Transforming Agri-Food Sectors to Mitigate Climate Change: The Role of Green Finance

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Summary: Globally, food systems have become heavily industrialized and are currently threatening both environmental sustainability and human health. Feeding a growing world while remaining within safe social-ecological planetary boundaries, as dictated by the UN Social Development Goals and the Paris Climate Agreement, is feasible but requires a paradigmatic shift in agricultural value chains and their financing: a "Great Food Transformation." Tracing today's agri-food main global developmental and financial trends, this paper proposes a set of financially-oriented public policies to accelerate this transition with a focus on advanced and large emerging market economies. Suggested measures include public lending, insurance and guarantee schemes to aid the transition; financial training schemes; changes to prudential regulation to account for financial risks of non-sustainable farming; alongside a bolder approach to ESG investment of public funds and steps to expand green and sustainable bond markets.

Zusammenfassung: Weltweit sind die Nahrungsmittelerzeugungssysteme stark industrialisiert und bedrohen derzeit sowohl die ökologische Nachhaltigkeit als auch die menschliche Gesundheit. Es ist machbar, eine wachsende Welt sozial und ökologisch sicher zu ernähren, wie es die sozialen Entwicklungsziele der Vereinten Nationen und das Pariser Klimaabkommen vorschreiben. Dies erfordert jedoch einen paradigmatischen Wandel in den Wertschöpfungsketten der Landwirtschaft und ihrer Finanzierung: eine „große Transformation der Nahrungsmittelerzeugung". In diesem Papier werden die wichtigsten globalen Entwicklungs- und Finanztrends der Nahrungsmittelindustrie nachgezeichnet und eine Reihe finanzpolitischer Maßnahmen vorgeschlagen, um diesen Übergang zu beschleunigen. Vorgeschlagene Maßnahmen umfassen öffentliche Darlehens-, Versicherungs- und Bürgschaftssysteme zur Unterstützung des Übergangs, finanzielle Ausbildungsprogramme und Änderungen der Aufsichtsvorschriften zur Berücksichtigung der finanziellen Risiken einer nicht nachhaltigen Landwirtschaft. Daneben wird ein mutiger Ansatz für die ESG-Investition öffentlicher Mittel und Maßnahmen zum Ausbau grüner und nachhaltiger Anleihemärkte gefordert.

→ JEL classification: F4, F6, G3, H8, I0, N50, Q14, Q18, Q20, Q28
→ Keywords: green finance, agri-food, land use, sustainability, diets, green bonds, Paris Climate Agreement, Great Food Transformation.

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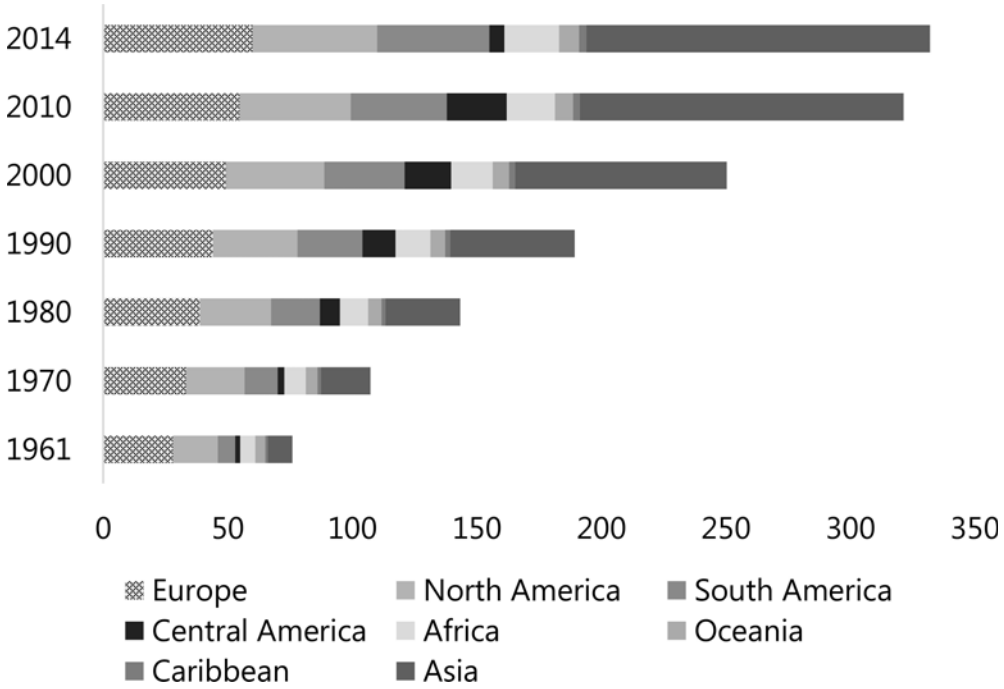
1 Introduction

Globally, food and agriculture, also known as the agri-food sector, is a circa $6 trillion industry responsible for feeding the planet and hiring well over 40 percent of it (McKinsey, 2015; Food and Agriculture Organization, 2018; Euler Hermes, 2019).[1] In recent decades, however, following sectoral policies aimed at boosting production volumes and profits and a hasty national and international financialization all along the "food chain" (Clapp, 2016; Schmidt, 2016), the agri-food sector in advanced and large emerging market economies has become heavily industrialized and reliant on chemicals and deforestation to produce growing amounts of meat, dairy and eggs (Willet et al., 2019) (Figure 1).

Figure 1

Meat Production, million tonnes



Source: Rithche and Roser, 2017.

1 Agri-food is here defined to include: (i) agriculture and aquaculture: raising crops, livestock, and seafood; (ii) manufacturing agricultural inputs: agrichemicals, farm machinery, seeds, livestock pharmaceuticals, and other supplies; (iii) food processing: the preparation of fresh products, manufacture of prepared food products and ingredients; (iv) non-food processing: extraction of bioenergy and biomaterials from agricultural crops and products; (v) marketing, wholesale and distribution, logistics, transportation, and warehousing; (vi) retail and foodservice: grocery, farmers' markets, restaurants, and other retailing; (vii) consumer cooking and food discovery; (viii) regulation: food quality, food security, and food safety; (ix) research and development; (x) financial services.

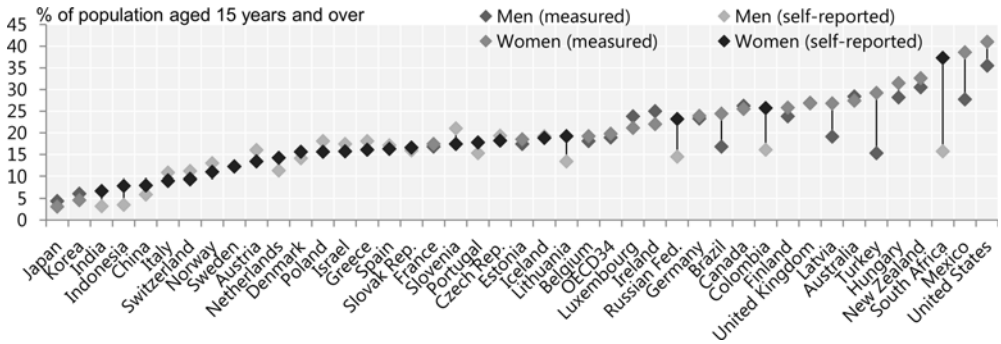
Reflecting these trends, the sector has also become responsible for a large portion of the world's greenhouse gas emissions (GHGEs): recent scientific evidence concurs in identifying modern agriculture (notably industrial crop and industrial animal production) as the single one most climate-changing human activity contributing to about 25 percent of all GHGEs (Willet et al., 2019), even excluding the contribution to GHGEs of supply chain processes before food reaches the consumer, such as food processing, transportation, and retail. When GHGEs from agriculture are combined to emissions from change in land use and food transformation the share reaches 30–35 percent (Eaglesham, 2011; Bajzelji et al., 2014; and Foley, 2016). By 2050, in a business-as-usual scenario, this share is expected to become 50 percent as the demand for food increases with populations and the trend in current dietary shifts continue (Willet et al., 2019).

The agri-food sector is also the number one contributor to the depletion of key, non-renewable resources via air pollution, land, soil and water degradation and the reduction in biodiversity worldwide[2] (Bajzelji et al., 2014; De Longe et al., 2015; Hyner, 2016; USDA, 2015; Food and Agriculture Organization, 2018 and 2019; IPBES, 2019, among others).

In turn, the supply of increasingly cheaper and abundant animal-based and highly-processed food has fostered a generalized adoption of unhealthy diets in both advanced and large emerging market countries. This has contributed to an escalation in obesity and diet-related non-communicable diseases which is having an ever-increasing impact on private and public finances worldwide (WHO, 2018; Etemadi et al., 2017) (Figure 2). In a number of other countries, the global system of food supply

Figure 2

Obesity among adults by gender, 2015 (or nearest year)



Source: OECD Health Statistics 2017.

has created or reinforced, rather than removed, distortions leading to several hundreds of million people being chronically undernourished. As a result, numerous large advanced and emerging countries display a simultaneous over- and undernutrition problem (WHO, 2014) (Figure 3).

2 A nonrenewable resource is a resource of economic value that cannot be readily replaced by natural means on a level equal to its consumption. Most fossil fuels, such as oil, natural gas and coal are considered nonrenewable resources in that their use is not sustainable because their formation takes billions of years. Polluted air and degraded soil, while in principle renewable, also take decades to be cleaned up, if at all, while extinct biological species cannot be reproduced by definition.

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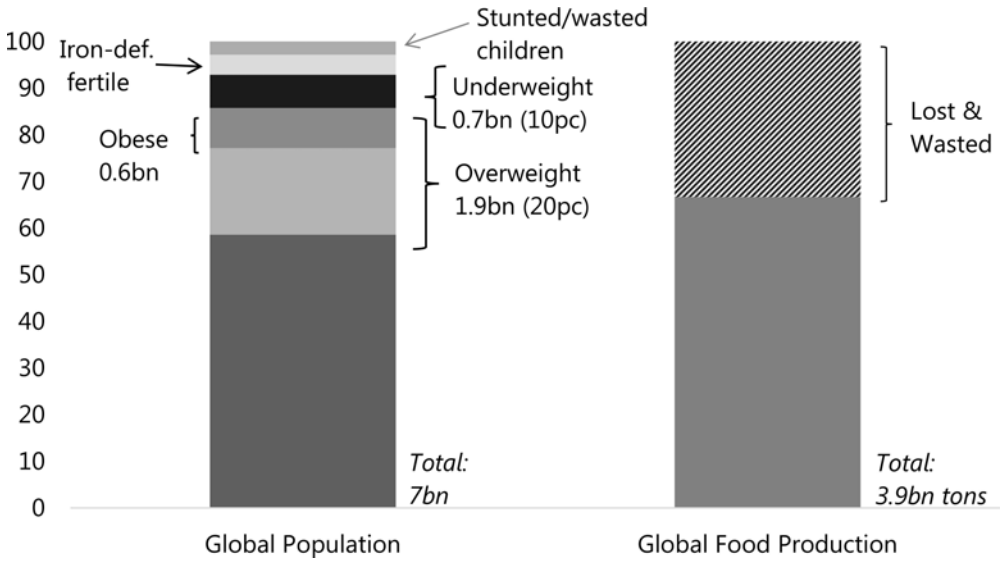
Figure 3

Global Malnutrition and Food Waste



Source: WHO, 2018; FAO, 2019.

Several global trends and natural constraints are expected to worsen this picture considerably in coming decades, influencing the overall sustainability of global food and agricultural systems and, thus, casting a dark shadow on global food security (Food and Agriculture Organization, 2018, 2019).

