

MEGATRENDS

FOOD FOR THOUGHT

Investment Opportunities Across a Changing Food System

SPRING/SUMMER 2023

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INTRODUCTION

From farm to fork, our global food system is vast, complex, inefficient and increasingly unfit for purpose (Exhibit 1). But with the global food system representing just 10% of global GDP, why should institutional investors care?¹ We believe understanding and navigating the rapid evolution of our fragile global food system is important for asset owners for four primary reasons:

1. Vulnerabilities in the food supply chain drive critical macroeconomic outcomes

Food can be a key driver of consumer price inflation. This, in turn, impacts a whole array of critical macroeconomic outcomes. High food inflation can influence central bank monetary policy as well as government regulatory and fiscal actions. And higher food prices from disruptions in food supply chains can have a dampening effect on overall economic activity as discretionary consumer spending may get crowded out – especially in emerging markets where food can account for up to 40% of household spending. In addition, food policy is a significant part of fiscal budgets, with

global support and subsidies for farmers totaling over \$700 billion.²

2. Food security is critical in evaluating domestic political stability and geopolitical risks

Food *insecurity* is a key driver of domestic political instability, especially in emerging and frontier markets. Most recently, food shortages and inflation led to the toppling of governments in Tunisia and Egypt during the Arab Spring of 2010. Equally important, the food sector employs 40% of the global workforce and has tremendous political influence. From France to Peru and from India

Exhibit 1: Current tensions in the global food system

Unequal distribution of calories	<ul style="list-style-type: none"> Over 800 million people are affected by hunger (one of every nine humans)³ 29% of global population living under moderate or severe food insecurity⁴ 	<ul style="list-style-type: none"> Over two billion people worldwide are obese or overweight⁵ 68 obesity rates over 25% with people on average eating 50% more calories than needed⁶
Food security aspirations vs. reality	<ul style="list-style-type: none"> COVID and the war in Ukraine highlight the vital role of food security for national security The need to meet caloric needs and preferences of a growing and more affluent population in emerging and frontier markets 	<ul style="list-style-type: none"> Increasing reliance on food imports and long supply chains as diets converge 2.5 billion tons of food lost or wasted each year throughout the food value chain⁷
Farming methods from different eras coexist	<ul style="list-style-type: none"> 21st century precision agriculture in the Americas and Europe using AI and advanced analytics Large-scale mechanized farming in Argentina, Brazil and China 	<ul style="list-style-type: none"> In India, more than 80% of farms are smaller than 10 acres and rely on manual labor⁸ 1960s “Green Revolution” technology still used in South Asia and Africa
The interaction between climate and agriculture	<ul style="list-style-type: none"> 40% of global cropland has already been exposed to water scarcity⁹ Climate change will cause a 12% decline in crop yields and up to a 35% decline in fishery production¹⁰ 	<ul style="list-style-type: none"> Agriculture accounts for: <ul style="list-style-type: none"> 30% of global greenhouse gas emissions¹¹ 80% of deforestation¹² 70% of freshwater consumption¹³

to China, this power manifests itself in electoral outcomes, vast subsidies, regulatory changes and trade barriers.

Food security is also re-shaping geo-politics. Given the recent impact from COVID-19 and the fallout from the Ukraine War, food security is increasingly seen as national security. The growing bi-partisan political pressure in the US to curtail Chinese-linked ownership of agricultural land is an example of growing tension around access to food.¹⁴ Similarly, the focus on acquiring or leasing agricultural land as part of the Chinese government's Belt and Road Initiative has raised significant concern across multiple countries in Latin American, Asia and Africa.¹⁵

3. There are attractive investment opportunities in public and private markets as the global food system is transformed

With the global food system rapidly transforming, investors will find a shifting landscape of opportunities and risks. The evolving investable opportunity set ranges from cold storage and

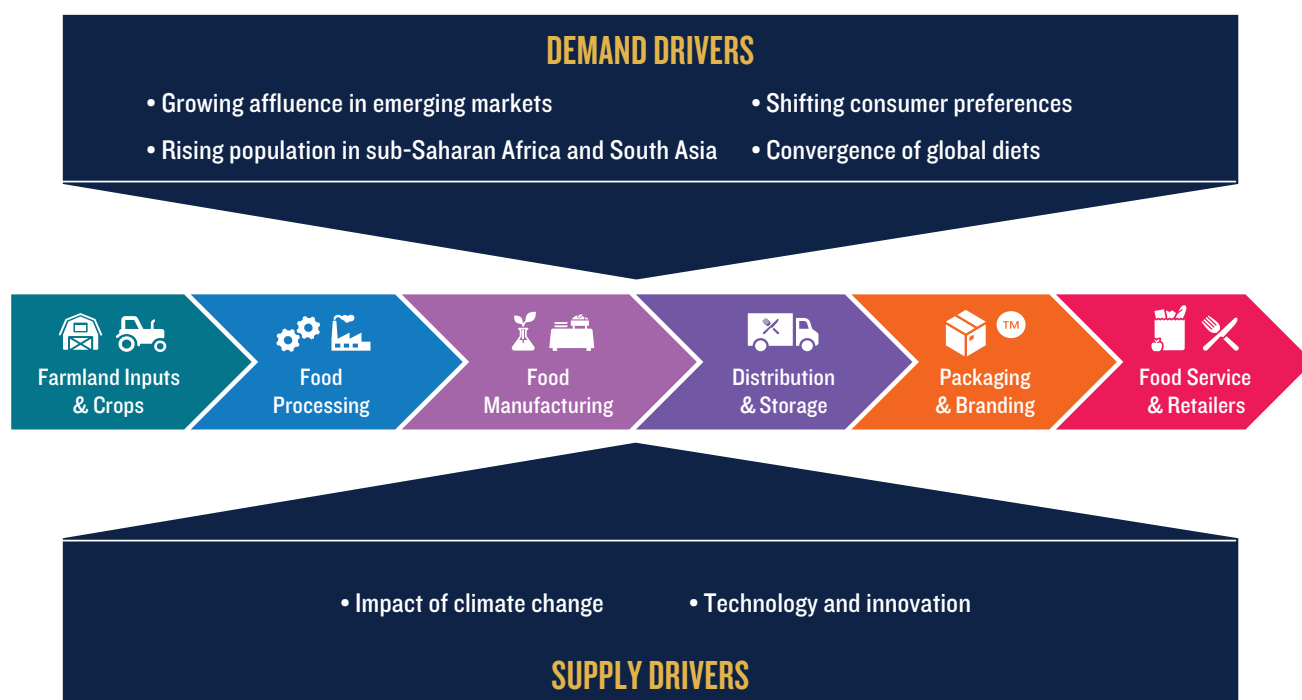
many elements of “AgTech” to typically under-allocated sectors such as farmland debt and equity. Equally, there are real investment risks around over-hyped trends such as alternative meats and vertical farming.

4. Investing in the food system provides opportunities for investors to further ESG goals and have measurable impact

In some ways, today's food system, resembles the energy sector from a decade ago. It provides a vital good for human survival – but does so with some important negative externalities. This creates both tensions and opportunities for ESG-driven investors. Given the complex interlinkages and feedback loops between climate change and food production, there are significant opportunities for investors to make a tangible difference as they invest behind a more inclusive, sustainable and nutritious food system.

For investors, it is especially critical to identify the powerful supply and demand forces re-shaping the entire global food value chain (Exhibit 2).

Exhibit 2: Overview of the food value chain



Source: PGIM Thematic Research.

To understand the emerging investment opportunities and hidden risks from this ongoing transformation of the food system we have drawn on the insights of over 40 investment professionals across PGIM's fixed income, equity, real estate and private alternatives managers – as well as leading policymakers, academics, entrepreneurs, private equity and VC investors.

Given the recent impact from COVID-19 and the fallout from the Ukraine War, food security is increasingly seen as national security.

We unpack the critical drivers and resulting investment implications of the new global food system in the rest of this report. Starting with the demand side, Chapter 1 evaluates investment opportunities and risks emerging from rising incomes (and populations) as well as changing consumer food preferences. Shifting to the supply side, Chapter 2 focuses on investment themes linked to climate change and an array of innovation across the entire food supply chain, from AgTech through lab-grown meat. Finally, Chapter 3 examines the menu of cross-portfolio options for CIOs to consider when they consider the opportunities and risks embedded in the global food system.

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The background of the slide features a close-up, slightly blurred photograph of several silver forks arranged horizontally. Each fork has a different food item balanced on its tines: a yellow potato, a red tomato, a slice of yellow lemon, a green broccoli floret, and a round orange slice. The overall color palette is muted, with a dark blue-grey overlay on the left side where the text is placed.

CHAPTER 1

RISING AFFLUENCE AND SHIFTING PREFERENCES ARE RESHAPING FOOD DEMAND

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Rising incomes, convergence of global diets and a shift to convenience and healthier options are critical in shaping demand.”

