FEEDING THE FUTURE
How Innovation and Shifting Consumer Preferences Can Help Feed a Growing Planet

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How Innovation and Shifting Consumer Preferences Can Help Feed a Growing Planet

It’s a simple question: Will we be able to feed everyone if the population of the planet rises from about 7 billion people today to 9-10 billion in 2050? If you are a student of Thomas Malthus and buy into his Essay on the Principles of Population, then you believe this type of population increase will result in famine and poverty. The good news is that when Malthus published his famous paper in 1798 the global population was only 800 million and despite an almost nine-fold increase in population, his predictions luckily have not been realized. Advances in agriculture, food manufacturing, and food distribution together have increased the efficiency of the global food industry to supply an ever-growing population. But if we look at today’s global food industry, we find that it is unsustainable for future demand in its current format. For the industry to keep up with a 60-70% increase in food demand over the next 30 years, it can’t continue to operate in a “business as usual” mode.

What’s wrong? Three main issues plague the global food industry: sustainability, waste, and nutrition. On the sustainability front, agriculture today consumes 70% of surface and groundwater and uses 50% of habitable land while the entire food industry is responsible for up to one-third of human-caused greenhouse gas emissions. Globally, around 1.3 billion tonnes of food — almost one-third of all food produced — gets lost or wasted every year. Malnutrition — in the form of hunger and undernourishment, obesity or micronutrient deficiencies — affects almost 40% of the global population and the impacts on public health and economic development now cost the global economy almost $3.5 trillion per year.

Is there a simple answer? No, not simple. But the first step towards a solution is to understand the problem ahead of us — identify the need for more sustainable agriculture, more efficient manufacturing and distribution, and consistent delivery of nutritious food.

In the report that follows, we look at ways the industry can use innovation and technology to become more sustainable. In farming, using big data and digital agriculture such as the use of sensors, field monitoring, and aerial imaging as well as new technology in farm equipment and aeroponics can increase sustainability and decrease the amount of land required for food production. New seed technology, feed additives, alternative proteins and biofortification also help increase nutrition. Expanding agriculture in the Southern Hemisphere is also an opportunity as improving yield gaps leads to better sustainability.

On the consumer front, a shift towards health and wellness is driving food manufacturers to alter their portfolios to deliver more nutritious, indulgent, safe, and sustainable products. Consumers are also changing the way they shop for food and are becoming more conscious of where their food comes from, leading to increased supply-chain transparency.

Can we get there? We think so, but it will require (1) easier access to financing; (2) the removal of distortions in the agriculture and food market; (3) vertical integration across the supply chain; (4) easier and faster access to the market for innovation and technology; (5) better data and information; and (6) better healthier products and a change in diets to continue to prove Malthus wrong.
Feeding a Growing Population

The global food industry is plagued by issues of sustainability, waste, and nutrition while the demand for food is increasing.

Agriculture is responsible for 70% of global freshwater withdrawals.

Food-related emissions account for up to one-third of human-caused greenhouse gas emissions.

77% of agricultural land is used for livestock production, which supply only 17% of global calories.

-1.3 billion tonnes of food gets lost or wasted per year — enough to feed 2 billion people.

Malnutrition costs the global economy $3.5 trillion each year.

The global population is expected to reach 9.7 billion by 2050 from 7.3 billion today.

Meeting 2050 food demand under current industry practices results in:

- 65% increase in irrigation water.
- 67% increase in land.
- 87% increase in greenhouse gas emissions.

The biggest opportunity to expand agricultural production is in the southern hemisphere, where unlocking productivity gains and increasing crop production per hectare of planted area is key.

Global Corn Yields (metric ton/hectare)

Source: Springmann et al. (2018)

Source: USDA, Citi Research
HOW DO WE MAKE THIS HAPPEN?
WE HIGHLIGHT SIX STEPS

INNOVATION AND INVESTMENT CAN HELP TO ADDRESS THE THREE MAIN CHALLENGES OF TODAY’S FOOD INDUSTRY IN FEEDING THE POPULATION OF THE FUTURE

**Waste**
- Shelf-life extension
- Supply chain technology
- Upcycling of food waste
- Secondary marketplaces
- Precision Ag/Analytics
- Digital Land Mapping
- Adaptive Irrigation
- Vertical Farming
- Livestock Monitoring
- Food Additives
- Gene Editing
- Better Data and Sensors

**Sustainability**
- Biological and Microbial solutions
- Enzyme-based solution to reduce GHG
- Alternative feed and proteins
- Algae-based Fish Oil
- Precision Ag/Analytics
- Digital Land Mapping
- Adaptive Irrigation
- Vertical Farming
- Livestock Monitoring
- Gene Editing
- Better Data and Sensors

**Nutrition**
- Personalized nutrition
- Biofortification
- Production of healthier products
- Natural ingredients
- Functional foods
- Algae-based Fish Oil
- Food Additives
- Gene Editing
- Better Data and Sensors

**怎样实现？**
我们强调六个步骤

创新和投资可以帮助解决当今食品行业三大挑战

在养活未来人口方面

**废物**
- 延长保质期
- 供应链技术
- 食物浪费的再利用
- 二级市场
- 精密农业/分析
- 数字土地测绘
- 适应性灌溉
- 垂直农场
- 家畜监测
- 食品添加剂
- 基因编辑
- 更好的数据和传感器

**可持续性**
- 生物和微生物解决方案
- 酶基减缓GHG的解决方案
- 替代饲料和蛋白质
- 阿尔戈拉基鲑鱼油
- 精密农业/分析
- 数字土地测绘
- 适应性灌溉
- 垂直农场
- 家畜监测
- 基因编辑
- 更好的数据和传感器

**营养**
- 个性化营养
- 生物强化
- 生产更健康的食品
- 天然成分
- 功能性食品
- 阿尔戈拉基鲑鱼油
- 食品添加剂
- 基因编辑
- 更好的数据和传感器
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Introduction

We need to change the whole food system; we need to change the way we produce food, and the way we eat it.

The above quote by the Director-General of the Food and Agriculture Organisation of the United Nations (FAO), José Graziano da Silva, captures the fact that the current global food system is unsustainable and it is not just one part of the supply chain which needs changing but the entire system needs improvements – from the way we produce food to the way we consume it.

The global food industry is a complex system, including companies that supply inputs to agriculture production, farmers, processing, trading and manufacturing firms, retail outlets, and finally end users. Food production grew more than three-fold since the early 1960s, growth that was primarily achieved through crop intensification and yield improvements. However, the system today is inefficient and unsustainable with one-third of all food produced wasted throughout the supply chain at a value of almost $1 trillion per year. The agriculture sector alone uses 70% of the world’s freshwater supply and 50% of total habitable land, while the food system (including agriculture, processing, manufacturing, and distribution) is responsible for up to 30% of global greenhouse gas (GHG) emissions. The global food system has also failed to feed and nourish everyone – over 800 million people are still hungry, while at the same time over 650 million people are currently obese. Many countries face the challenges of both hunger and over-consumption and it is estimated that 1 in 3 people on the planet suffer from diet-related malnutrition.

Over the next few decades, food demand is expected to increase by 60-70%. Meeting this demand sustainably with less waste and better nutrition for all is challenging. If we continue with ‘business as usual’, we may need up to 67% and 65% more farm land and irrigation water withdrawals, respectively, to be able to feed the expected 9-10 billion people on the planet by 2050. This in turn could translate to an 87% overall increase in agriculture-related greenhouse gas emissions. In terms of nutrition, if we continue on the same path as today, the number of people suffering from diet-related malnutrition worldwide could increase from 1 in 3 to 1 in 2.

However as we discuss in this report, the industry is changing. Technology and scientific innovation are helping to increase the productivity of agriculture production while at the same time reduce unsustainable water and land use. New innovation is coming to the forefront such as gene editing and precision agriculture, which could have a positive impact on agriculture production. Other innovations such as vertical farming and alternative proteins have the potential to disrupt current food supply chains. Consumers are also demanding healthier products, natural ingredients, and more traceability which is encouraging the food manufacturing industry to produce more nutritious and healthier foods and improve transparency of their supply chain.

There are huge opportunities for the Southern Hemisphere to increase the production of food to meet future demand with Brazil, Argentina and Sub-Saharan Africa in particular with further room to expand crop harvests through higher planted area and yield improvements.
Solving the issues faced by the global food sector has become an international priority. Zero Hunger (SDG 2) is the second UN sustainable development goal (SDG) with the aim of ending hunger by 2030 and malnutrition by 2025, doubling agriculture productivity and improving the income of small food producers, ensuring sustainable food production and maintaining the genetic diversity of seeds, cultivated plants, and domestic animals. Responsible Consumption & Production (SDG 12) addresses sustainable consumption and production patterns, including a target on food waste which aims to halve per capita global food waste at the retail and consumer levels by 2030 and reduce food losses along production and supply chains. The 2017 Global Nutrition Report (Development Initiatives, 2017) also highlights that improving nutrition can have a multiplier effect across the SDGs and can help to support equity and inclusion, provide infrastructure for economic development, and enhance peace and stability.

In this report we attempt to answer the following question: Can we feed 9-10 billion people with more sustainability, less wastage and more nutrition? We start the report by describing how the food industry currently works, followed by a description of the challenges the food industry is facing. We then discuss the potential increase in food demand and analyze its drivers including population demand, income growth, and dietary preferences. We then look at two areas (1) the opportunities in the food industry from a commodity perspective, highlighting the important role the Southern Hemisphere could play in meeting future demand and (2) the opportunities available from a sector perspective where we highlight what companies are doing in this space focusing on how innovation and technology are playing an important part of the solution, and how consumers are demanding healthier options and better traceability of the products they consume. We end with a discussion on the steps needed to improve the system including: (1) better access to finance; (2) removing distortions in trade; (3) vertical integration across the supply chain; (4) faster and easier access to innovation and technology; (5) better information and data for all; and (6) production of healthier and more nutritious products.

This report brings together solutions and opportunities across the full supply chain, looking at the issues from both a commodities perspective and a sector perspective and across geographically diverse industries from agricultural chemicals and machinery to consumer staples, and food retail – areas that are usually discussed separately.
The global food system is currently inefficient and unsustainable

The Global Food Industry Is Complex

The global food industry is complex. There are millions of people who are employed in the industry (about 866 million just in agriculture in 2017) and thousands of companies involved across the supply chain from the production of food, to the processing, manufacturing, and distribution of food to the end consumer. (ILOSTAT, 2018) The system can be divided into upstream activities which includes agriculture production and all the inputs that are needed to produce food such as seeds, chemicals, machinery and equipment, labor etc. and downstream activities which includes primary and secondary processing, manufacturing and distribution to the end consumer (see Figure 1).

The system is currently inefficient and unsustainable: one-third of all food produced for human consumption (FAO, 2011) is lost or wasted along the supply chain with losses and waste at every stage in the food system. This system is also currently unsustainable as the agriculture sector consumes 70% of surface and ground water and uses 50% of habitable land. Before we discuss the challenges facing the food industry in more detail, it is important to understand how the system works – we do this by breaking down the different stages of the food supply chain and discussing the processes and players involved in each.
Figure 1. Food Supply Chain — from Inputs, to Production, Processing, Distribution, and End User

Source: Citi Research
Upstream Activities

As the agriculture sector becomes more intensive it requires a number of inputs such as seeds, fertilizers, crop protection, and machinery and equipment to grow food. The production of dairy and meat requires additional inputs such as feed (maize, wheat, soybeans etc.) and animal health services (veterinary services and antibiotics). Over the years, the use of big data has become increasingly important for this sector and includes detailed weather information, data needed for digital agriculture such as the use of sensors and field monitoring, and aerial imaging. There are hundreds of companies that are involved in providing these inputs and as we will see later in this report, biotechnology and innovation are increasingly changing the way seeds and chemicals are being produced, whilst automation and mechanization is increasing the productivity of crop production.

Over the years animal husbandry and aquaculture has also become more intensive — from the use of genetics in livestock production to the increasing use of antibiotics in animals. The production of meat also requires feed. According to the International Feed Industry Federation, in 2016 world feed production reached an estimated one billion tonnes and global commercial feed manufacturing was estimated to be worth over $400 billion.

Agriculture / Aquaculture Production

Every day, agriculture produces an average of 23.7 million tonnes of food with a total value for that one day of agriculture production estimated at $7 billion. (FAO 2014) Cereals, roots, tubers, fruits, and vegetables account for 82% of daily production. And while meat makes up only 5% (1.1 million tonnes), 36% of the crop calories produced goes straight to animal feed. (Cassidy et al., 2013) Globally, there are more than 570 million farms worldwide, most of which are small and family-run; small farms (less than 2 hectares) operate about 12%, and family farms about 75% of the world’s farmland. Over the past few decades, average farm size has decreased in low- and lower-middle income countries, whereas in high-income countries, average farm size has increased. (Lowder et al., 2016)
The agricultural sector employs one in three of the world’s workers estimated at over 866 million workers (27% of total employment). Agriculture share as a percent of total employment is decreasing in all regions; however a large number of people are still working in the agriculture sector in Sub-Saharan Africa and South Asia estimated at 57% and 42% of total employment (see Figure 5). The overall agriculture share as a percent of total employment across low-income countries is much higher (69%) than it is in high-income countries (3.1%). (ILOSTAT, 2018) The composition of jobs across the whole food system is also very different from low- to high income countries; over 90% of jobs within the food system are in farming in low-income countries, compared to 20% in high-income countries (food services account for 65% of food system jobs). (World Bank, 2017).

The value add of agriculture, forestry, and fishing as a percent of GDP has been decreasing over time, and contributed 3.5% to global GDP ($2.5 trillion) in 2016. However, there are again significant regional differences and the agriculture sector plays a more important role in many developing countries — more than 16% of GDP is derived from agriculture in Sub-Saharan Africa and South Asia (see Figure 4).

Figure 4. Agriculture, Forestry, and Fishing Value Added (% of GDP)

![Figure 4](chart1.png)

Figure 5. Agriculture Share (%) of Employment

![Figure 5](chart2.png)

Downstream Activities

Upon harvest, some agriculture requires initial processing such as crushing for soybeans, rice milling, pasteurization etc. and is either sold through domestic or international markets. Most food is consumed domestically - about 85% of food is produced in the country where it is consumed. (IMF, 2016) The bulk purchase of raw food material such as grains, meat, cocoa, tea, coffee, and nuts can be done through either strategic partnership with the producers, through traders, or by buying it as a commodity item. In some cases agriculture produce is sold directly to consumers through farmers markets or directly to retailers. Commodity items are subject to future contracts meaning that two parties sign a contract to buy or sell an item for a (future) price agreed today, with delivery and payment happening in the future. (Dani, 2015) Primary players in food processing, commodity trading and market and distribution include Archer Daniels Midland, Bunge, Cargill, and Louis Dreyfus — known as the ‘ABCD’ group. In recent years Chinese-owned grain company COFCO has caught up with the ABCD group. These companies process and sell a variety of commodities.
A quote from Cargill captures the diversity of their portfolios – ‘We are the flour in your bread, the wheat in your noodles, the salt on your fries. We are the corn in your tortillas, the chocolate in your dessert, the sweetener in your soft drink. We are the oil in your salad dressing and the beef, pork or chicken you eat for dinner. We are the cotton in your clothing, the backing on your carpet and the fertilizer in your field.’ (Cargill, 2001) These companies are increasingly expanding their business from traditional commodity traders into more primary production, food processing and manufacturing, as well as specialty ingredients.

**Food Manufacturing and Retailing**

Following initial processing, these products are either sold directly to retail outlets or sold for further processing to become the brands and products that we are most familiar with and that we buy in supermarkets/food retail outlets. Companies in the food and beverage industry process raw materials into food products and package and distribute them through various channels to both individual customers and retail outlets. In some cases food manufacturers also have strategic partnerships with farmers and buy raw materials directly from them, rather than through the market. The market size of the packaged food industry (excluding fresh food) is estimated at $2.2 trillion compared to the non-alcoholic beverage industry, which is estimated at $80 billion. (Euromonitor, 2016) There are hundreds of food manufacturing companies including Nestle, Unilever, Danone, Kraft Heinz, Tyson Foods, Mondelez, and others. Once processed and manufactured, the product is distributed to retail outlets and then ultimately to the consumer.

Food retail channels vary regionally with traditional markets still commonplace for people in Asia Pacific, Middle East, Africa, and Latin America to buy food from, whereas hypermarkets and large supermarkets dominate (>70%) food retail in North America. A more diversified retail landscape exists in Europe (Figure 6). Large food retailers which include Tesco, Carrefour, and Walmart use third-party suppliers. In some cases, the retail sector also has strategic partnerships with farmers and other food cooperatives to source items, especially for perishable goods like fruits, vegetables, and meat. The food retail sector is changing around the world; and emerging forms of e-commerce are bringing in new players such as Amazon Fresh and Ocado. According to Citi Research, although online grocery penetration is still low at just under 7% in the U.K. and under 2% in the U.S., the potential for scaling up multiple times is there.
In the last few years we have also seen a growth in the takeaway market with online platforms such as Deliveroo, Just Eat, UberEats, Grub Hub, and Delivery Hero in the U.S. and Europe and Mietuan Dianpin and Ele.me in China. While the global online food delivery market is estimated at $96 billion according to China Daily, the online food delivery market in China increased 23% from 2016 to $31.9 billion in 2017. (Xinhua, 2018) These online platforms work with a number of restaurants to provide fast online purchasing and delivery of restaurant food to consumers. They have allowed restaurants that do not have facilities available for food delivery to enter the delivery and takeaway market.

Other online platforms that are changing the way consumers purchase their food are meal kits companies such as Blue Apron and Plated which provide consumers with measured ingredients and recipes to cook a meal. There are also online platforms such as Able and Cole that provide fresh supplies such as fruit and vegetable boxes to your doorstep straight from farms. The global meal kits market is estimated at $2.2 billion and expected to grow rapidly. (Sifferlin, 2017) However, it is worth noting that these meal kit companies have started to expand beyond their online presence and are partnering up with supermarket chains to attract new customers.

The Global Food Industry Is Changing

The global food supply chain is changing rapidly. As stated above traditional commodity traders are moving both downstream and upstream into directly producing raw materials and producing finished products. Consumers are also demanding more traceability and want to know exactly where their food is coming from, encouraging both retailers and food manufacturers to establish transparent and well-documented supply chains. Innovation and technology are also changing the food value chain with the increased use of sensors and data analytics in production, new online delivery platforms, and potentially disruptive novel production systems. However, as we will see, food demand is expected to increase in many regions and meeting this higher demand sustainably will be a huge challenge.
Challenges Facing the Food Industry

The global food system faces growing challenges as demand for food increases. However, the question of “Can we feed a global population of 9-10 billion people?” is not straightforward as consensus believes the current systems are unlikely capable of producing enough food. (FAO, 2017) The challenges ahead are multi-faceted and influenced by many drivers but we believe they distill down to three key issues: increasing sustainability, reducing waste, and improving nutrition. Therefore, the more realistic question is “How can we feed 9-10 billion people with more nutrition, less waste, and more sustainability?” To address, this question, the current global food system needs to change to ensure more sustainable production and consumption and nutrition for all. This is will not be simple, as emphasized by the FAO – “Business-As-Usual” is not an option.¹

Mapping the Challenges Across the Supply Chain

The three challenges we explore are not disconnected and in order to assess their inter-linkages as well as better understand in what stages of food production and consumption they are most prevalent across, we map the challenges onto the food supply chain in Figure 7 below. It could be argued that all three challenges are relevant to all sectors across the supply chain, but highlighting the key inputs and stages will help us to better identify where the key opportunities reside and who is best positioned to do what in tackling the challenges of sustainability, waste, and nutrition.

¹ We define sustainability as the sustainable use of natural resources.
Figure 7. Challenges Facing the Food Industry Across the Supply Chain

- **Inputs:** Seeds, Chemicals and fertilizers, Machinery and equipment, Livestock and food, Food, Animal health, Land/Water/Energy, Data, Labor

- **Production:** Agriculture/Aquaculture Production, 2600km/3/year water withdrawal (70% of total water withdrawal), 51 million km2 of land use (50% of habitable land), 6 billion tonnes of GHG emissions (10-12% of total emissions)

- **Primary Processing:** Processing of grains, meat and milk
  - Commodity Trading and transport
  - Domestic Use and transport

- **Secondary Processing and Manufacturing:** Food Manufacturing and Processing

- **Distribution/Retail:** Wholesale/retail, Restaurants/hospitality
  - Meal Kits and Fresh Produce
  - Online Delivery/Service Platforms

- **End Use:** Consumer
  - 1 in 3 people in the world are malnourished
  - Main nutrition costs the global economy $3.5 trillion a year
  - 796 million are undernourished
  - 2 billion lack sufficient micronutrients
  - 1.9 billion adults are overweight

- **Waste, Sustainability, Nutrition:**
  - 54% of food waste occurs upstream
  - 630 million tonnes of food are wasted in developing countries costing $320 billion – 40% of waste happens at post-harvest and processing stages
  - 46% of food waste occurs downstream
  - 670 million tonnes of food are wasted in developed countries costing $680 billion – more than 40% of waste happens at retail and consumer stages
  - Food waste costs global economy $1 trillion a year

Source: Citi Research
We see waste as an issue for all stages of the food supply chain, whereas the challenge of nutrition is most relevant to food production, processing, and consumption. The challenge of sustainability lies mainly in agriculture and aquaculture production, which is also a focus for all three challenges. As discussed earlier, the three challenges also have close inter-plays between them. For example, the effects of diet and changes in consumer demand on health and sustainability have been well researched, and there is growing attention on the environmental implications of food waste. Therefore, the challenges should not be viewed as separate silos but as a nexus of issues that need to be addressed in order to transform the global food system into one that is sustainable and delivers good nutritional and environmental outcomes. Let’s look at these challenges in more detail.

The Current System Is Unsustainable: The Abuse of Water

Food production grew more than three-fold since the early 1960s primarily through crop intensification and yield improvements. During the same period, net cultivated land expanded by only 12%, while intensity and productivity grew dramatically. The growth of irrigated agriculture was an important driver of these gains – growth in land equipped for irrigation more than doubled since the mid-1900s, accounting for the entire net increase in cultivated area. The growth of irrigation not only allowed for greater water control and intensified production in arid and semi-arid regions, but also made possible the practice of double cropping and supported the rise of high-yielding fertilizer-responsive crop varieties. Irrigated systems typically have yields roughly twice those of non-irrigated systems under similar conditions. However, in many parts of the world, these practices have begun to put a significant strain on local water supplies through the depletion and degradation of ground and surface water resources. Indeed, with agriculture accounting for ~70% of global freshwater withdrawals, water scarcity issues are often closely tied to agricultural activity. (FAO, 2011) Agricultural practices, especially intensive farming, also have detrimental effects on water quality – as farmers ramp up fertilizer application, agricultural runoff can carry a large amount of nitrogen and phosphate into waterways causing toxic algal blooms, reducing oxygen and light penetration necessary for marine life, and creating colossal ‘dead zones’ such as those in the Gulf of Mexico, Chesapeake Bay, and Baltic Sea.
Over the last several decades irrigated agriculture has expanded rapidly in East and Southern Asia as populations have exploded and economies prospered, with India and China alone accounting for ~40% of the world’s area equipped for irrigation today. These areas are now experiencing some of the most severe water shortages due to relatively limited renewable water resources to support this growth, leading to overexploitation of aquifers and rivers (see box below).

Dwindling Water Resources - The Yellow River in China

The Yellow River in China is the second largest river in the country by length and basin area, flowing through nine provinces and emptying into the Bohai Sea. Since the 1950s, irrigation of the land around the river has risen dramatically, with an estimated ~91% of all surface water abstracted from the Yellow River used for irrigation purposes. (Chen, J. et al., 2003) Since the rise of irrigated agriculture in China, the river has experienced a significant decline in downstream flows, leading to severe depletion of the water level in the lower river such that it no longer discharges to the sea year round. Irrigation has also caused degradation of the water quality in the river, with major ions and salinity increasing in concentration. (Chen et al., 2003) Despite the implementation of water allocation quotas, overexploitation continues by the provinces in upper basins as regulators possess insufficient resources for monitoring water use and imposing restrictions.

In the Middle East and Central Asia, the ratio of agricultural water withdrawals to renewable resources is 47% and 57%, respectively, increasing to 170% in North Africa.

As stated in our 2017 Citi GPS Report Solutions for a Global Water Crisis the ratio of total water withdrawals to renewable water resources is often used as a measure of water scarcity, with a ratio above 20% considered “stressed” and a ratio above ~40% considered “severely stressed”. In the Middle East and Central Asia the ratio of agricultural water withdrawals to renewable water resources is ~47% and ~57%, respectively, while in North Africa, this ratio is ~170%. (Chen et al., 2003) Thus, water resources in these desert regions are severely stressed (even before accounting for other water use from municipal and industrial demand) due to severe overexploitation of water for agricultural use. On the other hand, some regions use only marginal proportions of their renewable water resources for agriculture, either due to a great abundance of water resources, like in South America, or due to minimal agricultural industrialization, like in Sub-Saharan Africa.
The production of beef, pork, and chicken uses around nine, four, and three times, respectively, the amount of water per kilogram as cereal grains.

Increasing competition from non-irrigation claims puts further strain on water security, among which the leading factor is livestock production. The production of beef, pork, and chicken uses around nine, four, and three times as much water per kilogram, respectively, compared to cereals. (Bailey et al., 2014) Currently, the global water footprint of livestock production makes up almost one third of the water footprint of total agriculture production, and is most likely going to increase as the global appetite for meat grows. (Hoekstra & Mekonnen, 2012) Water is a critical resource for agriculture and therefore needs to be used and managed more efficiently and effectively in order to deliver sustainable food production.
The Current System Is Unsustainable: The Use of Land

Currently 50% of habitable land is used for agriculture production and more than three-quarters of this land (40 million km²/ 4 trillion hectare) is used for the rearing of livestock through a combination of grazing land and land use for animal feed production. Even though the production of meat and dairy uses the most land, they only supply 17% of global calories and only 33% of the global protein supply. The 11 million km² (1.1 trillion hectare) used for the production of crops supplies 83% of global caloric supply and 67% of food protein supply. (Roser & Ritchie, 2018)

The development of agricultural land has led to environmental degradation including deforestation, soil erosion, and loss of biodiversity

The expansion of agricultural land has enabled food production to increase substantially, however this expansion is responsible for over 80% of the deforestation occurring over the last few decades. The clearing of forests leads to severe environmental degradation which includes soil erosion and loss of biodiversity, and affects ecosystems which are important for local people’s livelihoods. Latin America has already lost 40% of its forests to expansion of land for export-oriented agriculture such as livestock and soybeans. Over 70% of deforested land in the Brazilian Amazon is used for grazing or growing soybeans for pig and chicken feed. (Smith School of Enterprise and the Environment, 2015)
There are debates as to whether the land used for agriculture needs to expand (and by how much) to meet future food demand. Increases in crop production can come from increasing yields and/or expansion of farmland, but yield increases are often preferred given the environmental damages of agricultural expansion. Based on current yield trends, agriculture is not on track to meet future demands and would require an additional 67% of cropland (Springmann et al., 2018) which has severe consequences for natural ecosystems. This has led to calls for “sustainable intensification” of agriculture (Garnett et al., 2013) which aims to increase crop yields while improving resource use efficiency such as water, fertilizer, and pesticides. The closure of yield gaps offers great potential to increase crop production especially across developing countries which have the largest yield gaps. The FAO states that if yield gaps in different regions are closed and agriculture is intensified, only 100 million hectares of additional land is needed to meet future food demand. (Alexandratos & Bruinsma, 2012) However, the closure of yield gaps is not without its challenges especially as yields have stopped improving (with current technology) on 24-39% of the world’s most important cropland areas. (Ray et al., 2013)

The question is if land expansion is needed where should this occur and what are the consequences to the natural ecosystems, local communities, and the use of water resources? According to the International Monetary Fund (IMF) the most suitable land for agriculture expansion is found in Sub-Saharan Africa and South America as shown in Figure 12. There is very little suitable land for agriculture left in Asia, Europe or North America.

Figure 12. Used-to-Available Land Suitable for Agriculture by Region, 2013

Source: IMF World Economic Outlook (2016): Commodity Special Feature, Citi Research
Another challenge agriculture faces is the loss of suitable land to degradation and urban expansion. Fertile soil is being lost at an alarming rate of 24 billion tonnes a year and one-third of the world’s land has severely degraded as a result of intensive farming. (UNCCD, 2017) Sub-Saharan Africa is currently the worst affected but forecasts on future land use also draw out South Asia and Middle East & North Africa (MENA) as regions facing growing pressures and challenges. This has led to a UN-backed call to move away from resource-intensive production toward more sustainable practices and management policies.

Countries facing land scarcities with rising demand for food may have to explore other options which include increasing trade with the land-abundant or investing in land abroad. The latter has been a popular strategy among rich nations such as the Gulf States, South Korea, and Japan who lease or buy land in Africa, Latin America, South & South East Asia, and Russia. (Smith School of Enterprise and the Environment, 2015) China has also been increasing its agricultural investments abroad and holds a diverse portfolio in Latin America, Africa, and South East Asia. However, China’s overseas agricultural investments may be more driven by business opportunities and profit-making than meeting domestic food demand. (Zhan et al., 2018)

The option of overseas investment may not be a feasible option for poorer countries in need of land expansion for agriculture, and therefore trade represents a more viable option. Connecting countries with growing demand and those with abundant land also benefits the latter that can profit from expanding their exports, for example, soybeans in South America and oil palm in Southeast Asia.