First, the world's population is expected to grow to almost 10 billion by 2050, boosting agricultural demand – in a scenario of modest economic growth – by some 50 percent compared to 2013 (UN, 2017). Second, income growth in low- and middle-income countries is expected to hasten a dietary transition towards higher consumption of animal protein, relative to plant-based protein, requiring commensurate shifts in output and adding pressure on natural resources (Bajzelji et al., 2014; Willett et al., 2019). Third, biodiversity is shrinking at an exponential rate, posing major risks to the future of global food and agriculture: crop and livestock total diversity has narrowed over the past 50 years because of the expansion of industrial monoculture and global seed patenting, and consequently the composition of the diet at the global level has become more uniform at the expense of regionally important crops, as shown by a meta-study across 150 countries (Khouri et al., 2016). While 6,000 plant species are cultivated for food, just nine of them account for two-thirds of all crop production. When it comes to livestock, around a quarter of breeds are at risk of extinction: just a handful provide the vast majority of meat, milk and eggs; and more than half of fish stocks are at risk of extinction (IPBES, 2019). This lack of dietary diversity is an additional threat to food security and human health. Wild food species are also rapidly disappearing, with just under a quarter of known wild food species are still in existence. In addition, species that contribute to the food ecosystem, such as pollinators, soil organisms and natural enemies of pests, are under sever threat. Examples include bees, butterflies, bats and birds (Food and Agriculture Organization, 2019;

IPBES, 2019). Finally, while the share of agriculture in total global production and employment continues to decline at different speeds, the needed acceleration in productivity growth to ensure that supply keeps up with demand is hampered by the degradation of natural resources, the loss of biological diversity, and the spread of transboundary pests and diseases of plants and animals, some of which are leading to the spread of zoonotic diseases such as avian and swine flu, while others are becoming resistant to antimicrobials with potentially pandemic consequences (O'Neill et al., 2016).[3]

Meeting increased demands on agriculture with current farming practices is expected to give rise to larger greenhouse gas emissions, intensify competition for natural resources, and exacerbate deforestation and land degradation. It follows that greening agri-food sectors and demand-managing food is scientifically recognized as a necessary condition for meeting both the 2030 UN Agenda for Sustainable Development and the environmental pledge behind the UN Paris Climate Agreement (Rockström et al., 2017; Food and Agriculture Organization, 2018; UNEP 2019).

On the other hand, making food systems sustainable for a growing global population, as well as healthy and fair, is technologically possible but requires a fundamental reconsideration of production and consumption, namely a "Great Food Transformation" (GFT) – as referred to in the scientific literature (Willet et al., 2019), similarly to the great energy transformation (GET) envisaged to reduce fossil-fuel-generated GHGEs (Goldstein and Qvist, 2019).

This paper explores the role of finance in the sustainable development and transition of the global agri-food sector and proposes ways in which public policy can foster the GFT, with a specific focus on financial levers to support a shift in agri-food market equilibria for advanced (AEs) and emerging market economies (EMEs). Section II describes main production trends in sustainable agri-food production and consumption. Section III examines key financial agri-food-sector trends. Section IV briefly explores the link between large agricultural bank lenders and agri-food sustainability in two advanced-economy cases. Section V proposes a condensed and actionable palette of public policy financial interventions that can help accelerate agri-food transitions to sustainability. Conclusions follow (Section VI).

2 Agri-food sustainability and major agri-food market trends

2.1 What is a global sustainable agri-food system?

Global sustainability in agri-food systems can be defined as a scenario in which global agri-food production is aligned with planetary boundaries – in turn including maximum or minimum 'safe' levels of climate change, ocean acidification, stratospheric ozone, biogeochemical nitrogen (N) cycle and phosphorus (P) cycle, global freshwater use, land system change, and the rate at which biological diversity is lost – while at the same time, production is sufficient to provide appropriate nutrition to the global current and perspective population (Rockström et al., 2017; Willet et al., 2019).

3 The cost of a global zoonotic pandemic has been estimated at 1 % of Gross World Product per severe pandemic (see World Bank, 2016). The cost of widespread antimicrobial resistance has been estimated to range between 3 % and 6 % of Gross World Product per year, every year, by 2050 (see O'Neill, 2016).

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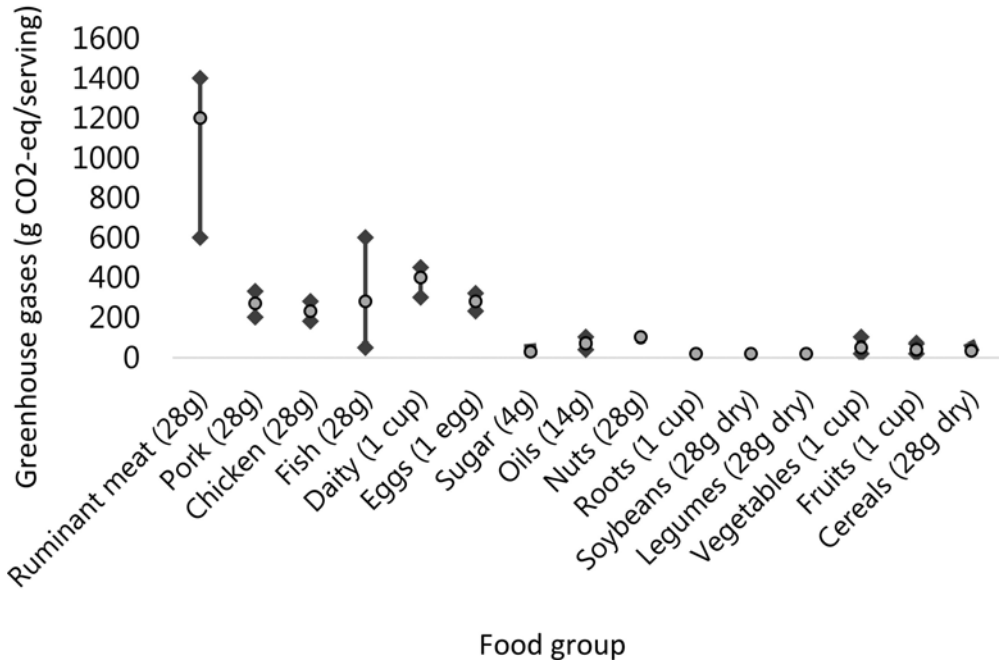
Research suggests that attaining global sustainability in agri-food systems requires simultaneously working on two endpoints of the global food system: final consumption (healthy diets) and production (sustainable food production) (Willet et al., 2019).

On the supply side, in turn, two main shifts are necessary. First, a large-scale shift away from conventional agriculture towards agriculture-related practices that support biodiversity, such as organic farming, sustainable soil management and ecosystem restoration. To say it with the Food and Agriculture Organization (2018): "needed are innovative systems that protect and enhance the natural resource base, while increasing productivity, implying a transformative process towards 'holistic' approaches, such as agro-ecology, agro-forestry, climate-smart agriculture and conservation agriculture, which also build upon indigenous and traditional knowledge. Technological improvements, along with drastic cuts in economy-wide and agricultural fossil fuel use, would help address climate change and the intensification of natural hazards, which affect all ecosystems and every aspect of human life." Such shift would contain and potentially invert some of the hazardous dynamics emerged over the past few decades as a result of the spread of conventional agricultural methods, namely the anthropogenic nonlinear acceleration in the biogeochemical nitrogen (N) cycle and phosphorus (P) cycle, the unsustainable use of global freshwater and land system change, and the accelerating pace of biodiversity loss associated with the relentless expansion of farmland and the use of synthetic pesticides and herbicides. Second, it is necessary to concert a sizeable reduction in animal-based food production coupled with a swift increase of plant-based food production. Fundamentally, this implies a substantial reduction in global livestock (now counted in excess of 77 billion against a global human population of 7.6 billion). Livestock enteric fermentation is the prime cause of agri-food GHGEs together with land use change related to the expansion of farmland into forested areas that has been shown to critically contribute to the shrinking of the planet's carbon sinks and the calamitous trend observed in the loss of global and regional biodiversity (Food and Agriculture Organization, 2019; World Bank, 2019).

On the demand side, the GFT requires a global shift to healthy diets based on scientific targets of optimal intakes of calories and consisting of a diversity of plant-based foods, low amounts of animal source foods, unsaturated rather than saturated fats, and small amounts of refined grains, highly processed foods, and added sugars. Over the past decades, rising incomes and urbanization in advanced and emerging market economies alike have moved diets in the opposite direction (Tilman and Clark, 2014). By 2050 these dietary trends, if unchanged, would be a major contributor to an estimated 80 % increase in GHGEs from food production and land clearing. The advocated shift to healthy and sustainable diets would validate the supply side shift to sustainable food production and lead to many additional public health, public finance, equality, and livability criteria. It is well known that food choices are strong determinants of human health, but recently awareness has grown about the fact that the foods and beverages we produce, choose and consume may significantly affect the environment (Amine et al., 2002; Duchal, 2005; Stefest, 2014). Since plant-based diets often emerge as nutritionally and environmentally advantageous (Joyce et al., 2012; Willet et al., 2019), a potential strategy to reduce both the rate of many human non-communicable diseases and prevent environmental deterioration might lie in promoting a predominant consumption of plant-based instead of animal foods (Joyce et al., 2012; De Marco et al., 2014; Baroni et al., 2007; Tilman and Clark, 2014). For example, age-and-sex-adjusted mean GHGEs (in kg of CO_2 e/2000 kcal) were 7.2 for high meat-eaters (>100 g/d), 5.6 for medium meat-eaters (50–99 g/d), 4.7 for low meat-eaters (>0 and<50 g/d), 3.9 for fish-eaters, 3.8 for vegetarians, and 2.9 for vegans (Scarborough et al., 2014; Willet et al., 2019) (Figure 4). Thus, reducing the fraction of animal source foods in human diets can lead to benefits for both the environment and human health.

Figure 4

GHGEs per Food Group



Source: Willet et al, 2019.

Overall it has been estimated that transitioning towards more plant-based diets could reduce global mortality by 6–10 % and food-based GHGEs by 29–70 % (Springmann et al., 2016) compared to a 2050 reference scenario provided by the FAO (Alexandratos and Bruinsma, 2012; Gustavsson et al., 2011). However, significant changes in the global food system would be necessary for regional diets to match the dietary changes discussed above (Springmann et al., 2016). The EAT-Lancet Commission (2019) has provided universal scientific dietary targets with a high potential of local adaptation and scalability, which thus allow considerable flexibility to accommodate all food cultures and productions systems in the world (Willet et al., 2019).

2.2 Global agri-food market trends

Globally, agri-food systems have been dominated by three primary production and consumption trends.

a) *The rise of non-conventional agriculture and food*. Today, conventional agriculture is by far the predominant method of production in advanced and large emerging market countries. However, sustainable agriculture, usually marching under the banners of "organic farming", i. e. the production of food, fiber, or other plant or animal products using scientific farming techniques that protect the environment, public health, human communities, and animal welfare, is slowly emerging in advanced and large emerging market economies alike

as a viable alternative to conventional agriculture in response to consumers' rising demand for healthier, more humanely-raised and more environmentally-friendly-produced food (Ikerd, 2017).[4] In 2016, the global organic farming market accounted for around 58 million hectares of organic agricultural farmland, with the United States accounting for nearly half the global market – followed by Europe (nearly a third) and China (6 %) (Lernoud and Willer, 2018). Nearly 180 countries reported organic acres in 2016–1.2% of global agricultural land. The market is expected to triple in value by 2024 becoming around $320 billion worth, reflecting a global average growth rate of nearly 15 percent per year between 2017 and 2024 (ZMR, 2017; Technavio, 2019), with some market analysis predicting even faster growth (Allied Market Research, 2018). Within this, both Asia-Pacific and Europe are expected to show a significant market growth, owing to expanding organic agricultural land in these regions. Greater production of organic food responds to a sharp increase in its consumption, with demand constantly exceeding supply in most markets. Over recent years, organic products have shifted from being a lifestyle choice for a small segment of consumers to being purchased at least occasionally by many given their nutritional health benefits, non-toxicity, and tastiness as well as socio-ecological benefits, including the low environmental footprint and the greater attentiveness for animal welfare. Recent food consumption surveys reveal that, for example, in the United States over half of millennials actively try to include organic foods in their diets – a higher share than for other age groups, and that preferences for organic food are comparable across different income group levels (Gallup, 2017).

b) *Meat production is on the rise, but more people are embracing a plant-based lifestyle*. Global meat production has increased rapidly over the past 50 years, growing in total terms 4–5-fold since 1961 (Ritchie and Roser, 2017). Regionally, Asia is now the largest meat producer, accounting for around 40–45 percent of total meat production having surpassed Europe and North America that have traditionally been the dominant meat producers globally, accounting for 42 and 25 percent, respectively in the early 1960s, when Asia produced only 12 percent.[5] Looking at animals types raised for meat, main ones include poultry, cattle (which includes beef and buffalo meat), pig, and sheep and goat to a lesser extent. Across the world, cattle meat production (the most polluting) has more than doubled since 1961 – increasing from 28 million tons per year to 68 million tons in 2014. The United States is the world's largest beef and buffalo meat producer, producing 11–12 million tons in 2014. Other major producers are Brazil and China, followed by Argentina, Australia and India (Ritchie and Roser, 2017).