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01

CHAPTER 1

RISING AFFLUENCE AND SHIFTING PREFERENCES ARE RESHAPING FOOD DEMAND

Understanding the drivers of global food demand is key to any investment decision across the food system. Going forward, three factors will be critical in shaping demand. First, the shift from population growth to income growth will be an increasingly important factor. Second, the convergence of global diets is altering food supply chains and agricultural production. And third, changing consumer preferences towards more convenient, healthier and safer food options – factors that are inextricably linked but not always congruent.

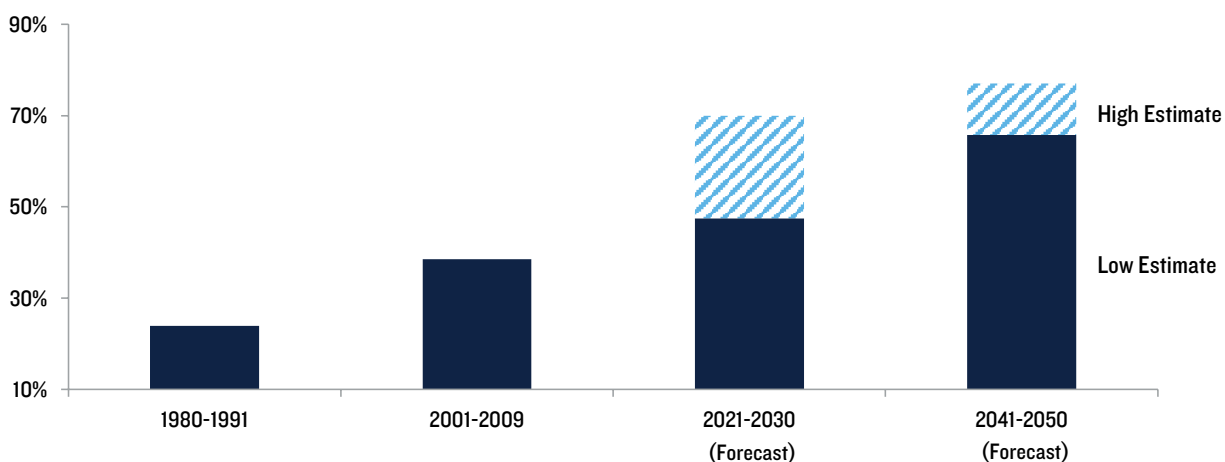
1. Alongside population growth, affluence will drive future food demand

Over the past 60 years, the world's growing population has been the main driver of food demand. Looking ahead, global population is poised to increase 25% to almost ten billion by 2050 with more than 80% of this growth coming from South Asia and sub-Saharan Africa. Population growth so narrowly concentrated in one or two regions is a deviation from the past where growth was more widely dispersed.

That population growth will be highly concentrated in lower-income countries has direct implications for food demand. As countries grow in affluence, their food consumption patterns change drastically. There are multiple stages to this evolution – also known as Engel's law.¹⁶ For lower-income countries, food consumption increases sharply as income rises before leveling off as they approach middle-income status. This income effect will be a key driver of future food demand (Exhibit 3). In fact, some research suggests this income effect could be substantially larger over

Exhibit 3: Rising income is becoming an increasingly important driver of food demand

Share of incremental food demand driven by income growth



Source: PGIM Thematic Research analysis, International Institute for Applied Systems Analysis, World Bank and International Food Policy Research Institute.
Note: Low and high estimates based on the Shared Socioeconomic Pathways (SSP).

the next 30 years than in the past and may very well account for most of the increase in food demand over that time.¹⁷

In addition, higher income causes diets to shift towards more resource-intensive foods – such as meat, fish and processed foods. To understand the implications, it is crucial to consider the energy needed to produce food compared to the calories they provide. For example, every calorie of beef consumed requires about 25 calories of energy in production. That is, it takes 25 calories of energy to produce every edible calorie of beef – a 25 to 1 ratio. Other meats are rather energy inefficient as well – pork has a ratio of 9 to 1 and poultry 5 to 1.¹⁸ One consequence of the shift towards more animal-based proteins is greater demand for

feed grain like corn and soy. It is no coincidence that as China's pork consumption grew between 2010 and 2020, its soybean imports almost doubled to 102 million tons.¹⁹

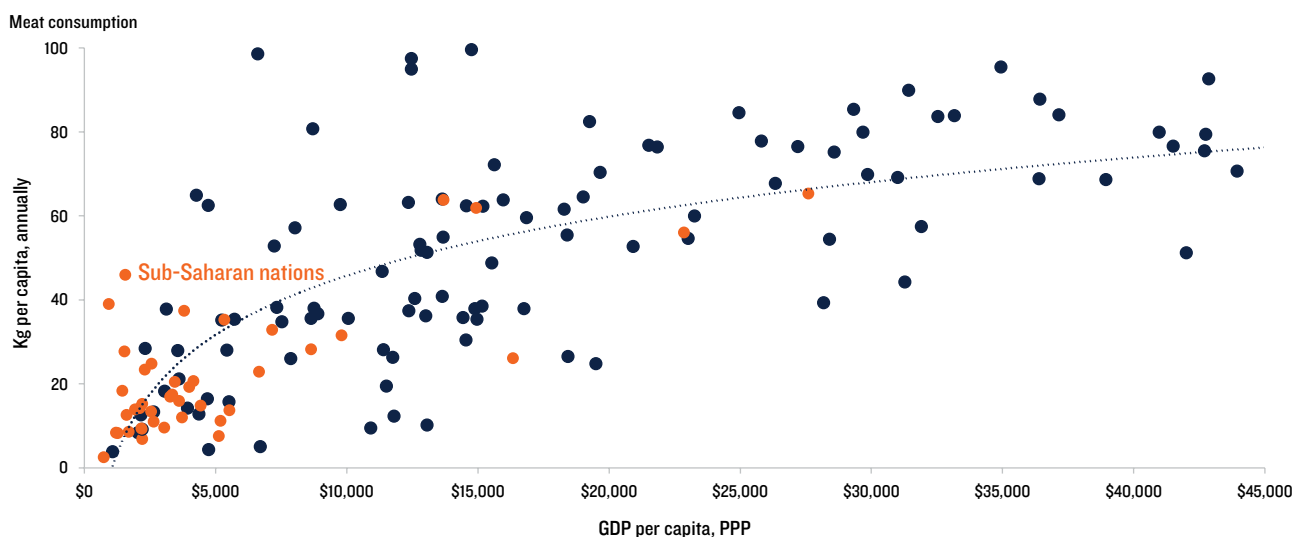
Consequently, as consumers become more affluent and shift their diets, the energy required to meet their daily intake increases significantly. Importantly, the regions where population growth is most concentrated over the next 30 years – South Asia and sub-Saharan Africa – will *also* increase their meat consumption sharply given their expected income growth (Exhibit 4).

2. Diets are converging globally

Income growth not only leads to more resource-intensive diets, but it has also led to a convergence of diets across regions. This is the second factor driving future food demand. Over the last 60 years, emerging and frontier markets with growing per capita income have seen not only an increase in meat consumption but a general shift to a diet heavy on animal proteins, dairy products, wheat, oils and sugar – often referred to as a “western diet” (Exhibit 5).²⁰

Higher incomes cause diets to shift towards more resource-intensive foods – such as meat, fish and processed foods.

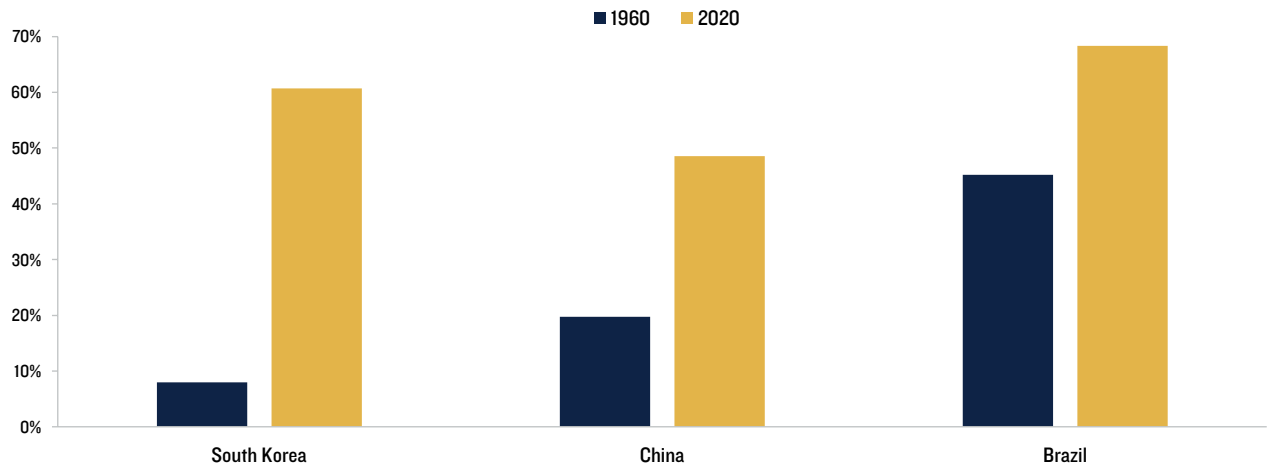
Exhibit 4: Meat consumption increases with affluence
Sub-Saharan nations versus rest of world



Source: World Bank and Food and Agriculture Organization of the United Nations.
Note: GDP per capita in PPP, constant 2017 \$US.