**The Current System Is Unsustainable: Greenhouse Gas Emissions**

Agriculture is a significant source of greenhouse gas emissions and makes up 10-12% of total anthropogenic emissions. (UNFCCC, 2014) If the entire food industry is considered, food-related emissions account for up to one-third of human caused emissions. (Gilbert, 2012) Agriculture is the biggest contributor of non-CO₂ emissions which is mostly made up of methane and nitrous oxide, the largest sources of which come from cattle belching and the application of fertilizers and wastestos soils. (WRI, 2014) Out of all food products, the carbon footprints of beef and mutton stand out and are substantially greater than other types of meat (Figure 13). Using a set of environmental indicators which include GHG emissions, land, and energy, ruminant meat (beef/mutton) was found to have environmental impacts 3-10 times those of other animal products and 20-100 times those of plant based foods. (Clark, & Tilman, 2017)
Reducing agriculture’s carbon footprint is essential to combating climate change, but adapting to its effects is also required. Agriculture production is vulnerable to climate change which can affect a county’s domestic supply as well as disrupt global food markets. Global temperature increase could have serious effects on the production of staple crops, and therefore global food supply. (Zhao et al. 2017) found that each Celsius increase in global mean temperature could on average reduce global yields of wheat by 6%, rice by 3.2%, maize by 7.4%, and soybean by 3.1%. There is a need for climate-smart farming systems around the world but especially in low-latitude developing countries. South Asia and Sub-Saharan Africa are often highlighted as regions most vulnerable to climate change with many economies depending heavily on agriculture. (Maplecroft, 2015) Globally, extreme weather events are likely to become more frequent which will increase risks and uncertainties to people, food systems, and natural ecosystems. “Climate-smart” agriculture emphasizes the capability and capacity to implement flexible, context-specific solutions which are supported by innovative policy and financing. (Lipper, 2014)

The Current System Is Inefficient: Food Waste

About one-third of all food produced for human consumption is lost or wasted along the supply chain — from the production of food, to the processing, manufacturing, retail and end use. Clearly, this is an inefficient way of using resources. Food waste has a negative impact on the economy and limits the availability of natural resources such as water and land. According to the FAO, food losses and waste amount to roughly $1 trillion globally ($600 billion in developed countries and $310 billion in developing countries). (FAO, 2018)
Food wastage, which includes loss and waste, refers to the decrease in the quantity or quality of edible food that is intended for human consumption. (FAO, 2011) “Food loss” differs from food waste and largely takes place during the earlier stages of the food supply chain – production, processing, distribution, and may be the unintended consequences of food processes, or the result of inefficient systems and infrastructure. Examples of food loss include crops left behind due to poor harvesting (whether mechanical or manual), produce lost to disease during storage and transport, and livestock and fish leftovers from industrial processing. “Food waste” typically takes place at the retail and consumer end of the value chain and could be due to negligence or active choice to throw away food that is still fit for human consumption. The over-consumption of food (difference between food consumed and nutritional requirements) has also been considered by some as a type of food system loss, and was found to be at least as large a contributor to losses as consumer food waste. (Alexander et al., 2017)

Globally, approximately 1.3 billion tonnes of food gets lost or wasted every year. This is roughly dispersed equally across developed and developing countries accounting for 670 and 630 million tonnes, respectively. Fruit and vegetables, and roots and tubers have the highest wastage rates where 45% of production is lost. This is followed by fish and seafood with 35% wastage.

In developed countries, more than 40% of food waste takes place during retail and consumption, whereas 40% of losses occur during post-harvest and processing in developing countries.

Losses and waste take place throughout the supply chain but distribution of losses varies across regions. In developing countries, 40% of losses occur during post-harvest and processing, whereas in developed countries, more than 40% of wastage takes places at the retail and consumer levels. (FAO, 2018) More regional insights are shown in Figure 15 — Latin America and Sub-Saharan Africa have the greatest percentage of food waste during harvest and post-harvest with 21% and 25% of losses, respectively. Large losses during production stages in developing countries can be mostly attributed to lack of infrastructure, poor equipment, and lack of knowledge and investment in production.
The greatest losses take place in small- and medium-scale agricultural and fisheries production and processing. (FAO, 2017) Europe, North America, Oceania, and East Asia have the greatest food losses in consumption with an average of 11% compared to 1.3% in Sub-Saharan Africa. On average, consumers in Europe and North America waste 95-115kg of food per person per year, compared to 6-11kg in Sub-Saharan Africa, South, and South East Asia. (WEF, 2015) However, the amount of food wasted by consumers across developing and emerging economies is rising as a result of urbanization and the growth of supermarkets.

Figure 15. Food Losses and Waste by Region

Substantial amounts of food are wasted across the supply chain due to selection standards from both retailers and consumers that over-emphasize appearance. This has driven farmers in Europe to produce more food than they are obligated to supply, translating into more than a third of farmed fruit and vegetables (over 50 million tonnes) being discarded each year. (Porter et al., 2018) Changes need to be made to how food is advertised and sold, and retailers are in an important position as influencers of both upstream activities and consumers on the downstream end. This is not lost to food retailers who are becoming more aware of the issue and taking action. Intermarche launched a successful campaign in 2014 to encourage shoppers to buy “ugly” produce, and a number of U.K. supermarkets including Tesco, Sainsbury, and Waitrose have started campaigns to sell less-than-perfect produce (see section on sector opportunities for more detail).

Losses and waste along the food supply chain are also important sustainability issues as they translate into waste of inputs and natural resources. According to a 2016 FAO report, the environmental impacts of food wastage are substantial:

- the carbon footprint of food waste is estimated at 4.4 gigatonnes CO$_2$eq. (FAO, 2016)
- 28% of the world’s agricultural land (1.4 billion hectare) is used annually to produce food that is lost or wasted; and

More than a third of farmed fruit and vegetables are discarded every year across Europe due to cosmetic imperfections.
Food waste also translates into waste of inputs and natural resources.

To put this in perspective, if we consider food waste as a country, it would be the third largest GHG emitter, second largest country by land mass, and the largest blue water consumer of agricultural products. (FAO, 2013)

Tackling food waste around the world will not be an easy task, especially as the causes of food wastage vary greatly by region, but it makes social, environmental and economic sense. Reducing food waste can help improve food security, reduce the environmental impact of food production as well as save businesses, consumers and governments billions of dollars. Recent research from a coalition of executives dedicated to progressing food waste reduction found that for every $1 companies invested in reducing food loss and waste, they saved $14 in operating costs and consumer savings could be even greater. (Hanson et al., 2017) Greater awareness of food waste has also led to global coordinated action which includes the inclusion of the issue in the UN Sustainable Development Goals — SDG12.3 sets out to halve per capita food waste and reduce losses by 2030. Another global initiative is the FAO-supported SAVE FOOD initiative which will develop regional programs and support national action.

Every country in the world is affected by malnutrition which costs the global economy $3.5 trillion each year.

The Current System Does Not Provide Enough Nutrients

Malnutrition can arise in three main forms: (1) hunger and undernourishment, (2) obesity, and (3) micronutrient deficiencies (hidden hunger). Approximately 3 billion people worldwide have low quality diets and every country in the world is affected by one or more forms of malnutrition. (GLOPAN, 2016) Malnutrition has both high economic and health costs — impacts on public health and economic development now cost the global economy $3.5 trillion every year, (UN News, 2016) and what we eat has become the second-highest risk factor for early death after smoking. (Forouzanfar et al., 2016)

The world has made significant progress in reducing undernourishment; however 815 million people worldwide still suffer from hunger. This figure has increased after a steady decline for over a decade, and the recent addition of 38 million more people to this figure than the previous year is largely due to the rapid spread of violent conflicts and climate-related shocks. (FAO et al., 2017) The majority of undernourished people live in lower-middle income countries where over 90 million children under the age of five are dangerously underweight, and in Africa, one in four individuals still go hungry. (UNDP, 2018)
However, global spending on undernutrition by donors is only 0.5% of Official Development Assistance (ODA). (Development Initiatives, 2017)

Obesity is another form of malnutrition and is on the rise. In 2016, more than 1.9 billion adults (aged 18 years and older) were overweight, of which over 650 million were obese. (WHO, 2018) Rates of overweight, obesity, and diet-related non-communicable diseases such as diabetes are increasing rapidly in low- and middle-income countries — the growth rate of overweight and obesity for Sub-Saharan African men now exceeds that for underweight. (GLOPAN, 2016) Paradoxically, many countries around the world face the need to address both hunger and obesity challenges.

Two billion people worldwide suffer from “hidden hunger” which is a lack of essential micronutrients

Even though undernutrition and obesity are important aspects related to food, other factors contribute to these issues such as affordability of food and lifestyle factors which are beyond the scope of this report. However, as we will see in the chapter on opportunities, consumers in many countries are increasingly requesting healthier products, and this demand has encouraged many food manufacturer companies to invest in healthier products and also to deliver better nutritious food through increased micronutrient content in their products.

The third aspect of malnutrition is the deficiency of micronutrients (vitamins and minerals) also known as ‘hidden hunger’ given that health impacts of micronutrients deficiency are not always acutely visible. Certain micronutrients are essential for growth and development, but the lack of them is often limited in discussions of food and diets. Globally, two billion people worldwide suffer from hidden hunger, with women and children most at risk. (GLOPAN, 2016) According to the World Health Organization (WHO), iodine, vitamin A, and iron are the most important micronutrients in terms of public health, and their deficiency represents a major threat to global health and development. (WHO, 2018) Other important micronutrients include zinc, vitamin D, calcium, folate, thiamin, and riboflavin.
One of the major challenges faced today by the agriculture and food system is providing an adequate diversity of nutrients necessary for a healthy life. (Remans et al., 2014) While yields in the production of grains and other cereals have increased over the past century, it is argued by many that a move from more diversified cropping systems towards cereal-based systems have contributed to a poor diet diversity, resulting in malnutrition or a deficiency of important micronutrients. Nutrient deficiency is more severe in lower income countries where people depend largely on cereals or tubers which are calorie dense but nutrient poor. Worryingly, over half of adolescent girls in low- and middle-income countries lack essential micronutrients for good health. (GLOPAN, 2016)
The prevalence of “hidden hunger” is not just limited to low-income countries. Figure 22 shows that nutrient adequacy is extremely low for calcium around the world and no population currently has adequate vitamin D intake. Other nutrients that have low adequacy intake globally are folate and vitamin E. Chaudhary et al. (2018) also found that regions with the highest levels of nutrient adequacy, i.e., North America, Europe, and East Asia, also had the highest intakes of public-health sensitive nutrients such as sugar, cholesterol, and saturated fats. On the other hand, developing regions such as South Asia and Sub-Saharan Africa had low intakes of both essential and “unhealthy” nutrients. Economic growth can help to reduce chronic hunger and introduce more diverse and nutritious diets, but at the same time, it can also lead to increased intake of health-sensitive nutrients through the increased consumption of ultra-processed foods.

Ultra-processed foods are industrial formulations manufactured from substances derived from foods, typically with five or more ingredients which include sugar, oils, salt, fats, and preservatives. These products are usually energy dense and are depleted from protein, dietary fiber, and micronutrients. (Moubarac et al., 2014) Regional surveys carried out on consumption of ultra-processed foods and drinks (including Europe, the U.S., Canada, New Zealand and Brazil) show that they contribute between 25% and 60% of total daily calorie intake. (Foilet et al., 2018) Both processed and ultra-processed foods dominate purchasing patterns in the United States and collectively provide over 75% of daily calories. (Popkin, 2017) Packaged and processed foods are on the rise across developing countries, and ultra-processed products are becoming more prevalent in lower-middle income countries.

Improved nutrition requires systems of food production in which safe, nutritious, and healthy diets — wholegrains, fruits and vegetables, legumes, nuts, fish, moderate amounts of dairy and small amounts of meat — are produced sustainably. (Development Initiatives, 2017) This may prove to be a difficult balancing act, as most countries with high nutritional quality have been found to also have high environmental footprints. (Chaudary et al., 2018) There are other solutions available besides a better well-balanced diet including (1) supplementation, which is the delivery of important micronutrients in pill, powder, or liquid form; (2) food fortification, or the addition of small amounts of micronutrients to food products; and (3) biofortification, or the use of agronomic and plant breeding approaches to increase micronutrients in staple food crops. We address these later in the report.

Nutrition features prominently in the UN Sustainable Development Goal on Zero Hunger. Target 2.2 aims to end all forms of malnutrition by 2030 and specifically draws out the needs for women, children, and the elderly. In support of the Sustainable Development Goals, the UN have designated 2016-2025 as the Decade for Nutrition given the growing challenges to food systems and human health. Tackling malnutrition can also help to improve outcomes across the SDGs and significant opportunities exist for governments and others to invest in nutrition, with potential returns of $16 for every $1 invested. (Alexandratos & Bruinsma, 2012)
Food Demand Is Increasing

Food demand is estimated to increase by 60-70% by 2050 (FAO (2009), Alexandratos & Bruinsma (2012), and Springmann et al., (2018)). Meeting this increase in food demand sustainably with less waste and more nutrition is a challenge. If we continue to operate ‘business-as-usual’, we may need up to 67% and 65% more farmland and irrigation water withdrawals (Springmann et al., 2018), respectively, to be able to feed 9-10 billion people by 2050. This could translate into an overall 87% increase in agriculture-related GHG emissions. In terms of nutrition, if we continue on the same path, the number of people suffering from diet-related malnutrition worldwide could increase from 1 in 3 to 1 in 2. (GLOPAN, 2016) In order to devise solutions and explore opportunities to address these growing challenges, we need to understand what drives and influences food demand, including population growth, income growth and diet preferences. We analyze these in more detail below.

Figure 23. Global Food Production Is Expected to Increase by ~70% in 2050 Based on a ‘Business-as-Usual’ Scenario


² Cons (consumption), waste (food waste at household level), loss (food loss at production), othr (industrial and other demand for agricultural products, feed (feed demand), intr (intermediate demand for processing into oils, oil meals and sugar
Population Growth

Population growth is a key factor behind food consumption. The global population is expected to increase from 7.3 billion people to 9.7 billion people in 2050 under the UN medium scenario. (UN DESA, 2017) According to the OECD/FAO (2018), two key regions, Sub-Saharan Africa (SSA) and India, are predicted to account for over half of the total population growth with an estimated 1.1 billion additional people living in Sub-Saharan Africa (SSA), and over 580 million additional people in South-Central Asia. Worryingly, several of the most food-insecure countries in SSA are expected to experience the greatest population growth pressures, e.g., Niger, Yemen and Uganda. Some of the world’s fastest growing populations are also in the Middle East which accounted for the top five fastest growing populations in the world between 2010 -2015. Qatar topped the list with a growth rate of 6.65%, followed by Oman at 6.45%. (UN DESA, 2017)

Figure 24. Population Change from 2015 to 2050

In South Central Asia the largest increase in population will occur in India with an estimated 350 more million people projected to be living there in 2050 compared to 2015. This is followed by Pakistan which is expected to see a population increase of 118 million from 2015 to 2050. Demand for food products is likely to increase at a much greater rate than population growth given that a large number of people are currently undernourished. The region has made significant progress in increasing domestic food supplies over the past few decades, but productivity levels are still low for crop and livestock compared to those in developed countries. Imports of agricultural products into the region have increased substantially to help meet growing demands, but intra-regional trade and investments in agricultural goods are low with high tariffs and non-tariff barriers. (ADB, 2015) This represents a missed opportunity for these regions as some countries have food deficits and others have potential for surplus, largely from India and Pakistan.

Intra-regional trade can help support food security across South Asia

Food insecurity is defined as the state of being without reliable access to a sufficient quantity of affordable, nutritious food countries
The liberalization of trade between South Asian countries is increasingly recognized as a way of improving regional food security, (Mukherji, 2014) and regional integration may come to play an important role in supplying future demands across South Asia.

The population story is rather different in Eastern Asia where the overall population is projected to decrease by almost 50 million between 2015 and 2050. The population in China is expected to peak in 2029 and then decrease over time to reach approximately 1.36 billion in 2050 (see Figure 26). China has developed an insatiable appetite and is utilizing both self-sufficiency strategies and agricultural imports to meet its large and growing demand for food. The country is largely self-sufficient when it comes to cereal staples of wheat and rice, but depends on other countries for soybean (and maize to a lesser extent) which are used to meet the country’s growing demands for meat and dairy.

Developed countries will contribute little to overall population growth as birth rates have been declining and are unlikely to pick up in the future. Therefore, food consumption in developed countries is not expected to increase substantially by 2050. Also, the average food consumption in developed countries is already over 3,500 kcal/person/day, which leaves little room for per capita calorie intake improvements. (OECD/FAO, 2018)

Urbanization and Income Growth

Rapid urbanization and higher income growth also affect food consumption. In 2050, more than two-thirds of people could be living in urban areas — a net addition of 2.2 billion people. Changes in agriculture practices especially the adoption of labor-saving technologies have helped underpin this phenomenon. Currently most of the urbanized regions are found in North America, Latin America, and Europe, but over the coming years Asia and Africa are expected to urbanize faster than any other region. (UN DESA, 2014) By 2050 it is estimated that over 800 million and 1.2 billion more people are expected to live in urban areas in Africa and Asia, respectively. Lifestyle changes that accompany urbanization include evolving dietary habits (including more diversified diets) which means food production systems need to adapt to meet the demands of growing urban populations.
Urbanization also presents challenges to food availability and supply as urban expansion often comes at the expense of productive farmland. Rapid urban expansion has resulted in the loss of farmland around the world including in China, India, and the United States and future urban growth could result in a 1.8-2.4% loss of global croplands by 2030, with about 80% of global loss from urban expansion in Asia and Africa. (d’Armour et al., 2017)

Income growth also reorients the composition of demand from the consumption of grains towards meat, dairy, vegetables, fresh fruit and an increase in consumption of processed and prepared foods. For example China’s remarkable economic growth over time which brought large increases in consumer income, resulted in a reduction in the consumption of grains and a move towards a more diversified and higher-quality diet. However, income growth does not ensure healthier diets and is a double edged sword when it comes to improving diets. (GLOPAN, 2016) The sales of ultra-processed foods are increasing rapidly across low- and middle-income countries, especially in East and South-East Asia countries. Again using China as an example – the country now has the largest overweight population in the world and the combined rate of overweight and obese adults is projected to increase to over 50% by 2030.

**Figure 27. Per Capita Consumption of Wheat Against GDP Per Capita in China**

![Figure 27. Per Capita Consumption of Wheat Against GDP Per Capita in China](image)

Source: OECD-FAO, OECD, Citi Research

**Figure 28. Per Capita Consumption of Grains and Proteins in China**

![Figure 28. Per Capita Consumption of Grains and Proteins in China](image)

Source: OECD-FAO, Citi Research

### World Diets Are Changing

Globally, we are consuming more calories and eating a wider range of foods than before, but cereal grains (which include wheat, rice, maize and coarse grains) still account for the majority of our diet composition. ‘Meat’ and ‘Sugar and Fat’ increased the most of all the food groups between 1980 to 2013 in terms of daily caloric intake; with an increase of 53% for ‘Meat’ and a 25% increase for ‘Sugar and Fat’. They are also the only food groups that have increased their percentage share in the global daily diet. In this report, we focus on diet composition by common food groups but another way of analyzing composition is by macronutrients which are nutrients that provide energy and are needed in large amounts. The three classes of macronutrients are carbohydrates, fats, and proteins which can also be broken down into animal and plant protein.
This global dietary change to larger diets with a greater intake of meats, sugars, oils and fats has implications for environmental sustainability and public health. A more diversified diet is a good thing in terms of nutrition but only if the right foods are eaten (eating less food high in trans-fats, sugar, and salt/sodium and eating more fruit, vegetables, and wholegrains). Current dietary trends are increasing the incidence of type-II diabetes, coronary heart disease, and other chronic non-communicable diseases. (Tilman & Clark, 2014) Worryingly, if current trends on diets continue, the number of people worldwide that suffer from diet-related malnutrition could increase from 1 in 3 to 1 in 2. (GLOPAN, 2016)

Diet size and composition vary substantially around the world, and diet choices are influenced by a number of factors including culture and religion, availability and cost of food, physiological needs, taste, and public policy. However, regional trends (refer to Figure 29 and Figure 30) do exist and provide useful insights:

- North America, Europe and Oceania currently have the most calorie-dense and diversified diets but the sizes and composition of Asian and African diets are growing and changing rapidly.

- Current Asian and African diets are still far more grain-dependent and less meat heavy than diets in other regions — cereals make up on average 50% of daily calorie intake across Asian and Africa compared to 30% in Europe and 22% in North America.

- However, an outlier that’s worth pointing out is China — the country has already shifted to relatively high levels of daily meat intake which now makes up 18% of total daily calorie intake, compared with the average 10% across Asia.

- Over the past 30 years, ‘Sugar and Fat’ is the only food group that has increased across all regional diets.

- Meat consumption per capita has plateaued in developed countries and consumption of ruminant meat (bovine/mutton) has started to decrease across North America and Europe, which may be partly due to growing awareness of their health and environmental impacts.

Figure 29. Global Daily Diet in 1961, 1985, and 2013

Figure 30. Regional Diet Compositions in 2013
Looking ahead, diets in developed countries are not expected to increase substantially over the next few decades, but the greatest changes in diet size and composition will likely come from developing regions such as South Asia and Sub-Saharan Africa. Daily grain intake is expected to grow across Latin America, South Asia, and Sub-Saharan Africa but decrease in other regions. (Alexandratos & Bruinsma, 2012) The biggest increase in daily meat intake will likely come from South Asia (India is the exception – see Appendix 1) and the MENA region. Overall, more regions are projected to meet recommended minimum intakes of fruit and vegetables over the next few decades but at the same time fewer regions are expected to meet recommended maximum levels of red meat, sugar, and total energy intake. (Springmann et al., 2016) Calls for dietary changes towards less animal- and more-plant-based diets highlight both health and environmental benefits (Bajželj et al., 2014) and also show regional variations – the greatest number of avoidable deaths is projected to be across developing countries, especially East and South Asia, whereas per capita benefits are likely to be greater in developed countries.

The Importance of Cereals and Soybean

Cereal grains play a vital role in diets around the world and contribute roughly half of the average global daily calorie intake. Three key crops — wheat, rice and maize — are the foundation of global food security, but production of these crops is concentrated in a few regions. The United States, China and India produce roughly half of the world’s wheat, rice and maize and large shares of production in the United States and India are exported whereas the majority of cereal grains produced in China is consumed or stored for domestic use. Globally, the total shares of cereal grains that were traded in 2016 were 25% for wheat, 5% for rice, and 14% for maize. (FAO, 2018)

The top exporting countries of rice are mostly in Asia with the top three exporters (India, Thailand, and Pakistan) accounting for 60% of total exports. Wheat exporters on the other hand are more diversified where the top three producers (United States, Russia and Canada), account for 34% of total exports and other major exporters include France, Australia, and Ukraine. Egypt was the largest importer of wheat in 2016 and imported 13 million tonnes, almost half of which came from Russia. Wheat is the main component of Egyptian diets and is heavily subsidized; however, domestic production is challenging with land and water scarcity as well as high input costs (i.e., seeds and fertilizers) resulting in production being unable to keep up with demands from a growing population. In order to maintain national food security, the country imports 45-55% of its total wheat consumption, (Veninga & Ihle, 2018) which makes it highly dependent on the global wheat market.
Cereals are not only an important source of food, they are also used for animal feed and fuel. The global dietary shift to more animal-based products is driving growing demands for animal feed. Another key crop worth highlighting is soybean which is the world’s largest source of vegetable protein for livestock feed. Many countries rely on the import of feed components for livestock production, but the exports of maize and soybean depend largely on three countries — the United States, Brazil and Argentina who together account for 66% and 83% of total exports of maize and soybean, respectively. Japan and Mexico are the top importers of maize accounting for 10% and 9% of total imports, respectively, whereas China dominates the soybean market and makes up nearly 40% of total imports, followed by the Netherlands with 4%. Global trade of all four staple crops have increased over the past 20 years, but the growing demand for soybeans (largely from China) has driven trade in that commodity to increase by 126% since 2000.

The Future Consumption of Agricultural Commodities

The OECD-FAO predicts that global demand for agricultural commodities (used for food, feed, and fuel uses) will grow between 2018 and 2027 but at a slower rate than the previous decade (refer to Figure 33). This is due to changing demand drivers — China’s consumption along with biofuels were largely responsible for driving global demand growth over the past decade or so but looking ahead, these drivers are expected to slow down. In terms of commodity groups, fresh dairy will be the fastest growing group over the next decade, followed by sugar and vegetable oil. Even though the demand for food accounts for the majority of total demand of most agricultural commodities, the demand for feed and fuel are important to consider for commodities such as cereals and oilseeds. Maize and soybean are the two main crops used for animal feed but wheat and other coarse grains are also utilized. The world’s growing appetite for animal products will drive the demand for feed which will continue to outpace food demand in the coming decade.

The majority of additional food demand will likely come from Sub-Saharan Africa, India and MENA

The per capita consumption of many commodities, including cereals, roots, tubers as well as meat will likely be flat at the global level. This means that population growth will be the main driver of food demand growth, and therefore the majority of additional food consumption will likely come from Sub-Saharan Africa (SSA), India, and the Middle East and North Africa (MENA). Along with population growth, higher per capita income will also help to drive food demand growth across developing countries.

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4 The FAO Agriculture Outlook assumes strong growth in per capita GDP in China (5.9% per year) and India (6.3% per year), and a 2.9% p.a. per capita growth in Sub-Saharan
Despite a global dietary shift to fewer grains, cereals will still make up the largest share of food demand growth over the next decade as a result of population growth largely across MENA, SSA, and India. Demand growth for meat and fish has a different narrative — the demand growth for fish will mostly come from China, who will also contribute a large share of additional meat demand. On the other hand, the availability of meat and seafood is especially low in Sub-Saharan Africa, where low-incomes limit consumption.5

As we can see from the graphs above, fresh dairy products will be the fastest growing commodity group over the next decade. India alone will account for nearly 60% of the additional global fresh dairy demand up to 2027. Dairy is an essential part of Indian diets and continued population and income growth in India will continue to drive demand for dairy products beyond 2030 (See appendix for India case study). The story is rather different for developed countries, which are seeing a decline in fresh dairy products and a preference for processed dairy products which includes cheese, butter, and powdered milk. The consumption of processed dairy products in India and China is still small compared to developed countries but demand is growing. Strong growth in global demand for butter over the next decade will be largely supported by growing consumption in India. However, it is worth noting that a significant proportion of the global adult population (especially across Asia) is lactose intolerant, which may hinder the global growth potential of dairy-based foods.

Challenges (and Opportunities) Ahead for Developing Countries

The trends projected by the OECD-FAO up to 2027 does not bode well for Least Developed Countries (LDCs) where increases in calorie intake over the next decade are expected to mostly come from increased uptake of sugar and vegetable oils, whereas per capita consumption of meat and fish is likely to remain low or decrease. Diets that are largely made up of cereal grains, roots and tubers, sugars, and fats lack essential macro- and micro-nutrients. This means malnutrition will remain and in addition to challenges of chronic and hidden hunger, LDCs will also face growing issues of obesity and non-communicable diseases. If these trends continue over the next few decades, the impacts on human health and economic development in LDCs could be potentially disastrous.

The situation may be worse in the shorter term, i.e., over the next decade, but there is growing awareness and momentum to address diet-related challenges in developing countries. The second UN Sustainable Development goal calls for an end to all forms of malnutrition by 2030, even though this may not be attainable within this time frame, it is driving initiatives and policies in the right direction. Policy-makers in low- and middle-income countries need to know that they do not have to follow the long and arduous route high-income countries are taking to better quality diets. (GLOPLAN, 2016) We now know more about the links between diet and health and opportunities exist for developing countries to leap-frog to better quality diets that focus on delivering nutrition.
As discussed above, diet choices and consumption patterns vary regionally and two key regions of interest are Asia and Africa which will generate the lion’s share of additional food demand in the future. [Refer to Appendix 1 for detailed case studies of China, India and Nigeria (one of the fastest growing economies in Africa).] Each of these countries is heading in a different direction in terms of food consumption: India is expected to continue following a mostly meatless diet, whereas China will continue transitioning to a more Western-style diet with more animal products. Nigeria is likely to face difficulties in meeting its growing demand for food if it does not receive economic support. India and China are the two most populous countries in the world, what they eat and will eat in the future matters to the global food system. [Refer to Appendix 2 for a discussion on who is feeding and who will feed these two countries in the future, and Appendix 3 for a case study on edible oils for which India and China are key markets.]