4 Definitions of organic farming (and its produce, organic food) can vary depending on certification requirements, but the term tends to identify agri-food production systems which exclude the use of the synthetic inputs such as fertilizers, pesticides, feed additives, and hormones, while extensively relying upon animal manures, crop rotation, crop residues, and off-farm organic waste. Organic farming also excludes genetic engineering and animal cloning, and the use of ionizing radiation; while organic food, when processed, excludes artificial preservatives, flavors, or colors. Generally, prohibited products and practices must not be used on certified organic farms for several years (usually at least three) prior to harvest of the certified organic products; livestock must be raised organically and fed 100% organic feed ingredients; certified farms are regularly inspected for compliance. As a result of this return to nature in production, organic farming provides healthy soil, healthy food, healthy plants, and organic environment. Various certified organization such as United States Department of Agriculture (USDA) have established criteria for inputs for organic farming that ascertains it to produce only organic food. In pure organic farming, the farmer uses only organic manures as fertilizers.

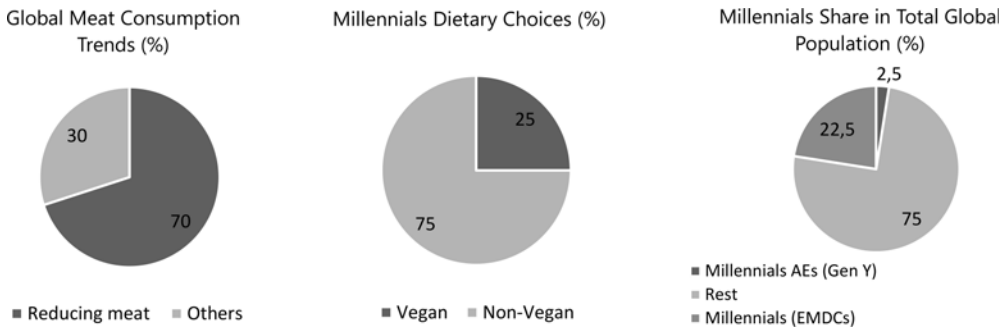
5 By 2013, Europe and North America's share had fallen to 19 and 15 percent, respectively. This reduction in production share was despite a large increase in production in absolute terms: Europe's meat output has approximately doubled over this period, whilst North American output has increased 2½-fold. Production increases in Asia, however, have been staggering: meat production has increased 15-fold since 1961. Absolute increases in production in other regions have also been substantial, with output in all regions (with exception to the Caribbean which approximately tripled) growing more than 5-fold over this period. (See Ritchie and Roser, 2017).

On the consumption front, as a global average, per capita meat consumption has increased approximately by 20 kilograms since 1961, with the global per capita average meat consumption reaching around 43 kilograms of meat in 2014 (OECD, 2018). This increase in per capita meat trends implies that total meat production has been growing at a much faster than the rate of population growth.[6] At a regional level, the average European and North American consumes nearly 80 kilograms and more than 120 kilograms, respectively. However, changes in consumption in high-income countries have been much slower – with most stagnating or even decreasing over the last 50 years. Consumption trends across Africa are varied: some countries consume as low as 10 kilograms per person, around half of the continental average, while higher-income nations, such as South Africa, consume between 60–70 kilograms per person.

Despite these secular trends, data show that a large and growing number of millennials are adopting flexitarian and meat-free diets, signaling a change in purchasing habits that is a significant shift from that of earlier generations (Figure 5). These consumers are increasingly re-

Figure 5

Global Meat Consumption Trends



Source: Ritchie and Roser, 2017; Forbes, 2018.

ducing meat intake to improve their health, a behavior typically driven by a growing awareness of a causal link between high meat consumption and some non-communicable diseases (NCDs), a finding supported by a mounting body of scientific evidence (WHO, 2004; WHO-IARC, 2015; Bouvard, 2015; Song et al., 2016; EU, 2017; WCRF-AICR, 2018; AHA, 2019, ACC/AHA, 2019, among others).[7] In contrast, consumers see health benefits in plant-based proteins, and associate

6 The direction and rate of change across countries is highly variable. Growth in per capita meat consumption has been most marked in countries who have underwent a strong economic transition – per capita consumption in China has grown approximately 15-fold since 1961; rates in Brazil have nearly quadrupled. The major exception to this pattern has been India: dominant lactovegetarian preferences mean per capita meat consumption in 2013 was almost exactly the same as in 1961 at less than 4 kilograms per person.1 Meat consumption is highest across high-income countries (with the largest meat-eaters in Australia, consuming around 116 kilograms per person in 2013). (See Ritchie and Roser, 2017).

7 A 2017 study published in the British Medical Journal linked high levels of red meat consumption to a 26 % increase risk of contracting nine NCDs, including cancer, type 2 diabetes, strokes and Alzheimer's (Etemadi et al., 2017). The World Health Organization, in a high-profile announcement, has also classified red and processed meat as carcinogenic (WHO-IARC, 2015). A 2016 University of Oxford study found that a 'healthy' diet (i. e. one containing less meat) could prevent 5.1 million deaths a year globally by 2050 (Springmann et al., 2016).

these products with positive health effects and superior nutritional value. This dietary trend is facilitated by the fact that meat-free protein products are no longer limited to the relatively narrow consumer group that identifies as vegetarian or vegan. For example, 39 % of Americans are actively trying to incorporate more plant-based foods into their diets, and millennials are driving this shift: 30 % of them eat meat alternatives every day, while 50 % eat meat alternatives a few times a week (Nielsen, 2017).

As a result, annual global sales of plant-based meat alternatives have grown on average 8 % a year since 2010. Currently, growth is about twice the rate of processed meat, with annual sales of about $2 billion (Bloomberg Intelligence, 2017). Industry estimates project that the sector globally will expand at a compound annual growth rate (CAGR) of about 8.3 % between 2017 and 2021 (Research and Markets, 2017), with the plant-based meat market reaching $5.2 billion by 2020 (Research and Markets, 2017). Longer term, it could make up a third of the market by 2050 (Lux Research, 2015).

This dietary trend is observable across different world regions. In the United States, retail sales of plant-based foods that directly replace animal products grew 8.1 % in the 12 months to August 2017 (Good Food Institute, 2017; Plant Based Foods Association, 2017; and Nielsen, 2017). This compared with a fall in sales of 0.2 % for all foods sold across American grocery stores. Plant-based cheese alternatives were the fastest-growing category, enjoying 18 % growth. Alongside, Europe is the largest market for meat substitutes, accounting for 39 % of global sales (Allied Market Research, 2016). With 8 % annual growth rates in the EU and flat consumption for traditional meat products, Rabobank's 2017 Annual Report suggested that alternative proteins could represent a third of total EU protein demand growth in the next five years (Rabobank, 2017). In Germany, one in ten consumers buy meat alternatives, rising to one in five for Germans aged between 16 and 24. A decade ago, only 1 % of Germans considered themselves vegetarians; this has risen to 7 % (Mintel, 2015). Around half of Italian consumers say they are lowering their red meat intake, while 24 % say they are increasing the amount of vegetarian processed foods in their diet (Mintel, 2017). Similarly, between 2012 and 2016, new vegetarian and vegan product launches increased by 140 % and 440 % respectively in Southeast Asia alone. The Asia–Pacific region is poised to register the highest CAGR of 6.3 % between 2017 and 2025 (Persistence Market Research, 2017).[8]

c) *The advent of agri-food technology and agri-food green technology.* The agri-food sector has a wide supply chain spanning industrials, farming, logistics, wholesale distribution, processing, retail distribution, and the consumer. In many cases, technologies such as marketplaces connect different links in the supply chain. As with all industries, technology plays a key role in the operation of the agri-food sector, but the pace of innovation has not kept up with other industries: according to the McKinsey Global Institute's Digitization Index, even in countries which are at the frontier of digitization, agriculture is the least digitized of all major sectors (McKinsey, 2015).

However, there are signs that this may be about to change: in advanced economies, the sector is slowly becoming increasingly more automated and digitized. In these countries, the digitization of agriculture is enabling new agricultural techniques, notably precision- and smart-farming that are

8 A useful illustration is the acquisition of plant-based protein producer Quorn Foods by Philippine food giant Monde Nissin. Following the deal, Monde Nissin pointed to the fact that the meat alternatives market is currently concentrated in Europe and North America while Asia, currently lagging behind with a market share of just 12 % to 15 %, offers significant growth opportunities for investors.

in turn based on novel combinations of robotic technology, innovative agricultural designs and big data reporting to increase efficiency (Rotz et al., 2019). Output from data collection and algorithms is integrated with platform technology like customized software-as-a-service (SaaS) solutions to better manage crops and businesses; wireless technology also is playing a larger role allowing to perform monitoring and evaluation using smartphones and tablets; while Radio Frequency Identification (RFID) and similar wireless technologies are being used for agricultural tracking and security.

In the developing world, digital technologies are timidly but successfully emerging as a way to overcome information problems that hinder market access for many small-scale farmers, increase knowledge through new ways of providing extension services, and provide novel ways for improving agricultural supply chain management. Examples are still scant but are proliferating, and include: (i) app-based e-commerce platform to share real-time information about surplus and demand in order to reduce food waste and support local farmers' income; (ii) holistic agricultural approaches that increase income while supporting sustainability; (iii) data monitoring and satellite imaging to create vegetation maps that provide information used to help protect and restore the local farmlands; (iv) affordable sun-powered irrigation systems to empower farmers to take charge of their crops even during droughts; and (v) methods combining agriculture and aquaculture to create food systems that are more productive and sustainable. Although there are many promising examples beyond these of "digital dividends" for rural livelihoods in these countries, often these have not scaled up to the extent expected. The main reason is that technology can only address some, but not all, of the barriers faced by farmers in the poorer countries (Deichman et al., 2016).

Crucially, both advanced and less-advanced countries have also witnessed the emergence of climate technologies and practices that, beyond helping make agricultural and food systems more efficient, also make agriculture, forestry and fisheries more sustainable. These include technologies to expand biomass energy production from energy crop and agri-food wastes, manure management, renewable energy-based farming systems, solar/wind powered water pumping, drip irrigation, innovative greenhouse technologies, and efficient field machinery, among others (see, for example, EBRD-FAO, 2017).

More specifically, among key agri-food and green-agri-food tech areas of innovation, upstream areas of innovation include: (i) agricultural biotechnology (like on-farm inputs for crop and animal agriculture including genetics, microbiome, breeding, animal health); (ii) farm management software (such as sensing and Internet of things – 'IoT' – agricultural data capturing devices, decision support software, big data analytics); (iii) farm robotics, mechanization and equipment (like on-farm machinery, automation, drone manufacturers, grow equipment); (iv) bioenergy and biomaterials (such as non-food extraction & processing, feedstock technology, cannabis pharmaceuticals); (v) novel farming systems (like indoor farms, aquaculture, insect, and algae production); (vi) supply chain technologies (such as food safety and traceability technologies, logistics and transport, processing technologies); (vii) agribusiness marketplaces (like commodities trading platforms, online input procurement, equipment leasing); (viii) innovative food (like cultured meat, novel ingredients, plant-based proteins). Downstream areas of innovation instead include: (a) in-store retail and restaurant technologies (like shelf-stacking robots, 3D food printers, POS systems, food waste monitoring IoT); (b) restaurant marketplaces (e. g. online tech platforms delivering food from a wide range of vendors); (c) e-grocery: online stores and marketplaces for sale and delivery of processed and un-processed agricultural products to consumer; (d) home and cooking technologies (like smart kitchen appliances, nutrition technologies, food testing devices); (e) online restaurants

and meal kits (including startups offering culinary meals and sending pre-portioned ingredients to cook at home). Crucially, some of these areas of innovations coincide with emerging technology innovations areas identified by a World Economic Forum-McKinsey report on levers for a successful global food system transformation that have the potential to drive rapid progress in the sustainability, inclusivity, efficiency and health impacts of food systems to achieve the Sustainable Development Goals (WEF-McKinsey, 2018).