Exhibit 5: Global diets are converging

Share of total daily calories from a “western diet”



Source: United Nations, Food and Agriculture Organization.

Note: In this chart, “western diet” refers to animal proteins, dairy products, wheat, vegetable oils and sugars.

The convergence of global diets has three key implications. First, the distance food needs to travel from where it is grown to the end-consumer will increase. Second, the reliance on food imports and multinational supply chains will create new infrastructure and transport needs while simultaneously increasing the risk around disruptions of supply and its impact on food security. Third, the merging of global diets means we are increasingly dependent on fewer crops, making our food system less resilient to crop-specific disease or pests.

3. Global consumer preferences are evolving in different ways

The third key factor shaping food demand is evolving consumer preferences. While many changes will prove to be short-lived fads, some will endure and are critical to understand.

Developed-market consumers seeking out healthier food options

As diets have moved from legumes and vegetables towards meat and processed foods high in sugars and sodium, there has been a measurable increase in hypertension, diabetes, obesity and cardiovascular disease. In 2017, over 20% of all deaths worldwide were related to diets.^{21, 22}

Both consumers and the food industry are increasingly aware of the critical linkages between diet and health, and it is becoming a factor in driving consumer behavior. For an increasing number of consumers in developed markets, the importance of health and wellness influences their product choices, from ingredient sourcing to food processing.²³ Food manufacturers and processors are adapting to these shifts by tilting towards healthier formulations higher in fiber and lower in sugar and fat. For example, production of high-fructose corn syrup in the US has declined by about 20% since peaking in 1999.²⁴

Over the last 60 years, emerging and frontier markets have seen a general shift to a diet heavy on animal proteins, dairy products, wheat, oils and sugar.

This change in preferences is being further supported by policy shifts in developed markets. In both the US and EU, government initiatives are aiming to increase transparency around nutrition claims as well as funding medically tailored food – meals designed and approved by nutritionists to address specific chronic conditions or diseases – as part of health insurance.²⁵

Convenience becomes paramount for global consumers

The trend towards greater convenience in dining at home was accelerated by the pandemic and is still thriving.²⁶ Additionally, urbanization and smaller household sizes have changed eating habits universally. As people reduce the number of meals prepared at home, consumption of packaged foods and delivered food has increase manifold, especially in emerging markets.²⁷ Today, the food-for-delivery segment spans

far beyond restaurant deliveries and includes ghost kitchens as well as subscription services for ready-to-cook meals. Global demand for prepared foods and meals is set to grow by 60% to \$250 billion by 2029.²⁸

Increasingly, grocery stores are also changing distribution models to facilitate online orders and adapt to value-conscious and health-driven customers. In the US, online grocery will comprise almost 30% of the food-at-home market by 2030.²⁹ This has led to an expansion of grab-and-go offerings by supermarkets that offer healthier options to traditional fast food.³⁰



Food Loss and Waste*

As much as 40% of food that is grown or produced – roughly 2.5 billion tons or \$1 trillion worth – goes uneaten around the world each year.³¹ In fact, consumers in developed countries waste almost as much food as the total food production of sub-Saharan Africa. This has a significant toll on food security, economic well-being and the environment. The land, water and other resources used in its production account for approximately 4.4 gigatons of greenhouse gas emissions (GHG) – making it the world's third-largest emitter after China and the United States.^{32, 33}

Food loss happens at nearly every stage of the value chain, but the degree of loss at each stage varies across the world. For example, in industrialized nations, over 40% of total food waste happens at the retail and consumer stage. By comparison, in developing regions, post-harvest losses during processing amount to roughly 40% of total food loss there.³⁴

For investors and policymakers, this means the opportunities to minimize food loss and bolster food security will vary by region. For example, investments in cold storage in emerging markets improve the infrastructure of the food supply chain outside the farm gate and can contribute meaningfully to limiting fruit and vegetable loss in developing regions. In developed markets, finding ways to repurpose discarded fruits and vegetables as feedstock for other animals or incorporating it as an input in processed foods may limit food loss as well.

*The UN's Food and Agriculture Organization defines food loss as the decrease in quantity or quality of food between harvest up to but not including the retail level. Food waste refers to the decrease in quantity or quality of food from the retail level until end- consumers.

Investment Implications

Three demand drivers – population and income growth, converging diets, and shifting consumer preferences – will transform food demand over the coming decades. They represent deviations from the past and have significant investment implications. There are five themes that will be paramount for investors to consider as they evaluate opportunities and risks:

1. Meat producers offer a contrarian opportunity, while plant-based meat has peaked

Plant-based meats have dominated headlines, but reality does not match the hype.³⁵ The steep growth rates for plant-based meats producers have either plateaued or peaked. Only a few years ago – as fast-food chains began to offer Beyond Meat burgers – there were expectations for continued exponential growth and drastic changes in consumer preferences. But growth rates have faltered, and today, the alternative meat market remains a tiny sliver – less than 0.2% – of the \$1.7 trillion global meat market.³⁶ In fact, alternative meat demand is in decline while global demand for animal-based meat is set to grow by 14% by 2030.³⁷

Almost universally, consumers demand more meat in their diet as income grows. Global meat producers are poised to benefit from this growing demand – especially among the rising middle class in emerging markets. Livestock is a commodity-based business dominated by economies of scale. There are a handful of players operating at the global level – Tyson Food and OSI from the US or JBS from Brazil – that are diversified across both meat products as well as regions. These characteristics enable leading producers to better manage cyclical supply factors and make for stable cash flows.³⁸

From an ESG perspective, the carbon emissions and environmental impact of conventional meat production can be problematic. But investors should consider the opportunities to make measurable impact by actively engaging with (rather than excluding) a range of firms in the food system. This is discussed further in Chapter 3.

2. Cold storage and transportation provide global growth opportunities

As consumers demand more fresh foods, online grocery and food delivery, expanding the stock of refrigerated warehouses becomes essential. For investors with an ESG lens, investments in the cold transport chain also represent an opportunity to reduce food loss at various stages of the supply chain. In the US, cold storage real estate is particularly compelling. The US is the largest single market for cold storage, and its consumers are most accustomed to year-round variety and food delivery. New direct-to-consumer businesses (such as Imperfect Food and Misfits Market) also provide real estate investors with customers for existing cold storage facilities as well as new ones with proximity to urban population centers. Investors can find cold storage opportunities in Asia and Latin America as well. A growing middle class in these regions is adopting e-commerce and demanding higher-quality and fresher food options. This not only has led to higher rents for cold storage properties compared to general warehouses but is also driving a booming cold storage market from China to Vietnam to India and Mexico with expected growth rates well above 20% in the next decade.^{39, 40}

Investors can find cold storage opportunities in Asia and Latin America, where a growing middle class is adopting e-commerce and demanding higher-quality food options.

Logistics providers in Southeast Asia and Latin America, such as Nichirei and Frialsa, respectively, also benefit from the increasing convergence of diets and have established cold-chain operations to serve producers and retailers.^{41, 42} Equity and debt investors may find such companies attractive given their strong growth, steady cash flows and recession resilience. Certain specialized transport companies, such as

US-based Echo Global Logistics, may be especially attractive as they provide *both* warehouses and long-haul transport and benefit from demand for both cold transport as well as storage. For example, many vegetables and processed foods need temperature-controlled hauling and are susceptible to damage such as freezing, breakage or spilling.

Established food-packaging players are a way of taking advantage of the growing market for prepared foods without depending on volatile consumer behavior.

3. Packaging offers steady cash flows, no matter the underlying food fads

Changing consumer preferences have a direct impact on packaged food. Prepared meals necessarily involve packaging but also create a need for convenience such as resealable pouches and innovations to address concerns around excessive packaging.⁴³ But the increased demand for packaging goes beyond the rise in ready-to-eat meals. It is also driven by the desire to reduce food waste and diets that are increasingly dependent on food imports.⁴⁴

Established food-packaging players are a way of taking advantage of the growing market for prepared foods without depending on volatile consumer behavior or the latest food fad. The demand for packaging is sticky but at the same time requires constant innovation to improve characteristics (e.g., lightweight or resealable) as well as recycling rates and overall sustainability. Investors should look for companies that are leaders in their market segment – such as Novolex or Berry Global in the US. One segment that has seen strong growth over the past few years has been single-use metal containers. The growing demand for beer and energy drinks makes US companies such as Ardagh Metal Packaging and Crown Holdings potentially attractive investments.