**The Role of Trade**

Trade has played a significant role in meeting food demand across economies with different resource allocations (e.g., land and climate) and amid changing consumer patterns (e.g., globalization). However, trade in agricultural goods has grown less than trade in manufacturing goods, and at the same time the share of agricultural exports in total merchandise exports has moderated from 22% of global merchandise trade in 1962 to 9.2% in 2017 while the share of manufacturing exports moved from 54% to 70% during the same period. According to the FAO, the reduction in industrial tariffs (e.g., from 40% to 4% during the trade negotiations under the General Agreement on Tariffs and Trade (GATT)) was a key factor behind the strong growth in merchandise trade, whereas high tariffs and other market-distorting measures remain in the agricultural sector. Currently, less than a quarter of food produced for human consumption is traded internationally. (D’Odorico et al., 2014). Figure 36 below, shows the trend in food trade across different regions — positive values mean a region is a net exporter, while negative values means a region is a net importer. LatAm has become a net exporter whereas East Asia & Pacific has been exporting less compared to what was the case in the 2000s.
According to the OECD, government agricultural policies reached about $620 billion per year during 2015-2017, which have distorting effects for production, prices, and incentives among producers and consumers. Government policies can take many forms and have different effects. For instance, many countries impose tariffs on food imports or grant subsidies on food exports in order to provide support for domestic producers and deal with food surpluses. Other things equal, these policies would drive local food prices up, and depending on the relative size of the economy imposing these trade barriers on it would lower international food prices. Other forms of policy support include programs that give direct payments to farmers (either tied or not to their production level), assistance for natural disasters, programs to support biofuel production, price controls and supply management programs, farm credit services, subsidized inputs (e.g. fertilizer, fuel), and support for agricultural research.

Figure 37. Select Economies – Total Support to the Agricultural Sector (% of GDP)

Source: OECD, Citi Research

Even though distortions in the market affect the trade of agriculture commodities the market currently involves 2.1 billion tonnes of goods worth $1.1 trillion. (Chatham House, 2018) Global food has evolved into a complex network of trade flows involving a wide range of agricultural commodities as well as a growing set of nations engaging in imports and exports. This trade can help increase food availability, diversity, and security around the world, but it also introduces new risks including increased reliance on imports and vulnerability to market shocks. The trade of agricultural products also relies on a complex network of transport systems which Bailey and Wellesely (2017) found to contain a number of critical chokepoints (junctures on transport routes through which large volumes of trade pass). They also report that chokepoint risks are increasing due to growing trade, increasing climate change risks, and lack of investment in infrastructure. Despite the risks, global trade is growing and becoming increasingly important for achieving food security worldwide — nearly 2 billion people now rely on imported food. (Porkka et al., 2017)
So What Is Traded and Who Are the Key Players?

Trade composition varies significantly by commodity and by region, but certain regional trends can still be observed — Asia is the largest producing and consuming region for all agricultural commodities except beef, and is the fastest growing net importer. Both Sub-Saharan Africa and MENA are growing net importers. Significant increases in production has made Latin America the largest net exporter of agricultural products, whereas sluggish consumption in North America has led to the region becoming the second largest net exporter. (FAO, 2015)

Figure 38. Trade Balance in 2016 by Region and Agricultural Commodities (Net exports, Million Tonnes)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Asia</th>
<th>Africa</th>
<th>LatAm</th>
<th>EU</th>
<th>N. America</th>
<th>Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>-71.2</td>
<td>-46.5</td>
<td>-8.3</td>
<td>69.7</td>
<td>45.5</td>
<td>21.8</td>
</tr>
<tr>
<td>Rice</td>
<td>17.4</td>
<td>-14.9</td>
<td>-1.0</td>
<td>-12.2</td>
<td>2.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Maize</td>
<td>-61.1</td>
<td>-19.7</td>
<td>5.4</td>
<td>16.9</td>
<td>57.2</td>
<td>-0.1</td>
</tr>
<tr>
<td>Other coarse grains</td>
<td>-27.8</td>
<td>-1.2</td>
<td>-0.1</td>
<td>16.8</td>
<td>9.1</td>
<td>10.7</td>
</tr>
<tr>
<td>Soybean</td>
<td>-117.8</td>
<td>-4.1</td>
<td>83.2</td>
<td>-12.7</td>
<td>61.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Other oilseeds</td>
<td>-9.1</td>
<td>-0.3</td>
<td>-0.7</td>
<td>-4.3</td>
<td>10.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Protein meals</td>
<td>-22.0</td>
<td>-5.4</td>
<td>43.4</td>
<td>-20.0</td>
<td>10.9</td>
<td>-2.8</td>
</tr>
<tr>
<td>Vegetable oils</td>
<td>5.0</td>
<td>-9.4</td>
<td>6.2</td>
<td>-2.6</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Meats</td>
<td>-12.6</td>
<td>-2.4</td>
<td>4.7</td>
<td>2.4</td>
<td>-6.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Fish and fish products</td>
<td>1.9</td>
<td>-0.9</td>
<td>2.7</td>
<td>-1.6</td>
<td>-3.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Dairy products</td>
<td>-5.0</td>
<td>-1.1</td>
<td>-0.6</td>
<td>2.4</td>
<td>0.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Sugar</td>
<td>-41.8</td>
<td>-17.1</td>
<td>68.0</td>
<td>-2.2</td>
<td>5.8</td>
<td>7.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume of net exports (mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import</td>
</tr>
<tr>
<td>0-40</td>
</tr>
<tr>
<td>41-80</td>
</tr>
<tr>
<td>Export</td>
</tr>
<tr>
<td>0-40</td>
</tr>
<tr>
<td>41-80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Importer</th>
<th>Importer</th>
<th>Exporter</th>
<th>Exporter</th>
<th>Exporter</th>
<th>Exporter</th>
<th>Exporter</th>
</tr>
</thead>
<tbody>
<tr>
<td>202.98</td>
<td>63.62</td>
<td>194.61</td>
<td>46.76</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall, the balance of exporting and importing countries is rather uneven where production is largely concentrated in a few countries and regions, while importing countries are more diversified. However, we can also observe that top exporting countries of agricultural commodities are also major importers, and there are some key players in the global food market — namely the United States, Brazil, and China. In terms of commodities, cereals remain a key commodity group, but other products are growing in prominence including oilseeds, fish and seafood, as well as fruits and vegetables.

Fertilizers

Nitrogen, phosphorus, and potassium are three vital nutrients need for crops to grow. International trade of fertilizers is largely driven by the uneven distribution of phosphate and potassium deposits, as well as natural gas (needed to produce nitrogen fertilizer). This has resulted in a few countries dominating production, with six nations — United States, Canada, China, India, Russia, and Belarus producing 70% of the world’s fertilizers. (FAO, 2018) China is the largest producer of nitrogen and phosphate fertilizers, accounting for 42% and 31% of total production, respectively. The largest producer of potash is Canada making up a quarter of global production. Top exporters of fertilizers are also major crop producers which mean significant proportions of fertilizers produced globally are used domestically and large exporters are also major importers.
Opportunities

As shown in this chapter population growth and income growth will increase food demand, while urbanization and a change in world diets will influence the types of food we consume. Food demand is expected to increase by 60-70% by 2050 and meeting this increase in demand sustainably with less waste and more nutrition will be a challenge. The good news is that there are plenty of opportunities available which we explore in the next chapter. We divide these into opportunities from (1) a commodity perspective — which regions and countries have the opportunity to increase their production to meet future demands and (2) a sector perspective — addressing the importance of technology and consumer preferences in driving some of these changes.
Opportunity Knocks for the Southern Hemisphere Feed/Grain Farmer

There are plenty of opportunities for the Southern Hemisphere to expand agriculture production. Economies south of the equator have more available arable land when compared to countries north of the equator. There are also large yield gaps in these economies versus the U.S. for key crops like corn and soybeans, allowing the Southern Hemisphere producers to play catch up with the U.S. to boost global export share at an increasing rate. Improving yield gaps should be the priority to ensure that agriculture production in these economies continues sustainably and within ecological limits, therefore avoiding an expansion of crop areas. This does not mean agriculture production in the Northern Hemisphere has reached its peak. As we will see from the next chapter on sector opportunities, innovation and technology such as gene editing, precision agriculture, and other smart agriculture techniques can increase yields further in economies such as the U.S. where yields are substantially higher than other economies.

Expanding agriculture in these southern economies however is not without challenges — greater investments are needed in this sector especially in agriculture innovation to ensure productivity growth can be achieved in a sustainable way.

Opportunities in the Southern Hemisphere

When it comes to agriculture supply security, cereals matter most: corn and soybeans in particular, but also wheat and rice. In addition to being staple crops directly consumed by the human population, these are commodities, along with sugar, that serve as direct inputs and feedstock for the production of meat, dairy, cooking oils, confectionaries, and processed foodstuffs. In short, the global cereals market underpins the broader agriculture supply/demand cycle and trends in food price inflation. Demand for Southern Hemisphere feedstocks, particularly soy, will increase as the world becomes richer and uses more animal products and biofuels.
The global soybean trade, including co-products such as meal and oil, has overtaken the trade in coarse grains, wheat, and rice — a trend that is expected to continue over the coming decades due to Chinese demand. Indeed, annual consumption of soybeans in China has grown 20-fold since the late 1990s while Brazil has surpassed the U.S. as leading exporter of the oilseed in recent years. U.S. government estimates suggest almost all of the growth in global soybean gross imports will accrue in the Northern Hemisphere over the next decade, with 70% of those gains in China alone.

From a 2016/17 base of 95 million metric tons (mmt), China soybean imports are expected to reach 140-145mmt in 2027/28, to meet feed demand for hogs and poultry and to utilize its domestic crush capacity.
Brazil and Argentina are expected to see cumulative soybean exports grow 40mmt over this same period. The U.S. is also projected to see foreign sales rise ~9mmt in this window, but its overall trade share is set to fall from 40% to 33%.

In addition to price differentials, protein content, and processor margins, growth in Southern Hemisphere feed trade is fundamentally enhanced by seasonal factors. Large swaths of unused arable land and opposite summer/winter cycles are prompting greater commercial trade opportunities in the Southern Hemisphere to importers across China, East Asia, and Europe, providing export volumes to the consumers in the Northern Hemisphere during times of low seasonal inventories.

Row crops such as soybeans and corn can only be grown once per calendar year on a farm, with limited opportunities for double-cropping. The Northern Hemisphere plants during its spring (2Q) and reaps during its fall (4Q). For Southern Hemisphere players it is the opposite. So the 3Q period is often tight for stocks globally, opening up windows for Brazil, Argentina, Australia, and South African exports of feed grains. This is also when price volatility for benchmark prices is the highest, seasonally — as the weather in the Northern Hemisphere from June-August has the largest impact on harvest potential in U.S., Europe, Black Sea, India, etc.

The exportable surplus of feed crops like corn and soy are also concentrated and extreme compared to other staples. Rice consumption has plateaued in the OECD and is typically grown domestically in Asia and is not a large portion of global agriculture trade. Wheat is a relatively weather-resilient crop, grown in the Northern and Southern Hemisphere and in some cases year-round. The exportable surplus of soybeans is limited to the U.S., Brazil and Argentina – globally. For corn, only Ukraine is a meaningful seller in addition to the aforementioned exporters.
Unlike metals and energy commodities that are mined or drilled, agriculture crops are unique in that the supply-side is significantly weather dependent, with heightened seasonal supply and trade patterns. The U.S. is currently the most important feed grain producer and the benchmark for agriculture efficiency. Yet Brazil, Argentina, and other grain economies are increasingly competing with the U.S. for export share. And even the Midwest farmer cannot withstand the whims of Mother Nature, which can prompt record harvests (2016-2017) or wreak havoc on harvests (2011-2012). Controlling for those factors and assuming normal weather, there are only two ways grain crop farmers can boost output:

- **Increase area planted.** While promising for a decade or so, this will reach a limit and faces issues of sustainability. Increasing planted area is also less of a driver for production gains versus crop yields over the long-run, regionally and globally.

- **Increase crop yields** via precision farming, seeds, fertilizers, irrigation, etc. that underpin broader efficiency gains and larger harvests.

Brazil, Argentina and other grain economies are increasingly competing with the United States for export share
IMF data from the 2013/14 crop year show the global land area available for agriculture use totaled 1.978 billion hectares, of which ~80% was being used, leaving 0.403 billion hectares as idle farmland. More than 88% of this unused but suitable farmland was concentrated in Africa, South America, and Oceania. Capacity utilization of arable farmland across North America, Europe, and Asia was around 95%, on average, compared to less than 60% in Africa and South America and 76% in Oceania. Similarly, the yield gap in the Southern Hemisphere remains wide versus the U.S. All this suggests that Brazil, Argentina, and Sub-Saharan Africa have further room to expand crop harvests via planted area and farming technology.

Brazil, Argentina and sub-Saharan Africa have further room to expand crop harvests via planted area and farming technology.

Using corn as an example, overall we can see that yield growth has been the most important factor for world production growth. On average, yield growth has contributed to 64% of the harvest growth for corn versus the remaining 36% being driven by acreage. In 42 of 57 years in our production dataset, yield growth has been the primary (>50%) driver of the corn production growth. Indeed, if we regress world production growth over changes in yield the r-squared (i.e., how well changes in yield predict world production growth) is as high as 90%. Notably, this conclusion also holds true for the U.S. although not as tilted as for the world, while Brazil has seen an almost equal contribution from yield growth and acreage growth. Yield growth clearly shows the strongest explanatory power for production growth of crops (world and regionally) though analyzing the rolling betas suggests that production can still be quite sensitive to acreage. So growth in both area and yields are required, although yields matter more in the long-run.
For the world as a whole, corn yield elasticity (i.e. the sensitivity of price to yield) has risen from 1.5-1.6 in the 1960s/1970s to above 2.0 over the past decade, while the sensitivity to harvest area has declined. The sensitivity is a lot more volatile at the individual country level (that may have had adverse weather or government policy). Interestingly, since 2000, the production growth of corn has shown a much stronger elasticity to acreage than yields. The passage of the 2005 Renewable Fuels Standard, which today drives 40%+ of the U.S. corn-crop to ethanol output, prompted an acreage shock, which U.S. production is sensitive to. But yield growth has been the primary driver of production, even in the highest yielding global corn producer, the U.S.

Similar to corn, for the world as a whole and the U.S. as well, yield growth has been the dominant factor in driving total production growth over the past half-century. For Brazil, the yield gap has a lot of room to run.
The aforementioned snapshot in agriculture production dynamics ties into the long-term growth rate of plantings for the staple grains per U.S. Department of Agriculture (USDA) data. Global soybean harvested area had a compound annual growth rate of 4.4% from 1990-2017 versus 1.3% for global corn in the same time period. Most of the growth, outside of India, has been concentrated in Brazil, Argentina, and Sub-Saharan Africa. Meanwhile, global rice and wheat area was flat-to-down over this period. Population, trend, and supply chain factors explain this divergence:

UN data show total world population of 7.4 billion people in 2015 of which 20% are in South America, Sub-Saharan Africa, and Oceania. Yet these are the areas where crop production expansion has been growing at the fastest pace. This trend is set to continue, according to FAO and USDA data, even as population growth may accelerate south of the equator going forward.

Corn and soybeans are protein-rich grains, often grown with genetically modified (GMO) seeds, used largely to feed livestock, hogs, and poultry (and also to produce biofuels), positively correlating to growth in meat consumption and fuel blending. Taking the U.S. as an example, 40-50% of annual corn and soy harvests are directly used to feed animals in the meat and dairy industry. On the other hand, less than 10% of wheat and rice supplies are consumed in this manner. As global pork, poultry, and dairy consumption grows, particularly in Africa and India, there will be greater need for maize, oilseeds, and meal for animal feed.

Wheat and rice are human foodstuff crops that are non-GMO and not fertilizer/chemical-intensive; and cheaper to grow versus corn and soybeans. The rest-of-world (ROW) has also caught up to the U.S. in wheat yields but lags in the more profitable cash crops like corn and soybeans. These latter two crops are the main area of growth in countries such as Brazil and Argentina.

Long-term trends point to a large yield gap (U.S. benchmark versus rest-of-world) for GMO crops such as corn and soybeans. The global growth in meat and dairy consumption will underpin greater demand for animal feed — requiring emerging market producers to increase corn and soybean productivity. But as expanding farm area reaches an ecological limit, the key to unlocking harvest growth will have to come from productivity gains and increasing the number of harvested bushels per

![Figure 52. Global Corn Yields – U.S./World Gap Remains Wide](source: USDA, Citi Research)

![Figure 53. Global Wheat Yields – U.S./World Gap Is Non-existent](source: USDA, Citi Research)

© 2018 Citigroup
A key wildcard for the Southern Hemisphere is the availability of freshwater resources when compared to the Northern Hemisphere (please refer to Citi GPS Solutions for a Global Water Crisis); however as described below, some countries in the Southern Hemisphere still have water issues which could limit their agriculture expansion. Global water withdrawals by end-use sector are already dominated by agriculture, at 70%, and will require further investment and capital allocation in the coming decades.

Economic expansion is closely associated with two major trends in food consumption: (1) increase in calories consumed per capita; and (2) a shift in dietary preferences towards greater meat/dairy consumption. Livestock herding requires not only large quantities of water-hungry crops for feed, but they are also relatively inefficient in converting into consumable calories (e.g., food purchased at the store). This significantly increases the water intensity of meat; one calorie derived from beef can require 20x more water to produce than the same calorie derived from cereals. Scarcity is compounded by unequal distribution of water resources. The World Resources Institute analyzes the ratio of water withdrawals to supply of key crops through 2040 (see figure below), and notes shortfalls in Argentina, Chile, Southern Africa, and Oceania across the Southern Hemisphere. Other than the broad, unpredictable weather cycle, the availability of water resources might be the biggest challenge that could undermine the growth of Southern Hemisphere output.

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6 10.9 liters of water/calorie for bovine meat vs 0.5 liters of water/calorie for cereals
Case Study: India Becomes the New Queen of Dairy

- Although per capita consumption of dairy products is higher in advanced economies, consumption in emerging markets is rising fast. According to estimates by the OECD-FAO, fresh dairy products will be the commodity that will experience the highest growth rate through 2027 (at around 2.2% per year), and with growth driven mainly by emerging markets and by India in particular. According to the OECD-FAO estimate, however, the demand for fresh dairy products in advanced economies will be moderate as consumer preferences shift away from consumption of dairy fats and into consumption of produced dairy products (e.g., cheese, butter).

![Figure 55. Select Economies – 2027 OECD-FAO Projections Per Capita Consumption of Dairy Products (kg/cap)](source: OECD-FAO, Citi Research)

- There are different factors that could help explain the demand for dairy products. For instance, consumption may be affected by changes in relative prices (e.g., an increase in prices would reduce dairy consumption) or income (e.g., an increase in income would raise dairy consumption), population growth (e.g., more consumers) or shifts in consumer preferences (e.g., concerns about health and nutrition).

- India grew 6.7% in 2017 and growth is expected to accelerate to 8.3% in 2022, increasing its contribution to global growth 6.7% in 2017 to ~10% in 2022. As a comparison, Emerging Market ex-India contribution to global growth is expected to increase from 53% to 59% in the same period; while China’s contribution is expected to slightly moderate from 33.9% of total to 33.6%. Meanwhile, India’s population reached 1.4 billion people in 2017, about 17.7% of global population. Although India’s population growth is expected to moderate from 1.1% in 2017 to 0.86% in 2027 (vs. 1.1% to 0.98% globally), and still represent around 17.7% of global population growth by 2027, it is expected to surpass China’s population by 2024.
India is the largest producer and consumer of milk globally, and the dairy sector represents about 20% of India’s agricultural output. In 2017, India accounted for roughly 27% of global production of fresh dairy products, while India’s consumption of dairy products accounted for a similar share of global consumption (growing up to 33% for both production and consumption by 2027 according to the OECD-FAO estimates).

Assuming it grows at its long-term growth average, and taking economic growth as a proxy for income, a linear model would suggest that India’s consumption of fresh dairy products would continue growing at rates between 4.6-5% during the next decade. Similarly, considering population growth estimates for India (~0.97% per year on average for the next decade), dairy consumption would grow between 5.6-6.6% on average. These estimates suggest there is strong potential for dairy’s demand (e.g., a 60% increase by 2027 from 2017 levels). The OECD-FAO estimates, however, are somewhat more conservative as they expect India’s dairy consumption growth to continue accelerating over the next 3 years (and peak at 4.7%) and then to start moderating to 3.6% by 2027.
Case Study: Brazil

- The agricultural sector in Brazil represents about 5% of GDP and grew 13% in 2017. Estimates suggest that about 80% of Brazilian food production is consumed domestically, and although it is a relatively closed economy (exports plus imports amount to only ~10% of GDP), it has become the largest producer and exporter of several commodities like sugar, coffee, and orange juice, and among the top for soybeans, beef, corn, and poultry. As Brazil’s plant crop areas cover about 8% of its territory, there is potential for extending the land available for cultivation (e.g., according to Embrapa there are 115 million hectares of available land). However, preference should be given to improving yields rather than expanding land especially in areas which are important for ecosystems. Brazil has been specializing in raw agricultural products compared to processed foods, and according to the OECD, in order to diversify its agro-food export base and meet the increasing demand for processed and differentiated products, Brazil would need to invest in infrastructure, improve access to credit and reduce tariffs on inputs.

- The World Bank highlighted that Brazil experienced an increase of productivity in the agricultural sector (e.g., 105.6% increase from 2000-2013, compared to ~12% in services and -5.5% in manufacturing) mainly driven by policies to boost investment in innovation (including in Research and Development, like Embrapa) and increase trade liberalization. However, Brazil spending in agriculture innovation (7.5% of total support to producers) and overall support to the agricultural sector (4.6% of gross farm receipts) is still small compared to OECD countries.

Investment requirements for agriculture in Emerging Markets could amount to US$9.2 trillion by 2050

Brazil has become the world’s largest producer and exporter of sugar, coffee and orange juice and among the top for soybeans, corn, beef and poultry

Brazil has increased investment in agricultural innovation but it is still small compared to OECD countries
The Agricultural and Livestock Plan 2018-2019 budgeted for a financing amount of $48 billion (78% for loans, 20.5% for investment credit, 1.3% for commercialization support, and 0.3% for insurance subsidies). The amount budgeted represents a 3.1% growth in financing from last year, but there has been an under-allocation of resources in recent years. Compared to previous years, changes in the plan include: (1) Higher limits to be eligible for support programs (for both family farming and medium-sized commercial farming); (2) Lower interest rates, including on rural loans for expanding storage capacity with the construction of warehouses; (3) financing the acquisition of breeding herds with genealogical records to improve livestock productivity and quality; and (4) increasing the limits for financing of sustainable agricultural practices and technologies, among others.

During the presidential campaign, Brazil’s Agriculture Confederation (CAN) presented a plan for ‘Agriculture’s Future 2018-2030’ which aims at increasing Brazil’s agro production by 30% by 2030. Among others, the plan identifies a number of priorities to deal with Brazil’s agriculture bottlenecks, including investment in infrastructure for distribution logistics, changes in the sector’s legal framework, signing international trade agreement, as well as public policies targeted at increasing biofuels production.

The FAO notes that within emerging markets Latin America would be the only region that would produce more food than what it would demand (self-sufficiency rates of 130 by 2050). In particular, the OECD-FAO expect Brazil’s production to cover about 40% of global food demand, which is set to increase by 20% by 2027. However, gross fixed investment in the agriculture and livestock sector moderated significantly after peaking in 2013. Meanwhile, the share of agriculture in GDP increased bottomed out since. While the ongoing fiscal consolidation adds a degree of uncertainty, a simple linear model suggests that agriculture investment in Brazil would evolve at around rates of 5.5%-7%, after recovering from the weak levels in recent years. We stress that further investments in innovation to keep productivity growth in a sustainable way would be required for allowing Brazil to fully consolidate its position as a global food producer.

Brazil aims to increase agricultural production by 30% by 2030

Brazil is expected to supply 40% of global food demand by 2027, but further investments are needed to drive productivity growth sustainably.
Global Investment Needed

- Higher investment in agriculture would be needed in order to lock in the productivity gains required to meet food demand. According to the FAO, about 57% of global investment needs by 2050 ($9.2 trillion cumulative from 2005-2007, in 2009 constant dollars) would come from Asia (roughly 39% from India and China), followed by Africa with 23% and LatAm with 20%. From these, about 60% would be required just to replace existing capital stock.

Global investment in agri-food research and development increased 89% from 1990 to 2011 but the share of public spending has moderated

- Global investment in food and agricultural research and development totaled $75.9 billion in 2011 (in purchasing power parity terms), an increase of about 89% from 1990. However, the share of public spending moderated, which according to the USDA could suggest further risks if not offset by higher spending by the private sector or emerging markets. According to the USDA, the share of public investment by high-income countries declined from 36% to 24% during the same period, while it increased for both public spending by emerging economies (to 32% from 27%) and food manufacturing companies (to 25% from 18%). Estimates from the FAO suggest that global food demand by 2050 would increase by 60%-70%. However, growth in crop production would come mostly from increases in productivity: increases in yields (80% globally, 73% developing economies) and cropping intensity (10% globally, 6% developing economies).
Conclusion

When it comes to global food security, four crops matter the most: wheat, rice, corn, and soybean. In addition to being dietary staples around the world, these crops especially corn and soybeans are also important feedstocks for meat, dairy, and processed foods consumption.

We have shown that capacity utilization of arable land across the Northern Hemisphere has peaked but there is further room to expand crop harvests in the Southern Hemisphere via both planted area and yield improvements. While the former may be promising for a decade or so, it faces issues of sustainability and so in the long-run, yields matter more.

However, this growth is not without its challenges. Greater investments in agriculture are needed to lock in the productivity gains required to meet growing food demand. It is estimated that $9.2 trillion are needed in Emerging Markets by 2050 (from 2005-2007), which translate into annual capital requirements of $210 billion. Within Emerging Markets, Latin America is the only region that is expected to produce more food than it will demand in the future. In particular, Brazil shows most promise in becoming a global food producer but further investments in agriculture innovation are needed to ensure productivity growth can be achieved in a sustainable way. Other challenges the Southern Hemisphere is likely to face include unpredictable weather cycles and the availability of water resources, even though the availability of water is more abundant than the northern hemisphere, certain countries like Argentina and South Africa could face some scarcity in the years to come. In summary, opportunity knocks for the Southern Hemisphere grain/feed farmer where there is potential for significant productivity gains as well as room for expansion.
Opportunities from a Sector Perspective: Regional Analysis

It is clear that the global food system needs to change if it is going to feed 9-10 billion people with more nutrition, less waste, and more sustainability. The sector needs to innovate — it is the least digitized of all major industries (MGI, 2016) but technology can help address many of the challenges it faces. Springmann et al (2018) state that technology, a reduction in food waste, and a change in diets can reduce the water, land, and greenhouse gas emissions in the agrifood sector compared to a business as usual (BAU) scenario. For example under their technology scenario (see definition in figure below), greenhouse gas emissions would reduce by 9%, land use by 30%, and water by 28% when compared to a BAU 2050 scenario.

Figure 67. Percent Decrease of GHG Emissions, Land, and Water Used when Compared to a BAU Scenario in 2050


* BAU scenario in 2050 — a middle of the road development pathway with global population reaching 9.2 billion and global GDP reaching US$231,439 ppp in 2050 respectively; Tech-Closing of yield gap to about 75%, rebalancing nitrogen and phosphorous fertilizer application between over and under-applying regions, improving water management and implementation of agricultural mitigation options such as changes in irrigation, cropping, and fertilization that reduce methane and nitrous oxide emissions for rice and other crops., as well as changes in manure management, feed conversion, and feed additives that reduce enteric fermentation in livestock; 1/2 waste Food losses and waste are reduced by half, in line with pledges made as part of the UNSDGs; HSV-Dietary shifts towards global dietary guidelines including maximum intakes for red meat and sugar and minimum intakes of fruit and vegetables and energy intakes in line with recommendations on health body weight and physical activity; FLX-Dietary shifts towards a more plant- based flexitarian dietary patterns based on health eating- and more stringent limits for red meat, white meat and dairy.
The agri-food sector is ripe for technology innovation and disruption and as we will see from this chapter- many companies are waking up to this. For the upstream stages of the food supply chain, i.e., inputs and production, innovation, and opportunities that companies are embracing can be largely summarized to focus on “Doing more with less”. Recent advancements in sensors, robotics, and data and analytics are driving innovation in precision agriculture, and developments in genomic techniques, such as CRISPR, and microbial research, look to revolutionize crop and livestock inputs. On the downstream end, consumers are becoming more health-conscious which is driving food manufacturers and retailers to innovate. Manufacturers are developing healthier and more functional products as well as sourcing more natural ingredients, and retailers are embedding more sustainable practices into their business models. New Agtech developments are also coming to the forefront, which include alternative proteins, biofortification, and vertical farming which have the potential to disrupt traditional farming methods.

Below we map these new innovations across the supply chain and across waste, sustainability and nutrition. There is an abundance of opportunities across the food value chain, especially in inputs, all of which can help to tackle the three challenges but in particular waste and sustainability. The theme of “Doing more with less” seems to resonate across these solutions. With regards to improving nutrition, many opportunities lie downstream across consumer staples, retail, and the end consumer and can range from production of healthier alternatives to personalized nutrition. We also believe sensors, better data, and overall digitization of the agri-food supply chain can help to improve efficiency, sustainability and nutrition.
Figure 68. Mapping the Opportunities Across the Supply Chain

Source: Citi Research

Technology and innovation are changing the agriculture chemical sector. Gene editing technologies such as CRISPR and TALENS can revolutionize the seed sector and accelerate plant breeding techniques beyond what was previously imaginable. (Gao, 2018) These gene editing technologies can make plants higher yielding, drought tolerant, disease resistant, and more nutritious — tackling our three challenges simultaneously. Biological solutions such as bio-stimulants are also being used to increase plant health and to strengthen yields while fertilizers containing micronutrients can improve the nutrition of crops. Biofortification which is the use of agronomic and plant breeding approaches to increase micronutrients in staple foods could also make a huge difference to countries where diets are mostly composed of energy-dense but nutrient poor foods (see section below for more detail).