3 Agri-food financial trends and the role of private, non-bank green finance

Agri-food's profound and continuous transformation over the past decades has encompassed more than just a progressive shift in agricultural methods, types of crops and animals farmed, or technological advances: one of its major directions and determinants of change involves the revolution observed in agricultural finance.

Below, two avenues of change in agri-food finance are examined: (a) the progressive involvement of non-commercial actors in the financing of agri-food production and sales, and, more recently, (b) the emergence and rapid evolution of "green" agri-food finance. Understanding the mechanisms through which financial entities can penetrate and reshape agri-food industries is key to identify public policy measures to promote financial practices that are compatible and/or conducive to sustainable farming outcomes and can thus support a fast and durable global Great Food Transformation.

3.1 The financialization of agri-food

Since the onset of the 'supermarket revolution' in the early 1990s, the agri-food sector has become increasingly 'financialized' (Reardon et al., 2009; Burch and Lawrence, 2009; Isakson, 2014; Bjørkhaug, Lawrence, and Magnan, 2018) and several overarching trends have emerged in agri-food financial development by looking at key nodes in the agri-food supply chain.

First, the line between finance and food provisioning has become increasingly blurred in recent decades, with financial actors taking a growing interest in food and agriculture and agri-food enterprises becoming increasingly involved in financial activities. For decades, agriculture was considered a poor investment and it was rare for institutional investors to be interested in land or food production. Yet, this slowly began to change in the mid-2000s in many countries of the world, as investors started cobbling together agricultural portfolios by buying farm properties and other agricultural assets. Traditionally considered exotic, investment in "farmland assets" has picked up steam thanks to improved economic conditions globally, numerous new investment models, the advent of farmland investment experts and boosters, and the rising influence of benchmarking tools like the "farmland index" (Conrad, 2018). This resulted in a range of investors including hedge funds, pension funds, sovereign wealth funds, other institutional money managers, and wealthy individuals acquiring large tracts of farmland domestically or abroad (Fairbairn, 2014), with important implications for the way in which agri-food systems and rural economies are being transformed around the world given the significant divergencies among investors on tolerance for risk, time horizons and investment strategies (Sippel, 2015). Such "land-grab" movement was accompanied by a parallel financialization of food commodity trade with the introduction of multiple financial innovations, such as commodity index funds (CIFs), as well as a massive expansion of financial firms' involvement in this trade throughout the 1990s and 2000s, thanks to a

systematic deregulation that exempted from regulatory oversight firms selling "over the counter" derivatives in commodity exchanges (Clapp, 2016).

Second, financialization has led to a greater market concentration of agri-food corporations, by enabling a seamless integration of food supply chains around the globe with funds levered across the whole global financial market. A 2017 report from The International Panel of Experts on Sustainable Food Systems (IPES) indicated that, as a result of this, agri-food mega-mergers sparked an unprecedented consolidation in seed, agri-chemical fertilizer, animal genetics and farm machinery industries while creating ever-bigger players in the processing and retail sectors across human food systems. This consolidation, the report argued, only reinforces the logic of the industrial food and farming model and its widespread social, environmental, and economic fallout rather than leading food systems towards sustainability because these mergers enable firms to pool their economic and political capital, reinforcing their ability to influence decision-making at national and international levels. According to the report, dominant firms have become too big to feed humanity sustainably, too big to operate on equitable terms with other food system actors, and too big to drive the types of innovation needed. It is estimated that merger deals struck in the 2015–2018 period alone will place as much as 70 percent of the agro-chemical industry in the hands of only three companies, thus cornering 60 percent of the global seeds industry and 75 percent of the pesticides market. This consolidation across the agri-food sector has made the world's 570 million farms – of which 30 percent are large-scale farms and 70 percent are smallholders – increasingly more reliant on a handful of suppliers and buyers, squeezing their incomes and eroding farming choices on what to grow, how to grow it and for whom (IPES, 2017).

Third, financialization reinforced the position of food retailers as dominant actors within the agri-food system, which is now globally in the hands of a few dominant retail chains, though they are largely subject to the dictates of finance capital and face renewed competition from financialized commodity traders (Burch and Lawrence, 2013). Food retailers have obtained a favorable position as a result of their proximity to the customer; the development of a new form of retail company that is characterized by the full control of the product chain – from farm to shelf; the development of a kind of competition based not only on price but also on quality of products (Konefal et al., 2005); and the greater internationalization and consolidation of retailer chains outsourcing globally (Trienekens and Zuurbier, 2008). Due to their position and control within the global economy, retailers have gained the capacity to adopt, implement, and enforce private retail standards which have important implications and effects on environmental – in addition to social, governance, and economic – sustainability of the global agri-food system (Rossignoli and Moruzzo, 2014).

Fourth, financialization has intensified global competition among food workers, imparting a downward trend in real wages and raising the marginal probability of unemployment relative to other economic sectors, while a large number of small-scale farmers have disappeared reflecting increasing farmland concentration (see ILO 2018/19; and see Eurostat, 2018, and USDA, 2018, for advanced economy country examples).

3.2 Old roots, green shoots: the "greening" of agri-food finance

In conjunction with the general financialization of the sector, four specific additional trends have accompanied the sector's financial development in response to emerging changes in the demand and supply of more sustainable food production and consumption and accompanying advances in "green" agricultural technology.

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a) *Non-conventional agri-food investing*

Multiple recent studies suggest that non-conventional agriculture is 3–6 times more profitable than conventional agriculture even receiving smaller or no subsidies relative to conventional farming (Crowder and Reganold, 2015; Rodale Institute, 2015).[9] Part of the competitive edge of non-conventional farming comes from the premium price – driven by consumer demand – that organic farmers can get for their products which consumers consider more healthy and tasteful. Several comparative studies find that, even when profits are adjusted for 50 per cent of the current organic premium, organic agriculture still comes out ahead of conventional agriculture because of a series of additional advantages. To begin with, organic agriculture not just delivers better quality but produces similar or larger quantities than conventional agriculture, since it is more resilient to climate volatility.[10] Second, organic agriculture implies lower input costs that conventional agriculture, being less dependent on fossil fuels as well as on expensive inputs like pesticides or herbicides, water, and associated annual loans, which make it less vulnerable to financial market fluctuations even in the face of more field operations (Delbridge et al., 2011). Third, organic agriculture is a low-waste system and uses less land for the same profit. Fourth, in contrast to conventional agriculture, farms engaging in organic agriculture also accumulate "natural capital" – an array of farming byproduct with economic value from ecosystem services and resources and that increase the value of the farmland. These include soil enrichment, implying that soil can sequester considerable amounts of carbon; greater soil water retention, which can improve yields by 40 percent during droughts providing a natural insurance against climate volatility; biodiversity, which via the organic diverse crop system means a succession of blooms that can feed insect populations (and provide them with habitat) year-round. These beneficial insects help to keep down populations of harmful insects, reducing or eliminating the need for pesticides, and providing pollination services to increase harvest yields; as well as genetic diversity on organic vegetable and seed farms, which acts as a well-endowed gene bank for potential new varieties that will be resilient against future environmental changes, insect populations, and diseases.

Organic premia and additional economic advantages have attracted considerable capital over the past decade or so and, as a result, the organic market is going through a simultaneous process of expansion and concentration. Globally, the market, which is about ½ US-owned and operated, is dominated by 15–20 top players and is seeing an increasing collaboration between farmers and top food brands (Cernansky, 2019). By securing demand, this collaboration allows farmers to at least partially overcome the financial constraints and lessen the initial economic risks of venturing in non-conventional methods of production, especially in the years when the new organic crops or animal breeds are established (Cernansky, 2018).

9 Crowder and Reganold (2015) analyzed the financial performance of organic and conventional agriculture from 40 years of studies covering 55 crops grown on five continents. When actual organic premiums were applied, organic agriculture was significantly more profitable (22–35 %) and had higher benefit/cost ratios (20–24 %) than conventional agriculture. Although premiums were 29–32 %, break-even premiums necessary for organic profits to match conventional profits were only 5–7%, even with organic yields being 10–18 % lower. Total costs were not significantly different, but labor costs were significantly higher (7–13 %) with organic farming practices.

10 Results from 30-year side-by-side comparisons of conventional and organic farming methods at the Rodale Institute in Pennsylvania showed that, contrary to conventional wisdom, organic farming can outperform conventional farming in every measure, in this case in the United States. The Rodale trials show that after a three-year transition period, organic yields equaled conventional yields. What is more, the study showed that organic crops were more resilient. Organic corn yields were 31 percent higher than conventional crops in years of drought, for example. Drought-year yields for organic crops are remarkable when compared to genetically modified (GM) "drought tolerant" varieties, which showed increases of only 6.7 percent to 13.3 percent over conventional (non-drought resistant) varieties. This is of particular interest considering that climate change is likely to bring drier conditions in many areas.

Whether organic agriculture can continue to expand will likely be determined by how much the choice to go organic by farmers becomes less complicated and risky, and by the removal or becoming less binding of those barriers that currently prevent many farmers from switching. Several financial constraints from switching to organic farming – similar across world regions – can be identified. First, relative to conventional farming, organic farming requires both different equipment and other costly up-front investments and more labor, mainly to tackle weeds. Second, during the initial years, organic farming may produce reduced yields. Third, most nationally-recognized organic certifications require crop rotation, which limits the crops farmers can produce in a given year, whereas a conventional producer can select a crop that appears to be most profitable that year and plant it. Likewise, agricultural infrastructure – for example grain storage facilities and transportation networks – is designed for conventional crops; organic farmers need to tap into a different market structure. At the same time, funding for organic research pales in comparison to conventional support, which means organic farmers have fewer tools available to them, such as improved crop varieties and strategies for battling weeds or disease, as well as fewer experts to consult.[11] Finally, the transition period to organic farming itself can be a money-losing proposition. Farmers need to keep their land free of most chemicals for a full three years before they can be certified as organic, which implies that during the transition farmers are basically farming organically but cannot get the premium. To overcome this financial hurdle, in recent years some large organic companies/brands have launched "certified transitional" initiatives, which formally certify when a farmer is undergoing a shift to organic methods and secures them at least a limited premium to help get through those initial years (Cernansky, 2019).

b) Plant-based investing

In recent years, fossil-fuel-free investing has become an important response from investors of all sizes to growing awareness of the need to bring the fossil-fuel age to a close. As people take action to address the climate crisis, concerns about the climate impacts of food systems and the benefits of a plant-based diet are also increasingly coming to the fore. Against this background, protein diversification is increasingly recognized by institutional investors and individual investors as a relevant "SRI" (Socially-Responsible Investing), "impact investing," "green investing," or "ESG" (Environmental, Social, and Governance) theme; in this sense, the ESG is the investment communities equivalent to corporate social responsibility: not only is this intrinsically linked to multiple social and environmental issues, but it also helps investors improve their portfolio performance against the Sustainable Development Goals (SDGs). Socially-responsible investing strategies continue to evolve to reflect new concerns and heightened values that investors seek to integrate with their investment decisions.

In practice, plant-based investing is an approach that encompasses positive and negative investment screens, i. e., the criteria for including or excluding specific investments in a portfolio: as a result, plant-based investors can build portfolios that reflect their ethical choices (climate mitigation, animal welfare, biodiversity, conservation, etc.). Other investors may be interested because they may be able to mitigate risk in their investments by supporting companies building more resilient supply chains and actively positioning themselves to grow in the green economy.

11 A US-based study of 1,800 farmers transitioning to organic agriculture pointed to mentoring and one-on-one technical assistance as both critical and hard to come by (see Cernansky, 2019).