The specialized machinery and equipment required for food packaging also offers potentially interesting opportunities for investors. For example, the now ubiquitous plastic pouches with resealable spouts commonly used for apple sauce or baby food require specialized machinery for packaging. Large players in the space – like Duravant in the US or Germany's Kronen – have strong cash flows to fund new innovations, are relatively resilient to recessions and have a sticky customer base.

4. Health and wellness options drive grocery and food innovation

Consumers are increasingly conscious about healthier food options.⁴⁵ While still early in their development, startups that present healthier and sustainable products may offer attractive venture opportunities for investors. In the US, companies like Voyage Foods focus on producing alternatives to ingredients with health, environmental or social challenges. Their line of products includes nut-free peanut butter (for those with allergies) and cocoa-free chocolate and coffee (both cocoa production and coffee trade can be unethical). Another example is the growing list of personalized meal services – such as Hello Fresh and Dinnerly in Europe and the US – targeted at the health and wellness segment by supplying ready-to-eat meals that meet specific dietary restrictions. Investors looking for VC investments should seek out companies closing the gap on price and taste, rather than those relying on compelling consumers to change their behavior or preferences.

The health trend has also created opportunity in food retail. Regionally dominant grocery stores, like privately owned Wegmans and Hy-Vee in the US or publicly traded Tesco and Carrefour in Europe, are particularly well positioned for these changes. Customers are increasingly loyal to retailers' private label brands, and these players have expanded their offering to include healthier and higher-margin products. As a result, these grocers have greater flexibility in pricing. The super-regionals are also leveraging technology and digitization to provide consumers with the convenience of either an advanced online or physical shopping experience.^{46, 47}

Concerns around food safety and unpacked products have led to a marked uptick in demand for recognized brands, ready-to-eat snacks and packaged foods in rapidly urbanizing countries.

5. Convenience and food safety drive emerging market opportunities

Concerns around food safety and unpacked products have led to a marked uptick in demand for recognized brands, ready-to-eat snacks and packaged foods in rapidly urbanizing countries such as India, Brazil and China.^{48, 49} Investors should seek companies that offer exposure to food and beverage staples, with strong brand names and local logistic expertise.

For example, Asia offers investors opportunities in publicly traded companies such as India's Britannia (producer of baked goods) or Varun Beverages (PepsiCo and Tropicana beverages).

Similarly, Indonesia-based and family-owned Indofood specializes in convenience foods – instant noodles, beverages and ready-to-eat snacks – in Southeast Asia and Africa.

In Latin America, investors may want to consider the debt of family-owned businesses like Grupo Bimbo – the largest baking company in the world given their trusted brand and excellent distribution networks throughout the Americas. Investors may also want to consider bottling companies such as Central America Bottling (PepsiCo) and Coca-Cola FEMSA, which offer global brand exposure as well as vast local distribution networks. These are examples of companies in Latin America and Asia that will continue to see growth from the shift to convenience and converging diets.

Chapter 1 examined the dynamics altering the food system from the demand side. The next chapter will review the major forces driving change from the supply side. Namely, how climate and technology are reshaping agriculture and food production.



CHAPTER 2

FOOD SUPPLY: CLIMATE AND INNOVATION ARE TRANSFORMING PRODUCTION

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The global food system,
despite all its imperfections,
provides over 20 trillion
calories every day.”

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CHAPTER 2

FOOD SUPPLY: CLIMATE AND INNOVATION ARE TRANSFORMING PRODUCTION

The previous chapter focused on the key factors driving demand and how they are shifting the investment landscape. We now turn to the supply side of the global food system, which, despite all its imperfections, provides over 20 *trillion* calories every day.⁵⁰ There are two key drivers in the food supply chain that investors cannot ignore. First, how agriculture and climate change really impact each other. Second, the relentless push of technology and innovation into every corner of food production.

1. The feedback loop between the environment and agriculture

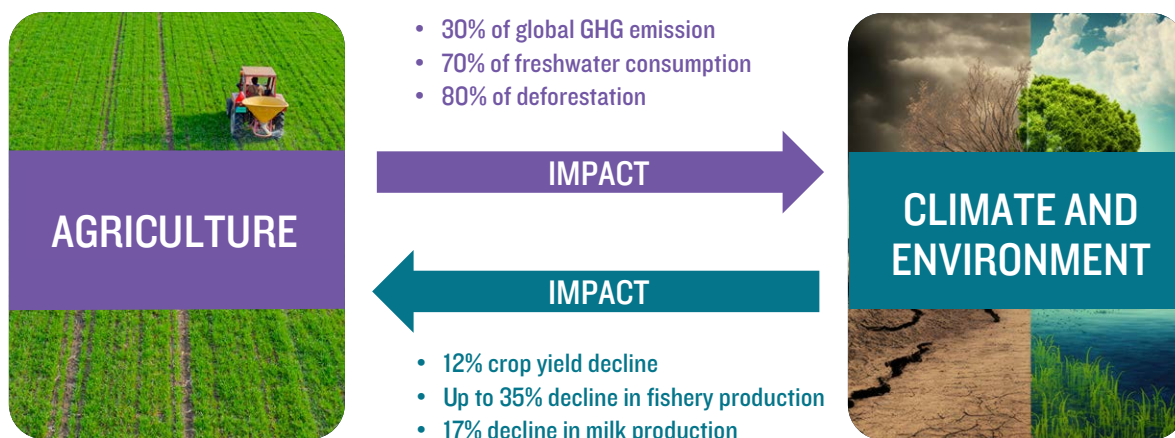
While there is much discussion around climate change and the food system, what is frequently overlooked is the complex two-way causality (Exhibit 6). While the adverse effects of climate change on food production are well-reported, less attention is paid to the large imprint the food system leaves on the environment. In fact, global food production accounts for 70% of freshwater consumption and 30% of greenhouse gas emissions.⁵¹

Food production impacts the environment and climate change

The basis of today's global agriculture – especially in key crops like corn, wheat and rice – can be traced to the 1960s Green Revolution.⁵² The tremendous increase in productivity from that time was driven by a combination of new seed breeding techniques as well as the proliferation of synthetic fertilizers and pesticides.

Even today, these methods remain dominant in most parts of the world. However, as we view food production through a 21st-century lens of

Exhibit 6: Agriculture and the environment impact each other



Source: PGIM Thematic Research.

sustainability, it is clear this template for agricultural production needs upgrading.^{53, 54}

Synthetic fertilizers can impair water sources and marine life

While fertilizers are a simple and effective way to boost crop yields, the persistent use of nitrogen-based fertilizers contributes to environmental degradation in several ways.⁵⁵ Current methods of farming that have few cover crops, less fallow time and lots of tilling do not allow for the soil to replenish nutrients on its own. This results in the need for more synthetic fertilizers just to keep growing crops.⁵⁶ It is estimated that one-third of the fertilizer applied to US corn crops each year is merely to compensate for the ongoing loss of soil fertility – costing farmers more than \$500 million.⁵⁷

40% of global croplands have already experienced water scarcity and the upper end of future estimates are nearly twice that figure.

Methane emissions from livestock production

Livestock production has damaging effects on the environment – including deforestation for pasture or to grow feed crops. Also, any credible plan to curtail GHG emissions must include food production. Livestock account for roughly 15% of global emissions.⁵⁸ Much of this is in the form of methane – which is 80 times more potent as a GHG than carbon dioxide. Cows, sheep and goats produce methane in their stomachs as they digest hard fibers from grass. Most of this enteric methane from livestock digestion is expelled into the atmosphere and accounts for roughly a third of all methane emissions globally.⁵⁹ With greater demand for animal-based food products, livestock methane emissions are projected to grow 30% by 2050 under current policies and practices.⁶⁰

Climate change directly impacts agriculture in multiple ways

Aside from remote polar regions, the direct impact of climate change – namely, extreme heat, water stress and rainfall variability – on crop yields is detrimental.⁶¹ For example, in 2022 India experienced its hottest March in over a century. The blistering heat reduced wheat yields by an average of 15% and prompted the country to ban wheat exports.⁶² This is not an isolated situation limited to one crop or one region either. Global corn production is forecast to decline by as much as 20% by 2030 due to climate change.⁶³

Water scarcity is another source of concern for farmers and can no longer be considered a hypothetical risk. Research suggests roughly 40% of global croplands have *already* experienced water scarcity and the upper end of future estimates are nearly twice that figure.⁶⁴ For example, Europe is emerging from a drought that may be its worst in 500 years, and yield forecasts for corn, wheat and other staple crops are being slashed by 25% or more.^{65, 66}

Livestock are less productive with heat stress

Heat stress – the combination of high ambient temperatures, humidity and solar radiation – has a negative impact on animal welfare and reduces the productivity of livestock. Animals respond to heat stress by reducing their feed intake by up to 5% for every additional degree of warming.⁶⁷ This diminishes weight gain, dairy production and fertility generally, but affects larger livestock, such as cattle, more acutely. Total losses in milk and meat production from heat stress alone are expected to reach \$40 billion *annually* with the US, U.K. and West Africa projected to lose up to 17% of milk production by the end of the century.^{68, 69}

The effects of rising sea temperatures are often overlooked

Global warming impacts not only temperatures on land but also ocean and sea temperatures. Evidence is mounting that rising sea temperatures are already reducing seafood production in some parts of the world.⁷⁰ Fish and other marine life have limited ability

to regulate their body temperature and even subtle changes in their aquatic surroundings can have a substantial impact on their health.⁷¹ In fact, ocean warming has already led to material declines in fishery production between 15% and 35%.⁷²

Forward-thinking investors will want to focus on several key areas including crop science, AgTech and “alternative agriculture” that transform food production.