Innovation is also having a positive impact on the meat industry. The meat industry is currently inefficient — the conversion of feed into protein is only 7% efficient. However new feed additives can improve the efficiency and quality of meat production by ensuring the efficient supplementation of vitamins, minerals, and probiotics to ensure feed conversion is optimal. They enable the animal to better utilize the ingredients of feed itself, ensuring less wastage and a reduction of feed that needs to be used. Enzyme-based solutions, such as the one produced by DSM which can reduce a cow’s methane emissions by ~30%, could make a huge difference to agriculture-related greenhouse gas emissions. Private companies such as Memphis Meat and Mosa Meat are also developing cultured meat (lab-grown meat) while Beyond Meat and Impossible Foods are developing plant-based meat which can ultimately decrease the amount of feed needed for animals and the emissions related to animal production entirely.
Seeds, Fertilizers, and Crop Protection

Three of the most important inputs for crop production are seeds, agricultural chemicals (such as herbicides, insecticides, and fungicides), and fertilizers. Globally, these three segments of crop inputs are a >$200 billion market (Figure 71). Seeds are the foundation of any crop and a key focus for R&D, crop protection chemicals help support efficient plant growth by addressing environmental factors such as weeds and diseases, and fertilizers boost soil fertility to allow for optimal plant yields. Below we discuss of the emerging R&D trends for each sub-sector, as well as discuss the rapid growth of Digital Ag software applications, which is a key focus for investment for many companies in this space.

![Figure 71. Key Crop Inputs Market Size ($ billions)](image)

Source: Cropnosis, Bloomberg, Company Reports, Citi Research

Seeds

The Ag biotech revolution kicked off in 1996 with the launch of Monsanto’s Roundup Ready soybean, a soybean which was resistant to herbicide glyphosate. In the subsequent 20 years, genetic engineered (GE) soybeans like Roundup Ready and its progeny have grown ubiquitous and account for ~95% of all soybeans planted in the U.S. Currently, over 90% of U.S corn, upland cotton, soybeans, canola, and sugar beets are GE, and U.S. farmers have grown quite comfortable using these products.
Companies such as Monsanto (recently acquired by Bayer), DowDuPont, Syngenta (acquired by ChemChina) and others have invested 10% of sales or more in R&D to develop biotech traits to help farmers grow better crops mainly through resistance to certain herbicides or insects. Using current technology, it can take 10 years or more to bring a new agronomic trait to market at a cost >$100 million per product, with ~30% of that cost being related to regulatory matters.

Core to the next leg of development in seeds is the use of gene-editing technologies such as CRISPR or TALENS. Our Citi GPS Disruption Innovation Report V covers this technology in more detail. The promise of these new technologies is that they may: (1) Increase the potential types of edits to seeds to broaden its agronomic traits and/or provide traits which could be favorable to consumers such as healthier plant-based oils or higher fiber; (2) Shorten development timelines to 3-5 years and greatly reduce total R&D costs; and (3) Since no foreign DNA is used in many gene-editing applications, regulatory costs are lower and the product may not be considered GMO. Gene “knock-outs” (disabling a specific gene in a plant) have favorable rulings from the USDA that it is not GMO and in early 2018 the European Court of Justice said crops using these modifications techniques may not have to be regulated like GMOs, potentially opening a major new market for these crops.

In 2018 Calyxt launched a gene-edited high oleic soybean while DowDuPont plans a gene-edited corn seed by 2020. Most of the global major seed producers have licensed CRISPR and are working to develop new seeds, while smaller companies are also expanding development of next-generation non-GMO seed products. For example, Cibus just raised ~$70 million of funding to expand its sulfonylurea herbicide tolerant canola seed in Canada and is launching a non-GMO flaxseed in the U.S. in 2019.
Crop Protection

Demand for synthetic chemistry for crop protection chemicals has stabilized following several years of challenges as the industry adjusted to lower crop prices. Longer-term, usage of synthetic chemistry per acre is declining as farmers improve the accuracy of applications (in part thanks to innovations in Digital Agriculture – see below), and producers of chemicals improve the efficacy and efficiency of formulations in response to both economic and environmental concerns from their customers.

Further, the pace of introductions of new synthetic active ingredients has slowed with 146 introduced during 2000-2017 but currently only less than 45 are in various stages of the R&D pipeline (can take 5-10 years to bring to market). Instead, there is more focus on developing biological and microbial solutions, although these products remain more "niche" than mass market with the total revenues from these applications below 10% of the total market.

Biological solutions use natural materials instead of synthetic chemistry to boost plant health. Some examples of bio-based chemistry include bio-stimulants, which attempt to reduce plant stress or strengthen the plant to boost yields, and bio-based pesticides. Microbial products introduce beneficial microbes either topically on plants or as treatment for seeds. For biological and microbial solutions there are lower regulatory barriers to introduction, since they do not use synthetic chemistry and they help crop chemical producers continue to grow despite increasingly stringent crop protection chemical application regulatory requirements.

Additionally, biological and microbial solutions have been a major focus for emerging companies. For example, Indigo Ag launched a microbial seed treatment which they state improves yields for wheat by 13%. In late 2017 the company closed a Series D funding round raising $203 million. In addition to developing products which compete with tradition synthetic chemistry, biological and microbial solutions are being researched to improve plant performance in low water stress conditions and improve the efficiency of fertilizer absorption.

Fertilizers

On a relative basis, R&D investments (and advancements) in fertilizers are far less than in seeds and crop protection chemicals. Bulk commodity fertilizers (such as urea, diammonium phosphate (DAP), and potash) are dominant. Innovation in recent years has emerged in a few forms, including formulating new blends of fertilizer which contain micronutrients (examples include Mosaic’s MicroEssentials line of fertilizers) and nitrogen fertilizers coated in polymers which control the rate which the nitrogen is introduced into the soil (examples include Nutrien’s ESN line of fertilizers). Other companies are attempting to use bio-based chemicals instead of polymers to control the release of fertilizers in the soil. We think these are incremental improvements, but for through medium-term we continue to see most farmers focused on incorporating bulk commodity fertilizers in their farm management programs.

Digital Agriculture

Digital Agriculture encompasses a broad range of emerging services which help support a farmer’s business and/or help growers improve the performance of their crop. These services have built on some of the precision agriculture advances over the past decade, including variable rate planting and fertilizer application. Some key markets for Digital Ag applications include:
■ Automation & Adoptive Irrigation – Applications which automate processes which farmers currently do manually (or not at all). Some examples include robot-enabled weed sprays (Blue River Technology), automated fertilizer application, and advanced/automated and individualized irrigation systems.

■ Big Data Aggregation – Includes companies which help farmers catalog, organize and use data collected on their farms. Also includes services which allow farmers to share data.

■ Input Efficiency Optimizers & Growing Prescriptions – Services which utilize farmer data to help with crop growth or farm management practices. A prominent service is Farmers Business Network, which provides transparent pricing for crop inputs as well as crop analytics and marketing services for growers.

■ Sensors and Field Monitoring – Equipment and supporting software/services which allow farmers to monitor crop growth, fertilizer, weather, disease/insect pressure.

■ UAV & Imagery Systems – Provides aerial imagery of fields using planes, satellite images, or drones. Applications to process/analyze imagery data to identify such issues as water or fertilizer deficiencies, and disease or insect pressure.

Monsanto (now owned by Bayer) was among the leaders among large agriculture companies in developing a Digital Ag business. In 2013 the company purchased Climate Corp for approximately $1 billion, and over the subsequent years developed applications, including FieldView which was used on over 35 million acres in 2017, as well as the Climate Corp platform, in which third party developers can launch tools for imagery, soil testing, and farm management (in total used on more than 120 million acres in 2017). Several other large agriculture companies are also developing major digital agriculture offerings, including Nutrien (Echelon) and DowDuPont (Encirca).

Animal Nutrition: Improving Conversion Efficiency and Sustainability

Role of Animal Nutrition

The crucial input into the meat industry is feed, with the key challenge of the industry being how can you convert, most efficiently, your feed (chiefly grain), into protein. Currently, on average in the U.S., out of the ~1,187 petacalories of feed fed to animals, only 83 petacalories are converted into edible products (reflecting a mean conversion efficiency of approximately 7%). (Shepon, 2017)

Not only is this a meaningful issue in terms of sustainability, noting that ruminant meat has an environmental impact 20-100 times those of plant based foods. But it also has a defining effect on profitability: feed costs make up 73% of overall poultry production costs. They define margins at that point of the value chain.
The animal nutrition market (i.e., the market for nutritional ingredients and feed additives aimed purely at animals) is designed to solve both of these issues. Notably, it is the chemical industry that is the primary supplier into this market, specifically the specialty chemical focused businesses.

The purpose and value proposition of feed additives is to improve the efficiency and quality of meat production by ensuring the efficient supplementation of vitamins, minerals, amino acids, enzymes, and probiotics to ensure feed conversion is optimal. Effective supplementation has three effects,

- Improves the overall quality of the end-product.
- Enables the animal to better utilize the ingredients of the feed itself, ensuring less waste and a reduction in the amount of feed that actually needs to be used — as an example: enzymes allow an animal to process portions of the feed (certain carbohydrates) that would otherwise be indigestible
- Ensures the animal reaches its target weight for slaughter earlier and hence ends up consuming less energy (feed/grain) than would otherwise be the case.

The nutritional supplements pay for themselves from the savings in energy (grain) associated with meat production.

To give a sense of the effect that effective feed can have on the efficiency of production consider that: In 1970 it took almost 70 days for a chicken to reach 2kg (4.4lbs). By 2010 this was down to ~35 days and it is expected that this will come down to 22 days given the current trends in technology and the development of nutrition and genomics.
To understand why effective nutrition can have such a meaningful effect, it is necessary to understand the concept of the rate-limiting minimum. The analogy to consider is that of a barrel made of uneven planks of wood. The water level in the barrel is the growth potential of an animal, and each plank of wood represents each individual nutrient, including carbohydrates but also various minerals, vitamins, and amino acids. Necessarily a grain only diet will provide differing amounts of each nutrient (hence the uneven planks) and in each case there will be one nutrient that will not be available in sufficient quantity to allow protein creation, i.e. the water level will be limited by this plank being lower than the others.

There are two solutions to this problem: (1) you add more grain in entirety, raising the level of all the planks, including the crucial rate limiting plank, in turn allowing more growth — an inefficient solution or (2) you specifically supplement the missing nutrient — raising what is currently the rate-limiting minimum, and allowing the better utilization of all the other nutrients in the feed. As an example, supplementing feed with a full range of amino acids, which themselves can be the rate limiting factors in nutritionally poor feeds, can reduce production costs by ~23%.

**Figure 74. Presentation of the Rate Limiting Roles of Nutrients in Animal Meat Production**

![Diagram showing the rate limiting roles of nutrients in animal meat production.](image)

*Supplemented with MetaAMINO®*

*Plex-based*

*Increased soybean meal*

**Figure 75. Efficiency Gains Are Material**

![Bar graph showing 23% reduction in production costs.](image)

Basic Feed vs. w/ Amino Supplement

*Source: Evonik, Citi Research*

Note: MetaAMINO is a brand name for Methionin — a rate limiting amino acid

**Spectrum of Feed Additive Offerings**

There are a number of different key nutritional ingredients with different companies operating in some and indeed all of the potential segments. The total market is in the region of $12 billion globally, with growth rates consistently above meat production, driven by the efficiency gains these products enable.
**Vitamins**: Vitamins are essential micronutrients that are required for optimal health and normal physiological functions. Importantly, they can’t be synthesized by animals and must be obtained from feed. Split into fat soluble (A, D, E, and K) and water soluble (The B’s, Niacin (PP), Folic Acid (M), Biotin (H), and C). Vitamin requirements change by animal and due to the different stage of the lifecycle.

**Key Companies**: DSM, BASF, NHU, Adisseo

**Amino Acids**: Amino acids are the building blocks for proteins and play a critical role in metabolism, health (e.g., antibody production), transport (e.g., hemoglobin), repair, and other important body functions. There are many amino acids with some being essential and as such cannot be synthesized internally. The key ones are well-known rate-limiting factors to the growth of animals and maximize the conversion efficiency from grain to protein. Lysine is the key rate limiting amino acid for swine and cows, and methionine the key limiting amino acid for poultry. Soy and corn are inherently deficient in methionine.

**Key Companies**: Evonik, Adisseo, Sumitomo Chemical

**Feed Enzymes**: Naturally occurring catalysts, typically organically derived through fermentation, that improve the digestion of feed. Phytase, for helping to facilitate increased bone-mass and reducing the need for mineral phosphate additions; proteases for greater availability of proteins and amino acids and thus increases in meat; and carbohydrases for better energy delivery to the animal. One of the fastest growing segments in the overall feed additive market.

**Key Companies**: Novozymes, Dupont, DSM, BASF
- **Eubiotics**: Products primarily designed to improve and sustain the microflora of the gastrointestinal tract and thereby improve feed conversion. The definition includes probiotics: Live strains of selected microorganisms that confer a benefit when ingested, prebiotics: certain non-digestible nutrients which can support the growth of healthy gut flora. They have seen a spark in demand in particular due to the push to reduce antibiotic use in animal rearing. Another sharply growing segment.

  **Key Companies**: Novozymes, DSM, Christian Hansen, Addisseo, Dupont

- **Carotenoids**: Naturally-occurring pigments which function as antioxidants and colorants. They aren’t produced in livestock and must be provided to fulfill the consumer’s expectation for color of many meat products. They also play a role as pro-vitamins, as many can be enzymatically transformed into vitamin A once ingested.

  **Key Companies**: DSM, BASF, NHU, Adisseo

**The Spectrum Expands: Sustainability in Focus**

While the ingredients above all play a role in improving the sustainability of the meat production process they primarily do so by improving the efficiency of production. However, a number of chemical companies have started to focus specifically on solutions that look at other ways to improve the overall sustainability of meat production, in a more holistic fashion.

**Methane reduction in ruminants**: Cattle emissions are the second largest source of methane emissions globally after fossil fuels. Methane has a greenhouse gas index of 120; i.e., it is 120-times more potent than CO₂, noting it only has a half-life of about 9 years. The cattle industry, especially the dairy industry, is coming under increasing pressure to manage these greenhouse gas emissions. DSM has developed an enzyme based solution that can reduce cow’s methane emissions by ~30%. Its product is relatively unique in being able to reduce methane emissions with no further changes to feed, breeding, or habitation.

This issue is of particular import for nations like New Zealand where the productive economy is focused on agriculture: 48% of the countries’ emissions come from farming. The government has committed to a 30% reduction of greenhouse gas emissions by 2030 (from 2005 levels) but expects to achieve this end while also doubling agricultural exports by 2025. New Zealand agriculture needs to get more efficient. We would therefore expect farmers to be incentivized in order to provide a commercial reason to limit their emissions, perhaps a carbon trading scheme or subsidy based on CO₂ efficiencies.

**Sustainable Fish Oil in Aquaculture**

Feed for fish (in fish farms) has typically been supplemented with fish oils to enable two effects: (1) the effective nutrition of the fish; and (2) the appropriate oil content in the fish when considered for further consumption (i.e., sufficient Omega-3s). A significant aspect of the relative appeal of fish as a source of protein is the health offering. As an example the WHO advises at least 1-2 servings per week, with the serving importantly providing an equivalent amount of 200-500mg of DPA and EPA – Omega-3 oils. The historical method for supplementing the fish feed content with fish oils has involved the mass catching of wild fish (typically anchoveta), which are then processed and re-fed to farmed fish in order to provide the appropriate feed input.

The replacement of fish oil additives in aquaculture with algal-based alternatives can help to reduce the unsustainable catching of wild fish.
The innovation, which comes from Evonik and DSM, is an algal-based fish oil, which can be fed directly to the fish in aquaculture. This production process is simply a shortening of the natural food chain. The fish oils present in all fish oils originate from natural marine algae, which pass up the food chain to fish (typically anchoveta) which are then caught and processed to be fed back to farmed fish — this process just cuts out the middle man, by moving straight from algal fish oil generation (this time in tanks, on land) to fish feed for aquaculture. One kilogram of their oil saves roughly 60kg of wild caught fish.

**Figure 77. Cattle is the Second-largest Source of Methane Emissions Globally**

![Pie chart showing sources of methane emissions.]

**Figure 78. Expected Fish Production – Fish Farms Will be the Key Sources of Growth to Match this Expected Demand**

![Graph showing fish production over time.]

**Other Innovations to Disrupt the Agrochemical Sector**

**Biofortification**

Delivering improved nutrition does not only have to come from a well-balanced diet — biofortification could be one possible solution. Biofortification is the use of agronomic and plant breeding approaches to increase micronutrients in staple food crops and is especially relevant across developing countries where diets mostly compose of energy-dense but nutrient-poor grains or roots and tubers. There are three common approaches to biofortification: (1) agronomic which provides temporary micronutrient increases through fertilizers; (2) conventional plant breeding beginning with a plant already containing some vitamins or minerals, which is then bred to general plants possessing a higher level of these compounds; and (3) plant breeding using genetic engineering. (Saltzman et al., 2017)

HarvestPlus leads a global effort to develop and scale up micronutrient-rich staple crops using conventional plant breeding techniques. It partners with crop breeding centers of the international agricultural research network known as CGIAR to develop conventionally bred varieties of nutritious, high-yielding, and climate smart staple crops. Examples include a Vitamin A orange sweet potato, Vitamin A Cassava, Iron Bean, Zinc Rice and others. (HarvestPlus, 2018) To date more than 290 biofortified varieties of 12 staple food crops have been released or are in testing in more than 60 countries around the world. In total 50 million people in farm households are growing and eating biofortified foods. (HarvestPlus, 2017) A number of food manufacturers are committed to developing a supply chain of biofortified crops. For example Nestlé has participated in an academic study with Harvest Plus on the biofortification of wheat, rice, and maize with iodine with trials in Turkey and India and also explored the viability of zinc-fortified wheat in India. (Access to Nutrition Index, 2018)
Another example of biofortification is ‘Golden Rice’ however since rice does not contain any vitamin A or vitamin A precursors, selective breeding of rice cannot be used to prevent vitamin A deficiency leading to genetically engineered Golden Rice. However scientists have determined that just 72 grams (about 1/3) of dry GR2rice (the new strain of Golden Rice) per day would provide enough beta-carotene to prevent vitamin A deficiency in a child. (Gearing, 2015) The prospects are huge, however GMO crops do come with their controversies and there are many organizations that prefer promoting adequate diets to improve nutrient deficiencies rather than reliance on GMO solutions.

Alternative Proteins

“If we can grow the meat without the animal, why wouldn’t we?” – CEO, Tyson Foods Inc.

As we have discussed earlier in the report, animal-based foods are more resource intensive than plant-based foods and the production of beef has the greatest environmental footprint. Campaigns to raise consumer awareness on the environmental impacts of food products have seen limited success, and changing the kind of meat we eat may have more potential for success than cutting the amount of meat we consume. (Wellesley, 2017) This has driven research and development into the realms of alternative proteins, especially in meat “analogues” which can be split into lab-grown (cultured) meat and plant-based meat.
The key players currently operating in the space include Memphis Meats and Mosa Meats for cultured meat, and Beyond Meat and Impossible Foods for plant-based meat. Apart from Mosa Meats which is a Dutch company, the other three are based in the United States. Both Memphis Meats and Mosa Meat anticipate commercial release of products around 2021, whereas plant-based meat products are now available at select supermarkets and restaurants across the U.S. Producing the Impossible Burger uses about 75% less water, generates about 87% less greenhouse gas emissions and requires around 95% less land than the conventional ground beef from cows (Appelgren, 2018). Impossible Foods has raised nearly $500 million in equity and debt while its nearest competitor Beyond Meat has raised $72 million to date. (Cosgrove, 2018)

Start-ups in alternative proteins have attracted high profile investors including Bill Gates, Google Ventures, Peter Thiel's Founders Fund, as well as meat incumbents such as Cargill and Tyson Foods. Leading meat producers are backing a meatless future and building an investment portfolio in plants, insects, and cultured meat. (CB Insights, 2018) Tyson Foods is the second largest meat producer in the world and have invested in a number of “meatless” start-ups including Memphis Meats and Beyond Meat. There are also alternative protein start-ups that are exploring other protein analogues which include “dairy without the cow”, “eggs without the chicken”, and “seafood without the fish”, as well as the use of insect protein which FAO has identified as an unexplored nutrition source that can help address undernourishment. In order to make insects more appealing, some companies are incorporating insect flour/powder into common foods. For example, Exo Foods manufacture protein bars from cricket protein, and Chirps uses cricket flour to make tortilla chips and cookie mix. The cultured meat market is projected to reach $15.5 million in 2021 and $20 million by 2027, with North America expected to account for the largest share of the market in 2021 but the Middle East and Africa market will increase the most during the forecast period. (MarketsandMarkets, 2018) The edible insects market on the other hand is expected to reach $1.2 billion by 2023, at a CAGR of 24% between 2018-2023, the North America market is expected to grow significantly due to growing concern about meat production and increasing demand for environmentally friendly diets. (Research and Markets (2018), EXO/EatChirps, (2018)).

**Vertical Farming and Controlled-environment Agriculture**

The need to feed a growing population combined with rapid technology developments is driving the innovation of new production systems. The vertical farming model aims to increase crop production by adopting a multi-level factory design, and does not require soil if controlled-environment techniques such as hydroponics, aeroponics or aquaponics are used. These systems are closed to prevent contamination and ensure controlled conditions, usually inside buildings and greenhouses, and use LED lighting to optimize photosynthesis. Hydroponics supply a targeted nutrient solution directly to the roots ensuring the plant always has an optimal supply of minerals and water. Aeroponics is a variation where the roots are sprayed with nutrient mist, and aquaponics is a combination of aquaculture and hydroponics, bringing together fish and crop farming in one recirculating system. And it turns out old semi-conductor plants make great indoor farms - electronic giants such as Sony, Toshiba, and Panasonic are all getting into food production and developing agribusinesses.
Figure 80. Vertical Farming

Source: Sky Greens

Controlled-environment agriculture allows (1) all year round crop cultivation and supply, (2) production closer to consumers which reduces transportation needs and costs, (3) more efficient cultivation which include savings in water and chemical use, and (4) cultivation in areas unsuitable for traditional agriculture i.e., desert regions or urban areas. However, these new systems are currently limited to plants that grow well under these conditions which include salad greens, tomatoes, cucumbers and herbs. Calorie-rich stable crops such as wheat and rice that are needed for food security aren’t able to be cultivated in this manner. Other challenges that face adoption of these systems include high set-up and running costs, high energy demands, and need for expertise. Critics of vertical farms argue that they will not be able to feed the world or reduce the substantial environmental footprint of agriculture. (GlobalEcoGuy, 2018)

The solution might lie in a hybrid system that combines conventional and novel production techniques — for example, Sky Greens is a company in Singapore that has developed a vertical farming system that is low-carbon and driven by hydraulics. Natural sunlight is used which saves energy demands for artificial lighting, and plants are grown in shelves which rotate throughout the day to ensure uniform sunlight, water and nutrients. The approach is able to reduce water, land, and energy use compared to traditional farming systems, and can produce 5 to 10 times more vegetables than conventional methods using the same land area. (Singh, 2016) The rotating shelves are able to accommodate different growing mediums, i.e., soil or hydroponic systems. Vertical farming is on the rise in Singapore which has limited land resources and has developed beyond vegetables to include fish and other aquatic farming. There are also many start-ups in the United States that are developing indoor farming systems. AeroFarms is considered an industry leader, and partners with a leading tech company for their IT infrastructure needs. The company has raised over $130 million since 2014, and has a global list of investors which include IKEA and investors from the Middle East and China.
Future market size forecasts for vertical farming vary with reports of $6.4 billion by 2023 to $13 billion by 2024 but growth rates in the low 20s have been reported throughout. Hydroponic systems are likely to continue holding the majority share of the market. (Allied Market Research, 2017)

**Autonomous Hydroponic Farm**

Iron Ox, a company based in California has developed an autonomous hydroponic indoor farm. The company is opening up its first production facility in San Carlos, near San Francisco. The facility will be producing leafy greens at a rate of roughly 26,000 heads a year—this level of production usually occurs in a farm which is roughly five times larger. The farm consists of a series of robotic arms and movers—the arms pluck the plants from their hydroponic trays, while the mechanical movers move the plants around the facility. The founders claim that it was tricky to get the robots to collaborate together, so to fix this problem they developed software called the ‘brain’ that oversees the process and monitors things like nitrogen levels, temperature and robot location (MIT, 2018).

**Machinery & Equipment**

Farm equipment is especially important to increase agriculture productivity. Rising crop yields especially in the U.S. mean that harvesters must process significantly more material than in previous years while volatility in weather patterns compresses windows for optimal planning and harvest time which require farmers to process higher volumes in tighter timeframes. Original equipment manufacturers (OEMs) have responded in producing faster and more efficient machinery—for example Deere has launched its ExactEmerge which enables farmers to plant at speeds of 10mph-plus. OEMs are also investing in precision agriculture which a set of technology-based devices which enhances the growers to manage their farms such as GPS utilizing equipment, yield mapping, soil sampling and mapping and fleet management. For example Deere has partnered with agriculture drone companies to provide farmers with tools to monitor their crop conditions; the company has also developed Blue River Technology that allows machines to identify weeds and precisely spray herbicides on them, reducing herbicide use by 90%. Our analysts estimate that that global penetration of precision agriculture is only ~25% with North America and Australia leading the adoption (~75%), followed by Europe (~50%), and Latin America (~20%).
So there is significant scope for precision agriculture to expand globally, however the challenges that each region faces are different. In Japan Kubota has developed a range of autonomous tractors using GPS technology while also developing smaller rice trans-planters and rice combines to accommodate the size of a typical rice plot (~10,000 m²) in the country. In India what we are seeing is a consistent growth of tractorization and leading OEMs in the country such as Mahindra & Mahindra (M&M) have also launched a driverless tractor with DigiSENSE technology.

**Advances in Machinery Technology Contributing to Rising Farm Crop Yields: U.S. Perspective**

In order to keep up with rising global food demand farmers need to continue driving further productivity out of their land. This means optimizing inputs, maximizing planting, and harvesting windows and utilizing advanced crop monitoring data to drive higher annual crop yields (bushels/acre). Based on industry estimates, farmers have improved annual food production by over 250% since 1950, while using 2% fewer inputs over the same period. A large part of this growth has come from efforts of agricultural machinery OEMs, including “full-liners” like Deere, CNH Industrial and AGCO which have supported rising yields through advancements in machinery performance and technology.

Farm equipment manufacturers have boosted productivity growth via multiple avenues. First, rising crop yields mean harvesters must process significantly more material than in years past. Further, due to more volatile weather patterns, the windows for optimal planting and harvesting have compressed, requiring farmers to process higher volumes in much tighter timeframes. OEMs have responded by introducing increasingly higher horsepower/faster machinery and more efficient planting/harvesting equipment.

As an example, Deere launched its ExactEmerge planter around 2014. This planter enables farmers to plant at speeds of 10mph-plus, a significant step up from the 6 mph average of prior generations. This provides a big advantage for growers looking to hit precise planting windows, which have compressed from 20+ to ~7 days currently. As shown below, these advancements have significant impacts on potential daily production, which will allow farmers to better optimize their planting/harvesting windows.
The recently-completed planting season in the U.S. provides a good reference point. Unusually cold, wet weather across many parts of the U.S. pushed planting progress well behind schedule at the start of the season. However, when conditions finally did improve, farmers were able to get in to the fields and quickly catch-up. This would not have been possible 5-10 years ago with older generation planters.

As a proxy for precision technology adoption in the U.S. and Canada, John Deere currently has over 100 million “engaged acres” (40 million hectare) — out of ~320 million total farmable acres.

In addition to improvements in machinery size and speed, technology content packed in agricultural machinery continues to increase. This technology is broadly referred to as Precision Agriculture, which is a generic term encompassing a variety of products and services. At its core, we see Precision Agriculture as: (1) a set of technology-based devices which enhances the ability of growers to manage their farms; and/or (2) analytics and services which provide farmers insight or predictive tools to lift productivity and reduce production volatility. Generally speaking, Precision Agriculture is about giving farmers the ability to maximize the capability of a given acre of land. Examples of this technology include:

- **GPS Utilizing Equipment**: Farm equipment like planters, tractors, and harvesters which utilize GPS to steer, or is used in support of yield/soil monitoring. According to Purdue University, upwards of 60% of U.S. farmers utilize at least some equipment with this technology, up from 20% in 2006. Demographic shifts on the farm (i.e., older farmers retiring) are only going to increase this penetration rate.

- **Yield Mapping**: Sensors which detect crop yield and quality characteristics while harvesting, allowing farmers to analyze data to determine high/low quality regions within a field to adjust future production optimization needs.