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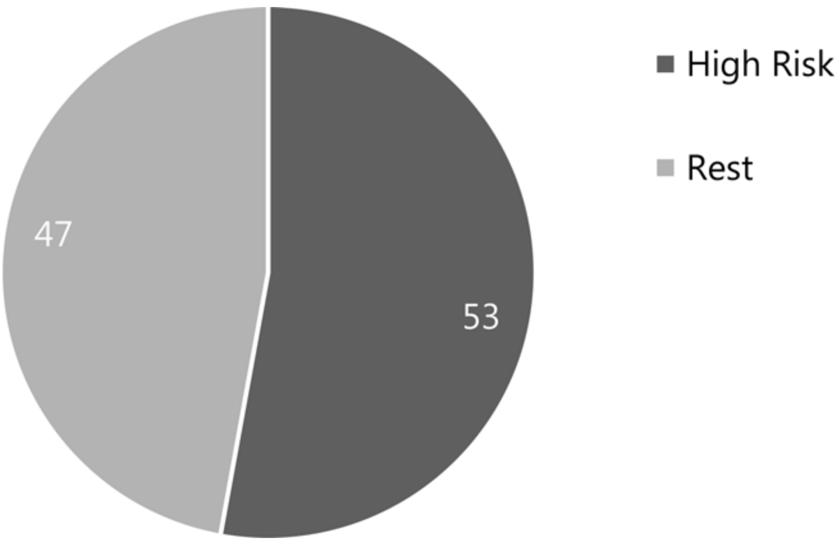
With the aim of supporting the development of plant-based investment, the Farm Animal Investment Risk and Return (FAIRR), a collaborative investor network, has launched an initiative to begin benchmarking industries intensive livestock and fish farming impact on environmental, social and governance issues (FAIRR, 2018).[12] To this end, FAIRR has developed an index, the "Coller FAIRR Protein Producer Index", that analyzes the largest global meat, dairy and aquaculture producers by combining nine environmental, social and governance (ESG) risk factors with the Sustainable Development Goals (SDGs). The index assesses 60 of the largest livestock and aquaculture companies, with a combined market cap of close to $300bn, on behalf of the world's largest investors. With ESG policies having rapidly become a vital part of investors' toolkits, and emerging demand in United States and Europe for alternatives to animal proteins,[13] it is significant that the financial industry now has access to the first ever index to look holistically at the animal protein sector through the lens of ESG issues.

The first set of results for the Coller FAIRR Index show the vast risks and opportunities that are building in this area. Key results of FAIRR analysis using this index are: (1) 60 % of companies, worth $152 billion, are ranked 'high risk' on overall management of sustainability (Figure 6);

Figure 6

High ESG Risk Companies in Coller FAIRR Index (in percent of total index capitalization)



Source: FAIRR, 2018.

12 FAIRR's (2018) "Plant-Based Profits: Investment Risks and Opportunities in Sustainable Food Systems" examines the market opportunity, innovation potential, and ESG (environmental, social and governance) impacts of protein diversification.

13 Rabobank estimates that the strong and persistent drivers supporting the current growth of alternative proteins will continue over the medium term. Alternative proteins have the potential to capture a material share of animal protein demand growth in the EU and capture more market share in the United States and Canada. (Rabobank, 2018).

(2) 77% of companies, worth $240 billion, are ranked 'high risk' on antibiotics management – the most poorly managed of all sustainability risk factors; (3) 43% of companies, worth $100 billion, are ranked 'low risk' on waste and pollution management – the best managed of all sustainability risk factor; (4) 5/60 Index companies currently account for the alternative proteins sector (FAIRR, 2018).

Other key findings from the Coller FAIRR Protein Producer Index include (FAIRR, 2018): (a) aquaculture producers lead the animal proteins sector in the quality of their reporting of critical sustainability issues. Three Europe-based firms have been identified as displaying the best management and disclosure across all eight risk factors; (b) antibiotics mismanagement is the most poorly addressed risk, in an industry that is the primary global consumer of medically important antibiotics. Despite increasingly urgent calls for the sector to phase out the use of medically important antibiotics – 46 companies worth a combined $240bn have no policies or process in place to eliminate the routine use of antibiotics; (c) reporting and management of greenhouse gas emissions is inadequate, unstandardized and unverified across the animal protein sector. Although the livestock sector contributes nearly 14.5% of global greenhouse gas emissions[14] over 72% of Index companies showed poor or no reporting on this issue; (d) waste and pollution is the best managed risk factor with 43% of Index companies ranking as 'low risk' on this risk factor. However, despite increasing potential for community advocacy and litigation should animal waste pollute local water sources or the wider environment, only around a quarter of the terrestrial companies specifically referenced their management of animal waste; (e) only 35% of Index companies report on water use from their operations. This is a concern as agriculture accounts for 92% of global freshwater use, nearly one-third of which is for animal agriculture. 82% of Index companies do not impose any specific requirements for suppliers on water use and management; (f) only five of the 60 companies are prepared to capitalize on opportunities in the rapidly growing alternative (non-meat or dairy) proteins sector. The alternative protein market is expected to reach $5.2 billion by 2020.

Reflecting availability of new information to help navigate the industry's ESG scores as well as growing investors' demand for sustainable food from improved awareness of ESG impacts linked to intensive food production, and, finally, accelerated innovation in food technology, plant-based investing totaled $8.7 trillion in assets under professional management in the United States alone as of 2016, according to the Forum for Sustainable and Responsible Investing (FSRI, 2018. See also Green America's Green Business Network, 2019).

Multiple financial instruments are available for plant-based investing. On the equity side, custom stock mixes or exchange traded funds seemed preferred options, but some investors have resorted to mutual funds managed by leaders in animal or cruelty-free investing like, primarily, portfolio managers who have signed onto the FAIRR initiative.[15] Another way to support plant-based investing is by investing in fund companies engaged in shareholder advocacy on this topic.[16]

14 According to FAO (2013). But prominent research by the World Bank Group questions these calculations, indicating that emissions from livestock account for a much higher share of total GHGEs when breathing and a better accounting for misallocated GHGEs to other sectors is accounted for. See Goodland and Ahnang, 2009.

15 Organizations that have joined the FAIRR initiative – now representing $4.1 trillion in assets – acknowledge the risk associated with factory farming.

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In terms of returns, investing using ESG ratings has been shown to reduce risk and offer tangible financial advantages relative to unscreened investments (CSSP-South Pole Carbon Asset Management, 2016; Gregory, 2017; In et al., 2019; Gorte, 2019; Bloomberg Intelligence, 2019), promising a physiological increase in investment bias toward those products.

c) Alternative-protein technologies investing

One parallel evolution of the shift-to-plant-based-protein movement is the recent invention and development of "clean meat".[17] Clean meat is meat produced by in vitro cultivation of animal cells, instead of from slaughtered animals (Datar, 2010) – a form of cellular agriculture that has been shown to generate 90 % less GHGEs, to require 46 % less energy, and to have over 99 % less impact on water scarcity and 93 % less impact on land use than conventional animal agriculture for comparable unit of output.[18] Cultured meat is produced using many of the same tissue engineering techniques traditionally used in regenerative medicine (Post, 2012 and 2013). The concept of clean or cultured meat was popularized by Jason Matheny in the early 2000 s after co-authoring a seminal paper (Edelman et al., 2005) on cultured meat production and creating New Harvest, the world's first non-profit organization dedicated to supporting in vitro meat research (Schonwald, 2009). In 2013, Mark Post, professor at Maastricht University, was the first to showcase a proof-of-concept for in-vitro lab grown meat by creating the first lab-grown burger patty. Since then, several cultured meat prototypes have gained media attention: however, because of limited dedicated research activities, cultured meat has not yet been commercialized, although some companies plan to bring cultured meat to the market by 2021. In addition, it has yet to be seen whether consumers will accept cultured meat as meat (Bekker et al., 2017), although a recent comprehensive global study has found high levels of acceptance of clean meat in the three most populous countries worldwide, and with even higher levels of acceptance in China (62 %) and India (63 %) compared to the United States (33 %) (Bryant et al., 2019) (Figure 7).[19] These results underline the importance of clean meat producers exploring new markets for their products, especially as meat consumption in developing countries continues to rise. On the production front, the process still has much room for im-

16 Green Century, for example, filed the first and only shareholder resolution on the opportunities associated with plant-based protein, with Tyson Foods in 2016. Following the proposal, Tyson took an ownership stake in Beyond Meat, a leading plant-based protein company, launched a $150M venture capital fund focused on exploring alternative protein innovations, and has become a vocal proponent of the plant-based industry.

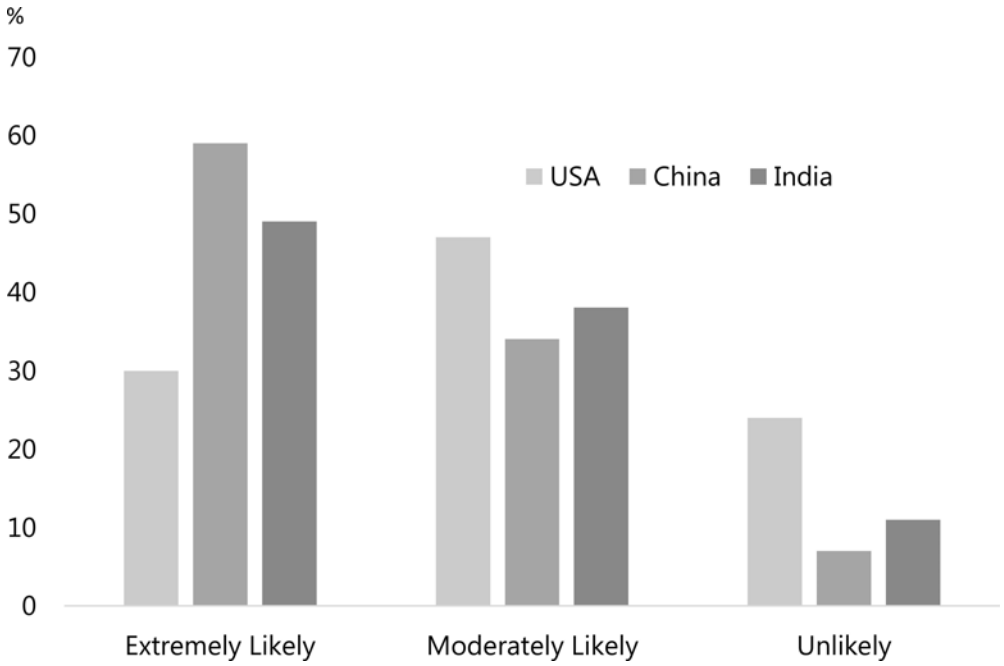
17 Besides clean meat, the terms in vitro meat, vat-grown, lab-grown meat, cell-based meat, cultured meat, and synthetic meat have all been used by various outlets to describe the product. Clean meat is an alternative term that is preferred by some journalists, advocates, and organizations that support the technology. According to the Good Food Institute, the name better reflects the production and benefits of the meat and surpassed "cultured" and "in vitro" in media mentions as well as Google searches.

18 The theoretical possibility of growing meat in an industrial setting has long captured the public imagination. Winston Churchill suggested in 1931: "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium."

19 Bryant et al., 2019, ran one-way ANOVAs (analyses of variance) to compare the different countries surveyed on measures of (a) likelihood of purchasing clean meat, (b) likelihood of purchasing plant-based meat, (c) food neophobia, and (d) meat attachment. All of these variables were measured on a 1–5 scale, where 5 represents higher purchase likelihood, higher food neophobia, and higher meat attachment. Measures of behavioral intentions toward clean and plant-based meat were adapted from Wilks and Phillips 2017, p. 6), and modified to address common concerns about product availability and taste. Participants answered these questions about how likely they were to try, purchase regularly, eat in place of conventional meat, and pay more for clean and plant-based meat on a 5-point Likert scale, ranging from 1 (not at all likely) to 5 (extremely likely). The Food Neophobia Scale employed to control for aversion to novel, non-traditional food contained minor modifications from the original measure (Pliner and Hobden, 1992), asking about "foods from other countries" rather than "ethnic foods" to make it more relevant to participants in India and China.

Figure 7

Clean Meat Purchase Likelihood by Country



Source: Bryant et al, 2019.

provement, but it has advanced in most recent years, leading up to a first successful trial in 2013 and a progressive abatement of cost per kilogram of clean meat, under various companies.

The potential for rapid scale up and cost reduction in the production of clean meat, alongside the clear benefits from a prospective health, environmental, cultural, and economic impact's perspective, makes an attractive case for investment. Plant-based meat companies that are near competitors to clean meat companies and have already hit the markets, have announced significant investment rounds from venture capital investors in the past year. Impossible Foods is the most highly funded, with $258 million in disclosed financing since its founding in 2013, most recently $75 million in August 2017. Beyond Meat follows with almost $50 million in disclosed funding to date. Earlier stage companies focused on fermentation and cell culture technologies also raised meaningful amounts over the past year, with Memphis Meats announcing their $17 million Series A in August 2017. Strikingly, it is notable the mainstream investment interest in these companies with large conventional players from Tyson Foods and Cargill to Singaporean sovereign wealth fund Temasek and UBS.

