The global animal food market: drivers and challenges

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### Abbreviations and acronyms

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<th>Description</th>
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<tbody>
<tr>
<td>ABARES</td>
<td>Australian Bureau of Agricultural and Resource Economics</td>
</tr>
<tr>
<td>AFOLU</td>
<td>Agriculture, forestry and other land use sector</td>
</tr>
<tr>
<td>AHDB</td>
<td>Agriculture and Horticulture Development Board</td>
</tr>
<tr>
<td>AIDADS</td>
<td>An Implicitly, Directly Additive Demand System</td>
</tr>
<tr>
<td>AIDS</td>
<td>Almost Ideal Demand System</td>
</tr>
<tr>
<td>ASF</td>
<td>African Swine Fever</td>
</tr>
<tr>
<td>CAPRI</td>
<td>Common Agricultural Policy Regionalised Impact</td>
</tr>
<tr>
<td>CCLLS</td>
<td>Country-Commodity Linked System</td>
</tr>
<tr>
<td>CDE</td>
<td>Constant Difference of Elasticities</td>
</tr>
<tr>
<td>CEPII</td>
<td>Centre d'Études Prospectives et d'Informations Internationales</td>
</tr>
<tr>
<td>CH₄</td>
<td>Methane</td>
</tr>
<tr>
<td>CS</td>
<td>Cross Section</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>CO₂eq</td>
<td>Carbon Dioxide Equivalent</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EFSA</td>
<td>European Food Safety Authority</td>
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<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>FAOSTAT</td>
<td>Food and Agriculture Organization Statistics Division</td>
</tr>
<tr>
<td>FBDG</td>
<td>Food-Based Dietary Guidelines</td>
</tr>
<tr>
<td>FPCM</td>
<td>Fat and Protein Corrected</td>
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<tr>
<td>GATT</td>
<td>General Agreement on Tariffs and Trade</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GE</td>
<td>General Equilibrium</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>GTAP</td>
<td>Global Trade Analysis Project</td>
</tr>
<tr>
<td>HS</td>
<td>Harmonized System</td>
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<tr>
<td>IFCN</td>
<td>International Farm Comparison Network</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>LADS</td>
<td>Linear Almost Ideal Demand System</td>
</tr>
<tr>
<td>LCA</td>
<td>Life-Cycle Assessment</td>
</tr>
<tr>
<td>LUC</td>
<td>Land Use Change</td>
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<tr>
<td>LULUC</td>
<td>Land-Use and Land-Use Change</td>
</tr>
<tr>
<td>MENA</td>
<td>Middle East and North Africa</td>
</tr>
<tr>
<td>MFN</td>
<td>Most Favored Nation</td>
</tr>
<tr>
<td>n.d.</td>
<td>Non dated</td>
</tr>
<tr>
<td>N₂O</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>N/A</td>
<td>Not Available</td>
</tr>
<tr>
<td>NFDM</td>
<td>Nonfat Dry Matter</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PE</td>
<td>Partial Equilibrium</td>
</tr>
<tr>
<td>PPP</td>
<td>Purchasing Power Parity</td>
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<tr>
<td>QAIDS</td>
<td>Quadratic Almost Ideal Demand System</td>
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<tr>
<td>SDG</td>
<td>Sustainable Development goals</td>
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<tr>
<td>SMP</td>
<td>Skim Milk Powder</td>
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<tr>
<td>SPS</td>
<td>Sanitary and Phytosanitary</td>
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<tr>
<td>SSP</td>
<td>Shared Socioeconomic Pathways</td>
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<tr>
<td>TS</td>
<td>Time Series</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WMP</td>
<td>Whole Milk powder</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
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DANSK SAMMENDRAG


Der foregår en betydelig international handel med animalske fødevarer, selv om omfanget af handelen med disse varegrupper er mindre end for visse andre landbrugsprodukter. Animalske fødevarer er således genstand for komplekse handelssystemer, som også påvirkes af forskellige handelsbarrierer, handelsaftaler, produktstandarder og andre reguleringer. I 2019 blev 36 mio. tons kød (opgjort i slagtevægtækvivalenter) og 76,7 mio. tons mejeriprodukter (opgjort i mælkeækvivalenter) handlet internationalt.

Derfor forventes befolknings- og indkomstmåltid for at øge i de komende år, og forbrug af animalske fødevarer. Det er imidlertid sandsynligt at forbrugsudviklingen per indbygger vil udvikle sig forskelligt i forskellige lande. Eksempelvis kan stigende indkomst og befolkning især forventes at fremme forbruget i udviklingslande, mens lande med et allerede højt forbrugs niveau for disse varer sandsynligvis ikke vil opleve en tilsvarende stærk vækst i efterspørgslen. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer. Ligeledes kan sammensætningen af forbruget på forskellige animalske fødevarer (oksekød, svinekød, fjerkær, mælk, smør, ost, melkekonserves) ændre sig over tid i kraft af ændrede forbrugerpræferencer og ændrede produktionsmønstre i takt med blandt andet at øge de eksterne forbrugerpræferencer.

Forventet vækst i forbruget af kød og mejeriprodukter i udviklingslandene kan også påvirke de eksisterende handelsmønstre. I tilfælde af forholdsvis ulige ambitionsniveauer mellem landene for så vidt angår reduktion af landbrugets drivhugasudledninger, og i særdeleshed hvis lande med forholdsvis høje emissionsintensiteter udviser relativt lave reduktionsambitioner, så vil lande med høje reduktionsambitioner kunne finde behov for
at beskytte deres nationale landbrugssektorer med handelspolitiske instrumenter. Denne problemstilling har tiltrukket sig stigende opmærksomhed i EU og på det seneste også i USA. Sådanne handelspolitiske tiltag vil kunne øge handelsomkostninger og barrierer i forhold til handelen med animalske fødevarer og vil kunne give yderligere rystelser i et internationalt handelssystem, som de senere år har været påvirket af begivenheder som Brexit, handelskonflikter mellem USA og Kina og stillstand i WTO’s multilaterale forhandlinger om handelsliberaliseringer.