- **Soil Sampling and Mapping**: Tests soil for nutrient levels to determine fertility needs. Typically soil sampling is done at the beginning or end of the season. Next generation applications include real time analysis and mapping to develop variable rate fertilizer application algorithms.
- **Fleet Management**: Wirelessly tracks a range of machinery statistics including operating hours, engine load and usage rates. Management software allows farmers to remotely optimize equipment settings, improve fuel efficiency through logistics, and identify potential maintenance issues.

As shown below, farmers and dealers alike have become increasingly accustomed to the technology, with over half of U.S. dealers now offering a range of precision ag offerings and a growing number of farmers using the tech in their operations.

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**Smart agriculture - drones and beyond**

Drones are being used more and more to collect data on farms such as plant counting and yield prediction, plant health indices, nitrogen content, drought stress identification etc. Sensors and digital imaging capabilities together with intelligent software systems can allow farmers no matter where they are, to evaluate their crops at scale and in real time, and allow them to make smarter decisions to improve crop yields. Drones can also be used for crop spraying, by scanning the ground, and maintain the right distance from the crops to spray the right amount of chemicals, reducing chemical use in the process. Aerial spraying can be done five times faster than with traditional machinery. There are a number of companies that offer these services including Precision Hawk, Senterra, and DJI Enterprise. DJI Enterprise state that their Smarter Farming Package saved corn growers across the Midwest in the U.S. a total of $9.80 per acre by targeting nitrogen application rates across their land. According to PWC in 2015 the total addressable value of drone powered solutions for agriculture totaled $32.4 billion.
To the extent that these innovations continue to benefit the farmer, whether through cost reductions via input optimization (i.e., more efficient herbicide/fertilizer application), or through yield improvements we expect the major Ag OEMs to continue to invest in the space. As shown below, tech advancements and horsepower growth have already helped drive productivity gains in NA. As long as OEMs and farmers continue to invest in the technology we expect these gains to continue.

**Figure 89. Equipment Improvements Have Helped to Drive Productivity**

Source: USDA, Citi Research

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**Japan’s Unique Agricultural Challenge – Are There Any Lessons for Others?**

Japan’s population is around 126.5 million but over the next thirty years forecasts by the National Institute of Population and Social Security Research show this number will decline by more than 15% to around 105 million. A declining population is the absolute opposite of the title of this report and makes Japan a special situation, especially in an Asian context, but given a range of additional headwinds faced by Japanese farmers we think the responses of Kubota and some of the other domestic ag equipment makers hold some lessons, for example, in autonomous tractors and small-size combines. The gradual contraction of the domestic workforce and changing diets means Japan is also an attractive market for OEM suppliers of milking robots such as DeLaval (Sweden) and Lely (Holland). We are reminded of the old proverb “necessity is the mother of innovation”.

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Innovations in domestic ag equipment include autonomous tractors and small-size combines
Japan aims to increase food self-sufficiency to 45% by 2025 but domestic farmers and suppliers of ag equipment face a tough outlook

Data from the Ministry of Agriculture, Food and Fisheries shows that Japan’s self-sufficiency ratio (on a calorie basis) is only 38%, a level that has been unchanged for the past twenty or so years, highlighting the dependence that Japan has on food imports. While the self-sufficiency ratio for rice is close to 100%, even though per capita consumption has roughly halved over the past fifty years, the ratio for vegetables is ~75% and livestock it is ~65%. The government has a target of raising the self-sufficiency ratio to 45% by 2025 but against a backdrop of a falling population, it seems that the outlook for domestic farmers and domestic suppliers of agricultural equipment is tough and will only get tougher. Some other characteristics only complicate the outlook.

Most of Japan’s rice farmers are part-time and work elsewhere to supplement their income which is used to maintain the farm

The average size of a rice farmer’s plot in Japan is 1ha (10,000 m²) and this generates an annual income of ~¥500,000 ($4,500). This is not enough to live on which is why most of Japan’s rice farmers are part-time, working elsewhere to supplement their income which allows them to replace aged equipment, buy fuel and materials etc., and allow them to keep on farming. However, given Japan’s hot summers and cold winters many older farmers are giving up (the average age of a farm worker in Japan is around 66), and younger people are reluctant to follow in their parents’ footsteps. The decision to join the TPP (Trans Pacific Partnership) and the recent EU / Japan Economic Partnership Agreement means many tariffs on a wide range of imported food will be reduced over the coming years and this will put even more pressure on farmers.

Larger farmers are more able to utilize new technologies such as autonomous tractors

For some larger farmers it is not all bad, as they can establish limited liability companies, consolidate into larger units, invest in new equipment, automate more processes, and also export their produce directly. Partly with these farmers in mind, Kubota has developed a range of autonomous tractors (Agri Robo, based on a 60HP model) using GPS technology while also developing smaller rice transplanter and rice combines (with plans to launch in December 2018). Given the increasing availability of data, the growing number of ways to analyze and process this information coupled with the need to increase yields, Kubota has also rolled-out its Kubota Smart Agri System (KSAS). We note that Yanmar plans to launch its own autonomous tractor in October 2018, with Iseki also expecting a similar product this year.

The growth strategies of companies like Kubota, Yanmar and Iseki remain focused on overseas

While third party forecasts of the market size for ‘smart agricultural equipment’ show a more than doubling in size between 2017 and 2025, the overall scale is still less than $150 million. For this reason, the main focus of these companies’ growth strategy remains overseas, mirroring the current revenue split at Kubota of 20/80 (domestic / overseas).
While it is hard to argue that Japan is spearheading the promotion of information &
communication technologies in agriculture, the recent 34th International Agricultural
Machinery show in Hokkaido had almost 200,000 visitors, 12 unmanned tractors
and a big presence from Topcon. This company has three main divisions
(Positioning, Smart Infrastructure, and Eye Care) and this year the largest one
“Positioning” division is expected to generate more than 50% of total revenues and
65% of operating profit (with an operating profit margin of 12.0%). In the U.S.,
Topcon Agriculture (a division of Topcon Positioning) recently announced a new
collaboration with Kansas State University to develop tools and systems to further
help promote precision agriculture and support local farmers.

Source: JFMMA, Citi Research

Source: Company Data, Citi Research

Source: Kubota, Citi Research

Source: Company Data, Citi Research
Asia: An Example of Mechanization in India

India is no. 7 in the world with 3.2 million km² (320 million hectares) of land. The share of arable land is also amongst the highest in the world, with more than half of the total land mass.

But agri holdings are fragmented — the ownership of India’s agricultural land is quite fragmented. As per the agriculture census of 2010-11, around two-thirds of land owners are categorized as marginal with average land size of 0.4 hectares and another one-fifth are small with average land size of 1.4 hectares. Large land parcels with operating holdings > 20 hectares are <1% of the total. There is a prevalence of subsistence farming with poor agricultural productivity. The consolidation of land holdings could enhance the productivity of the land including economies of scale.

And crop productivity is low — as can be seen from the table below a combination of fragmented land holdings, insufficient irrigation, and lack of knowledge about the use of inputs (fertilizers and pesticides) has resulted in crop yields falling below that of other countries for most of the large grain crops.
Farm mechanization can help to enhance crop productivity as well as the productivity of labor. 

Farm Mechanization is part of the answer and is becoming increasingly necessary for the following reasons: (1) to enhance cropping intensity and productivity; (2) the general wage inflation in wages paid to agricultural workers, which is leading to higher cost of operations; (3) the non-availability of labor for critical operations in farming; (4) the expected decrease in the number of agricultural workers by around 11% to 230 million workers between 2011-2020; (5) the need to enhance the productivity of labor — 52% of the workforce is engaged in agriculture, but the latter’s contribution to GDP is only 14%.

The agricultural value chain has broadly 5 steps: (1) seed bed preparation (in which tractors, levelers, ploughs, and dozers can be used); (2) sowing and planting (the use of drills, seeders, planters, and dibblers); (3) weeding and plant protection (using of harrows, tillers, sprayers, and dusters); (4) harvesting and threshing (use of harvester, digger, reaper, and thresher); and (5) post-harvest and processing (use of dehusker, huller / dehuller, cleaner, grader, and seed extractor). In each stage, mechanization levels are quite low, as shown in diagram below.
In general, what we’ve seen is the ‘tractorization’ of the farming sector in India, in which there has been a consistent growth of tractors, and also a shift to higher horsepower tractors. The latter is for two reasons: (1) larger tractors are being used in combination with more implements to address other parts of the value chain, and (2) tractors are also lent out by farmers (when not being used for agricultural purposes) for non-agricultural purposes (e.g. haulage of sand, bricks, etc.).
As can be seen from both the figures above, the long term growth CAGR for tractor sales in India is around 6%.

From a horsepower perspective, tractors are also becoming larger — with the 41-50hp segment now accounting for around 47% of volumes in fiscal year 2018 — up from 27% in fiscal year 2012.

Farming is evolving from products being sold to various participants in parts of the value chain to products and solutions being sold across the value chain. So companies like Mahindra & Mahindra which earlier sold mostly tractors are now focusing on implements and other tools as well, to cater to the other segments of the value chain.

At the same time, farmers also need products equipped with more technology and sensors to improve on (1) guidance – the implement guides the tractor; (2) better coordination between the tractor and the implements; and (3) push button operations. There is a need for equipment with better telematics (data management), better connections with service providers and better connectivity with farm management systems.

From a location services perspective, smart phones and tablets have GPS embedded in the software, which can make field mapping simple and portable.

Leading OEMs have already begun to deploy some of these technologies – for example, Mahindra & Mahindra launched a driverless tractor with ‘DigiSENSE’ technology that is equipped with features like (1) Auto steer – GPS-based technology enables the tractor to travel along a straight line; (2) Auto-headland turn – Enables the tractor to orient itself along adjacent rows for continuous operation without any steering input from the farmer; (3) Auto-implement lift – Feature in the tractor that automatically lifts the work tool from the ground at the end of a row and lowers the tool after the tractor has oriented itself for operation at the next row; and (4) Skip passing - This technology feature enables the tractor to steer to the next row for continuous operation without any intervention of the driver.

Data and consumer technologies are also beginning to mesh with farming. This includes remote monitoring — e.g., using GPS to determine the location / coordinates of the vehicle; real time locating and logistics; positioning support. Real-time access to market data (crop prices), weather data etc. And finally there are operator based apps for aspects like chemical, fertilizer and seed data, etc.
The World of Food Multinationals

How Can Food Economics Coexist with the Search for Care?

Packaged Food multinationals have portfolios, organizations, cost structures, and constraints implying that the big private sector is not best positioned to address the topic of mass hunger in the world. Over time most fast-moving consumer goods (FMCG) multinationals have prioritized the development of mass standardized branded offerings serving primarily urban populations in emerging or developed markets with access to structured points of sales.

This was less the case in non-perishable home or personal products, where multinationals could use their routes-to-markets to address more rural areas with lower-end brands in soaps or detergents. Consequently, the cost base and organizations of big Food companies (those which in theory could make an impact) have been designed for the branding and push of transformed products, and as such cannot be used as vehicles to answer the complex problem of feeding a growing population.

Of course Food multinationals are all looking to broaden their addressable market and sell products to new consumers, especially in emerging markets, and their earnings growth algorithm is all the more sustainable when driven by volume growth. However, in order to be profitable and self-fund the model of Food multinationals, those incremental volumes have to leverage, at least partially, their existing cost base which is not based on mass agricultural production, but more on the transformation of raw materials into finished products in a number of factories kept as low as possible to minimize capital intensity — while other investments such as advertising and R&D are being used to brand those products and give them an intangible value.

Those investments (advertising alone for Food multinationals typically range between mid to high single-digit as a percent of revenues) are very specific to branded Food and do not concern the agriculture industry — but are actually necessary to provide those finished products with some pricing capabilities thanks to a perceived added value (taste, nutrition, ‘brand equity’). This creates a very specific cost structure and imperatives incompatible with a change in those companies’ ‘mission’. Besides, multinationals also face a natural cost inflation which has to be covered not only by financial discipline but also price increases, which in essence can make those products less affordable for the most vulnerable parts of the population.

How about non-branded Food private actors, for instance private labels in developed markets? Those players clearly participate to give access to better food to lower income consumers. However, we would flag that the private label industry is very fragmented, and that most private players are rather small (in the grand scheme of things) with a vulnerable cost structure, operating close to the break-even bar, and operate only in the least capital intensive categories. As such, a lot of those players individually do not have the capacity to dramatically change the scale of production and are also very sensitive to swings in raw material costs given their low gross margin. We would thus simply flag that private labels, a lot like some small local players in emerging markets, do have a purpose in giving access to packaged Food categories to new consumers, but that their size and economics do not make them the solution to the topics addresses in this report.
This does not mean however that packaged food companies have been insulated from the broader trend of 'food' becoming a vehicle for 'care'.

While ‘care’ can mean feeding a population for the agriculture industry, food multinationals have on other hand chosen, or been forced, to change their narrative to insert this concept of care in their branded offering. This change in emphasis, branding food as a purveyor of something else, has also sometimes been the result of the erosion in traditional barriers to entry which had protected the monopoly rents of some incumbents, forcing those companies to reinvent themselves, and adapting their offering to new consumer needs rather than trying to shape them via traditional advertising firepower.

We have therefore seen various narratives emerging in the space, depending on the region and categories but also cost imperatives, including:

- Indulgence, i.e. Food as a purveyor of well-being;
- Health & Nutrition, i.e. Food as a purveyor of wellness;
- Safety, i.e. Food as a purveyor of peace of mind; and
- An overall move towards a more sustainable supply chain, where ‘sustainability’ becomes part of the branding of a product and not just a part of its manufacturing.

Below, we showcase below how these changes in narratives have happened across the world within the companies we cover, looking for instance at the rise of indulgence via snacking for U.S. companies, but also the narrative around Health & Wellness with European or Japanese multinationals (also via the rise of value-added ingredients companies), while also looking at the dairy industry in China and the rise of processed branded meat in Latin America.

**European Food Multinationals: The Evolution of an Industry Narrative**

We show below how European food multinationals have evolved in their narrative over the past 20 years, moving from a focus on ‘polarization’ (a dual push towards premiumization and affordability) to one of storytelling around nutrition and wellness, and how their offering has aligned with consumers’ new approach towards food.

**European Food Manufacturers Are Being Forced to Reinvent Themselves as their Ecosystem is Mutating**

The narratives of European food multinationals have fluctuated rather significantly over the past decades, and can be seen as the product of companies’ reactivity as well as the need to implement rather dramatic changes in their portfolio.

Why changing a narrative? Because in consumer staples, narratives and economics, i.e., the capacity to make a profit on an incremental product sold, are intrinsically connected. We identify four different period for the sector:

- **1980s-1990s:** The build-up of mass standardized food, with the search for economies of scale.
Mid-1990s to mid-2000s: A significant wave of portfolio reshuffling, marked by the need to address three different topics, with the overarching theme being to flee commoditization and embrace premiumization. This strategy could only be made via a clear change in the categories those groups were willing to operate and dominate.

- The need to abandon certain categories (i.e., prepared dishes and pasta) where private labels had become simply too competitive in Europe
- The move towards categories right for premiumization and trading up (i.e., dairy and pet food), mostly revolving around nutrition and wellness, where brands can still be perceived as adding value.
- The push in emerging markets where branded Food can be seen as both a purveyor of volumes and mix via premiumization

Mid 2000s to 2012: Pushing the previous strategy to the extreme, using scale and advertising as a way to milk monopoly rents and pushing the product to the consumer to make him trade up. This is what we would define as the golden age of scale and push strategies (versus pull strategies where the consumer is supposed to come to you).

2012-2018: The end of an ecosystem and the forced creation of new narratives. Digital and technological disruption have brought down barriers to entry in consumer staples and put the economies of rents those multinationals had been building via their scale under pressure. This has translated into a favorable ecosystem for new entrants and triggered a clear brand proliferation in many categories, facilitating the rise of new offerings, trends, and then diets and behaviors. As such, while a companies’ category and geographical mix were rather robust and fit, these big organizations initially lacked the flexibility (due the complexity of their portfolios) to accompany the development of the new trends within their categories. It’s only since 2015 we really started to see the second wave of portfolio reshuffling, not in terms of adding more categories, but in terms of looking for adjacencies more adapted to new consumers trends (i.e., lactose-free, functional, no/low (sugar, sodium) organic/non-GMO/clean label) while getting rid of tail brands clearly not aligned with new diets.

Figure 103 and Figure 104 below highlight what we see as the evolution in the narratives of European Food multinationals:

- Choosing the right category mix by looking for segments where brands can be seen as adding value in terms of wellbeing (which can be seen as wellness or ‘healthy indulgence’),
- Adapting the offering within those same categories via M&A or for instance the incubation of disruptors (some of the incumbents reinventing themselves as venture capitalists) to consumption patterns having evolved too quickly for those massive organizations.
Figure 103. A Narrative Was First Created by Focusing on Fastest Growing “Nutrition & Lifestyle” Categories10 Year Forecast to 2022

Source: Citi Research

Figure 104. ...But Has Been Forced to Evolve into an Even Broader ‘Wellness’ Narrative as Eating Habits/Priorities Become More Important than the Category Mix Itself

* Market size based on retail sales price, CAGR % 2010-15. ** Naturally Healthy: Food & beverage on the basis of naturally containing a substance that improves health & wellbeing beyond the product’s pure calorific value.
***High protein data not available directly, as new categories are investing in high protein variants. High protein supplements and nutrition products estimated at CHF 9bn; meat analogues and vegetarian products estimated at CHF 1.5 bn. Rough estimate related to Nestlé categories : CHF 4 bn.

As those companies are trying to align their narrative to the new trends and the new competitors seen in their categories, we have clearly seen a concomitant move towards focusing on sustainability, which has become part of the storytelling around a lot of brands. Further emphasis is placed on long-term sustainability via reducing greenhouse gas emissions throughout the value chain, managing water stewardship, and limiting waste production and packaging consumption.

This has also clearly been reinforced by stricter food regulation around the world (e.g., product traceability, allergens, etc.) with implications on consumer product manufacturing, packaging, and labelling. Moreover, public health organizations and supranational bodies are more concerned about the risk connected with poor nutritional choices, and are asking for increasing contributions from the food industry to help tackle public health issues. For example in the U.K., Public Health England’s Change4Life campaign is asking food manufacturers to cut calories by 20% before 2024.

Below, we showcase how the 3 biggest Food multinationals in Europe have reshuffled their portfolio to fit a new narrative in order to protect their long-term growth prospects.

**Food Multinationals Portfolio Transformations**

Despite having worked a lot on their portfolios, as we shall detail in the next section, European food manufacturers are also still busy trying to restructure their tail brands and monetize their assets which clearly no longer have the right narrative (and thus not the right economics, as both have become connected). We estimate that about 5-10% of the industry revenues could, or should, be sold.

However, we believe two things are more interesting to illustrate what is at stake:

- The proliferation of new entrants has turned big incumbents into venture capitalist funding innovations. The number of food and beverage start-ups has exploded over the last three years, with a lot of these new companies actually funded through the in-house incubator/venture capital programs of the multinational food and beverages companies (e.g. The Unilever Foundry, Danone Manifesto Ventures. Nestlé’s Terra Accelerator). We see sound strategic rationale to this, as the multinationals can eventually cherry-pick and internalize some of the most successful start-ups, to give them exclusivity in product or technologies that allows for end-product differentiation/market share gain.

- Looking at how companies have reshaped their portfolio since the mid-1990s shows how new priorities around how we eat Food have made those companies spend, or reallocate, billions of dollars to adapt to a new ecosystem.

Specifically, for each a few highlighted European companies:

**Danone**

As shown in Figure 105, Danone has changed its portfolio significantly over the past decade, moving in the 1990s from a conglomerate present in beer, biscuits, and pasta, to a group now focusing on healthy categories such as yogurt, functional waters, infant milk formulas, and plant-based dairy. This has been accomplished through massive disposals, the most recent being its biscuits business in 2007, while Danone has also drastically changed its business mix via transformational acquisitions such as the acquisition of Numico in 2007 and White Wave in 2016.
The tension between economics and the necessity to embrace changes in diets can be seen as the group’s share price experienced a rather severe de-rating in the aftermath of its big deals (Numico and WhiteWave), which were perceived as too expensive and badly timed. However, based on changing consumer preference, this push towards Nutrition and plant-based products could change the profile of the group for the best in the future.

Figure 105. Danone Portfolio (% of Sales) Evolution Over 1996-1H 2018

The group claims that 88% of its volumes sold in 2017 were in healthy categories (water, yogurt and other daily dairy products, baby milks and foods, milks and powders, medical nutrition and beverages with 0% sugar).

On top of changing its category mix, the group has also adapted its offering within those four pillars (dairy, baby, medical, waters) to new consumer behaviors, thus reinforcing its narrative based around packaged food companies being a purveyor of health. Specifically:

- The group called out sugar reduction as a priority. For example in 2017, the group reduced over 20% of added sugar in “Le mini-lactés” spoonable dairy in France, and reformulated its entire U.K. water portfolio to come below the sugar levy threshold.

- Commitment to Carbon Neutrality. Danone made clear investments to make its whole supply chain more sustainable (for instance a soil health program for animal feed).

- Danone intends to triple its plant-based offering by 2025 to €5 billion of revenues, bearing in mind that this category offers not only alternative source of protein to lactose-intolerant consumers, but soy-based dairy, which uses 4x less water, 2x less land, and 2.5x less CO2 than regular milk.

- Push to embed plastic circularity into its waters brand. Evian to be 100% circular by 2025, offering alternatives beyond plastic and single use (such as jugs, refillables, carton, and glass).
Nestlé

Nestlé’s evolution is interesting, as the group did not change its category mix as drastically as Danone, but clearly changed its narrative and focus over time.

Back in 2012, at an investor seminar, we remember that in a presentation on the AOA (Asia Oceania Africa) region, the group was convincingly showing they were addressing a significant portion of the income pyramid in emerging markets from premium to lower income (via its PPP or Popularly Positioned Products, combining taste, nutritional intake, and affordability), although we note two things from this presentation, shown in Figure 106

1. The bottom end was not being addressed, which in our view is an example of how the economics of a Food multinational do not really allow it to target the whole population of an emerging economy, including consumers having more pressing and essential needs than entering branded categories. Nestlé’s Popularly Positioned Products are actually in our view already pretty unique within FMCGs in terms of their mission, affordable price points, scale, and contribution.

2. We also note that the brands on this chart back in 2012 are not all aligned to a ‘health agenda’ (i.e., Munch, KitKat, BarOne, Movenpick), and instead seem to focus on indulgence and taste, with an emphasis more about REACH than health & wellness.

Figure 106. In 2012 in AOA Region, Focus on Targeted Branding by Income Clusters, less Talk about Health as a Paradigm

Source: Citi Research, Nestlé’ Investor Seminar presentation

We believe that Nestlé’s message has changed gradually over time. Although it has kept its REACH focus, it has also added a clear narrative on its nutrition, health and wellness (NHW) agenda, showing that a focus on health is not only compatible, but reinforces the economics of a Food business. Indeed, Nestlé products with above-average NHW content have:

- Growth 1.8x higher than products with below-average NHW;
- Underlying trading operating profit (TOP) 1.5x higher than products with below-average NHW; and
- This has justified the group push towards five clear categories: Coffee, Infant Nutrition, Waters, Pet Food, and Consumer health.
How about Nestlé’s other “less healthy” categories, some of which have been in the portfolio for a long time? Chocolate and U.S. frozen prepared dishes clearly spring to mind as less relevant to this agenda.

We note that the group has recently sold its U.S. confectionary business, and is also launching a new version of KitKat with a 7% reduction in sugar content. It also recently launched a new Milkybar based on a new candy floss-inspired sugar structure, which allows for a reduction of 30% of sugar content. In one way, confectionery can be seen as a purveyor of wellbeing as an indulgence product, as care can be a rather holistic concept.

The group remains committed to its Frozen division and flags that Frozen is the best form of preservation, supports portion control, reduces waste, and is aligned with key consumer trends (i.e., high-protein, natural, organic, etc.).

**Unilever**

Being a conglomerate made of both Health & Personal Care (HPC) and Food, and with a disproportionate exposure to emerging markets, Unilever’s imperatives have been somewhat different than competitors with historically three different priorities: (1) a focus on affordability in its home care division, heavily skewed towards emerging markets in particular Brazil and South East Asia; (2) a rather mainstream positioning in personal care which the group has tried to premium-ize via a flurry of acquisitions; and (3) a food portfolio where indulgence and taste had taken a big role (ice cream, mayonnaise, tea etc.).

We note several initiatives taken by the group

1. The disposal of the spreads unit in December 2017 is in our view interesting. The group had been willing for a long time to keep this business, which was highly profitable and cash generative given with rather low capital intensity. However, categories like margarine, which is heavily skewed towards mature markets, had been losing ground to products seen as healthier alternatives (or private labels), and this cash cow was weighing on the group sales growth algorithm. Under pressure from external events (a takeover attempt), the group finally answered to investors’ demands and sold this business to KKR – despite the stranded costs and margin dilution which made Unilever core margin targets more complicated in 2018. We believe this disposal, which may be growth enhancing but has also disrupted the group cost structure, highlights the tension sometimes between short-term imperatives and the painful choices to be made to adapt those multinationals’ portfolios to new consumer habits.

2. In Refreshments, the group has been advocating for the health benefits of tea (Lipton umbrella brand) to rejuvenate its sales growth, and even in its indulgence business (ice cream), the group has introduced non-dairy versions of Ben & Jerry’s and low-calorie ice creams (Breyers Delights).

3. Unilever states that by 2020 at least 60% of its portfolio will meet the Highest Nutritional Standards (based on WHO nutrition guidelines). So far, 39% by volume is already compliant. Reformulation is underway in all product categories and the company has made progress in reducing salt (in 2017 the salt levels in 63% of food products by volume met benchmarks consistent with WHO recommended intakes), saturated fats (in 2017, 80% of their global portfolio of soft vegetable oil spreads contained no more than 33% saturated fat) and sugar (since 2010, Unilever has reduced sugar in sweetened tea beverages by 15%).
Its overall exposure to emerging markets but also the variety of its sourcing and raw materials used have made Unilever very focused on sustainability with various initiatives across the whole supply chain, and this focus has become part of group narrative. In its Annual Report 2017, the group mentioned that “for the seventh consecutive year Unilever topped the GlobeScan/SustainAbility ranking of 1,000 sustainability experts around the world — the longest-running and most extensive survey of its kind. The study identified integrating sustainability into the heart of the business, demonstrating executive leadership, strong performance in supply chain management, and commitment to the Sustainable Development Goals (SDGs), as among key reasons behind the Group’s leadership, concluding that “Unilever continues to be seen as the global leader on sustainability”.

The Ingredients Sector Helps to Maintain Food Economics While Addressing the Search for CARE

We show below how the European ingredients names have also changed their portfolios and are offering to adapt to the change in the narrative built by Food multinationals in Europe. This is another example of how a change in consumer priorities around the whole concept of alimentation can have ramifications for a whole ecosystem down to the supply chain.

To overcome the challenges of a changing consumer ecosystem while continuing to deliver a consumer staples earnings algorithm, food multinationals are increasingly turning to their ingredients suppliers for collaboration to drive product innovation and sales growth.

Indeed, we believe the ingredients sector plays a key role in driving both the commercial as well as sustainability agendas of its food customers. The use of the right ingredient can result in higher resource efficiency in the production process (e.g., use of enzymes in brewing and cultures in cheese), lower resource consumption (e.g., energy, water) and sale of by-products (e.g., animal feeds). Moreover, technology advancements permit the extension of product shelf-life which allows food companies to address the problem of malnutrition in rural areas of developing markets with poor infrastructure (e.g., iron-fortified yogurt in Africa).

On the other hand, whereas once consumers may have compromised on taste in return for healthier foods, their expectations nowadays are much higher with taste often at a premium. In that context, the ingredients companies actually help their customers balancing the taste profiles in products that require a reduction in fat, sugar, and salt, and more often with further added benefits such as protein, fiber, vitamins, and probiotics.

More importantly, we believe the sector has a key role to play in the future of food consumption — namely the rise of personalized nutrition. Personalized nutrition is the development of unique nutrition guidelines for each individual based on a combination of genetic, environmental, and lifestyle factors. This allows for a targeted approach with precision to address any nutritional deficiency on a case-by-case basis and requires deep science support from the ingredients sector.

Above all, the ingredients sector also covers an important part of the consumer market that is not reached by the multinational food companies — the food service/out-of-home channel. This channel represents a growing share of consumers’ wallet in both developed and emerging markets with the ingredients companies helping to address the latest trends where the multinational food companies have limited reach.
In fact, in return for playing such an important role in the food ecosystem (and the future of food), and with consumer fragmentation and the pursuit of health and wellness showing no signs of abating, the ingredients sector is in a sweet spot in the new consumer environment. Bearing in mind that while ingredients are typically only a small proportion of end product cost of goods sold (~3-5%), they are critical to the taste, texture, and functional performance of the end product – a study by Nielsen found that taste of a product is the most important driver of consumer repurchase decisions (~45%) – significantly more than price, brand name or packaging.