Similar progress is being made in the market for vegetable eggs, that embraces (mostly U.S.) companies both reproducing egg proteins through yeast laboratories – along the lines of meat in vitro meat production – and companies that have developed egg-like products using plant proteins. The former group includes primarily, Clara Foods, a U.S. start-up which has made an agreement of

over $20 million with Ingredion, an important supplier of ingredients. Clara, part of the IndieBio biotech accelerator, is about to launch "the most soluble protein in the world" on the market, through an innovative production process that involves the use of DNA that codes certain proteins, that then exploits yeast as a protein factory to produce the protein in series. The company has successfully recreated three of the 80 chicken egg proteins and plans to launch a tasteless egg protein that can be used in beverages and food and another egg protein in 2020 that froths, especially useful for baked goods. The latter group includes companies like Just Inc., probably the dominant actor in this market – a billion-dollar company that launched Just Egg at the end of 2018, an egg substitute based on green bean sprout or mung bean proteins; as well as California-based Follow Your Heart, which launched VeganEgg in 2015 (a powdered egg originally made from algae, which is then replaced by soy powder), Spero, a Bay Area startup that produces liquid eggs obtained from pumpkin seed proteins, and Conagra, which is developing a liquid vegetable egg to be marketed under its own Earth Balance brand.

d) Agri-food tech investing

Agri-food tech investing is the small but growing segment of the startup and venture capital universe that is aiming to improve or disrupt the global food and agriculture industry. Financial experts have long posited that agriculture was headed for the "pharma model" of innovation, where large, entrenched players use acquisition as the primary mode of obtaining new technologies. However, so far, the large agribusinesses have been busier consolidating with smaller non-technologically innovating peers horizontally and vertically through M&A than with innovators. By contrast, agri-food tech is attracting a diverse range of investors that are mostly interested in the innovation technology aspects of the agri-food tech revolution, as these are not simply changing agriculture and food production (see Section III), bringing in more transparency and new products as well as shortening supply chains: they are also offering mega investors and sovereign wealth funds a road map they recognize from other industries that have also been transformed by technology.

In general, funding for agri-food tech startups seems characterized by large deals as the sector continued to mature and some large, international, non-agribusiness investors placed bets. The wide interest in this segment and its economic and financial potential coupled with the falling cost of available technology – from data processing to artificial intelligence and storage – has provided start-ups with a financial foundation to grow their operations, attract executives from a wide range of sectors, including Silicon Valley, and eventually look to float on the public markets.[20] The size of these funding rounds and the nature of the investors – which include private equity capital – indicate the intention to build stand-alone businesses with no plans for acquisition by the majors. Alongside, the number of unique investors participating in agri-food tech deals is increasing steadily and at a rapid rate on a year-on-year basis (growing, for example, in 2017 to 1487 from 670 in 2016), with a visible recent uptick in participation from notable sovereign wealth funds and mega-funds from outside the United States. Reflecting these trends, in 2017 agri-food tech financing increased by 29 % year-over-year, in line with global trends, recovering from a dip in funding the previous year that occurred in 2016 that, in turn, reflected a 10 % drop in the overall global venture capital markets in that year.

20 Silicon Valley VCs GV (Google Ventures), Sequoia Capital, Khosla Ventures and Andreesen Horowitz among others showed an increased interest in agri-food tech investments in 2017. GV alone participated in nine deals.

From a geographic point of view, agri-food startups raised funding in 59 countries globally, with the United States continuing to dominate the overall deal count with 42 % of deal activity and 45 % of deal volume (Agritech Funder, 2019). This is unsurprising with a robust startup ecosystem and an increasing amount of early stage support for agri-food entrepreneurs in the form of accelerators, incubators, pitch competitions and more. The investors' and startups' bases are also expanding well beyond the U.S. market, as several developing countries are stoking early-stage innovation through new accelerators and funds. Notably, Latin America – a region with some of the world's largest agriculture industries – is starting to catch up with its overseas counterparts, particularly in Brazil and Argentina, where SP Ventures and NXTP Labs were among the most active farm tech investors in 2017,[21] and, while agri-food tech investments can be slow to mimic global venture trends, several fintech and agri-food tech startups are expected to join forces in the region through multiple future Brazilian agri-food tech deals. Globally, a stronger connection between China and Latin America may also be beneficial to agri-food tech startups, as other countries – including Israel, Australia, and Ireland – are on an upward trajectory in terms of deal count.

Looking at agri-food tech investment categories, several trends are apparent. As consumers around the world become accustomed to buying food online, e-commerce continues to be a prominent force in agri-food tech investment despite having more startup casualties than most.[22] Farm technology (a segment of the sector that captures the companies with technologies in use exclusively on farms), which attract about ¼ of total agri-food tech funding volume, is another important and growing subset of the agri-food tech landscape. Agricultural biotechnology continues to boast some very large deals demonstrating the appeal of the diversity within this category that goes far beyond crop inputs and seeds to, for example, genetically-modified seafood and animal feed. At the same time, increasing demand for transparency, traceability, efficiency and safe food drives much of the innovation taking place in the midstream category (post-farm gate/pre-consumer) and investment in midstream technologies startups is growing strongly and consistently in recent years.[23] Agribusiness marketplaces, which includes startups like the novel Farmers Business Network (FBN) in the United States and Maihuolang in China,[24] is becoming one of the best funded sectors as is novel farming systems, which includes startups specializing in a variety of novel techniques, e. g. indoor vegetable farming, and insect or cannabis farming. By contrast, in-store retail and restaurant technologies continue to exhibit modest growth, and the subsector has accelerated by a mere 3 percent in 2017.

21 In 2017, Brazil's SP Ventures made six investments, while Argentina's NXTP Labs, an accelerator VC, made eight. This trend moved in line with overall venture capital figures; KPMG (2019) indicated Brazil's VC ecosystem grew 47% in 2017 to close $575 million in investment overall, with strong activity in fintech.

22 Ecommerce raised $2.4 billion in 2017 – up 96% from 2016. Chinese e-grocers dominate this list not only in funding, but in number.

23 Investment in midstream technologies rose by around 30% in 2017.

24 Maihuolang is a Chinese e-commerce platform for agriculture products that is focused on rural communities. Specifically, the company's platform offers agricultural specialty foods, agricultural supplies, electric motorbikes and parts, and household appliances via its website, mobile application and official account on Tencent which focused on rural communities, enabling consumers by providing professional services for rural e-commerce and serving the vast rural user community. It has raised a total of $150M in funding from Shenzhen Weiji Investment Company, Shenzhen New Industry Venture Capital and Qianhai Great Wall Fund Administration over a single Series A round in early 2017.

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4 Agricultural bank lenders and sustainability: the case of Rabobank and Crédit Agricole

While private non-bank finance in plant-based and agri-food tech startups is rapidly expanding, largely on the back of interest of venture capitalists favoring innovation technologies and/or ethical investors (see Section III), more traditional banking sector players face substantial difficulties in providing the solutions needed by farmers to change to more sustainable practices.

Long-term investments are often needed to make changes to key areas, such as irrigation, replanting, soil quality, forest and ecosystem protection/nature inclusive agriculture, new farm equipment or training. Almost all banks, irrespective of their mandate, perceive the risks attached to these investments to be too high, and regard the required loan tenors too big a step to comply with prudent and increasingly stringent banking regulations. While such perceptions are sometimes based on a lack of knowledge and experience of the agricultural sector, particularly in organic markets as well as developing countries and emerging markets, other factors also come into play. This leads to the agricultural sector aiming to transition to sustainability having access to limited banking finance, leaving small farmers, in particular, clearly underserved.

Very few banks in the advanced world deviate from this norm. Two of the most prominent ones are Rabobank, in the Netherlands, and Crédit Agricole in France. The business characteristics, financing tools and profitability profiles of these banks are sketched below, lending support to the view that financing sustainable agriculture can be as safe and lucrative as lending to other sectors.

4.1 Rabobank

Coöperatieve Rabobank U.A. – a Dutch multinational banking and financial services company – is the second-largest bank in the Netherlands in terms of total assets as well as a global leader in food and agriculture financing. It offers sustainability-oriented banking across all major food chains and is currently active in 40 countries, with 389 foreign places of business. Rooted in agriculture, Rabobank is set up as a federation of local credit unions, which offer services to the local markets.[25] Today, the group comprises 129 independent local banks, a central organization (Rabobank Nederland), and a large number of specialized international offices and subsidiaries. Rabobank Group is among the 50 largest financial institutions in the world with total assets amounting to $723 billion,[26] with a net income of $10.3 billion and a fully-loaded Tier 1 capital ratio of 16 % (650bp above P2R) in December 2018.[27] Global Finance ranks Rabobank 23rd in its 2018 survey of Europe's safest banks and 30th safest commercial bank in the world.

Rabobank's defining characteristic is social responsibility: in addition to being one of the largest and profitable banks in the Netherlands, Rabobank is committed to be a leading bank in the field of food and agriculture worldwide. Embracing the "Growing a Better World Together" mission, as well as the "Banking for Food" strategy for its international activities, the bank is continuously exploring ways to support its clients in food and agriculture value chains to change to more sustainable

25 The central organization is a subsidiary of local branches—not the parent, as is the case with most banks.

26 Asset figures from Fitch, Moody's, and company reports. Ratings valid as of Aug. 17, 2018.

27 Rabobank, 2018, Annual Report.

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practices, and also aims to strengthen food chains by optimization and financing, by taking part in initiatives for sustainable food security, by stimulating public debate and by contributing to the innovation financing that is necessary. Its large client base and international knowledge networks are considered strong assets in sourcing viable and impactful transition projects.

Today, Rabobank has around €98 billion outstanding in loans to businesses for crop finance, dairy and livestock financing, equipment loans, equipment leasing, real estate financing, and clean energy financing. Almost half of this total relates to the Netherlands, while the rest relates to food and agricultural customers outside the Netherlands.[28] In Africa, Rabo Development has alliances with banks that play an important part in their country in the development of agriculture. And in Africa and Asia, Rabobank Foundation supports the development of food production for people's own families towards production for the market, for instance by means of microcredit.

The banks' main agri-food lending and research activities are five: (1) Wholesale Banking, serving Dutch and international large corporates, commodity traders, private equity firms and financial institutions; (2) Trade and Commodity Finance, supporting Rabobank's largest international clients (including 17 of the top 20 global dairy farms and 18 of the top 25 top beverage manufacturers); (3) Rabo Research Food and Agribusiness, providing the bank's clients with tailored research and news on the latest market developments; (4) Rabo Loss and Waste Hub, helping the bank's clients turn food waste/loss into revenue (Rabobank is part of "Champions 12.3", a coalition of multinationals, NGOs, governments and activists that aims to halve food waste by 2030); and (5) "Kickstart" Initiatives (e.g. Kickstart Stability, Kickstart Nutrition, Kickstart Food Programme, etc.) helping accelerate the transition to a sustainable food supply, often partnering with like-minded businesses, representatives of civic society organizations and international governmental organizations like the United Nations Food and Agriculture Organization (FAO) and UN Environment, with which it has recently launched a $1 billion fund (AgriFund3) dedicated to accelerating forest conservation and sustainable agriculture.[29]

4.2 Crédit Agricole

Crédit Agricole Group, sometimes called "the green bank" ("la banque verte"), due to its historical ties to farming, is the world's largest cooperative financial institution. It consists of a network of Crédit Agricole local banks, the 39 Crédit Agricole regional banks and a central institute Crédit Agricole S.A.. Crédit Agricole, which in 1990 became an international full-service banking group, is the 11th largest financial institution in the world with total assets amounting to $2,114 billion,[30] with a net income of $7.7 billion and a fully-loaded CET1 ratio 15.0% (550bp above P2R) in December 2018. Global Finance ranks Crédit Agricole 30th in its 2018 survey of Europe's safest banks and 46th safest commercial bank in the world.

