined relationship. Climate change affects food security due to changes in the physical environment; but the food system also accounts for a significant part of the carbon budget and has an impact on the pace of climate change.

Nonetheless, while the impact of higher temperatures on productivity and inflation may appear marginal in purely numerical and percentage terms, considered together they can have potentially enormous consequences.

Not only is the world meaningfully more expensive and less productive the worse global warming becomes, but it is important to note that our data only analyses the direct consequences of declining crop yields. It does not incorporate other factors which are inextricably linked – such as higher fertilizer costs, the requirement to reskill workforces, entirely disrupted supply chains, societies and labor markets which are fundamentally reshaped, and the potential for food insecurity to lead to civil unrest, conflict, and mass migration. All of these are detrimental to productivity and standards of living globally.

Furthermore, a warming climate does not merely harm food production but does so in a time where we need to increase food production. The global population is expected to expand from eight billion people today to ten billion by 2050. A 25% increase in population, combined with economic growth leading to a demand for more complex foods, means that food demand will grow by 56% over the same period.

What remains clear is that the world cannot apply the same approach to farming the world and feeding its population in the future as we have done in the past, especially if we simultaneously seek to reach net zero and avoid further biodiversity losses.

The less productive an economy, and the greater the inflationary pressure, the greater the deterrent for capital allocation from global investors to try and solve some of these climate products.

The agricultural and food sector is at the epicenter of the major transitions of the 21st century. While we have the chance to effectively end hunger in the coming decades, the world will not reach net zero CO2, solve the water crisis, or reach a sustainable future, if the agricultural and food sector do not come up with solutions to produce more food with lower environmental impact.

From an investment perspective, the companies that will deliver the future of agricultural innovation will be in an attractive position to deliver value for shareholders and society at the same time for decades to come.

[9] United Nations Environment Programme (UNEP)

Cebr methodology

The impact of heightened food insecurity on GDP per capita and non-agricultural labor

In order to estimate the impacts of food security on economic performance, namely GDP per capita and non-labour productivity, under various climate change scenarios we have employed findings from a study conducted by Roson & Sartori.[10] In this study, climate change damage functions are used which relate variations in temperature to economic impacts.

The first stage in our modelling is to use the climate change impact parameters calculated in the study which look at relative changes in total agricultural yield at a country-by-country level under different climate change scenarios. In our model, the effects from 1°C up to 5°C average temperature increments are separately considered, as most impacts are non-linear. By applying these relative changes to current levels of agricultural crop yield supplied by the Food and Agriculture Organisation of the United Nations (FAOSTAT) we are able to find the absolute change in agricultural yield, by country, under different climate change scenarios.

The second stage in our modelling involves relating the absolute changes calculated above to the estimated impacts on GDP per capita. To do so, we make use of an academic paper by McArthur & McCord which estimated the relationship between the two variables, finding that a '500kg/ha increase in staple yields generates a 14 to 19 percent higher GDP per capita'.[11] This estimate refers to the percentage change in GDP per capita under the different climate change scenarios for the countries included in the paper. It must be noted that this association was calculated based on the 50 countries in the McArthur & McCord study, which means the results of any extrapolation beyond the countries in their sample should be interpreted with care.

To estimate the impact of climate change on the remaining countries which form part of our sample but are not included in the McArthur & McCord study, a total of 71 countries, we considered the share of agriculture, forestry and fishing sector to GDP for each country, as provided by the World Bank. For each country not included in the McArthur & McCord study, we calculated the share of agriculture, forestry and fishing sector output to GDP. We then scaled the average relative change in GDP per capita for the 50-country sample in the McArthur & McCord study based on this variable in order to calculate a GDP per capita change for the remaining countries. The underlying assumption here is that the size of the GDP impact for a given country will be proportional to the size of its agricultural sector.

Following this, we multiplied this ratio by the population weighted average percentage change for the 50-country sample in the McArthur and McCord study for each climate change scenario. This produces the GDP per capita percentage changes for all 121 countries—which considers the contribution of agriculture to the country's total output—in the sample for each of the different climate change scenarios.

To assess the regional and global impacts on GDP per capita arising from the various climate change scenarios, we aggregated the individual country effects observed in our dataset, encompassing a total of 121 countries. This aggregation process enabled us to discern broader patterns and trends in economic performance, shedding light on the intricate interplay between climate change and GDP per capita across diverse geographical regions and on a global scale. The methodology outlined above was also replicated in our examination of the effects of climate change on non-agricultural labour productivity, employing a separate association derived by McArthur & McCord study, which found that a 500kg/ha 'yield boost is associated with approximately 9 to 12 percent higher non-agricultural labour productivity.'