Indirect effects of climate change are numerous and costly as well

Climate change has a range of indirect effects on agriculture, from spreading weeds and pests to the declining nutritional value of crops. Going forward, climate change and its impact on food production will add substantial pressure on the food system to meet growing demand.⁷³

Many weeds, pests and fungi thrive under warmer temperatures and increased CO₂ levels. In fact, increasingly milder winters can trigger an expansion of the geographic range and reduced effectiveness of natural pest controls (e.g., winnowing of older generations from sustained cold temperatures in winter). These changes can lead to invasive insect species in new areas and more insect-transmitted plant fungi and diseases.⁷⁴ And these changes can be costly as well – US farmers already spend more than \$11 billion annually just to fight weeds.⁷⁵

2. Technology and innovation are critical to increase food sustainability and productivity

To meet the challenges of the future, technology and innovation will need to play a crucial role in finding new ways of growing and producing food. Innovation and adoption of modern technology are already taking place throughout the food value chain. It is important

for investors to recognize that both tech startups and global incumbents are driving change at every stage. Forward-thinking investors will want to focus on several key areas including crop science, AgTech and “alternative agriculture” that transform food production (Exhibit 7).

Crop science can boost climate resilience and crop yields

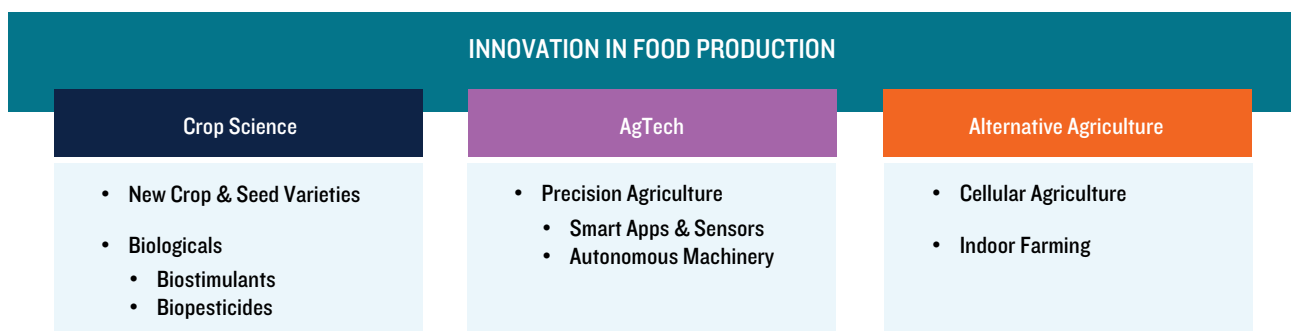
Crop science often refers to the development of new varieties of seeds or plant breeding as well as new fertilizers. Farmers have been breeding their own plants for centuries, and advances in seed varieties – like cross-bred or hybrid seeds – were a key element of the Green Revolution. Today, crop science continues to be a driver of innovation and adaptation across the agricultural landscape. Seed varieties optimized for local soil, water and climate conditions can enhance yields materially. Furthermore, seeds bred with resistance to new pests, diseases and fungi are an effective way to mitigate indirect effects of climate change as well. Specifically, breeding varieties with shorter (or longer) growing cycles to adjust to a shorter (or longer) growing season can enhance crop yields. Additionally, modifications of seed pathways can lead to faster-growing, more nutrient-rich crops or greater photosynthetic efficiency – all of which are ways to extract greater food production from a system that has largely maxed out on arable land and water.

New crop varieties can also propel a more resilient food system. For example, short-stacked corn is more resistant to high winds and extreme weather events than its predecessors. And breeding plants to have deeper and longer root networks can enhance resistance to drought and heat.

Biologicals offer minimal environmental impact but face adoption challenges

Synthetic fertilizers and crop protection come with environmental consequences. However, a whole new set of compounds are emerging that use nature’s own biology to safeguard plants against pests, prevent disease and improve yields. The segment is split roughly between biostimulants – which improve nutrient availability, uptake or efficiency to enhance growth – and biopesticides, which provide plant

Exhibit 7: Key areas of innovation in food production



Source: PGIM Thematic Research.

protection.^{76, 77} These new compounds – known as biologicals – are largely created from living organisms or natural materials and catalyze biological processes. These characteristics allow for a considerably smaller environmental footprint than conventional compounds. The global market for agricultural biologicals is still small – about one-sixth the size of the conventional crop protection market – but is expected to more than double in size by 2030.^{78, 79}

While adoption of biologicals is relatively high in Brazil and Europe, it is lagging in North America and Asia.⁸⁰ One challenge the industry faces is difficulty in clearly demonstrating that subtle changes to plant processes can lead to enhanced crop yields. With traditional herbicides, for example, the destruction of a weed is a clear demonstration of efficacy. With biologicals, the changes in internal organic processes may act over time and not be as obvious, making validation of efficacy more ambiguous.⁸¹

From tech to table: AgTech boosts productivity and sustainability

The basic inputs for agriculture are simple and little changed over time: seed, sun, water, fertilizer, pesticide and labor. AgTech often refers to leveraging technology to create more efficient methods of farming that reduce the need for these inputs – thereby increasing productivity and sustainability.

Precision agriculture

Precision agriculture is an advanced example of AgTech. It refers to a range of farm management

techniques that enhance productivity and address some environmental concerns around farming. It relies on measuring and responding to plant and crop variability across a field. Sensors embedded in crops monitor variables like temperature, moisture, and levels of key nutrients (like nitrogen) in the soil and air. This real-time data serves as an input for predictive analytics software to determine when and how much water, fertilizer or fungicide to deliver to specific areas of the field. It enables farmers to reduce their cost of inputs and boost productivity while also minimizing water usage and reducing some environmental impacts like nitrogen or chemical run-off.⁸²

New crop varieties can also propel a more resilient food system by creating plants that are more resistant than its predecessors.

However, as a nascent technology, precision agriculture faces challenges including a fragmented landscape for different components that may not be standardized. This can make it difficult for sensors to work seamlessly with software as well as water and nutrient delivery systems because they do not share a common tech platform. Furthermore, in some fields, internet or mobile connectivity can be inconsistent or weak.⁸³ Last, the sensors, software and delivery systems needed to engage in precision agriculture require a significant investment as well as ongoing

infrastructure and maintenance. The operational costs for this may be prohibitive for smaller farms and the payback period too long.

Cellular agriculture involves growing agricultural products directly from cell cultures using fermentation and biotechnology processes to stimulate cell growth.

Alternative agriculture offers innovative food production methods

Cellular agriculture and cultivated meat

Global demand for meat has tripled over the last 50 years, reaching 340 million tons in 2021.⁸⁴ Indeed, the \$1.7 *trillion* global market for meat reflects the primal human desire for it.⁸⁵ Cellular agriculture involves growing agricultural products directly from cell cultures using fermentation and biotechnology processes to stimulate cell growth. This raises the prospect of producing proteins in ways that may be more sustainable.

Cultivated meat is one example of cellular agriculture. Meat can be produced from a small sample of animal cells which are then fed nutrients and grown at high volume and density in enormous steel vessels called bioreactors.⁸⁶ These innovative production techniques may help meet future demand while minimizing land and grain use. They also offer the promise of reducing methane emissions from livestock as well as carbon emissions from long-haul transport of meat, as production can easily be moved closer to end consumers.

However, the industry is at a very early stage and faces significant challenges. First, consumer acceptance remains unclear. If the short-lived growth period of plant-based proteins is any indication, it is not certain consumers will easily adopt any alternative to conventionally raised meat. There also may be the

stigma of “genetically engineered” food and hesitations around eating something perceived as created in a lab rather than on a farm.