28 DLL, Rabobank's leasing operation, has a substantial lease portfolio in food and agriculture.

29 Rabobank recently joined the World Business Council for Sustainable Development (WBCSD) as part of its Banking for Food strategy. Aim of this membership is to step up our efforts to enable farmers to produce more efficiently and more sustainably and to strengthen food value chains. Rabobank will take up the chair of the Climate Smart Agriculture Finance Working Group to contribute to its ambition statement to make 50% more food available and reduce agricultural and land-use greenhouse gas emissions from commercial agriculture by 50% in 2030.

30 Asset figures from Fitch, Moody's, and company reports. Ratings valid as of Aug. 17, 2018.

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A leader in agriculture, Crédit Agricole's agri-food and local business financing and has developed through its many branches a system of locally-tailored financial solutions for smaller and larger farmers, providing loans for the construction or renovation of buildings, purchase of agricultural equipment, purchase of seeds, livestock, and shift away from conventional to organic agriculture.

More generally, Crédit Agricole focused on financing the real economy based on a series of social-environmental responsibility and has strongly contributed to create standards of good practice in this area of finance with the "Equator Principles" and the "Green Bonds Principles".

The "Equator Principles" represent a voluntary, unilateral commitment to perform a detailed analysis of environmental and social aspects of each new project financing and to link financings to compliance with a number of requirements. In following these principles, the bank develops its projects in line with the social and environmental standards of the International Finance Corporation (IFC). When the "Equator Principles" were launched in 2003, Crédit Agricole became the first French bank to sign them: in a few short years, the Equator Principles have become the benchmark for responsibility in project finance.

Similarly, green bonds are bonds exclusively reserved for financing projects or assets with an environmental and/or social purpose (see Breen and Campbell, 2017).[31] Crédit Agricole is a co-founder of the "Green Bond Principles" and the only European bank that took part in drafting them in 2013. The "Green Bond Principles" create a framework for the use of proceeds, the process for project evaluation and selection, the management of proceeds and the reporting for the issuance of these green bonds;[32] they offer investors the availability of the information required to evaluate the environmental impact of their investments. These principles have become a market standard. In 2016, under the leadership of 3 banks, including Crédit Agricole, they were extended to "social

31 A "green bond" is a debt instrument issued to holders to support or finance environmentally friendly projects, such as public transportation, renewable energy, energy efficiency, clean water, and sustainable land use. Global green bonds reached a record volume of $121.9bn and accounted for 87.1% of the total sustainable finance market. 2017 volume soared 53% to a full-year record, and activity increased 84% year-on-year. Ultimately, EMEA drove the record with $57.1 billion issued in 2017, followed by APAC with $43.4 billion. China facilitated the largest number of green bonds in 2017, totaling $30.9bn via 82 deals – with 50 debut issuances. As a result, emerging markets issued a record $47.2 billion of green bonds, accounting for 38.7% of global volume.

32 The eligible Green Project categories under the Green Bond Principles guidelines apply to all sector and are particularly germane for the agri-food sector. Listed in no specific order they include, but are not limited to: (i) renewable energy (including production, transmission, appliances and products); (ii) energy efficiency (such as in new and refurbished buildings, energy storage, district heating, smart grids, appliances and products); (iii) pollution prevention and control (including reduction of air emissions, greenhouse gas control, soil remediation, waste prevention, waste reduction, waste recycling and energy/emission efficient waste to energy); (iv) environmentally sustainable management of living natural resources and land use (including environmentally sustainable agriculture; environmentally sustainable animal husbandry; climate smart farm inputs such as biological crop protection or drip-irrigation; environmentally sustainable fishery and aquaculture; environmentally-sustainable forestry, including afforestation or reforestation, and preservation or restoration of natural landscapes); (v) terrestrial and aquatic biodiversity conservation (including the protection of coastal, marine and watershed environments); (vi) clean transportation (such as electric, hybrid, public, rail, non-motorized, multi-modal transportation, infrastructure for clean energy vehicles and reduction of harmful emissions); (vii) sustainable water and wastewater management (including sustainable infrastructure for clean and/or drinking water, wastewater treatment, sustainable urban drainage systems and river training and other forms of flooding mitigation); (viii) climate change adaptation (including information support systems, such as climate observation and early warning systems); (ix) eco-efficient and/or circular economy adapted products, production technologies and processes (such as development and introduction of environmentally sustainable products, with an eco-label or environmental certification, resource-efficient packaging and distribution); (x) green buildings which meet regional, national or internationally recognized standards or certifications. While the GBP's purpose is not to take a position on which green technologies, standards, claims and declarations are optimal for environmentally sustainable benefits, it is noteworthy that there are several current international and national initiatives to produce taxonomies, as well as to provide mapping between them to ensure comparability. This may give further guidance to Green Bond issuers as to what may be considered green and eligible by investors. These taxonomies are currently at various stages of development. Issuers and other stakeholders can refer to examples through links listed on the Resource Centre at https://www.icmagroup.org/green-socialand-sustainability-bonds/resource-centre/).

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bonds", by drafting a Guidance for Issuers of Green Bonds and a Guidance Note for Social Bonds (ICMA, 2018a and 2018b). Crédit Agricole has been working in the green bonds/social bonds market since 2010 and since then – up to mid-December 2017 – it has been involved in almost 150 billion dollars' worth of green bonds, thus confirming its position as this market's top arranger worldwide.[33] This led to the periodical IFR naming the Bank SRI Bond House of the Year in 2017, for the third year in a row.

In addition to contributing and abiding to specific environmental and social responsibility standards, the bank has drafted the so called "CSR sector policies" – i. e. policies that detail beyond the more general principles the social and environmental criteria considered in the bank's financing policies. These criteria mainly reflect the societal challenges that were identified as most relevant for a corporate and investment bank, concerning human rights, the fight against climate change and the protection of biodiversity. For each sector a framework of reference was defined to list the relevant norms and standards to appreciate clients' environmental and social practices compared with the sector's good practices; the policies specify the criteria used to analyze the transactions and the exclusion criteria used to define the projects and transactions the bank does not wish to support.

In 2019, the Crédit Agricole Group has announced the creation of CA Transitions, the first fund dedicated to the transition of agriculture and agri-food systems (and energy) launched by a bank in its own name, a move aimed to consolidate its position as the leading bank supporting the transition across its local areas.[34] The CA Transitions Fund will support the development of small, medium and intermediate-sized firms and cooperatives that are adopting sustainable farming. In particular, in the agri-food realm, the equity investments made by the CA Transitions Fund will support cooperatives and agri-food companies undertaking a transition, which are committed to delivering improvements in a number of areas, such as the sustainability of their supply chains, water and energy management, and waste processing, etc., as well as companies engaged in facilitating the transition of the agricultural and agri-food sector, by offering products and services to farmers and processing companies. This includes, for example, precision agriculture technologies, or solutions facilitating the development of short food supply chains. Finally, the fund will also focus on small, medium and intermediate-sized firms and cooperatives, to which it will offer, in co-investments with one of the Crédit Agricole Group's Regional Private Equity Companies, financing of between €1 million and €20 million over a period of 5–10 years.

Moreover, the bank is engaged in several additional financial activities to favor a transition to sustainable agri-food systems. Pacifica, the property and casualty subsidiary of Crédit Agricole Assurances, has offered a grassland insurance policy of potential interest to the 100,000 forage-producing farmers in France. Policy-holding farmers receive compensation for any decrease in forage production, measured precisely by satellite. Farmers thus have the capital with which to buy the feed required for their herds without having to file a claim. Similarly, in 2009, Crédit Agricole

33 According to the Dealogic ranking, Crédit Agricole CIB confirmed its position as the world's leading bookrunner for green, social and sustainable bonds. In China, the bank has participated in 80% of issues of Chinese green bonds worldwide since January 2017 (Dealogic, 2018).

34 The Fund will be managed by IDIA Capital Investment, Crédit Agricole Group's specialized investment management subsidiary, which has recognized expertise in the cooperative, agri-food and energy sectors. The aim is for Crédit Agricole's Regional Banks and the Crédit Agricole S.A. Group to raise €200 million for the CA Transition Fund.

CIB created the Sustainable Banking team, specialized in responsible finance, to foster socially-responsible and environmental projects from individuals and professionals alike.

In developing countries, the Grameen Crédit Agricole Foundation is contributing to the rise of index-based harvest insurance. This policy is linked to indices on rain, temperature and yield rather than the actual loss, and helps to protect farmers with holdings of under one or two hectares. Agricultural micro-insurance is contributing to the fight against poverty by fostering initiative and entrepreneurship. Through its not-for-profit status, the Grameen Crédit Agricole Foundation is charting new territory in the field with a view to developing innovative solutions of use to the poorest populations.

5 What can public policy do to support green finance for a GFT?

Fertile land represents the most important security for the future, and for generations to come. Unfortunately, the demand to produce more, combined with market imperfections, have led to an ongoing process of unsustainable industrialization, deforestation and land degradation around the globe. While green finance for this sector is advancing, financial players in general continue to face substantial difficulties in helping farmers to change to more sustainable practices, it is clear that the effective implementation of new agricultural practices often coincide with the availability of tailor-made finance and financial services along the value chain.

External impetus seems necessary to move out of this gridlock. This raises the question whether there is a way to incentivize commercial debt providers to remove the hurdles and structure finance in a way that it both contributes to economic growth and helps promote the change to more sustainable food systems. Finance is also essential in bringing knowledge to farmers and to familiarizing them with new, more sustainable farming practices.

Against this background, there are at least six levers through which public policy can help propel the Great Food Transformation by supporting the availability and cost of finance for non-conventional, innovative, and more plant-based food production.

- *Direct loans.* Surveys of farmer respondents in the United States – where half of all organic food is produced but where, concurrently, organic production struggles to expand as a share of total production – indicate that the number one barrier to getting a non-conventional farming operation off the ground is access to land and credit (National Sustainable Agriculture Coalition, 2017). The cost of affordable quality land is further exacerbated by the cost-prohibitive nature of becoming certified and maintaining certification through the National Organic Standards Board, an entity now present also in all other advanced economies.[35] This is especially the case for young farmers who might not have a lot of equity to begin with and who are based in rural communities where they might be the only organic farmer in the county[36] – plausibly a main hindrance to the development of non-conventional

35 In addition to upfront costs and the time-consuming nature of the certification process, farms must pay annual fees to remain certified.

36 In the United States, but also increasingly in Europe, beginning farmers are younger on average, and less likely to farm full-time than more established farmers. They also tend to operate smaller farms, have more diversified operations, and increasingly come from nonfarm

farming also in other advanced economies, where land is typically scarcer and pricier than in the United States because of higher population density.

As organic farming usually involves a transition away from conventional farming and equipment or a brand-new career in agriculture, access to appropriate credit is critical for organic farmers.[37] Credit not only needs to be accessible, but it also needs to be appropriate. For beginning organic farmers, this often means smaller loan sizes with reasonable interest rates, as beginning farmers with limited assets, and often other debt, cannot leverage new hefty levels of debt, nor do they generally need to take on so much debt. Alongside, it is critically important that available credit options are scaled to appropriately accommodate farmers at multiple points in their careers.

Hence, absent sufficient and affordable lending by private commercial banking institutions (like, for example, Rabobank*), direct and guaranteed farm ownership loans and microloans* tailored to the size of an average beginner non-conventional farm, given real farmland estate prices and trends and the price and trends of equipment for non-conventional farming, should ideally be disbursed or guaranteed by a national dedicated agency until the share of organic, non-conventional farming has expanded to meet the desired new supply equilibrium. In the United States, for example, the Farm Service Agency (FSA) provides guaranteed and direct loans to all eligible farmers independently of the production method used. Under an FSA guaranteed loan, a commercial lender makes and services the loan, and FSA guarantees it against loss up to a maximum of 95 percent of loan value. For those not yet meeting the qualifications for a loan guarantee from a commercial lender, FSA also makes direct loans, which are serviced by an FSA Official. FSA has the responsibility of providing credit counseling and supervision to its direct borrowers by making a thorough assessment of the farming operation. Eligible applicants may obtain direct loans up to a maximum indebtedness of $300,000.[38] Maximum indebtedness for guaranteed loans is $1,392,000 (amount adjusted annually for inflation). The maximum repayment term is 40 years for both direct and guaranteed farm ownership loans. In general, loan funds may be used to purchase a farm, enlarge an existing farm, construct new farm buildings and/or improve structures, pay closing costs, and promote soil and water conservation and protection. Following this, the FSA model could be reproduced elsewhere, with the proviso that lending is targeted specifically non-conventional sustainable farming producers. Similarly, in the United States direct and guaranteed new loans could be reserved exclusively to non-conventional farmers to accelerate a shift toward sustainable agriculture.