This asymmetric risk/reward profile means the multinational food companies are increasingly reliant on the ingredients sector to drive new product developments and reformulations of existing products in order to play to the evolving consumer trends around health and wellness. We believe this deeper partnership and effective outsourcing of R&D up the value chain to the ingredients companies may actually help to preserve the economics of the food multinationals' business models, allowing them to focus on repairing the barriers to entry via a focus on brand building and further distribution expansion in EM and online.

**Leveraging R&D Capabilities to Address Health and Wellness Trends**

In order for the ingredients companies to perform the key role in the food ecosystem and address the evolving consumer trends, they have been consistently investing 5-6% of sales behind their R&D capabilities. These R&D investments are often focused on identifying new technologies to deliver value-added ingredients, or to remove unwanted ingredients from the end product without changing the taste profile (e.g., sugar reduction in soft drinks). Specifically:

**Kerry Group** is the market leader in the fragmented food and beverages ingredients market. The depth and breadth of its portfolio and geographic reach means the group is at the forefront of shaping the health and wellness agenda of many consumers. Specifically, Kerry’s Health and Nutrition Institute develops technologies that meet consumer needs for healthier diets and lifestyles, and brings industry insight to government policies around health and general wellness.

One of the key focuses of the group is on the clean label opportunity. Consumers nowadays are increasingly looking for food that they can trust and with traceable sources. According to the group's estimate, ~36% of new launches in food and beverages now are clean label products, and the group is leveraging its 5R strategy (Replace, Remove, Reduce, Reposition, and Reinvent) to deliver products that play to this evolving consumer trend.
Tate & Lyle plays a key role in sugar reduction and thus the obesity epidemic.

Tate & Lyle is at the heart of the sugar reduction trend. The group has transformed itself from a commodity sugar business to now focus on specialty ingredients (including sweeteners), with value-added ingredients now accounting for ~50% of group profit. Despite the increasing popularity of sugar alternatives in the last 5-10 years, sugar still accounts for ~80% of the global sweetener market and it remains a key driver of the obesity epidemic. Tate’s sucralose sweetener — 600 times sweeter than sugar but without the calories — helped to remove more than 77 trillion calories from consumers’ diet globally since its invention. Moreover, the group’s soluble fiber product Promitor helps to address the obesity crisis by removing sugar and calories, while the added fiber helps to tackle the low fiber intake issue globally.

Even though Glanbia is increasingly becoming a branded food company, its focus is still firmly on health and wellness consumer trends.

Glanbia operates a world class dairy supply chain which underpins the safety of dairy products and is an important partner to many of the world’s leading infant milk suppliers. Moreover, the group’s nutritional fortification solutions and particularly its premixes now fortify a wide variety of products including infant and clinical nutrition, dairy products, bakery, confectionery, cereals, snacks, and health supplements. Although the group is gradually transforming into a branded consumer goods business, the focus is still around health and wellness lifestyle categories including sports nutrition and more recently in weight management (with the acquisition of SlimFast).

Figure 107. Kerry’s 5R Approach to the Clean Label Opportunity

- **Replace**: Replace ingredient(s) with clean label alternatives while retaining key functionality, taste and/or nutrition profiles.
- **Reduce**: Leverage Clean Label technologies to reduce specific ingredients and simplify ingredients statements.
- **Remove**: Eliminate specific ingredient(s).
- **Re-Position**: Customers asking for creative ways to reposition products in the marketplace.
- **Re-Invent**: Natural brand customers reinventing categories.

Tate & Lyle and Glanbia are key players in the movement towards healthier and cleaner labeling, each with their own unique contributions to the market.
U.S. Food: Perspectives on the Wellbeing Agenda

The relationship between food and wellness is not unidimensional, and narratives have sometimes to be adapted to local realities and existing portfolios. We highlight in the section below how the U.S. Packaged Food industry (which as we discussed earlier does not have the economics for being tasked with feeding a growing worldwide population) has been adapting its narrative to the topic of ‘wellness’ via the indulgence concept and the rise of snacking.

In recent years there has been heightened attention about a perceived shift in U.S. consumer preferences in food toward health and wellness, with the idea that consumers are more attuned about eating smarter and concerned about what is contained within their food.

Even though the demand by consumers for offerings with health and wellness attributes has been a clear trend within the U.S. packaged food sector for several years at this point, obesity levels have continued to rise in the U.S. over the past five years and carries on the longer-term trend seen for at least the past 15 years.

![Figure 108. Trends in Obesity Prevalence in the U.S.](source)

Critically, the concept of ‘health and wellness’ or ‘better-for-you’ is not one dimensional and has different meanings to different people. Often, we think the concept is oversimplified in the minds of investors and health and wellness is immediately equated in food as fresh or less processed, high in nutrients, and healthy for you.
“Health and wellness” is multi-dimensional and food is most relevant to “health” whereas “wellness” has more of a mental connotation.

For sure, that is one part of it, with ‘health’ in food having a biological or nutritional association. However, ‘wellness’ has more of a mental connotation, encompassing consumers’ emotional states. Wellness, for example, can originate from a snack that is indulgent, and may not be healthy in a traditional sense, but makes the consumer feel good after consumption.

Sales growth in snacks has outpaced other major food categories and is expected to continue over the next 5 years.

Bearing this out a little more, sales growth in snacks, (including cookies, crackers, snack bars, salty snacks, chocolate, candy, ice cream) at a 2.8% compound annual growth rate (CAGR) over the past three years, has notably outpaced other major food categories.

Furthermore, Euromonitor is forecasting snacks to grow at a +3.7% CAGR over the next five years, again faster than the 2-3% expected for other major categories. These higher than average growth metrics come even though the overarching category is not necessarily associated with health in the strictest sense, and demonstrates that there is that consumers value other attributes that help fulfill their mental and need states.

But foods with stated health and wellness claims are also on the rise.

On a broad scale, food with stated health and wellness claims have seen relatively robust sales growth rates across the store over the past three years compared to the flat to +1% sales growth CAGR experienced by total U.S. food over the same time frame. For example, organic food sales have grown at a +13% CAGR over the past couple of years, while items labeled "no artificial colors and/or flavors" grew at +6%.

Figure 109. Historical and Projected U.S. Food Category Sales CAGRs

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Figure 109. Historical and Projected U.S. Food Category Sales CAGRs

<table>
<thead>
<tr>
<th>Category</th>
<th>Historical 3-Yr Sales CAGR (2014-2017)</th>
<th>Future Est. 5-Yr Sales CAGR (2017-2022E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snacks</td>
<td>2.8%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Sauces, Dressings &amp; Condiments</td>
<td>2.2%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Baked Goods</td>
<td>1.9%</td>
<td>2.9%</td>
</tr>
<tr>
<td>Ready Meals</td>
<td>1.7%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Rice, Pasta &amp; Noodles</td>
<td>1.6%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Dairy</td>
<td>0.1%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Breakfast Cereals</td>
<td>0.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Soup</td>
<td>-1.2%</td>
<td>-1.6%</td>
</tr>
</tbody>
</table>

Source: Euromonitor
Small companies are gaining US food market share by finding areas incumbents are not addressing through innovation

Within the U.S. packaged food industry, the greater focus on health & wellness attributes by consumers created an opening for small companies to find niches to exploit that better connected with consumers in areas that larger food companies were not addressing through innovation or fundamental renovation, and further helped by consumers seeking authenticity with a greater distrust of ‘big food’.

In our view, these were key factors that, according to our analysis, led to small companies gaining +1.8 percentage points (pp) of U.S. food market share, in measured channels over the past four years, with growth outpacing the total industry.

For example, in snack bars, Kind has risen to prominence given its "better-for-you" positioning, with its novel transparent packing both showing off the quality and simplicity of its ingredients and instilling authenticity to the brand’s message, while , Quest and RxBar capitalized on differentiation in protein bars related to fewer and/or clean ingredients and functional benefits. While in popcorn, Amplify (Skinny Pop) and Angie’s Boomchickapop gained massive market share on highlighting real simple ingredients that were non-GMO and gluten-free.

Finally, Halo Top has exploded in the ice cream category by offering consumers a low calorie, high-protein, low sugar ice cream, with a pint having between 280 and 360 calories and 20g of protein. This compares to a pint of Haagen-Dazs or Ben & Jerry’s which can have 1,000 calories in a pint. As such, Halo Top has found success in positioning itself as ‘healthy’ offering on a relative basis, and that a consumer should have no guilt in eating a whole pint in one sitting.
Incumbents are also evolving to address the “health and wellness” trend

While the encroachment of small companies has been a thorn in the side of the large U.S. packaged food companies, it is critical to recognize that the incumbent, heavyweights of the industry have tried to tackle the increased focus of consumers of health and wellness head-on.

Importantly, company portfolios are not stagnant, and the large food companies are constantly evolving what (and how) they sell to better align with consumer demands and trends. Portfolio evolution across time includes innovation efforts with brand new products, but the initiative also pushes into the renovation of the many brands and products beloved by many consumers across the decades.

There are many examples on the actions the large companies have taken in regards to health and wellness, but here are a few highlights that were large in scope.

- General Mills overhauled cereal powerhouse Cheerios to be gluten-free, and now over 90% of its cereal portfolio contains no artificial flavors and colors. It also continues to expand its natural & organic (N&O) human food offerings, led by the Annie’s brand, and N&O now represents over $1 billion in sales or ~6% of total company sales. When you add wholesome natural Blue Buffalo pet food, those figures rise to $2.4 billion and ~14%, respectively. General Mills is the #2 N&O (human) food producer in the U.S.

- Kellogg has reformulated Eggo waffles with the removal of artificial ingredients, and is making progress toward its goal in removing artificials from its cereals and various snack bars by the end of 2018.

- Campbell has transitioned to non-BPA lining in all of its aluminum and steel cans in North America, while it has also been working to remove artificials from its products (now 95%), has reduced sodium across its portfolio, and plans to remove all antibiotics from its chicken supply. Moreover, it has put in place new product development requirements in its simple meals and beverage unit that requires no artificial flavors, colors, added preservatives, and MSG be used in any innovation, and that it will continue to look for ways to reduce the use of high-fructose corn syrup. On the innovation front, the company successfully launched Well Yes brand soup featuring clean labeling and ingredients such as farro, kale, and quinoa, and also now has a variety of its strong Goldfish cracker brand made with organic wheat and whole grains.
Mondelez is focused on expanding 10 existing well-being brands (including Belvita, Good Thins, Wheat Thins, Triscuits, Vea, Green & Blacks, & Enjoy Life) that meet a set of strict, category specific nutrition, and ingredient criteria and already represent more than one-third of the company's portfolio. The staged introduction of Belvita, a breakfast biscuit that offers consumers whole grains, B-vitamins, and energy in an on-the-go format, across the globe has been a success story for Mondelez in the wellbeing space. The brand now has sales of over $600 million from more than 50 countries worldwide. Moreover, the company has expanded more into wholesome savory snacks with the launch of Good Thins (2016) and Vea (2017), along with introducing non-GMO and organic Triscuits. Finally, Mondelez has expanded mindful snacking offerings to include lighter and portion-controlled chocolate and biscuit snacks, globally.

McCormick transitioned 80% of its U.S. gourmet spice line to organic, and has now labeled over 70% of its U.S. everyday spices, herbs, and extracts as non-GMO, just better highlighting to consumers an attribute that was already inherent in the products.

Candy has even gotten into the act, with Hershey converting its classic Milk Chocolate Bar and Kisses to simpler ingredients, and added front of pack nutritional labeling.

In addition, companies have used M&A in recent years as a way to reshape their portfolios toward the theme of health and wellness. Our review of M&A for large, publically traded U.S. food companies over the past five years found that these companies spent $9 billion in capital in aggregate for 23 smaller companies that played in attractive on-trend faster-growing spaces with acquired brands/products largely skewed as well-positioned from a health and wellness perspective.

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<table>
<thead>
<tr>
<th>Deal Date</th>
<th>Target Company</th>
<th>Purchase Price ($Mn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep 2016</td>
<td>Frontera Foods</td>
<td>$105</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>Duke's and Biggs</td>
<td>$215</td>
</tr>
<tr>
<td>Oct 2017</td>
<td>Angie's</td>
<td>$250</td>
</tr>
<tr>
<td>Feb 2018</td>
<td>Sandwich Brothers of Wisconsin</td>
<td>$87</td>
</tr>
<tr>
<td>Jul 2013</td>
<td>Plum</td>
<td>$250</td>
</tr>
<tr>
<td>Jun 2015</td>
<td>Garden Fresh</td>
<td>$230</td>
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<tr>
<td>Dec 2017</td>
<td>Pacific Foods</td>
<td>$700</td>
</tr>
<tr>
<td>Oct 2014</td>
<td>Annie's</td>
<td>$820</td>
</tr>
<tr>
<td>Jan 2016</td>
<td>EPIC</td>
<td>$84</td>
</tr>
<tr>
<td>Jul 2015</td>
<td>Applegate Farms</td>
<td>$775</td>
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<tr>
<td>May 2016</td>
<td>Justins</td>
<td>$285</td>
</tr>
<tr>
<td>Mar 2015</td>
<td>Krave</td>
<td>$220</td>
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<tr>
<td>Apr 2016</td>
<td>Barkthins</td>
<td>$245</td>
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<tr>
<td>Jan 2018</td>
<td>Amplify Snack Brands</td>
<td>$1,550</td>
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<tr>
<td>Oct 2017</td>
<td>Rxbar</td>
<td>$600</td>
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<tr>
<td>Feb 2015</td>
<td>Enjoy Life</td>
<td>$80</td>
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<tr>
<td>Jun 2018</td>
<td>Tate's Bake Shop</td>
<td>$500</td>
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<td>Aug 2015</td>
<td>Stubbs BBQ Sauces</td>
<td>$100</td>
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<td>Nov 2014</td>
<td>Gardien</td>
<td>$160</td>
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<td>Jan 2016</td>
<td>Boulder Brands</td>
<td>$975</td>
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<tr>
<td>Sep 2014</td>
<td>Sahale Snacks</td>
<td>$80</td>
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<td>Aug 2015</td>
<td>Wallaby Yogurt</td>
<td>$125</td>
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<tr>
<td>Aug 2015</td>
<td>Vega</td>
<td>$550</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$8,986</td>
</tr>
</tbody>
</table>

Source: Company reports, Citi Research
Success can come through buying rather than building with the large companies leveraging a target's authenticity with consumers and immediately gain a brand platform, yet the brands can benefit from scale in purchasing, R&D, and consumer insight/marketing capabilities. M&A examples include General Mills' deal for mom/kid N&O brand Annie's, Kellogg's late 2017 transaction for RxBar, and Campbell's acquisition of organic-focused Pacific Soup.

In conclusion, health and wellness attributes have risen in the consciousness of U.S. consumer in recent years. In the U.S. packaged food industry, the consumer first principal applies, with the consumer always setting the agenda, and companies large and small have responded in-kind.
Food Manufacturing Evolution: LatAm

In Latin America, health & wellness as a narrative is only very gradually picking up, but also how, thanks to an evolution in business model economics, processed branded meat now rivals the market size of the commodity and fresh industry markets in Brazil. This has clear implications on the Nutrition narrative around providing better sources of protein (low sodium poultry and pork, organic line).

Our research suggests that while health & wellness is fast growing in Latin America, and being bolstered by innovation and technology, it is rare to find it accounting for more than 10% of a given category’s sales. Part of the challenge of attaining broader appeal is that the price premium can put these products out of reach for the middle class consumer. In most LatAm countries, the upper A and B socio-economic classes make up less than 15% of the population.

In Mexico, the largest leading branded food companies boast of dominant 60%+ market share in many of their core, home market categories. These include tortilla/corn flour maker Gruma, global baking industry leader Bimbo, and dairy products leader Lala. A sustained product portfolio shift to more functional, healthy, artisan, and innovative offerings has gathered momentum as of only a few years ago, mirroring the more rapidly changing trends in consumer tastes and health awareness and product attributes of its neighbor, the United States. One example is at Lala, who in the first quarter of 2018, was the first to launch a branded organic milk product in Mexico. And two years ago, it launched a new dairy lactose-free product, Lala 100, with patent-pending technology that provides 70% more protein and 30% more calcium than those products based on fluid milk. The effect not only grew category sales, but also overall milk sales as many consumers were put off the category by the taste of “de-lactosed” dairy products in the market.

Mexico’s 2014 federal sugar tax on caloric foods and sugary beverages helped raise consumer’s awareness of ‘healthy foods’, and financed further education and research around food consumption. Three countries followed suit with national sugar taxes of their own, Chile, Ecuador, and Peru, and we would not be surprised if Argentina and Colombia implemented one over the medium term. In terms of sustainability, the largest Mexican food companies started implementing robust programs over the last decade and contracting renewable energy sources. We find gas, water, and waste treatment common in the industry as well. Most large food categories are consolidated around a few players, who build up capital intensive production and marketing economies of scale and finance large investments in technology that generate efficiencies. These factors in turn become industry barriers-to-entry, making it very difficult for start-ups, even those with new product innovation.

In Brazil, taking advantage of two annual corn harvests, ample grazing land, and slaughtering house efficiencies (relatively lower labor costs), protein processors supported the country’s rise to leading positions in the global meat export trade, namely in poultry and beef. Since export markets are volatile, being subject to trade dispute, changing tariffs/taxes, and sanitary risk, protein processors have had to further develop Brazil’s domestic market. Over the last decade, these companies have implemented packaging technology and branding techniques, mostly from developed markets, which resulted in significant growth of processed branded meat categories. Processed branded meat now rivals the market size of the commodity and fresh industry market, characterized by whole frozen poultry and parts. Although BRF formally established its first product innovation center in Brazil 10 years ago, it wasn’t until 2016 that health and wellness products were launched nationally.
Low sodium poultry and pork processed products under the Sadia brand was the first large scale roll-out which also marked the first true portfolio segmentation that differentiated on price. With its non-processed fresh whole poultry and parts, BRF is in the process of launching its first organic line, Sadia Bio, where all inputs in the production are vegetal, at a 15% premium price. Of its processed products portfolio, 30% is considered to cater to the health and wellness category.

Regarding sustainability and food safety, BRF is also allocating incremental management and resources. This year, its frozen meals are using flow pack technology for the first time, where non-recyclable cardboard is being replaced by sustainable plastic. Automation is being further introduced in production, and now inventory counting will no longer be manual. And to minimize the impact of sanitary risk (including for export markets) and the logistics of product recall, BRF is working on a poultry production traceability project. The goal is that each of the almost 2 billion poultry heads slaughtered annually by BRF in Brazil (50% of the industry) will be traceable from the originating farm. Traceability was rolled out in Brazil’s beef industry ten years ago, however the logistics of that relative to poultry are easier since approximately 50 million heads are slaughtered annually.
Food & Health: Japan

We highlight below how the Food industry in Japan, where demographics are different from other markets and where the topic is not about feeding, but care, has adapted its narrative and has clearly followed a path towards health as a claim.

Launch of a Wide Variety of Health Goods Continues

Japan’s processed food market was worth an estimated ¥24.3 trillion ($220bn) in 2017. Average annual market growth over the past five years was 1.3%. While Japan is universally considered a healthy country, the health needs of the Japanese are increasing.

Health food in Japan is typified by foods for specified health use (FOSHU) and foods with health claims (FHC). In both cases, the government approves labelling for a specific indication or effect. The combined FOSHU and FHC market was estimated at ¥830 billion ($7bn). Despite 8% growth over the past six years, these categories account for only 3% of the market, and high growth seems likely going forward.

In 2017, foods to improve gut health accounted for an estimated 47% of Japan’s health foods, while foods to prevent lifestyle-related disorders (triglycerides/ body fat/cholesterol reduction effects, etc.) made up 40%. With gastrointestinal health awareness in Japan traditionally high, foods aimed at improving gastrointestinal function account for a sizable share of the market. Recently, Japan has witnessed the launch of tea drinks that reduce body fat, carbonated drinks that reduce the absorption of fat, chocolate that suppresses the absorption of fat and sugar, soybeans that maintain strong bones, and frozen foods that lower triglycerides.

Food for Specified Health Use (FOSHU)

Foods that have been scientifically proven to be beneficial for maintaining and promoting health are permitted to indicate specific efficacy effects. The government evaluates the claimed effects and safety and the Consumer Affairs Agency (CAA) grants approval for the labeling of each food product that satisfies the requirements. Approved products can carry a specially approved FOSHU mark.

Food with Health Claims (FHC)

Any claims of efficacy and function made on functional food must be relevant and based on scientific ground. A food can be labeled FHC without the permission of the CAA, which is not the case for FOSHU products. FHC products require less development time and cost than FOSHU products.
Yakult was founded in 1935, with the probiotic Yakult as the company’s flagship product. With a proven positive impact on the functioning of the digestive system, Yakult was granted a FOSHU label in 1998. Yakult is a pioneering force in the probiotics market, and is the world’s largest yogurt drink maker. Japan accounted for 32% of the company’s sales in fiscal year to March 2018, China for 23%, India for 18%, Mexico for 12%, Brazil for 6%, and Hong Kong, and Europe each for 2%.

According to Euromonitor, the global yogurt market grew 5% year-over-year to $82.6 billion (retail price-based) in 2017. The market is expected to see average annual growth of 8% over the next five years, with yogurt drinks set to fuel overall growth. Drinks made up 41% of the yogurt market in 2017. Assuming average annual growth of 11% over the next five years would suggest a weighting of 47% in 2022. In 2017, the Yakult market penetration ratio was 7.7% in Japan, 0.5% in China, 2.0% in Indonesia, 2.9% in Mexico, 0.9% in Brazil, and 7.1% in Hong Kong. We think China, Vietnam, and the Americas are likely to fuel longer-term growth.
Food Waste in Japan

According to government food waste data, Japan consumed 82.91 million metric ton (MT) of food in fiscal year ending March 2016, binning 28.42 million MT of food waste, 6.46 million MT of which was still edible. In other words, Japan wastes some 7.8% of its food, or 51 kg per person. Data show food-related businesses (producers, wholesalers, retailers, etc.) waste 3.57 million MT of food, while households waste a further 2.89 million MT.

Government-issued food waste statistics for 2008–2015 show no major change in food loss trends during that period. We think Japan’s food waste levels could be low globally because (1) a predilection for freshness means shoppers in Japan tend to buy in small quantities; (2) partly because of the advance of the convenience store, retailers tend to tightly control food supply/demand levels; (3) food producers also adept at controlling supply/demand, as they are accustomed to a wide range of production; and (4) Japan has also introduced legislation to govern food recycling.

Japan’s government is launching measures to further reduce food loss, but no effective means have been found yet.
Infant Milk: China

We show below how safety concerns in the Chinese infant milk market (a highly sensitive one), and the resulting changing consumer behaviors have contributed to entirely reshaping a Food category and changing its economics potentially for good.

Food safety issues have been a great concern in China food & beverage sector, especially for infant milk formula (IMF) products. In the second half of 2008, the “tainted milk scandal” broke out, after the chemical substance “melamine” was found in many IMF products. A total of 22 companies were involved in the incident, including many well-known domestic dairy companies. This incident led to a long-lasting trust crisis for China domestic IMF products.

More Attention on Food Safety Problem

The milk powder scandal brought more government attention to food safety issue in China. Soon after the melamine incidence, China’s government enacted a series of new rules aimed at controlling the use of additives in food products and beefing up government coordination on food safety.

In January 2017, the Chinese government launched IMF registration regulation, which required manufacturers to register their IMF products with the intention to better control the IMF product quality in the market by limiting the number of IMF SKUs each company can provide. With new registration regulation fully put into effect in January 2018, consumers can identify qualified products from unqualified ones, meaning unregistered brands have been largely wiped out with lack of end-demand. Under the registration regulation, competition in China’s IMF industry has shifted from pricing to branding, and will likely to lead to further consolidation of the sector.

Food Safety Impact on China IMF Market Share

Due to persistent concerns on food safety issues and the prevailing trade-up trend in China’s consumer sector, Chinese consumers have a strong preference for foreign IMF brands, and tend to believe that foreign IMF products provide better quality than domestic products. This explains why China’s IMF industry has been dominated by foreign brands historically.

Recognizing the importance of food safety, many domestic dairy and IMF producers have also established digital quality tracking systems and optimized their quality test and control processes, in order to avoid any food safety issues.

Top domestic IMF companies have been focusing on brand investment and channel transformation, in order to improve their brand image among Chinese consumers. Yashili completed its channel transformation (which started in early 2016) by end-2017 and expects this transformation to bear fruit in 2018. In order to strengthen competiveness, H&H adopted its ‘Premium, Proven, Aspirational’ model to build a differentiated image from ingredient sourcing to lifestyle connection.

As a result, we have seen the market share of top domestic IMF players to pick up in the past three years.
Premiumization of China’s IMF industry

The frequent food safety incidences in the past have helped to accelerate the premiumization of China IMF industry. China parents have shown stronger willingness to purchase more expensive IMF products for their children, as they tend to believe IMF products with a higher retail price and higher quality and hence a lower possibility of leading to food safety problem.

In our view, the 11% IMF industry growth in 2017 was mainly driven by the premium segment, which grew 20%+ and offset the low/ mid-end decline. Niche high-end IMF categories (such as organic IMF) saw particularly high growth. According to Nielsen, Chinese organic IMF market recorded a growth of 45% in the past 12 months as of June 2018 and 47% in the past 12 months as of Dec 2017, driven by industry consumption trade-up.

H&H management believes that premiumization is a long term driver, and H&H is well positioned to benefit from the trend.
European Food Retailers

Retailers are Implementing More Sustainable Strategies

As we will see in the following section, retail companies are also working to reduce the amount of waste that they produce, are reducing their greenhouse gas emissions, and putting nutrition at the forefront of their campaigns. For example, Tesco has announced agreements with 24 of its suppliers to halve food waste by 2030 and is also targeting a zero carbon business by 2050. Sprout Farmers Market in the U.S. has set a goal of eliminating food waste in its communities by 2020 via food donations and diverting food waste to animals, while Kroger has outlined its Zero Hunger, Zero Waste initiative aimed at ending hunger in its communities and eliminating food waste by 2025. We are also seeing a huge increase in new technologies that aim to help reduce food waste — for example, Apeel and Bluwrap are developing shelf-life technologies to preserve fresh food for longer, whilst Olio has developed a mobile app that connects people with each other and with local shops and restaurants so that surplus food can be redirected. The company claims that they have helped divert over 1 million portions of food.

Progressively Embedding Sustainability Practices into their Operating Models

European Food Retail names have had annual sales in 2017 of around $400 billion, with operations spanning not only across Europe but also the Americas and Asia. Volume trends within the mature western markets are ~1% with a long run rate of inflation of ~2%.

While ‘everyone has to eat’, the way in which consumers choose to shop for food continues to evolve, with customers from around the globe choosing to shop closer to home, more frequently, and in smaller stores. This trend away from larger stores has, in part, been driven by the marked shift of non-food retail categories to the online channel; a trend we expect to be increasingly prevalent within the food retail industry as automation enables the grocers to meet the latent demand from consumers to shop for groceries online. (Ocado Group PLC, 2017)

As a sub-plot within the trend to smaller stores; the limited range discount format has also taken share in a number of grocery markets. The success of the discounters has served to underscore the importance of own label brands (with the discounters almost exclusively stocking own label products) and the relentless drive for operational efficiency.

In common with the food producers, health and wellness has also been identified by the food retailers as an important mega-trend influencing the future behavior of customers.

Most of the major European food retailers have recognized the importance of meeting the evolving challenges of the food retail industry and the changing needs and wants of its customers, by embedding sustainable practices within their business models.
By way of example, each of the three largest food retailers has a sustainability plan:

- **Tesco**: In October 2017 Tesco published its Little Helps Plan, whose aims include helping customers to make healthier choices from sustainable products, and to make sure no food that could be eaten is wasted. (Tesco, 2017)

- **Ahold Delhaize**: Ahold Delhaize’s sustainability strategy has an ambition to help drive a healthier society and lower food waste with decisions that benefit both its business and society. The company uses the UN Sustainable Development Goals (SDGs) as a framework to help shape its sustainability strategy. [Link here](#).

- **Carrefour**: In January 2018, new CEO Alexandre Bompard outlined Carrefour’s Food Transition strategy including a focus on food waste, improving the sustainability of packaging and to ensure food safety. [Link here](#).

**Tesco as a Case Study: The Little Helps Plan**

Tesco’s Little Helps Plan is a broad-based strategy to make a contribution to Tesco’s customers, colleagues and communities. As sourced from [https://www.tescoplc.com/little-helps-plan/](https://www.tescoplc.com/little-helps-plan/), a number of elements within the plan are relevant to the sustainability of food, most notably product sourcing, healthy eating, reducing waste, and carbon emissions.

**Sustainable Product Sourcing**

Tesco has targets relating to zero net deforestation and sustainable agriculture to help protect and sustain natural environments for future generations. The group has prioritized 20 products and ingredients, either because they are sold in large volumes or because of the sustainability impact.

Milk represents one of Tesco’s 20 priority products due to the high volumes sold and as a significant source of greenhouse gas emissions. Over the course of the last decade the Tesco Sustainable Dairy Group has paid ~£300 million ($390m) above the cost of production to farmers to ensure a fair price for its 700-plus farmers. The Dairy Group has also worked to improve animal welfare, identify emission hotspots and to encourage environmental best practice, with respect to soil health and on-farm biodiversity.