The impact of heightened food insecurity on inflation

The initial phase of our analysis centered around the assessment of the impact of variations in agricultural crop yields on the pricing dynamics of agricultural commodities. Consequently, we once again leveraged the Roson & Sartori study employed as part of our GDP per capita and productivity analysis. This dataset aggregates the country-level effects under different climate change scenarios to produce data points pertaining to changes in agricultural crop yield at the global level.

To ascertain the influence of alterations in worldwide agricultural yields under different climate change scenarios on the aggregate price level, we conducted desk research of existing literature to establish the elasticities linked to various agricultural crops. Notably, Roberts & Schlenker undertook a comprehensive study to discern the demand and supply elasticities governing agricultural commodities on a global level using yield shocks—departures from temporal output-to-area trends predominantly caused by weather fluctuations.[12]

As such, the supply and demand elasticities published as part of their research constitute the foundational framework for gauging the impact of global shifts in agricultural yields on the international pricing of agricultural commodities. While

[10] Estimation of Climate Change Damage Functions for 140 Regions – Roson & Sartori
[11] Fertilizing growth: Agricultural inputs and their effects in economic development – McArthur & McCord
[12] Identifying supply and demand elasticities of agricultural commodities – Roberts & Schlenker

the ramifications of climate-induced changes in agricultural yields primarily represent a supply shock, it remains imperative to acknowledge that such supply modifications inherently translate into non-price determinants that influence demand. Consequently, a shift in supply engenders a corresponding shift in the demand curve. Indeed, Wolf and Fornaro's research explored the dynamics of negative supply shocks, such as energy price shocks, and their consequential effect on depressing output, also known as a scarring effect. These scarring effects, in turn, trigger a negative wealth effect and depresses aggregate demand, while simultaneously exacerbating the inflationary consequences of the original supply shock.

For instance, the global supply shock induced by the Russian invasion of Ukraine resulted in elevated energy commodity prices. In response to increased energy costs and the resultant negative wealth effect associated with higher energy bills, consumers curtailed their energy consumption, leading to a decline in aggregate demand. This phenomenon is exemplified by Ofgem's downward revision of energy usage for the typical household in the UK recently, a direct consequence of the heightened energy prices reducing demand for energy.

To account for such dynamics, we incorporated both demand and supply elasticities to holistically encapsulate the multifaceted impact of evolving agricultural yields on the global pricing dynamics of agricultural commodities.

Building upon this, it is imperative to assess the degree to which fluctuations in global food prices contribute to national food price dynamics. In turn, we have incorporated the insights presented by Lee & Park as part of their comprehensive panel analysis, which explores the propagation of international food prices into domestic food price inflation. Their study details the transmission mechanism across distinct geographic regions, affording us the opportunity to account for region-specific idiosyncrasies.

Furthermore, our analytical framework encompasses an examination of food imports and their role in shaping domestic food price inflation. Notably, the investigation conducted by Lee & Park underscores the importance of food imports in dictating inflation dynamics resulting from supply shocks related to a fall in total agricultural yield. Their findings highlight that an abrupt surge in the share of food imports relative to total imports during times of high global food price volatility could potentially amplify food price inflation risks by exposing the country to elevated global food market prices.

Leveraging these research findings, we utilised World Bank data on food imports as a share of total merchandise imports, along with the change in the food imports as a share of total merchandise imports between 2006 and 2009 (in order to capture the surge in global food prices in 2007-08) to adjust the effect of the transmission of international food prices on domestic food inflation, on a country level. The culmination of the aforementioned analysis furnishes an intricate breakdown on a nation-by-nation basis, highlighting the impact of diminishing agricultural yields on domestic food price inflation under different climate change scenarios. A subsequent step involves calculating the impact on the headline rate of inflation within each market, achieved by proportionately scaling the upswing in domestic food prices in alignment with the relative weighting assigned to the food and non-alcoholic beverages category within the respective Consumer Price Indices (CPIs).

The analysis conducted above produced annual percentage change impacts on food price inflation and headline inflation across various markets under different climate change scenarios. To substantiate the expected effects of declining agricultural yields resulting from climate change, we integrated the aforementioned estimates with inflation forecasts from Cebr's World Economic League Tables (WELT) 2023. These forecasts extend through 2037, with the outer years of the forecast horizon assuming a steady state for each market. Extrapolating these steady-state conditions to 2050, while also adjusting these forecasts to account for developments since the WELT's release in December 2022 allowed us to establish baseline figures for both headline and food price inflation. Subsequently, we applied the derived annual percentage changes to these forecasts to yield percentage point upticks in headline and food price inflation, before these were applied to their respective 2050 forecasts to project the expected rates of headline and food price inflation, both at the market and regional levels, for 2050, under different climate change scenarios.

[13] The scars of supply shocks: Implications for monetary policy – Wolf & Fornaro
[14] International Transmission of Food Prices and Volatilities: A Panel Analysis – Lee & Park

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[15] As of September 30, 2023.
[16] Pensions & Investments, "The Best Places to Work in Money Management", December 12, 2022

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