Second, for cultivated meat or fish to compete against conventionally raised meat, it must be cost-competitive. This is an enormous challenge given the energy-intensity of current processes and the vast difficulties in scaling production.⁸⁷ Analysis of the economies of scale that could be achieved estimate a production cost of roughly \$11 per pound of cultivated ground beef – compared to the marked-up grocery store price of under \$5 per pound for conventionally produced beef in the US.⁸⁸ Even optimistic forecasts for its declining cost curve suggest the price of cultivated meat products may not be competitive with livestock meat for more than a decade.⁸⁹

Indoor farming

Plants have been raised in greenhouses for hundreds of years, but recent technology opens new possibilities. Growing crops in greenhouses or in buildings offers several promising features. The prospect of growing fruits and vegetables in places where climate and land are not supportive or reducing carbon emissions by growing crops closer to end markets is very appealing.

Despite being a tiny country with limited arable land, the Netherlands is a major agricultural exporter – primarily because of the 24,000 acres of crops growing in greenhouses.⁹⁰ With an acre of greenhouse yielding as much lettuce as ten outdoor acres, the Dutch have mastered the efficiencies and innovations of indoor growing with natural light.⁹¹

However, greenhouses can be energy-intensive given the cost of heating and cooling vast indoor spaces. Vertical farming, which relies on artificial light rather than the (free and dependable) sun can demand even more energy and is difficult to operate at the kind of scale that greenhouses can. When energy prices spike, the unit economics of indoor farming can become unattractive – and may even cause some growers to shutter operations altogether.⁹² This can introduce an unwelcome source of volatility in both the price and availability of food.⁹³

Investment Implications

The evolving landscape of agriculture and food production creates a range of investment opportunities. Some innovations are already being applied at scale and can make for attractive traditional debt and equity investments. Other opportunities remain nascent and may be best suited for venture capital portfolios as startups overcome their remaining challenges around cost, adoption and scale. There are six investment themes especially critical for investors as they consider the transforming agriculture and food production landscape.

1. AgTech is driving smarter, more sustainable food production on small farms

Improving the agricultural efficiency, profitability and sustainability of small farms often involves technology – like smart devices, sensors, data analysis and proprietary algorithms. For investors, the AgTech landscape is quite fragmented with many startups finding diverse ways to apply technology to farming, which may offer attractive venture capital opportunities.

In emerging markets, many farms remain small-scale. More than 80% of farms in India are on less than ten acres of land, for example.⁹⁴ Finding ways to enhance productivity of farms at this scale is critical to meeting the future food demands of Indian consumers and achieving food self-sufficiency. An Indian startup called Gramophone is an example of intelligent agriculture that can help small-scale farmers. Accessed by mobile phone and used by more than 2 million farmers, Gramophone provides regionally customized analysis to guide farmers through the entire crop life cycle – from selecting seeds to optimizing use of nutrients to managing harvests and even selling crops.⁹⁵

Water management is another area of opportunity for investors. Smarter irrigation systems are rapidly developing and becoming essential as water scarcity is impacting crops and poised to be even more widespread. Mobile irrigation systems are an example of optimizing water usage on small and mid-sized farms. US-based startup CODA Farm Technologies offers a mobile irrigation system to protect crops, reduce waste and minimize water usage. Similarly,

Saturas, an Israeli AgTech startup, has developed an enhanced sensor-based system for precision irrigation, embedding their sensors right into tree stems that enables continuous, precise, real-time readings through an app.

For cultivated meat or fish to compete against conventionally raised meat, it must be cost-competitive. This is an enormous challenge given the energy-intensity of current processes and the vast difficulties in scaling production.

2. Farmland debt and equity offer a unique exposure and an attractive investment

Farmland lending and investing offer a different and unique exposure to productivity gains across the global food system for long-term investors. As a maturing asset class with an established benchmark, institutional ownership of farmland is growing but is still at an early stage with only about 3% of US farmland owned by institutional capital.⁹⁶

While the scarcity of arable land is well understood, farmland's combination of long-term income and capital appreciation is often overlooked and offers a range of risk-return propositions for both debt and equity investors. Direct farming operations and leases, for example, can supply a steady source of income for investors while productivity gains from use of precision agriculture can drive capital appreciation of farmland.⁹⁷

Farmland investing can be broadly divided into two categories – row crops and permanent crops. Row crops – like corn, soybeans, rice and cotton – are mechanically planted and harvested annually and historically offer a lower risk profile with a relatively steady income. In contrast, permanent crops like tree nuts and tree fruits are more difficult to switch in

response to market conditions and offer a different risk-reward profile which relies more on operating income.

Investors seeking exposure to permanent crops should target one of the few areas with a Mediterranean-like climate – mild, wet winters and hot and dry summers – that offer an optimal environment for high-value permanent crops like grapes, citrus and nuts. California is one such region – along with Chile, South Africa and parts of Southern Australia – with this kind of climate. However, California presents especially attractive investment opportunities due to other features: its proximity to major commodity exchanges, a deep set of private and government-sponsored financial institutions supplying capital to the farm sector, and the advanced network of strategically located highways, railroads and ports.

Farmland's combination of long-term income and capital appreciation is often overlooked and offers a range of risk-return propositions.

3. Crop science and feed additives offer innovations that increase production and sustainability

Global leaders in crop science like Bayer and BASF from Europe as well as Nutrien, FMC and Corteva in North America offer real-world, scalable solutions to boost sustainability and productivity. They have diversified global businesses, steady demand for their products and the scale and expertise to engage in customized crop science for different regions and conditions. In India, investors should consider local leaders like PI Industries and Dhanuka Agritech. They have local expertise and strong distribution networks throughout the country.

Enhancing livestock productivity and reducing the emission of greenhouse gases is critical for a more sustainable food system. Investors can find attractive opportunities in these realms as well. Animal health companies like Zoetis and Elanco in the US or Royal DSM in the Netherlands offer products that enable farmers to achieve both objectives. Feed additives for cattle or pigs can better balance amino acids to make feed 15% more efficient and can boost livestock productivity.^{98, 99} Other feed additives can reduce enteric methane emissions from dairy cows by 35% and by as much as 80% in beef cattle by suppressing the enzyme that triggers methane production.¹⁰⁰ Both kinds of additives are already in production and likely to be in use for some time. The steady demand for these products and the scale of leading players can make for stable cash flows that debt investors may find attractive.

4. Precision agriculture improves efficiency of larger farms

With its market size expected to increase fourfold by 2030, precision agriculture offers investors ample growth opportunities.¹⁰¹ It is especially useful on large-scale industrial farms, and investors can find debt and equity opportunities in this segment. This kind of automation can also ease concerns over farm labor supply.

Today's farm machinery is almost unrecognizable from its predecessors even 20 years ago. These GPS-enabled machines can be nearly autonomous, adjust to specific field conditions and execute multiple tasks using a range of sensors and machine learning. They also enable more precise application of fertilizer and other inputs, thereby reducing usage by as much as 60% and minimizing deleterious environmental impacts.¹⁰² For example, cameras and sprayers mounted on the tractor leverage AI to discern between weeds and crops and supply herbicide only where it is needed.¹⁰³

A handful of global players – Europe's CNH, Kubota of Japan, and John Deere and AGCO of the US – are supplying large farms with autonomous planters, sprayers and other machinery. As more of their new sales involve smart machinery, these manufacturers

are adding software update fees as a source of ongoing revenue to smooth out the cash flows of the commodity cycle. Currently, the US is a leading market for autonomous machinery. However, with farms in Brazil and Argentina modernizing, Latin America has become an immense growth market as well.¹⁰⁴ There is much room for technology penetration there as farms upgrade to keep up.

Hydrosat is a startup that enhances moisture monitoring – a critical input for precision agriculture. Currently used on industrial-sized farms in North America and Latin America, Hydrosat provides highly granular infrared satellite images more frequently than what is publicly available. This higher frequency data can be used to identify moisture and water stress weeks in advance of actual acute episodes.

Enhancing livestock productivity and reducing the emission of greenhouse gases is critical for a more sustainable food system.

5. Fertilizers will remain essential to maintain and enhance crop yields

Given the environmental externalities, the fertilizer industry can be problematic from an ESG perspective. There is no question nitrogen-based fertilizers are overused in some regions and can degrade the environment. However, ESG-minded investors should strongly consider engagement with this sector, as the unpleasant arithmetic of food supply and demand means that nitrogen-based fertilizers will not be easily replaced and will remain vital to food production for some time.¹⁰⁵

Because of their underusage in parts of South Asia and sub-Saharan Africa, nitrogen-based fertilizers and crop protection could have an outsized impact on crop yields there. Indeed, greater adoption of fertilizer and crop protection could increase food security and self-

sufficiency in these regions, even as their populations grow, and climate change adversely impacts yields.