Palm Oil represents another of Tesco’s 20 priority products with a commitment to zero-net deforestation from the sourcing of palm oil by 2020 (alongside cattle products, soy and timber as the major drivers of deforestation). To date, over 90% of the palm oil used in Tesco’s U.K. own-brand products is from a certified sustainable source.

**Healthy Products**

Tesco has also worked to improve the healthy options available to its customers, with a notable focus on improving the nutrition and health of children. Examples of the simple but effective steps it has taken include:

- **Soft Drinks Reformulation**: ahead of the U.K.’s ‘sugar tax’ regulation[7] all of Tesco’s own-brand soft drinks contained less than 5g of sugar per 100ml.

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[7] The UK sugar tax came into force in April 2018. The levy is being applied to manufacturers – drinks with more than 8g of sugar per 100 ml with face a tax rate of 24p per litre and those containing 5-8g of sugar per 100 ml will face a tax of 18p per litre.
- **Free Fruit for Kids**: Tesco led the U.K. industry with the introduction of free fruit for children in its stores, and has given away in excess of 50 million pieces of fruit since mid-2016.

- **Sweets off checkouts**: Tesco no longer places confectionery items at its checkouts, instead offering healthier alternatives.

### Reducing Food Waste

Tesco’s position as a retailer, sitting between suppliers and customers, allows it to influence the waste management practices of both sets of stakeholders. We list some of Tesco’s initiatives in this area:

- **Supplier Partnerships**: In September 2017 Tesco announced agreements with 24 of its suppliers to halve food waste by 2030.

- **Bumper Crops**: Where warmer weather leads to bumper crops Tesco has sold larger boxes benefiting customers and suppliers, and lowering waste.

- **‘Wonky Veg’**: Tesco launched its ranges of Perfectly Imperfect — or ‘wonky’ — fruit and vegetables in 2016. The broader product specifications enable Tesco to purchase more of the crop, to provide products at lower prices and to lower waste.

- **Improved Food Processing**: Tesco has also moved to connect its suppliers and manufacturers to improve crop yields. The retailer cites the example of introducing a potato grower (Branston) to a manufacturer (Samworths) producing mashed potato.

- **Advanced Forecasting and Ordering Systems**: Tesco continues to invest in systems to minimize waste from issues such as order cancellation.

- **Reducing Promotions**: Tesco stopped ‘Buy One, Get One Free’ promotions on fruit and vegetables in 2014 to lower waste in the home.

- **Packaging Innovation**: Packaging innovation can be used to minimize waste in the home. For example, Tesco has introduced ‘skin packaging’ on their beef and lamb products to provide better freshness and in 2017 Tesco introduced re-sealable salad bags.

- **Product Innovation**: New products can also be used to lower waste, with Tesco citing the example of frozen ready-to-use, peeled, and halved avocados as a way of preserving freshness.

Within its own operations, Tesco distributes surplus food to charities at the end of each day. Through the Community Food Connection Tesco has donated over 25 million meals to over 7,000 charities and organizations.

Tesco also seeks to recycle its waste cardboard and plastic with ~80% of the content of its plastic carrier bags made from its own waste material.

As a result of its recycling efforts, no food waste has gone to landfill since 2009. Where other options such as feed for livestock or bio-diesel are not available, Tesco recovers the energy from food waste through anaerobic digestion or incineration. Of the 10.02 million tonnes of Tesco’s U.K. food sales, 0.07 million tonnes are surplus with only 0.04 million safe for human consumption.
Targeting a Zero Carbon Business

Tesco has stated that its zero carbon ambition is aligned with targets to keep global temperature rises below a 1.5 degree warming trajectory as it recognizes the threat of climate change and the impact of its own operations.

Figure 124. Tesco Aims to be a Zero Carbon Business by 2050

Tesco is targeting a zero carbon business by 2050, having reduced its carbon emissions by 26% from 2015/16 levels. As part of this plan, the group will aim to source 65% of its electricity from renewable sources by 2020 and 100% by 2030 (with 55% already certified as renewable).
Changing Consumer Preferences Spur Natural/Organic Food Growth and Focus on Sustainability from U.S. Supermarkets

Greg Badishkanian, Citi’s Leisure, Restaurants, and Food Retailers Analyst, notes that increased consumer preferences for cleaner and healthier products have led to natural/organic food industry growth that has far outpaced the growth of the overall food at home market. Given further emphasis on healthy products from consumers and expanded natural/organic offerings from supermarkets, we expect the natural/organic food industry to grow more than 3x faster than the food at home market over the next three years.
Consumers have also become increasingly conscientious of where the food they buy at supermarkets is coming from as more and more people believe that a healthy body and healthy environment are closely related. Natural Marketing Institute Solutions noted that 42% of the general U.S. population bought products in 2016 based in part on how these products influence the health and sustainability of the world, its environment, and its people (up from 31% of the general U.S. population in 2006). Given the increased consumer focus, several of the public supermarkets we cover (two of which we highlight below) have announced specific plans focused on improving sustainability and reducing food waste.

**Sprouts Farmers Market**

Sprouts Farmers Market (SFM) is a fast growing grocery chain (~300 stores across 17 southwestern/southeastern U.S. states), specializing in high quality produce and natural/organic items that remains committed to reducing food waste and improving its sustainable business practices.

- **Food Waste:** SFM has set a goal of eliminating food waste in its communities by 2020 via food donations (350 hunger relief agency partners received donations every week in 2017), diverting waste to animal feed (36 U.S. farms were provided with essential cattle feed in 2017), and composting (~100 acres/40 ha of cropland were supplied with compost in 2017).
- **Greenhouse Gas Emissions**: SFM remains focused on reducing greenhouse gas emissions through environmental initiatives for their supply chain and operations such as improving fuel efficiency with transportation carrier partners, piloting in-store battery storage systems, and implementing an in-store energy reduction program (night curtains, natural light harvesting, and LED lighting).

- **Sourcing**: SFM continues to hold its suppliers to high standards and maintains purchasing preferences for suppliers who employ sustainable sourcing and animal welfare standards. Additionally, over 70% of SFM’s private label packaged foods are non-GMO verified or certified organic (two segments which have experienced outsized growth recently) and 90% of SFM’s overall products are natural or organic.

**Figure 127. Organic U.S. Food & Beverage Sales ($bn)**

- Source: Citi Research, 2018 Organic Trade Association Survey

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales ($bn)</th>
<th>YoY Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
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</tr>
<tr>
<td>2016</td>
<td>$38bn</td>
<td>9.0%</td>
</tr>
<tr>
<td>2017</td>
<td>$42bn</td>
<td>6.4%</td>
</tr>
</tbody>
</table>

**Figure 128. Non GMO-Labeled U.S. Food & Beverage Sales ($bn)**

- Source: Citi Research, 2018 Organic Trade Association Survey

<table>
<thead>
<tr>
<th>Date</th>
<th>Sales ($bn)</th>
<th>YoY Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/16/2016</td>
<td>$21bn</td>
<td></td>
</tr>
<tr>
<td>7/15/2017</td>
<td>$29bn</td>
<td>7.4%</td>
</tr>
<tr>
<td>7/14/2018</td>
<td>$33bn</td>
<td>10.3%</td>
</tr>
</tbody>
</table>

**Kroger**

Kroger (KR) is the largest supermarket chain in the U.S. with ~2,800 stores across 35 states and continues to emphasize food waste reduction, a more sustainable/responsible supply chain, and eco-stewardship.

- **Food Waste**: As part of the company’s three-year Restock Kroger plan (announced at its October 2017 Analyst Day), KR outlined its Zero Hunger, Zero Waste initiative aimed at ending hunger in their communities and eliminating waste in the company by 2025. To achieve this goal, KR established a $10 million fund that provides grants for innovative solutions, and plans to accelerate food donations to 1 billion meals by 2020 and 3 billion meals by 2025 (company donated 1 billion meals over the last 4 years).

- **Supply Chain**: KR expects to source at least 90% of its wild-caught seafood volume (69% as of 2017) from fisheries that are Marine Stewardship Council (MSC) certified by 2020. Additionally, KR will transition to a 100% cage-free egg supply chain by 2025 (18% as of 2017) as they work with suppliers to increase the cage-free egg availability.
Eco-Stewardship: In addition to KR’s food waste initiative, by 2020, the company is also focused on reducing the amount of plastic resin by 10mm lbs for manufactured products (using 2015 as a baseline), improving its ton miles per gallon by 20% (using 2010 as a baseline), reducing cumulative energy consumption by 40% (using 2020 as a baseline), and reducing water consumption in its supermarkets by 5% (using 2015 as a baseline). The latter of these targets was helped by last year’s anaerobic wastewater treatment system introduction (at one of the company’s Indiana specialty food manufacturing plants), which turns byproducts into energy and improves the area’s air quality.

Innovations that can Improve Supply Chain Transparency and Reduce Food Waste

Blockchain

Increasing concerns about food quality and safety are driving demands for more transparency and traceability along the food supply chain as well the need to (re)build consumer trust. Blockchain offers a potential solution to many of the challenges the food supply chain faces — it is a distributed ledger that allows the storage and sharing of data across a network of actors. The technology has been dubbed “The Trust Machine” by The Economist which emphasizes its potential for addressing traceability of complex supply chains. It essentially allows everyone in the network to view and update the database but it does not allow any altering of previous transactions. Specifically for the food industry, the ability to record/track interactions with food items in real time as they move through the supply chain may prove the key to improving sustainability, accountability, efficiency, and transparency among the numerous producers, manufacturers, distributors, and retailers that are involved in delivering food to our tables. For consumers, the technology can help to reassure the ever increasing health-conscious and environmentally-minded public that the food they eat is what is being sold and advertised.

Blockchain technology is still in its development stage but several food incumbents including Walmart, Nestlé, Tyson Foods, Dole, and Unilever are already starting to test and integrate blockchain into their supply chains. Walmart is an early adopter of the technology and along with IBM have launched a global initiative with other food industry giants including Nestlé, to explore how blockchain can help the global food supply chain. Ambrosus has developed a blockchain and IoT platform for quality assurance for food supply systems, the company claims that they can radically improve the global supply chains by creating a trusted ecosystem where they can radically record the entire history of products and execute commercial transactions accordingly. International organizations are also getting involved — the WWF have teamed up with tech and fishing companies and launched a pilot project in the Pacific Islands to use blockchain to combat illegal, unreported and unregulated fishing.

However, the deployment of blockchain across the food industry is not without its challenges. The success of the technology depends on many factors which include (1) the accuracy of data provided which means it is still open to human error and tampering; and (2) adoption from all players in the supply chain which is no easy task given the multiple parties and limited digitization across the sector. As with vertical farming and cultured meats, scaling up is also a challenge for blockchain as current technology only permits limited transactions per second which will not be able to support a sector that processes millions of transactions a second.
Food Waste Technologies

Technology has huge potential to help address food waste across the supply chain, and many start-ups are coming up with innovative ideas beyond traditional waste management. ReFED has identified twelve additional categories for innovation but has highlighted four in particular that deserve attention and investment; shelf-life extension, secondary online marketplaces, upcycling edible food scraps, and value-added recycling.

- Fruit and vegetables (including roots and tubers) along with fish and seafood have the highest wastage rates of all food groups with 45% and 35% food loss respectively. Full Harvest connects food and beverage companies with farms to buy surplus and imperfect produce and therefore reduce food waste at the field. Companies like Apeel and Bluwrap are developing shelf-life technologies to preserve fresh produce for longer – Apeel has come up with a plant-based coating that can double the shelf-life of fruits and vegetables, and has recently signed a deal with Costco. Bluwrap on the other hand is targeting fresh protein products and uses oxygen management technology to keep fish and other seafood fresh for longer allowing for sea freight shipping. ColdHubs is tackling food waste in developing countries by creating a ‘plug and play’ modular solar-powered walk-in cold room for 24/7 off-grid storage and preservation of perishable foods. It is estimated that in developing countries, 45% of food spoils happen due to the lack of cold storage. ColdHubs has installed its systems in major food production and consumption centers and farmers places. The company claims that these systems can extend the freshness of perishable food items from 2 days to 21 days.

- At the beginning of the food supply chain, millions of tons of fresh produce go unsold as a result of cosmetic imperfections, and at the downstream end, large amounts are wasted as a result of surplus both at home and restaurants. Currently use-by-dates are only a simple estimation of how long a product will last and in fact many people dispose of food just because of these dates. A new company called Mimica is developing a new food label that will establish correctly the freshness of your product — this will enable you to waste less both in retail shops and in households. Secondary online marketplaces can also help to reduce food waste by connecting businesses and individuals with excess supply to those that are in need. An example includes Olio which is a mobile app that connects people with each other and with and their local shops and restaurants so that surplus food can be redirected. Olio claim that they over 630,000 people have joined the app and they help divert over 1,000,000 portions of food.

- Many start-ups are innovating in the space of upcycling and using food “waste” or by-products as a resource. Toast Ale tackles one of the most wasted food products across the supply chain — it takes bread waste and turns it into beer, the recipe for which the company has made open-source to get everyone involved in reducing bread waste. Food waste can also be used to produce fuel with second-generation bio-fuel technology, as well as other non-food products such as feed, fertilizers, textiles, and biodegradable plastics. For example, Entocycle takes organic waste from food producers, manufacturers and retailers and feeds it to insects which are used to produce animal feed.
Making it Happen

The food industry has many challenges however as we have shown in this report there are plenty of opportunities available. The agriculture sector is currently unsustainable — its use of resources is staggering with over 70% of global water use and 50% of inhabitable land and responsible for over 30% of greenhouse gas emissions. All these resources are used to produce food and yet we waste one-third of it. Some regions are already facing acute water stress which is caused by the use of water to produce food. Continuing with business as usual is not an option — it is estimated that 65% more irrigation water and 67% more land will be needed to produce the food demand in 2050, and 87% more greenhouse gas emissions would be emitted.

Therefore, meeting future demand in a sustainable way will require the industry to change — we can’t just expand land to meet future demand without having detrimental effects on forests and ecosystems and on water resources. So it is important that we start preparing for this — opportunities already exist. As we show in this report technology and innovation can change the sector, especially upstream. Gene editing technologies such as CRISPR can improve agronomic traits, making crops more abundant and resilient. Other innovations including enzyme-based solutions such as that delivered by DSM can reduce a cow's methane emission by 30%. Digital or Precision agriculture has the ability to enhance agriculture production through better on-farm management techniques, improvements in water use, and more efficient use of fertilizers. We are already seeing precision agriculture adoption in the U.S. farms such as soil sampling with GPS, field mapping with GIS, and yield monitoring. The market of precision agriculture is expected to reach $10 billion by 2024. Other technologies that could potentially disrupt the sector and improve sustainability include vertical farming which is taking off in cities which enables food to be produced without soil, and alternative proteins which is basically growing meat without the animals.

In the consumer and retail sector we are seeing ‘Better for You’ campaigns emerge focusing more on the offering of healthier options for consumers. It is quite astonishing to see how these campaigns are being embraced by food manufacturers with companies like Unilever stating that 60% if its portfolios will meet the Highest Nutritional Standards. The retail sector is also focusing on producing and selling food with better nutrition, for example, Tesco has published its ‘Little Helps Plan’ which aims to help customers make healthier choices from more sustainable products as well as reduce its food waste.

From the commodity side the Southern Hemisphere is in a great position to expand its agriculture market and meet the ever growing food demand. We have shown that the capacity utilization of arable land across the Northern Hemisphere has peaked but there is further room to expand crop harvests in the Southern Hemisphere via both planted area and yield improvements. While the former may be promising for a decade or so, it faces issues of sustainability and so in the long-run, yields matter more. There are some challenges that need to be overcome in the southern hemisphere which include the investment required to meet this demand and better management of water resources especially for countries like Argentina and South Africa.
So How Do We Make it Happen?

Even though the industry is changing, the rate of pace is rather slow. So how do we make this happen? There are many things that need to be done to improve the sustainability and efficiency of the food industry which include sustainable intensification of agriculture production, a reduction in the consumption of meat, and others. We focus on six main steps, which we believe could help change the industry from being inefficient and unsustainable to one that is more transparent, less wasteful and more sustainable. These include (1) better access to finance; (2) removal of distortions in the agriculture and food market; (3) vertical integration across the supply chain; (4) easier and faster access to market for innovation and technology; (5) better data and information; and (6) healthier products and a change in diets.

Access to Finance

Access to finance, especially to small holders and agribusiness small & medium enterprises (SMEs) is often cited as one of the key impediments for growth and transformation of farming in emerging markets. (World Bank Group, 2018) Without access to finance, many agriculture producers get stuck in low investment and low production cycles and have problems reaching optimal markets. A total of $9.2 trillion is needed to be invested in agriculture up to 2050 in order to meet future food demand.

There are a number of reasons why access to finance is difficult to obtain for some small holders and SME’s especially in emerging markets — these include high transaction costs especially in rural areas due to a more dispersed population and lack of available infrastructure, weather-related risks, seasonal factors of farming which require funding at particular times, a weak ability to provide collateral, lack of credit suitability, volatility of prices, and in some cases they are constrained by weak legal and regulatory frameworks. Below are some mechanisms that can help better access to finance.

Innovative Mechanisms for Public Private Partnerships

Governments should take an active role to help farmers in many regions — they can help to reduce risks by creating a more favorable environment and building necessary infrastructure. Increasing private investment in agriculture and the food industry is key to meeting future food demand with less waste and higher sustainability. Traditional Official Development Assistance through public-driven projects has in the past failed to attract significant private investment, mainly because their implementation is often too rigid and not market-driven and/or result-based. (FSTF, 2012) Innovative mechanisms can be created to provide entry points for public-private and project financing. For example, USAID created two specific mechanisms (1) the Global Development Alliance which can partner as a co-financier for projects such as the Certified Sustainable Product Alliance which leveraged $8.6 million public financing and $486 million from 12 corporations to expand sustainably forestry in a number of countries; and (2) the Development Credit Authority (DCA) that helps leverage capital for SMEs by agreeing to cover 50% of the loss on a loan (see below for more information on credit guarantee schemes). (CSIS, 2012)
Credit Guarantee Schemes

Farmers and small and medium agribusiness enterprises tend to be constrained by access to credit because they lack collateral, credit history and reliable financial accounts. Financial institutions are often reluctant to lend to these groups because of the inherent risks in financing agriculture production. Credit guarantees whether they are full or partial could help mitigate these risks. A credit guarantee simply substitutes part of the collateral required by the borrower — if the borrower fails to pay, the lender can resort to payment from the guarantor. Usually there are three actors involved in this sort of agreement — a financial institution as the lender, the borrower who is usually the agriculture producer and the guarantor that can either be a government, multilateral development banks or a private company.

Microfinance

Microfinance involves the precision of basic financial services to low-income individuals for whom it is currently not feasible to use commercial financial services. (Sagarick, 2016) Even though microfinance is not new it has been growing steadily over the last decade. The aim of microfinance is to provide individuals with money to invest in themselves or their business. It usually includes savings, credit, insurance, remittances, payments and in some cases guarantees to access finance. It is particularly popular in developing countries. (IISD, 2015)

Weather Insurance

Bad weather is a serious risk to farmers; therefore it is extremely important that farmers take out insurance to protect potential losses to their products. In developed countries like the U.S., crop insurance is purchased by agricultural producers, and subsidized by the federal government to protect against loss of crops due to natural disasters and a fall in prices. However crop insurance is expensive and is also hard to measure. Over the last few years weather-index based insurance has been growing — this type of insurance uses a weather index, such as rainfall to determine payouts and these can be made more quickly than is typical for traditional crop insurance schemes. For example if rainfall is below a certain threshold agreed upon, then the insurance provider pays out without actually having to visit the policyholder. However there are factors limiting this scheme, such as the lack of rainfall gauging stations across many emerging markets. (CGIAR, 2018)

Value Chain Financing

Value chain financing refers to credit or financial services that flow through various actors (e.g., producers, input suppliers, traders and processing firms and exporters, buyers) across the food supply chain. It may or may not include support from traditional financial institutions. Relationships between actors in the supply chain may facilitate financial flows either directly (between one actor and other) or indirectly by making the client more attractive to financial institutions. In emerging markets the majority of finance is provided directly within the value chain with no support from financial institutions. Three common types of value chain finance include trader credit, contract farming or outgrower schemes and warehouse receipts. (USAID, 2005)

- **Trader Credit**: Trade credit involves short-term loans usually between agriculture producers and either input supplies (e.g. seeds and fertilizers) or producer buyers such as processors or traders. Loans tend to be limited to working capital (for example to purchase inputs) and is usually provided in-kind. (USAID, 2005)
**Contract Farming:** Schemes such as contract farming, out growers schemes or joint ventures (agreements between buyers and producers) are particularly attractive for agro-food companies as they ensure control over supply, gain access to local markets while at the same time they guarantee farmers a regular buyer for their products. (OECD, 2013) Usually this type of agreement involves buyers of agriculture products lending funds (either in kind or in cash) to producers. The loan is generally tied to a purchase agreement. (USAID, 2005) Sometimes the company involved also agrees to support the farmer by supplying inputs, providing advice on improving yields and land preparation etc.

This type of agreement is usually direct financing, but it can also include the involvement of a financial institution. For a commercial bank, extending credit to farmers is less risky in this sort of agreement, as it is usually the agribusiness that can guarantee the credit. (FSTF, 2012)

**Warehouse Receipts System:** This is an example of indirect value chain finance that requires a financial institution to complete the transaction. It enables farmers to deposit storable goods such as coffee or grains in exchange for a warehouse receipt. It is a document issued by warehouse operators as evidence that commodities have been deposited at a particular place. This allows the producer to sell its produce at a later time, when prices for goods are higher than average- this allows the producer to avoid price risk.

**Mobile Payments and Branchless Banks**

Innovative schemes such as branchless banking services/mobile phone banking are enabling farmers to deposit, withdraw, transfer money, and pay for goods and services easily with a mobile device. The most popular system available is M-PESA which was launched by Vodafone’s Safaricom mobile operator in 2007 and consisted simply as a method of texting small payments between users. M-PESA has grown significantly over the years — it currently has over 18 million active users in Kenya and had more than 6 billion transactions made in 2016. M-PESA revolutionized the way farmers pay for services by enabling farmers to make the transition from cash to digital payments for the payment of inputs which reduced both time and high transaction costs. A survey done by One Acre Fund (OAF) (a non-profit organization that teaches better crop management techniques and provides seeds and fertilizers on credit to small holders in East Africa) stated that 100% of farmers they surveyed preferred mobile payments to cash, citing convenience and transparency as the main advantages. With the help of Citi Kenya and Citi Inclusive Finance, OAF managed to set up a digital system so that farmers can repay their loans for inputs via mobile banks, it also managed to negotiate a flat fee with Safaricom which eliminated customer fees on all bills payable to OAF. Digital repayments to One Acre from farmers also reduced fraud and payment times which fell from 16 days to 2-4 days.

**Innovative Financial Mechanisms**

In our Citi GPS report on the United Nations Sustainable Development Goals we included details on green bonds and social bonds which could be used to finance sustainable agriculture and rural communities. We focus on two other types of bonds: Development Impact Bonds and Sustainable Development Goals Bonds.

**Development impact bonds (DIBs)** incorporates the main principles of social impact bonds (refer to Citi GPS report on Sustainable Cities for more information on social impact bonds). DIBs finance development programs with money from private investors who earn a return if the program is successful, paid by a third party donor — usually involving donor agencies, either as full or joint funders of outcomes.
Because repayment to investors is contingent on achieving a particular outcome, DIBs are not bonds in the conventional sense. An example of such a project is the DIB set up by the Common Fund for Commodities (CFC), the Rainforest Foundation UK and the Schmidt Family Foundation (SFF) to support sustainable cocoa and coffee production by the indigenous Ashanimka people in Peru. The actors involved in this DIB wanted to experiment using such an approach and for this reason the DIB is rather small with a total investment of $110,000 covering the implementation of project activities and all administrative services and related fees and expenses. Four impact indicators (see below) were set up to enable easy measurement of whether the targets had been achieved. An independent verifier (KIT Royal Tropical Institute) was used to verify the accomplishment of the jointly agreed results and to establish the re-imbursement to the investor (see table below).

**Figure 129. Four Impact Indicators for Sustainable Cocoa and Coffee Production DIB**

<table>
<thead>
<tr>
<th>Impact Indicators</th>
<th>Achievements</th>
<th>Re-imbursement to investor (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60% of 59 Kemito Ene members increased their supply to the Association by at least 20%</td>
<td>At the end of the baseline year, 45% of members managed to increase their sales between 2013 and 2015</td>
<td>US$20,625</td>
</tr>
<tr>
<td>At least 60% of Kemito Ene members improve their cocoa yield to 600 kg/ha or more</td>
<td>15 members reached the target of cocoa productivity of 600 kg/ha or more</td>
<td>0</td>
</tr>
<tr>
<td>At least 35 tons of cocoa budget and sold by Kemito Ene in last year of the project</td>
<td>In 2015, Kemito Ene sold a total of 47,428 kg of cocoa exceeding the target of 35M</td>
<td>US$27,500</td>
</tr>
<tr>
<td>At the end of the project 40 producers have 0.5 ha of newly established coffee plots with leaf rust resistant varieties</td>
<td>62 farmers installed 0.5 ha of improved coffee varieties, exceeding the target set- full target achieved</td>
<td>US$27,500</td>
</tr>
</tbody>
</table>

Source: KIT, 2015, Citi Research

KIT in its final report did state that DIBs had the potential to really make a difference if implemented correctly. Accurately identifying easily measureable impact targets to be reached was fundamental to the success to DIBs. For example impact indicator #2 was not achieved in the study above — however KIT in their report stated that the target set of 600kg/ha was very difficult to achieve and a more realistic target of 450 or 500 kg/ha should have been set.

DIBs are still rather small, however they have the potential to grow and enable private investors (in particular impact investors) to get involved in rural and community projects and see some outstanding results that are being achieved.

**Sustainable Development Goal Bonds** are a type of sustainability bond which aligns the funding of environmental and social impactful projects with the UN SDGs. There are a number of examples of bonds linked to the SDGs- for example in 2017, HSBC launched a $1 billion bond in support of the UN SDGs; the proceeds will be used to support projects in education, renewables, sustainable cities and transport networks and helping communities adapt to the effects of climate change. The World Bank in 2018 also launched a sustainable development bond to provide investors to support the SDGs that address water, sanitation and marine protection. Most of the SDGs are interlinked so for example addressing the sustainability of water resources could also have a positive effect on sustainable agriculture.

There are also other financial mechanisms that could help provide access to finance for agriculture producers. We can’t cover them all, but we have tried to incorporate the main instruments that are currently available. Governments, multi-lateral banks, cooperatives, traditional financial institutions, actors across the supply chain, private investors, and farmers all have important roles to play to meet future food demand sustainably.

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8 [1] Kit (2015), Autonomous and sustainable cocoa and coffee production by indigenous Ashaninka people of Peru
Providing financial capital to small and medium agriculture producers will enable better crop yields, more efficient and sustainable use of resources, and less wastage across the supply chain as well as improve the livelihoods of 450 million small scale farmers around the world.

**Removal of Distortions in Trade**

Market distortions in trade occur when national governments create policies that increase or decrease prices of imported and/or exported goods. When these prices are distorted, consumers pay (and/or producers earn) either more or less than they would have done otherwise. Intervention by the government in the agricultural market could be aimed at protecting the agricultural sector from foreign competition (e.g., through barriers to food imports), increasing their domestic producers competitiveness (e.g., subsidies of exports benefits to deal with production surpluses), or creating incentives for farmers towards a specific policy goal (e.g., for food security or encouraging farmers to switch to growing crops for biofuel rather than food). As stated earlier agricultural policies reached about $620 billion per year during 2015-2017, which have distorting effects for production, prices and incentives among producers and consumers. This disarray in agriculture markets can sometimes result in the overproduction of agriculture products in high-income countries and the under production in low-income countries. (Rausser et al., 2013)

Over the years we have seen numerous developing countries re-structure their agriculture price and trade policies which have led to increase in trade – for example the liberalization of trade between South Asian countries is being increasingly recognized as a way of improving regional food security. However more needs to be done — President Trump’s trade war with China is a classic example of how trade conflict can affect an industry. China has placed a 25% tariff on U.S. soybeans which could affect the farming industry in the U.S., which has prompted President Trump to put forward $12 billion in aid to help U.S. farmers. This has led to both U.S. soy producers worried about selling their produce and Chinese consumers worried where to get their product from.

**Vertical Integration Across the Supply Chain**

Vertical integration is the common ownership of successive production stages in the supply chain, as opposed to horizontal integration which refers to the common ownership of similar businesses. The food supply chain is extremely complex with a number of different players as well as being unsustainable and inefficient. An example of vertical integration could be processing firms/retail or manufacturing firms having more control over the production of a particular product, therefore avoiding certain transaction costs, wastage, and quality loss. We see this is already happening in the sector where traditional commodity traders are moving into more primary production, food processing and manufacturing, as well as specialty ingredients. One does need to be wary of the fact that you do not want a few companies to control the food market and ultimately there is a need to protect the livelihoods of small-scale farmers. However removing certain steps in the supply chain can definitely improve efficiency and ensure more transparency and control.
Better vertical integration could also lead to better innovation. The link between innovation and vertical integration is not new — it was first mentioned by Frankel in 1955 where he attributed the slow rate of diffusion of innovations in the British industry in the late 1800s to early 1900’s to the absence of vertical integration in textile firms. (Karantininis et al., 2010) It is easier to innovate across the supply chain if a company is involved in all or part of the stages of food production. Karantininis et al. (2010) found that for Danish food firms, vertical integration had a positive impact on innovation together with good contractual agreements- they conclude that organization, size and market power are important determinants of innovation.