Crucially, public lending can be structured to be fiscally neutral (inasmuch as non-concessional) similarly to proposed forms of targeted fiscal interventions to aid phases of deleveraging from private debt (Batini et al., 2018) and are likely to end up buttressing fiscal sustainability in that, as discussed in Batini (2019), food system transitions can both raise potential GDP as well as generate substantive fiscal saving via an amelioration of the quality and redistribution of food domestically and an improvement of the trade balance.

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backgrounds with little access to farmland, which has traditionally been passed down from generation to generation. (National Sustainable Agriculture Coalition, 2017)

37 Rarely do existing beginning farmers have the cash to outright purchase equipment, inputs, and land. Credit allows farmers to purchase the supplies they need and get a crop in the ground before the fruits of that labor are available.

38 In 2017, the National Sustainable Agriculture Coalition has recommended raising the maximum cap on loans to $500,000 to align these to the value of purchasable assets, given real farmland estate prices.

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- *Financial training*. Direct and guaranteed loans should be flanked by an organic/non-conventional borrower training programs, as also done in the United States. The aim of these kind of programs is to improve the borrower's understanding of financial and farm management concepts associated with commercial organic farming, and to enable the borrower to better manage their organic/non-conventional farm operations. Where necessary, programs for rural microentrepreneur assistance should be designed and deployed. Most new farmers have little financial and business training at the onset of their farming careers and require more one-on-one technical assistance in order to be well-prepared to apply for a farm loan – whether from a national farm agency or a commercial lender. For these new and aspiring farmers that are in need of not only financial literacy skills, but also business and marking plans and one-on-one support in establishing a new viable farm business, public instruments beyond those provided by the nonprofit community and/or community development financial institutions should be deployed. In the United States, this role has been largely left to CDFIs (notably the CFDIs' Fund),[39] but there as well it may be desirable to develop a more systematic, publicly sponsored network of training providers that can be effective in reaching borrowers who are underserved by other lending institutions and are able to provide them with one-on-one support that new enterprises need to start and maintain a successful and viable new farm business.[40]
- *Crop insurance and big data*. Given the greater initial risks of organic operations, public policy can play an additional pivotal role is supporting the GFT by facilitating organic/non-conventional crop insurance programs, especially in the initial years of organic farming operations when risks tend to be higher. Where national crop insurance does not exist, this should be introduced or tax incentivized such that it is provided at a favorable rate relative to private insurance, if available, and at a relatively more favorable rate than private crop insurance accessible by conventional producers, who farm crops that have been scientifically proven to be more risky and less resilient to climate change than organic crops over the medium-to-long run. Publicly-sponsored insurance programs should promote conservation by linking premium subsidies to stewardship practices that protect land, water and health; likewise, the program's structure should be designed to prevent the unfairly influencing of markets, land access, or planting decisions and to promote farm consolidation and weakened rural communities, where necessary – a problem particularly serious in some parts of Europe and the United States (Cole and Xiong, 2017). Where available, like in the United States, it should be calibrated to eliminate insurance program barriers to sustainable farming practices and, rather, encourage sustainable farming practices like cover cropping while discouraging some unsustainable practices like short rotations; and it should be tailored to prevent large-scale farm consolidation by an appropriate design of implicit subsidies. Besides, technological advances can help expand the coverage and effectiveness of insurance scheme at transforming agri-food production to make it sustainable with a positive impact on investments, efficiency, nutrition and income. Recent studies show, for example, that for both index and conventional insurance applications, big data derived from current and new sources (e. g. crowdsourcing, cellphone

39 The CFDIs Fund serves mission-driven financial institutions that take a market-based approach to supporting economically disadvantaged sectors or communities that lack access to financing by injecting new sources of capital into them.

40 In the United States, there are few sources of funding for this critical loan capital and technical assistance funding, and the Rural Microentrepreneur Assistance Program (RMAP) is one of the few programs that provides both grant and loan funding to MDOs to help rural entrepreneurs launch new small rural businesses (including new farm enterprises).

apps, satellite and radar-based imaging and drone-based imaging) can be used to improve modelling and reduce the risks of providing insurance products to sustainable farmers (WEF-McKinsey & Co., 2018).

- *Prudential regulation*. In line with recommendations of the 34-country strong recent 'Network for Greening the Financial System' (NGFS, 2019),[41] central banks, financial markets' supervisory bodies as well as, where applicable, financial institutions themselves should start: a) assessing climate-related financial risks in the financial system arising from the agri-food sector, in addition to other sectors, like electricity or transportation – being agri-food the number one contributor to climate change. These risks should be integrated into financial stability monitoring and micro-supervision, as well as into financial supervision by engaging with financial firms to ensure that: (i) climate-related risks for firms involved in the agri-food sector are understood and discussed at board level, considered in risk management and investment decisions and embedded into firms' strategy; (ii) climate-related financial risks to agri-food farms and firms are identified, analyzed and, as applicable, reported and managed; and (iii) supervisory expectations are set to provide guidance to financial firms lending to the agri-food sector as understanding evolves.
- *Incorporation of ESG aspects in the portfolio management of public funds*. Similarly, in line with recommendations by the NGFS (2019), and without prejudice to their mandates and status while acknowledging the different institutional arrangements in each jurisdiction, central banks could set an example in their own operations by embedding sustainability factors into the management of some of the portfolios at hand like their own funds, pension funds and international reserves, to the extent possible.[42] In this respect, central banks could buy green bonds from a number of eligible issuers, and/or could potentially expand their investment universe to other asset classes where the ESG-compliant investment space is broader. This approach could help shift the needle for sovereign wealth funds who, as discussed in Section III.A and III.B, have been engaging in land "grabbing" as a form of asset investment or are involved in financing agri-food tech companies, too. In some countries, these funds are directly managed by central banks, which could now face pressure to shift their holdings towards greener agri-food companies or away from agri-food assets that could have a greater climate risk.

In addition to this, advocates of greater public policy involvement call for analyzing the relationship between central banks' mandates and climate change, beyond financial stability, and in particular the effects of climate-related risks on the monetary policy frameworks (NGFS, 2019). With climate change affecting agri-food production and consumption generally and making those and their prices erratic relative to past norms, integrating climate tendencies in inflation and real growth forecasting is becoming increasingly important as climate change can be expected to amplify the frequency of adverse weather shocks as well as the distribution of shocks by making tail risks more

41 The NGFS was composed by 34 central banks and supervisors by April 2019, plus observers, stretching from the People's Bank of China to central banks in Thailand, Greece, and Colombia. Institutions including The World Bank and the Bank for International Settlements are also involved. Thus, the membership currently represents a third of the global population, two-thirds of the world's systemically important banks and insurers, and nearly half of the world's greenhouse gas emissions.

42 The ECB, for example, has already taken concrete steps in this direction for its pension fund portfolio, as the broad investment universe and longer-term investment horizon allows it, for that fund, to pursue a sustainable investment policy based on selective exclusion and proxy voting guidelines. Not all portfolios are, however, equally suited to promoting green finance, which for example is more complicated when it comes to investing foreign exchange (international reserves) for which it is key to hold the most liquid and creditworthy fixed income assets as possible in a few major currencies, leaving little room for climate-related objectives (Cœuré, 2018).

likely altogether over time (Cœuré, 2018). Relative prices and inflation expectations would also be affected, is argued, in the transition towards a low-carbon economy implying that structural breaks, both to trends and cycles are plausible in the medium run, with important implications for the effectiveness of monetary policy absent a proper accounting of these phenomena in targeting short- and long-run goals (Cœuré, 2018).

Alongside these measures, as also recommended by the NGFS, the appropriate public authorities should share data of relevance to Climate Risk Assessment (CRA) and, whenever possible, make them publicly available in a data repository. Finally, central banks, supervisors and financial institutions should swiftly gear up to better understanding how climate-related factors translate into financial risks and opportunities by building in-house capacity and by networking domestically and internationally to receive and/or offer technical assistance where possible, including in emerging and developing economies.

- *Expansion of global and domestic green bond markets via mandatory regulatory support on green bond issuers.* While the green bond market has expanded drastically across large nations in Europe and Asia, market growth has stalled in other regions, notably the United States, in part due to a lack of promising domestic regulations that presently only exist in the form of nonbinding international guidelines. It has been argued that for the green bond market to further expand in the United States, mandatory regulatory support must be imposed on bond issuers by establishing clear-cut regulation for green bonds, and by preventing corporations from "greenwashing" bonds or otherwise deceiving green bond investors of the purported climate related benefits.[43] This can be achieved through the use of a tiered green bond system, mandated quarterly reports by bond issuers to investors, and imposition of stricter penalties for issuers who misuse the green bond money (see Wang, 2018).

6 Conclusions

Growing food to feed the estimated nine billion people that will be on the planet by 2050 while tackling climate change are among the most defining challenges of the 21st century. Right now, the world community is not on track to hold global temperature well below 2 degrees Celsius rise this century, and to drive efforts to limit the temperature increase to 1.5 degrees Celsius above pre-industrial levels as required to meet the Paris Climate Agreement. Achieving the UN's Sustainable Development Goals' and the Paris Climate Agreement objectives by 2030 depends on the way agricultural land and forests are managed in the years to come. In this respect, there is a growing global consensus about the need for a sizable shift in those economic sectors that contribute to climate change, including agricultural value chains and its financing.

Promising trends toward greater agri-food sustainability are emerging, including a global acceleration in land used for non-conventional, regenerative farming, a shift away among millennials from animal-based protein consumption, and technological advancements in agro-ecological methods of production. These trends are accompanied by parallel shifts in financing, which is

43 Greenwashing relates to cases in which an issuer promotes green bonds by advertising green initiatives, but instead operates in a way that damages the environment. It may also occur when issuers make misleading claims about how beneficial their project is to an environmental cause, or where they fail to establish supporting evidence for the green claims they make. (See Wang, 2018).

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slowly but relentlessly becoming more engaged in funding "green", sustainable agri-food production and consumption solutions. These novel investment trends, that largely respond to emergent demand trends, include plant-based investing, alternative protein investing as well as agricultural technology venture capital investing. They also comprise a growing class of green and sustainable bond investing which is no longer limited to green projects in the energy realm but increasingly incorporate a focus on land use. While the potential benefits of accelerating investment in making global food systems sustainable are enormous – not all of them can be achieved through a "business as usual" approach, and in fact, current trends in global investment do not yet reflect the potential for disruption in demand-side agri-food innovations – innovations which target and impact consumers.

The lower levels of investment in food systems are due in great part to the complexity of the sector. Fragmented rural markets, poor infrastructure, high regulatory burdens and other factors raise costs, while revenues are constrained by customers' limited ability and willingness to pay. In addition, much of the food systems' start-up activity is concentrated in developed countries and on improving the production landscape, indicating both the risk of unequal access to new solutions and the opportunities for scaling in developing countries and in demand-side innovations.

Coordinated efforts by policymakers, investors, educators and others to nurture and accelerate food systems enterprises in all regions can overcome those obstacles. These gaps demonstrate an opportunity to accelerate innovation investment and activity order to achieve an aspirational and inclusive future.

To this end, this paper proposes a set of (largely fiscally-neutral) public policy measures that can support a more abundant and affordable financing necessary to transform global food systems. Suggested measures include direct and guaranteed loans to non-conventional farming, temporary public crop insurance schemes during the transition, financial training for sustainable farmers, changes to prudential regulation to properly account for financial risks of institutions lending to non-sustainable agri-food firms; a bolder approach to ESG investment of public funds in assets associated with sustainable land use; as well as steps to expand green and sustainable bond markets that can help fund the transition.

Concrete steps on these various fronts promise a rebalancing of market forces, traditionally stacked through distortive policies favoring conventional, unsustainable agriculture and food systems. Crucially, the deployment of these policies should be prioritized in the race to mitigate climate change because they can contribute greatly to winning this time-bound challenge while also help attain desirable public health and public finance goals in both advanced and emerging market economies.

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