For debt investors in particular, the sector offers a variety of benefits. For one, the annual need for nitrogen fertilizers serves as a steady source of demand. The industry is also highly consolidated, as the economies of scale and high capital costs create barriers to entry and limit competition. Surges in input prices highlight the importance of dependably sourcing key inputs like nitrogen, natural gas or coal, phosphate and potash. Companies that have reliable access to key inputs, such as CF Industries and Nutrien in North America that can tap (comparatively) cheap natural gas or potash, or Morocco's OCP, which has access to the world's largest reserves of phosphate, are especially well positioned during times of increased input costs.¹⁰⁶

6. Cultivated meat: More sizzle than steak for investors

Though cultivated meat gets much media attention – and has attracted more than \$1 billion in venture capital – the industry remains at an awkward stage for investors. Few products are available outside of a lab – Singapore is the only country to approve a cultivated chicken nugget product for retail sale.¹⁰⁷ The market is very crowded and highly fragmented with more than a hundred startups and little visibility about which ones may emerge as winners.¹⁰⁸

All firms face similar challenges to match the taste and cost of conventionally produced meat or fish and scale their production. The market is likely to see much consolidation in coming years as it will not be economical to continue funding all these startups.

While the prospect of a cultivated rib-eye steak comparable in taste, texture and cost remains quite distant, VC investors should focus on more unsung aspects of cellular agriculture that are likely to be commercially viable sooner. Simpler forms of protein are closer to being efficiently mass produced and, while adoption by consumers remains unclear, adoption by food producing firms may come first. For investors, startups focused on simple proteins that have commercial use can be attractive. For example, Onego

Bio and EVERY Company are startups focused on fermentation production of egg protein (egg whites), which is widely used as a binding agent in cakes and other baked goods. Israeli startup Remilk – which produces milk proteins whey and casein – has a

While the prospect of lab-grown steak remains distant, investors should focus on startups that produce simple protein that have commercial use.

partnership with food giant General Mills to produce lactose-free, non-animal cream cheese.¹⁰⁹

Chapters 1 and 2 analyzed the shifting dynamics in the demand and supply of the broad food system as well as the resulting opportunities and risks in individual asset classes. However, the evolving landscape of the food system also has implications across investment portfolios. Chapter 3 turns to these implications and proposes a portfolio-wide action plan for CIOs.

CHAPTER 3

PORTFOLIO-WIDE INVESTMENT IMPLICATIONS



Food price inflation, sustainability and disruptions to the food supply chain all raise important macro implications.”

1

2

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03

CHAPTER 3

PORTFOLIO-WIDE INVESTMENT IMPLICATIONS

Food price inflation, sustainability and disruptions to the food supply chain all raise important considerations beyond the specific asset class opportunities we discuss in previous chapters. Here we highlight three broader, cross-portfolio implications arising from the changing investment landscape in the global food system.

1. Disruptions in food distribution may reveal geopolitical and macroeconomic vulnerabilities

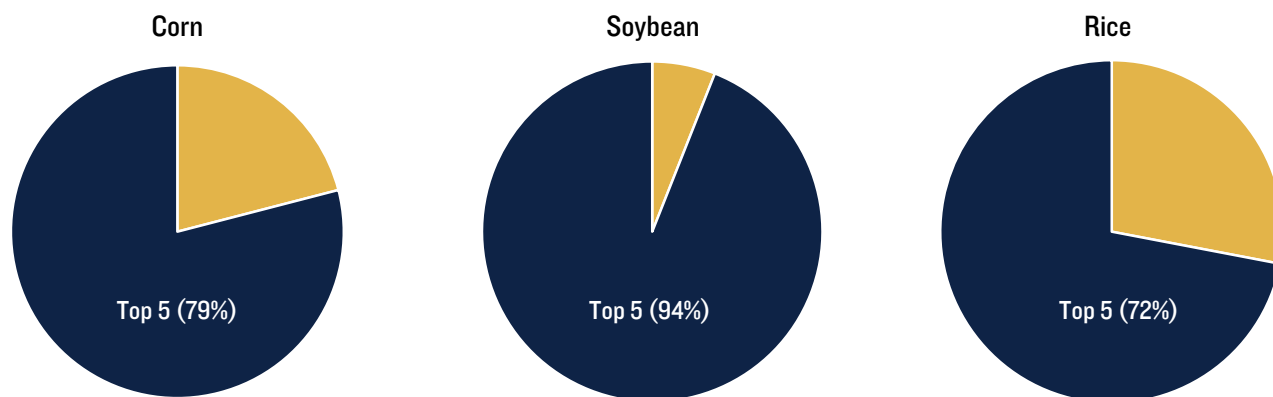
Given the reliance of the global food system on international trade, interruptions in food supply chains can be highly disruptive – especially given the export concentration of key agricultural crops and inputs (Exhibit 8).

Beyond the humanitarian tragedy unfolding due to Russia's invasion of Ukraine, the war serves as a stark reminder of the global dependence on a few regions for critical crops and resources. Russia and Ukraine

together account for nearly 30% of global wheat exports, and disruptions to their regular shipments sent global wheat prices soaring.¹¹⁰ The conflict also impacted global distribution of corn and fertilizer, causing their prices to surge as well.^{111, 112}

Indeed, the war in Ukraine revealed several vulnerabilities across the food system. The disruptions that cascaded from a single region triggered widespread food inflation that rippled across many regions and countries and led to further restrictions on food exports.¹¹³ Going forward, assessments of country risk will increasingly need to incorporate food security vulnerabilities from a food price inflation and import dependency standpoint.

Exhibit 8: Grain exports are highly concentrated
Share of top 5 global exporters for select key crops (2020)



Source: Food and Agriculture Organization of the United Nations.

For investors, there are two key takeaways from this ongoing episode. First, interruptions to food supply and distribution will likely be more frequent and widespread going forward. Developed markets are not immune to food shortages or surges in prices.¹¹⁴ Viral outbreaks in animal populations in the US, for example, led to a 70% surge in egg prices.¹¹⁵ Future turbulence around food distribution or supply can also arise from mounting geopolitical tensions, anti-globalization movements and deteriorating trade dynamics.¹¹⁶

In a world growing more polarized, the risk of the “weaponization” of food exports is only growing.

Second, it is critical investors acknowledge that food inflation can be particularly destabilizing from a social and political perspective – especially in frontier and emerging markets. For example, soaring food prices from droughts played a significant role in the Arab Spring movements of 2010 and 2011 that toppled regimes in multiple countries.¹¹⁷ Countries like Nigeria, Egypt, Kazakhstan and the Philippines where food accounts for a third or more of consumer spending may be most vulnerable in this regard.¹¹⁸ It is not clear current sovereign rating methodology takes food inflation and the ensuing political risks sufficiently into consideration, and investors may want to consider supplementing their assessments of country risk.

In a world growing more polarized, the risk of the “weaponization” of food exports is only growing.

2. The food system presents unique tensions and opportunities for ESG-minded investors

Applying an ESG lens to something as sprawling and essential as the food system can be exceptionally challenging. Today’s food system, in some ways, resembles the energy sector from a decade ago. It provides a vital good with inherent ESG tensions and

opportunities in its production system – but not much detailed data to make informed and nuanced trade-offs.

Nevertheless, food is becoming more prominent with ESG investors given the food system’s interconnections with climate and biodiversity. For investors with commitments to decarbonization and sustainability, there is a growing recognition that the broad food system needs to play a vital role in achieving both objectives. And it provides opportunities for them to make measurable impact.

ESG issues are, by their nature, complex. When looking at the current food system, several inconsistencies become apparent. One example is the use of synthetic fertilizers. Application of fertilizers in regions where they are underused – like sub-Saharan Africa – is one of the simplest and most cost-effective ways of increasing crop production from smaller farms and can go a long way towards eradicating hunger and malnourishment. Furthermore, there are no real replacements for nitrogen-based fertilizers today.

However, the production of industrial ammonia for fertilizers can be damaging to the environment in multiple ways. The production process, for starters, is very energy intensive and emits more carbon dioxide than any other chemical-making reaction.¹¹⁹ Additionally, some of the applied fertilizer runs off into sources of drinking water and waterways.¹²⁰ Fertilizers also account for a sizable portion of human-generated NO₂ emissions.¹²¹

So, how should ESG investors think about these apparent contradictions? More importantly, what should they do?

Engage with all sectors: ESG investors need to realize there are no perfect solutions when it comes to the food system. Instead, there are lots of imperfect options and alternatives. Given the criticality of meeting global food demand, excluding some segments of the food system based solely on carbon emissions, for example, seems ineffective. Rather, an emphasis on active research that focuses on the actions of the broader industry as well as individual companies to address their most material ESG issues can be more effective. For example, understanding what steps a fertilizer manufacturer is taking to reduce their carbon emissions and how this compares to their

peers can be a good starting point. Furthermore, using active stewardship to connect companies with external experts and industry associations to encourage them to use best practices can also be a constructive approach for investors.