Easier and Faster Access to Market for Technology and Innovation

Technology innovations can help to address many of the challenges the agri-food industry faces, but the route from research and development to industry-wide adoption is not always straightforward. The pace of innovation is slow in the industry and it is struggling to bring technology innovations to market and at scale. The lag time between research and implementation can take up to 15-25 years. (Jaruzelski et al., 2017) Both the private and public sector have roles to play in facilitating easier and faster access to market for agricultural innovations.

- **Private sector:** Investment in agtech is growing, backed by food giants and venture capitalists, and will continue to play a vital role in driving agri-food innovation in the future. Agtech start-ups face two key challenges in the innovation cycle which are support gaps between (1) foundational research and a viable start-up business and (2) start-up and an established business. Platforms arising to help address these challenges are borrowing from the tech world and the most common set-up so far is the rise of accelerator programs. (Agfunder, 2016) Their aim is to speed up the innovation cycle by bringing together promising agtech start-ups, investors, corporates, and other industry stakeholders. Agtech accelerators are largely based in developed countries but the initiative is spreading to emerging and developing economies. Brazil launched its first agtech accelerator in 2017 as a response to tough conditions faced by local start-ups. (Cossgrove, 2016) Agtech innovation is also forcing incumbents to rethink their business models and the ones that will continue to thrive will be the ones that adapt and embrace innovation and disruption (i.e., Tyson Foods and other meat incumbents that invest in alternative proteins).

- **Public sector:** Governments can help make it all happen by not only investing in agriculture R&D, but by creating an environment where agtech innovation is encouraged and supported. Streamlining regulation can help to reduce lag times of innovation uptake, or preferential access to land and market support can be offered to agri-tech innovations that show potential. (Jaruzelski et al., 2017) International organizations also have a role to play, especially in facilitating agtech adoption across low-income countries. The World Bank has started to incorporate precision technology into its agriculture projects and is exploring a range of technology innovations including sensors and data analytics as well as blockchain. (Ehui, 2018)

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9 In 2017, agri-food tech investment reached US$10.1 billion in across 924 deals and 59 countries globally (Source: Agfunder)
Public-private partnerships will also be important and can help to drive wider and more rapid adoption of innovation as well as direct better use of public funds. (OECD, 2016) Technology can help to reshape the agri-food industry for the better but commitment and resources that support a thriving agtech ecosystem are needed from both the public and private sectors.

Better Information and Data for All

The agri-food industry creates an enormous amount of data — big data is already revolutionizing the production of food in many countries from the use of satellite data for weather patterns, to the use of data for efficient use of water and fertilizer. Data is everywhere from the origin of a particular product’s harvest to where it went next, how long it spent in refrigeration and what product it ended up in. However none of this data is available to consumers. Consumers are demanding more transparency to understand where the products have originated, together with the nutritional value of the products that they consume. It is extremely difficult to understand where the food that we consume actually comes from.

Leveraging advanced sensor technologies and smart systems to collect, analyze, and share digital data promises to improve this. Supply chain management solutions such as blockchain can help reduce inefficiencies and waste across the supply chain. Data can also be shared across the supply chain — processing firms can share data with growers to enable them to improve the quality of their product. Fuller data integration throughout the supply chain from the production of food to the ultimate consumer could benefit the overall process and make the system more transparent and more efficient. The role of data is vital in meeting the objective of feeding a population while at the same time increasing levels of efficiency, reducing waste, increasing sustainability and improving traceability.

Consumers are also inundated with new ‘healthier’ products with campaigns such as ‘Better for You’. However there are dozens of products available that are being masqueraded as healthy options when in fact they are not. Over the years consumers have had to endure mix messages coming from the media on what is healthy. A study by the British Nutrition Foundation reveals that 43% of adults surveyed admit that they find it extremely difficult to find information on healthy diets, with changing messages and advice from experts being the major cause for confusion. Better and clearer information on what a healthy diet should consist of and better labeling on products should help improve nutrition in many countries around the world.

Healthier Products and Dietary Change

As described in the previous chapter, consumers whether they are from the U.S., China, Japan, Latin America, or Europe are demanding healthier products. Consumers are looking for minimally processed or unprocessed products with an increased desire for whole foods, plant-based proteins, natural ingredients as well as ingredients with particular health functionality. (Mascaraque, 2017) Food manufacturers are responding to these demands with companies like Unilever stating that by 2020 at least 60% of its portfolio will meet the Highest Nutritional Standards based on WHO nutrition guidelines. This is all good news- however healthier products come at a premium. A study by Jones et al., (2014) linked economic data for 94 foods and beverages in the UK Department of Health’s National Diet and Nutrition survey producing a dataset across the period 2002-2012. They assigned each item to a food group and categorized them as ‘more healthy’ or ‘less healthy’. 
The authors conclude that since 2002 more healthy foods and beverages have been consistently more expensive than less healthy foods, with a growing gap between them. This study is likely to be of interest to policy makers who are already introducing measures such as sugar taxes which aim to encourage food manufacturers to produce products with less sugar. However could this legislation/policy be taken even further to encourage and allow prices for healthier products to fall when compared to unhealthy options? Or could the increase in demand for healthier foods enable prices to fall? These are difficult questions to answer — but the cost of food-related diseases is increasing, so policy makers should start thinking very carefully about making these difficult decisions.

Many academics (Poore and Nemecek (2018), Bajželj, et al. (2014) and Springmann (2018)) are calling for people to consume less meat and less dairy to reduce the environmental impacts associated with the production of food. The production of beef, pork and chicken uses around nine, four and three times respectively as much water per kilogram compared to cereals. More than three quarters of land used for agriculture production is used for the rearing of livestock, whilst the carbon footprint of meat production is substantially higher than cereals and plant-based products. (Springmann et al., 2018) state that changing current diets to one that is more plant-based flexitarian diet can reduce water and land use by 10 and 11% respectively and greenhouse gas emissions by 52%. While this is hard (if not impossible) to achieve, the authors claim that just moving to a diet with less meat could also achieve a huge reduction in greenhouse gas emissions, land use and water use.
Appendix 1: Country Case Studies

Case Study: All About Dairy in India

Indian population and GDP are projected to keep rising at a relatively high and steady pace, yet we do not believe the country will behave in a similar manner to China and other high-growth emerging economies once it reaches their levels of income. We do not expect India to become a major consumer of meat due to its preference for vegetarianism which is largely driven by culture and religion, nor do we see it adopting a Western-type diet in the next few decades. Despite being one of the largest countries, on a global scale India is nowhere near being one of the key meat consumers; its share of global meat consumption in 2017 was 1.65% and is projected to increase only slightly to 1.80% in 2027. Poultry will drive the small growth in meat consumption share (Figure 130), whereas the demand for other meats is expected to stay flat due to lack of interest from consumers.

The preferred source of animal protein in India is fresh dairy products which we highlighted earlier as integral to Indian diets. The per capita consumption of fresh dairy products has increased by over 40% over the past decade to 84 kg/cap/year, and is expected to continue to grow over the next decade. To meet this growing demand, India will emerge as the largest global milk producer by 2027, leaving the EU in the second place with 30% lower output. (OECD/FAO, 2018) The prediction is supported by the currently observed trend of increasing investments in milking animal inventories as well as higher yields, which are driving the overall dairy production. (OECD/FAO, 2018)

Similar to many diets around the world, grains are an important source of calories in India. The country cultivates enough rice and wheat to be fully self-sufficient, with almost half of the workforce contributing to agricultural sector. (OECD/FAO, 2018) Over the next decade we expect per capita grain consumption to remain stagnant, but increase by 14% in aggregate terms mainly due to population growth. Under current production capabilities this could put a strain on Indian agriculture. Most cultivation is done by farmers with small holdings as 72% of them are smaller than 1 hectare. (Chatterjee & Kapur, 2017) Hence, efficiency-improving investments in such small family-owned farms are unlikely. Nonetheless, the outlook on grain production is not necessarily bleak.
The yield rates for wheat and rice in India are close to the world averages, but there is still room for improvement. A third of rice farmlands are using less than half of their potential. (Chatterjee & Kapur, 2017) In addition, underproduction is amplified by relatively low agricultural value added per worker, which declined further between 1990 and 2011. (OECD/FAO, 2018)

However, India’s food self-sufficiency model jeopardizes the country’s ability to address diet-related malnutrition and efforts to reduce emissions. The country’s food policy focuses heavily on wheat and rice production which is not providing sufficient macronutrients or micronutrients. More than two-thirds of Indian people suffer from micronutrient deficiencies – Iron and Vitamin A deficiencies affect 90% and 85% of the population, respectively. (Rao et al., 2018) If India continues on its current trajectory of grain self-sufficiency, severe shortfalls in the provision of macronutrients are expected up to 2050. (Ritchie et al., 2018) The emphasis on rice cultivation is also contributing to substantial methane emissions, but this is not only due to domestic demand as rice makes up more than a third of the country’s total food exports.

Case Study: China and its Insatiable Appetite for Meat and Fish

China, unlike India, has been undergoing a shift from crop-based to a more diversified and animal-based diet over the past decade. (Fukase & Martin, 2016) The two key contributors towards this trend have been higher income and urbanization. The pay gap between urban and rural areas remains high, thus influencing consumption patterns – the city population consumes not only more calories, but also higher amounts of fish, meat and dairy. (OECD/FAO, 2013) As a result, in 2027, Chinese people are expected to consume 115 grams/day/capita of protein which is 20% above the world’s average. (OECD/FAO, 2013)

China has a traditional preference towards pork and poultry, whose per capita consumption has increased by 19% since 2007. In addition, the belief that beef and veal are disease-free and healthier meat options has driven the 21% hike in bovine meat consumption over the past 10 years. (OECD/FAO, 2018) For the upcoming years we expect the growth rate of meat demand to slow down, but remain relatively high in comparison to global averages (Figure 132).

Grain consumption, on the other hand, is expected to decline as China shifts towards the Western consumption patterns. Similar trend was observed in parts of the developed world years ago, as higher household incomes push them to substitute grain staples for more calorie-dense food, such as meat and dairy.
The role of fish in Chinese people’s diet may seem surprising as it already contributes almost 40% to global fish consumption (Figure 133). Higher and rising consumption is a result of interaction between a couple of factors, namely higher life quality and consumer preferences as the aforementioned urban population rushes to consume more animal products. In addition, Chinese consumers have experienced increased fish availability due to rapidly developing aquaculture. Aquaculture will drive the supply of fish in China - by the late 2020s the country will account for over 65% of global aquaculture production. (OECD/FAO, 2018) FAO reports that there have been significant levels of investment into R&D of fish farming and that some scientists work directly in the fisheries, which allows the innovations to be applied quickly and smoothly.
Despite the large population and a distinct lack of arable land, Chinese food supply has managed to keep up with demand. However, a concerning trend has emerged over the past few years, whereby demand is growing at a slightly higher pace than production, which led to a slight deterioration of trade balance for food. (Fukase & Martin, 2016) This, together with higher demand for animal-products causes some concerns for the Chinese government. Animal-based products require more resources than agricultural goods, and whilst land productivity in China is similar to the global average, agricultural labor is not as productive because of the prevalent family-based farming. The trend is worrying from an environmental point of view as well as for public health. A key dietary challenge the country faces over the next few decades is the need to bring consumption of red meat more in line with recommended levels. (GLOPAN, 2016) China is already the world’s largest GHG emitter – additional production of livestock will further pollute the environment and contribute to greater emissions.

**Case Study: Troubles Ahead in Nigeria**

Nigerian population has skyrocketed since mid-1990s and will continue to grow at a rapid pace; hence the World Bank estimates that demand for food will increase by 60% in the next decade. However, in the absence of investments and innovation of farming practices, Nigeria already is and will likely remain unable to meet higher consumption needs. Crop harvests are not keeping up with the population growth; as a result, Nigeria has lost its self-sufficiency and has become increasingly dependent on food imports. The Minister of Agriculture and Rural Development, Chief Ogbeh has noted that Nigeria is experiencing a shortage of rice and fish, among other foods, and expressed vague hopes to attract foreign investors. (Ohuocha, 2017) Investment in agriculture is indeed vital as it remains one of the most important sectors in Nigeria, employing over two thirds of the labor force, (OECD/FAO, 2018) accounting for 24.5% of nominal GDP (2017) and providing income for small rural farms. (Nigerian Government, 2018)
And yet, agricultural sector suffers from low yields and low productivity – over the past years value added per capita has been increasing by less than 1% annually and only 1% of arable land has an irrigation system. Furthermore, eight years of conflicts in the Nigeria’s Northern region has led to food insecurity, a humanitarian crisis and destroyed already meager infrastructure. Subsequently, despite rapidly expanding population, FAO predicts that consumption of some more expensive products, such as dairy and meat, will decline (Figure 134).

![Figure 134. % Per Capita Consumption Change: 2007 - 2027](source: OECD-FAO, Citi Research)

On the other hand, roots and tubers feature prominently in the Nigerian diet which is representative of diets across Sub-Saharan Africa, but four times more than the global average. Local cassava “garri” and yam are particularly favored in Nigeria, and in total, roots and tubers contribute about 600 kcal (23%) to an average Nigerian diet. Cassava, in particular, tends to be the main calorie source for poor rural farmers, who often find it appealing as cassava is drought-resistant and grows better than yam in low fertility areas. (IFAD, 2010) Since most of the roots and tubers are harvested in small rural farms, the yield tends to be low – average yield for cassava is only a third of its potential, which makes meeting the increasing future demand for root vegetables difficult. (OECD/FAO, 2018)

Alongside root vegetables, grains are an important calorie source for Nigerians. Rice, wheat and maize are among few products whose per capita consumption is projected to increase by 2027 as in urban areas they tend to be cheaper than domestic tubers. Fonio, a local West African cereal, is one of the staples in Nigeria. It matures in 6-8 weeks and provides food early in the year, grows best in savannahs and has similar nutritional composition as wheat. (National Research Council, 1996) However, due to small farm size, lack of machinery and low yields, Nigeria experiences grain deficit every year. The country is the largest importer of rice in SSA, importing a third of its annual consumption, which makes Nigerians exposed to international grain price fluctuations and every year doubts arise whether the country has sufficient foreign exchange reserves to pay for the imports. (OECD/FAO, 2018)
Finally, over 50% of animal protein in Nigeria comes from fish, whose per capita consumption peaked at 15.3 kg/year in 2011, but has been declining ever since. The reasons behind the fall in fish consumption is the inability of local supply to meet the demand, higher fish prices, a growing population and lower fish imports. In general, unlike some less developed countries in Asia that are catching up with the Western world diets, Nigeria will experience a fall in animal-based protein consumption, which is already four to five times lower than the global average. (OECD/FAO, 2018) In addition, a projected fall in dairy consumption can be contrasted with higher expected consumption of fresh milk in India and China. While the latter two countries tend to invest into animal inventories and receive agricultural support from the governments, Nigeria is lagging behind. Without suitable substitutes, a fall in meat and dairy products consumption is likely to have a negative impact on already nutrient-poor Nigerian diets. (Chaudhary et al., 2018)

From the three case studies above, we can see that food demand is influenced by many country-specific factors which include population, income, consumer tastes and preferences as well as agricultural capabilities. We have also observed that future food consumption patterns have consequences for human health and the environment. For example, greater intake of animal products may help to improve nutrient intake in developing countries but will undoubtedly put a strain on the environment. In order to meet growing food demands, nations can deploy strategies that increase domestic production or food imports, or utilize a combination of the two. We explore this further in the following section and discuss the increasing role of trade in supplying a world with a growing appetite.
Appendix 2: Who is Feeding China and India?

In terms of food production and trade, China and India are similar in two regards – (1) both are largely self-sufficient in grains as a result of agricultural policies that focus on cereal production and food security; and (2) Oilseeds make up the biggest share of agricultural imports. But that is where the similarities fade.

We have seen in earlier sections that China and India have very different tastes. Rapid economic growth and an expanding middle class have driven demands in China for not just more food but also more animal-based products. The country's insatiable appetite for meat, fish, and dairy resulted in increased imports of feed which was the main driver of the country's shift from being a net exporter of grains in 2007 to a net importer. (Vorley & Lançon, 2016) China is the largest importer of all agricultural products which reflects the country’s food strategy that combines both food self-sufficiency and agricultural imports. The self-sufficiency ratio of cereal grains in China is 95% whereas about 80% of consumed soybean and other agri-food products such as sugar and milk are imported. (Cui & Shomemaker, 2018) India on the other hand is a much subtler player in global food trade and is not a major importer of agricultural products. The country’s strong reliance on domestically produced grains (and dairy) does not deliver sufficient nutritional needs.

China and India’s portfolio of agricultural imports vary by size, composition, and trading partners. Soybean makes up the majority of China’s oilseed imports, whereas India’s oilseed of choice is palm which accounts for almost 60% of oilseed imports. In China, not only is soybean used for animal feed, it is also the preferred oil for food consumption. Palm oil is mainly used for industrial preparations of foods. Recent trade war skirmishes which have led to 25% tariff on U.S. soybeans can have the capacity to alter China’s soybean consumption if these are sustained. Reduced soybean may serve to reduce availability of soil oil and serve as a tailwind for higher palm oil imports. In contrast, palm oil continues to feature as the edible oil of choice in India. Domestic production has failed to meet India’s growing demand for palm oil and edible oils in general. This had led India to become the world’s largest importer and consumer of palm oil globally. However, rising of import tax on crude palm oil (currently 44%) and refined palm oil (currently 54%) has dampened demand in recent months.
Where China and India import agricultural goods from also differ. Brazil and the United States are the largest exporters into China and account for over 50% of the country’s imports. The Americas as a region supply two thirds of China’s total agricultural imports. In contrast, India has a diversified portfolio of trading partners and relies more on countries within Asia; Indonesia is the largest exporter of agricultural goods to India supplying 19% of total food imports, and South East Asia is the biggest regional importer delivering 33% of imports.

Looking ahead, China’s food demand growth will slow down and it will be India’s moment to shine. However, India may have to change its current food strategy of self-sufficiency or risk continued and possibly even greater levels of malnutrition. In order to not only meet increasing food demand from population growth but also tackle the country’s nutrition gap, India will need to consider a combination of domestic measures that improve agricultural productivity as well as an increase in food imports. (Ritchie et al., 2018) This can also help to relieve pressure on India’s water resources which, like China, face scarcity challenges. Growing imports have significantly decreased pressure on China’s own land and water resources, and the importation of soybean has been the biggest contributor towards domestic resource savings. (Ali et al., 2017) There is also room for China to improve its agricultural productivity and practices which will not only help the country feed itself in the future but do so in a more sustainable manner.

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Appendix 3: Edible Oils Market

Edible Oil Consumption in Key Markets China and India

Growing middle income class and strong GDP growth levels led to the increase in edible oil consumption in China. China’s edible oil consumption per capita (food uses) has risen past world average levels since 2006, and now stands at 23.3kg/pax, vs world average of 18.7kg/pax. Going forward, we expect China’s consumption of edible oils to grow more modestly.

Figure 139. Edible Oil Consumption Per Capita and the Shifts in Breakdown of Edible Oils Over the Years

In China, soy oil is the preferred oil used for food consumption, while palm oil is mainly used for industrial preparation of foods, such as the cooking of instant noodles and bulk scale cooking. According to USDA statistics, in mid-2017, China consumed 4.8mt of palm oil, 13% of total edible oils consumed, while soy oil consumption was at 16.4mt, 45% of total edible oils consumed. Palm oil demand in China is seasonal, with spikes in imports occurring the months before Chinese New Year and major festivities such as Moon Cake Festival.

Source: USDA, World Bank, CEIC, Citi Research
Recent trade war skirmishes which have led to 25% tariff on U.S. soybeans can have the capacity to alter China’s soybean consumption if these are sustained. Reduced soybeans and may serve to reduce availability of soy oil and serve as a tailwind for higher palm oil imports.

As disposable income continues to grow, we see a shift in demand towards branded and more premium edible oil products. We also see a shift towards lighter cooking oils as consumers in China become increasingly health conscious. Future growth in demand for CPO in China should come from greater demand of palm oil derived specialty fats and oleo chemicals for use bakery, confectionary as well as materials for FMCG products (cosmetics, soaps etc.).

In contrast, India’s edible oil consumption per capita (food uses) has lagged world averages, and now stands at 15.2kg/pax, vs world average of 18.7kg/pax. Palm oil continues to feature as the edible oil of choice, with large demand growth experienced since the 2000’s. Upside from growth in per capita oil consumption as the country develops will be a driving factor for global CPO demand, only impeded by seasonal regulatory measures such as palm oil import duties (which serve to protect domestic farmers and/or edible oil refiners).

India is currently the world’s largest importer and consumer of palm oil globally. In mid-year 2017, India consumed 9.6mt of palm oil, 43% of total consumption. Raising of import tax on crude palm oil (currently 44%) and refined palm oil (currently 54%) has dampened demand in recent months.
Larger palm oil planters have been adopting ESG code since 2013. This has resulted in a decline in new planting growth with greater replanting efforts in recent years.

Since 2013, planters have stepped up on environmental, social and governance (ESG) efforts as global consumers and buyers signaled support. For example, major palm oil planter/processor and consumer conglomerate Wilmar International has undertaken a major commitment towards being environmentally and socially responsible since December 2013 with its "No Deforestation, No Peat, No Exploitation Policy". Similarly, Golden Agri Resources (GAR) has also adopted their GAR Social and Environmental Policy (GSEP).

These ESG efforts have led to a reduction in new plantings. In 2017, total planted area in Malaysia stood at 5.8m hectares, with 5.1m hectare mature, or 88% of total planted area. Growth in planted area was only +1%, lower that the growth rate of +3% in 2014. Similarly in Indonesia, planted hectarage is about 11m hectare in 2016, somewhat unchanged relative to 2015. Growth in planted area in 2014 was 3%.
Combined, these have resulted in the plantation industry, led by the major planters to sharply reduce planted hectarage growth, with a fresh focus on replanting efforts. On average, planted hectarage only increased by +1% amongst planters in 2017, vs +7% in 2012. Given a 7 years cycle for palm trees to reach maturity, palm oil production could exhibit reduced palm oil production beyond 2020. The adoption of these new ESG efforts was initially more meaningful at the larger firms. We note that small-mid planters continued to still register planted area growth but this has also slowed in the past few years.

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>Variance in growth from 2012 to 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>7%</td>
<td>4%</td>
<td>4%</td>
<td>5%</td>
<td>0%</td>
<td>1%</td>
<td>(6%)</td>
</tr>
<tr>
<td>Diversified</td>
<td>2%</td>
<td>(3%)</td>
<td>(1%)</td>
<td>8%</td>
<td>0%</td>
<td>(0%)</td>
<td>(2%)</td>
</tr>
<tr>
<td>Large planters</td>
<td>3%</td>
<td>2%</td>
<td>4%</td>
<td>2%</td>
<td>(0%)</td>
<td>(0%)</td>
<td>(3%)</td>
</tr>
<tr>
<td>Small-mid planters</td>
<td>12%</td>
<td>8%</td>
<td>6%</td>
<td>6%</td>
<td>1%</td>
<td>2%</td>
<td>(10%)</td>
</tr>
</tbody>
</table>

Source: Company Data, Citi Research

The top 3 planters are Sime, GAR and Wilmar and these are also the ones with the highest percentage of matured hectarage. Planters with the highest growth of matured hectarage are FR, IJMP and GENP.
In terms of replanting, planters have guided replanting areas of between 0.5% to 4%. Larger planters have also guided for larger percentage of replantings. Malaysia and Indonesia continue as the key areas for palm oil cultivation. Efforts to go to Africa have not scaled up due to disease, logistics and weather issues. While the palm oil tree variety originated in West Africa, countries in West Africa have dry seasons of up to three months without rain, which result in lower yields, compared to Malaysia and Indonesia where there’s rain all-year round.

**Competition between Food and Energy: Indonesia Leading the Way in Biodiesel**

Edible oil feedstocks such as palm oil have featured as an effective medium to also power engines and generators. Palm oil derived biodiesel (i.e. Palm Oil Methyl Ester, PME) have high-ignition quality. However, they also harden at colder temperatures, making them difficult to use in cold weather. In recent years, the focus on palm oil derived biodiesel has focused more on Indonesia, the world’s largest grower and exporter of palm oil.

In 2017, it is estimated that biodiesel consumption was at 2.5m kl. Higher crude oil prices have been a tailwind for biodiesel consumption, with 2018 possibly ending between 3.0-4.0m kl. Anecdotally, palm oil planters with exposure to biodiesel have seen larger volumes and more profitable operations in 2018.
The Indonesian government is currently finalizing a revised regulation to include non-PSO (public service obligation) sector in the 20% mandatory blending mandate (B20) in a bid to curb imports and strengthen the rupiah. The regulation is expected to be published this month with implementation starting in September 2018. According to government’s estimate, there could be an additional 1mn kl of biodiesel on top of the government’s 3.2mn kl target for this year. Meanwhile, when the program is fully implemented next year, an additional 3mn kl of biodiesel (from 3.2mn target this year) is expected, assuming 15mn kl of non-subsidized diesel. This will translate to 2.6mn tons of additional crude palm oil (CPO) demand or around 7% of Indonesia’s CPO production. Note that in the PSO sector, the 20% blending has been achieved with subsidized biodiesel consumption (PSO) of 2.9mn kl last year vs. 14.5mn kl of subsidized diesel consumption (ref ASEAN Planters - B20 Extension to Non-PSO, How Likely is the Implementation?).

Markets remained mixed on whether the Indonesian government can successfully revamp its biodiesel policies. With the recent depreciation of the Rupiah, and the upcoming 2019 elections, we believe the government will have the impetus to rely less on imports and implement stronger policies to support the local farm sector. Indonesia has led the way in recent years given its domestic program to tax palm oil planters to generate fund to subsidize PSO biodiesel.
References


Center for Strategic International Studies (2012), Private sector engagement in food security and agricultural development.


Chen, J. et al. (2003), The response of river water quality and quantity to the development of irrigated agriculture in the last 4 decades in the Yellow River Basin, China. Water Resources Research, 39(3).


FAO (2011), The state of the world’s land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.


FAO (2014), Building a common vision for sustainable food and agriculture – Principles and approaches. Rome.


FAO (2018), Key facts on food loss and waste you should know!. Rome.


Fiolet, T. et al. (2018), Consumption of ultra-processed foods and cancer risk: results from NutriNetSanté prospective cohort. bmj, 360, k322.

Food Security Task Force (2012), Innovative financing for agriculture, food security and nutrition, Report of high level expert Committee to the leading group on innovative financing for agriculture, food security and nutrition. FSTF.


IMF (2016), Earth’s Future, 2(9), pp.458469; IMF World Economic Outlook, Commodity Special Feature.

International Institute for Sustainable Development (2015), Investment in agriculture, policy brief #3, Financing for Agriculture: How to boost opportunities in developing countries.


Nicholas R.V. et al. (2014), The Growing Price Gap between More and Less Healthy Foods: Analysis of Novel Longitudinal UK Dataset, PLOS One, 8th October 2014


OECD (2016), Public-private partnerships for agricultural innovations: lessons from recent experiences


Poore, J. et al. (2018), Reducing food's environmental impacts through producers and consumers, Science 360 (6392) 987992.

Popkin, B. M. (2017), Relationship between shifts in food system dynamics and acceleration of the global nutrition transition. Nutrition reviews, 75(2), 7382.


Porter, S.D. et al. (2018), Avoidable food losses and associated production phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK. Journal of Cleaner Production.


Ray, D.K. et al. (2013), Yield trends are insufficient to double global crop production by 2050. PLOS one, 8(6), p.e66428.


UNDP (2018), Sustainable Development Goals – Goal 2: Zero Hunger

UNFCCC (2014), IPCC AR5: Key findings on implications for agriculture


WEF (2015), Which countries waste the most food?


Zhan, S. et al. (2018), China’s flexible overseas food strategy: food trade and agricultural investment between Southeast Asia and China in 1990–2015. Globalizations, pp.120.

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**Key Insights regarding the future of Food**

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<thead>
<tr>
<th>Category</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMMODITIES</strong></td>
<td>The current food system is inefficient and unsustainable using 70% of the world’s freshwater supply, 50% of total habitable land and generating up to 30% of greenhouse gases. Innovations in technology should increase crop yields, lower water usage and find meatless offerings lower demand for resource-intensive meat.</td>
</tr>
<tr>
<td><strong>SUSTAINABILITY</strong></td>
<td>About one-third of food produced is lost or wasted in the global food supply chain, equal to roughly $1 trillion globally. How consumers shop is evolving towards smaller stores and higher frequency and food retailers are moving towards a zero waste mandates.</td>
</tr>
<tr>
<td><strong>TECHNOLOGY</strong></td>
<td>Over 3 billion people worldwide have low quality diets. Changing consumer preferences towards health &amp; wellness has led to the development of bio-fortified foods and a push by food manufacturers towards healthier options to combat malnutrition and obesity.</td>
</tr>
</tbody>
</table>