Seek out innovative incumbents: With seemingly perfect options a long way off (e.g., biological fertilizers that are just as effective and cost-efficient as synthetic ones), investors need to have an approach that acknowledges current needs and limitations while also working to shorten the transition to a better, more sustainable option. This may mean, for example, identifying the most forward-thinking fertilizer manufacturers that are taking relevant measures to reduce their carbon footprint today and investing in startups working on biologicals. Examining their corporate strategy and getting more detail around how their research dollars are spent is also an effective way to learn what aspects of their business they are leaning into. For companies that have set a carbon emissions target, examining how realistic their targets are, the state of their progress and whether achieving these goals relies on current or future technology can be another way of discerning between forward-leaning and lagging incumbents.

Work to narrow the data gap: Investors need access to quality information and data to make informed trade-offs and to identify the most innovative incumbents. To achieve this, investors need to seek greater disclosures and information on a regular basis from companies in the food system. Greater transparency in data, however, is not costless and may be especially burdensome for small companies and farmers. Collective advocacy by investors for greater disclosure has led to better data in other sectors and

industries.¹²² The FAIRR Initiative, for example, is an investor network that has been effective in providing data on a range of ESG risks associated with food production. They publish research and offer tools and indices on the animal protein industry, for example.¹²³ Participating in initiatives like this may be a productive step for investors seeking more data disclosures.

The challenges of the 21st Century remain significant and are propelling the global food system towards an inflection point.

3. Farmland investing provides diversification and inflation protection for institutional portfolios

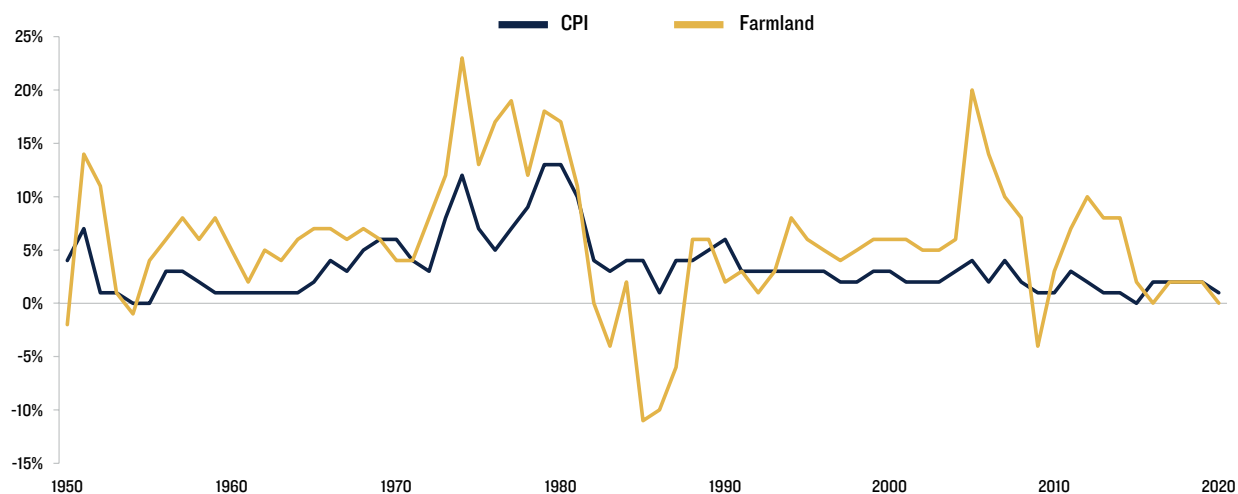
Farmland is still a maturing institutional asset class, and some investors may be unfamiliar with incorporating it into portfolio and liquidity optimization frameworks. However, CIOs may want to consider an allocation to farmland within their portfolio, especially given two important – and somewhat unique – features.

First, farmland returns are relatively uncorrelated with major asset classes. Over the last 20 years, US farmland returns have been negatively correlated with both stocks and bonds.¹²⁴ Second, farmland has proven to be a reliable inflation hedge (Exhibit 9). As a real asset, US farmland has proven to be an effective store of wealth in periods of high inflation and uncertainty as well.



Exhibit 9: Farmland can be an effective inflation hedge

US farmland price compared to US CPI (year-over-year % change)



Source: USDA Economic Research Center and Federal Reserve.

Conclusion

The food system has evolved tremendously since the technological advances of the Green Revolution in the 1960s. Nevertheless, our food system remains fragile and the challenges it faces are significant. Our future food system will need to be more productive as well as more sustainable to meet the shifting demands of a growing and more affluent population. Whether seeking opportunities or mitigating hidden risks, understanding the rapidly transforming global food system will be essential for institutional investors around the world.

INVESTMENT IMPLICATIONS ACROSS FOOD DEMAND

- | | |
|---|--|
| 1. Meat producers offer a contrarian investment opportunity | <ul style="list-style-type: none"> • More affluent populations and convergence of global diets create opportunity for meat producers • ESG investors should consider engaging with conventional meat manufacturers |
| 2. Cold storage and transportation provide global opportunities | <ul style="list-style-type: none"> • Proximity to urban centers and transportation hubs are key • Cold logistics providers and real estate in the US, SE Asia and Latin America can be attractive |
| 3. Packaging offers cash flows no matter the underlying food fad | <ul style="list-style-type: none"> • Irrespective of the trend, food innovation is reliant on new packaging and machinery • Seek out leading packaging firms as well as equipment makers in the US and Europe |
| 4. Health and wellness options drive grocery and food innovation | <ul style="list-style-type: none"> • Consumers are seeking healthier food options and may be willing to pay up for it • Look for companies that are closing the gap on price and taste rather than relying on changes to consumer tastes |
| 5. Convenience and food safety drives emerging market opportunities | <ul style="list-style-type: none"> • Concerns around food safety in EM has led to demand for recognized brands and packaged foods • Regional bakers and bottlers offer opportunities in India and Latin America |

INVESTMENT IMPLICATIONS ACROSS FOOD SUPPLY

- | | |
|---|--|
| 1. AgTech driving smarter, more sustainable food production on small farms | <ul style="list-style-type: none"> • Finding ways to enhance productivity of small-scale farms is critical to meeting future food demands • AgTech landscape is fragmented with many startups and can offer attractive VC investments |
| 2. Farmland debt and equity offer a unique exposure and attractive investment | <ul style="list-style-type: none"> • A range of risk-reward propositions for debt and equity investors • California is especially attractive for investors because of its optimal climate and proximity to major exchanges, ports and highways |
| 3. Crop science and feed additives solutions to boost productivity and sustainability | <ul style="list-style-type: none"> • Leaders in Asia have local expertise and established distribution networks • Leaders in Europe and North America offer real-world products and have diversified businesses and scale |
| 4. Precision agriculture improves efficiency of larger farms | <ul style="list-style-type: none"> • Opportunities in both large global agriculture equipment makers as well as tech startups • Latin America provides growth opportunities as farmers in Brazil and Argentina modernize |
| 5. Fertilizers will remain essential to maintain and enhance crop yields | <ul style="list-style-type: none"> • Annual need for some fertilizers provides steady source of demand that are not easily replaced • ESG-minded investors should strongly consider engagement with this sector as they will be vital to food production for some time |
| 6. Cultivated meat: More sizzle than steak for investors | <ul style="list-style-type: none"> • The market for cultivated meat is highly fragmented with serious challenges and much uncertainty • Investors should instead focus on production of simple proteins (i.e., whey or egg albumen) for commercial use |

PORTFOLIO-WIDE INVESTMENT IMPLICATIONS

- | | |
|---|--|
| 1. Disruptions in food distribution may reveal hidden risks and vulnerabilities across portfolios | <ul style="list-style-type: none"> • Disruptions may be more common and widespread in the future • Food inflation can be destabilizing from a social and political perspective – especially in emerging and frontier markets |
| 2. The food system presents unique tensions and opportunities for ESG-minded investors | <ul style="list-style-type: none"> • There are no perfect solutions for the inherent tensions of the food system • An approach that engages with companies and emphasizes active research as well as collective advocacy may be most effective |
| 3. Farmland investing has some unique investment characteristics | <ul style="list-style-type: none"> • Offers negatively correlated returns with both stocks and bonds • Farmland has proven to be a reliable inflation hedge |

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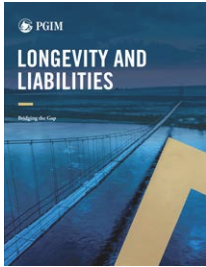
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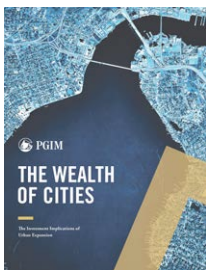
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