Formålet med nærværende rapport er at give et overblik over, hvordan disse forskellige aspekter – drivkrafter på henholdsvis udbuds- og efterspørgselssiden, handelsrelationer, klimapåvirkning, teknologiske fremskridt og potentielle fremtidige reguleringer – spiller sammen, og hvordan de i fællesskab kan forventes at påvirke udviklingen af de globale husdyrsektorer og markeder for animalske fødevarer. Herigennem er det målet at danne grundlag for vurderinger og analyser af udviklingen af markedsstigningsvægtede for forskellige husdyrprodukter på langt sigt. Rapporten er således første trin i en større forskningsindsats omkring den animalske sektors fremtidsudsigter, og rapporten bygger på et omfattende litteraturstudie, detaljerede data samt interviews og samtaler med beslutningstagere og markedsexperter i kød- og mejeribranchen.

Rapportens kapitel 2 og 3 undersøger drivkrafter på henholdsvis efterspørgselssiden og udbudssiden for animalske fødevarer, herunder et overblik over relevante metodemæssige tilgange til at undersøge disse drivkrafter i litteraturen, mens kapitel 4 giver et overblik over de animalske sektorens betydning for internationalandel, klima, miljø og sundhed. Herigennem er det målet at danne grundlag for vurderinger og analyser af udviklingen af markedsstigningsvægtede for forskellige husdyrprodukter på langt sigt. Rapporten er således første trin i en større forskningsindsats omkring den animalske sektors fremtidsudsigter, og rapporten bygger på et omfattende litteraturstudie, detaljerede data samt interviews og samtaler med beslutningstagere og markedsexperter i kød- og mejeribranchen.

Rapportens hovedresultater opsummeres kort i det følgende.

**Drivkrafter på efterspørgselssiden.** I den økonomiske litteratur betragtes indkomst og priser traditionelt som de fundamentale drivkrafter for fødevareefterspørgslen, for eksempel som beskrevet ved Engels lov (at fødevarernes andel af forbrugsbudgettet aftager med indkomstniveauet) og Bennetts lov (at andelen af animalske produkter i forbruget stiger med indkomstniveauet). De senere års forskning tyder imidlertid på markante forskelle mellem lav- og højindkomstlande: mens indkomst- og befolkningsudvikling fortsat er en væsentlig drivkraft for forbrugsmønstrene i udviklingslande, så ser stigende opmærksomhed omkring miljø-, klima- og sundhedsdomænerne af mæssige implikationer af animalske fødevarer ud til at have ændret forbrugernes præferencer i mange højindkomstlande.

**Metodemæssigt bygger analyser og fremskrivninger af forbrugerefterspørgslen traditionelt på økonometriske estimeringer af efterspørgselssystemer og Elasticiteter, som kan anvendes til at beskrive efterspørgselssadsfærdigheden. Imidlertid er de foreliggende studier og estimerer af sådanne efterspørgselssparametre for animalske fødevarer generelt fragmenterede og til dels forældede i forhold til bland andet produktkategorier, geografiske områder og tidsperiode, hvilket klart peger på en behov for at gennemføre nye og systematiske studier af sådanne adfærdssparametre for efterspørgslen efter animalske fødevarer.**

**Drivkrafter på udbudssiden.** Udbuddet af animalske fødevarer vedrører både den primære produktion (husdyrsektoren) og forarbejdningssentraliteter. Produktionssystemer for husdyr rækker fra ekstensive grænsningsbaserede systemer til intensive ”jordløse” produktionssystemer, afhængig af dyrekategori, tilgengældighed af areal- og vandressourcer, klimaforhold, adgang til foder, teknologi og tilstand til afgaderne. Reguleringer af miljø, sundhed og husdyrsundheds bestil spiller også væsentlige roller i forhold til udbuddet af animalske fødevarer. Husdyrsektoren påvirkes desuden både direkte og indirekte af
klimaændringer, hvilket fordrer tilpasninger af produktionen. Husdyrrproduktionen er samtidig også selv en vigtig bidragsyder til drivhusgasudledninger, og en række teknologiske løsninger til at begrænse disse udledninger er genstand for væsentlig interesse, ligesom også mere direkte politiske instrumenter som for eksempel afgifter på drivhusgasudledninger er genstand for generel debat. Både tilpasningsbehov og løsningsmuligheder må forventes at blive væsentlige fremtidige determinanter for såvel nationale som globale udviklinger i udbuddet af animalske fødevarer.

Der er udviklet en række kvantitative økonomiske modeller som for eksempel partielle eller generelle ligevægtsmodeller til at udarbejde vurderinger af, hvordan udviklingen i sådanne drivkræfter kan forventes at forme sektorens fremtidige udvikling, inklusive udarbejdelse af langsigtede fremskrivninger i institutioner som FAO, OECD, Europa-Kommissionen og USA’s landbrugsministerium (USDA). Fælles for disse modelanalysyr er, at de bygger på eksogene forudsætninger om generel makroøkonomisk og demografisk udvikling og på sektorspecifikke antagelser om udviklingen i teknologi og efficiens i udyttelsen af ressourcer. En væsentlig udeladelse i de eksisterende modelbaserede fremskrivninger er, at modellerne ikke – eller kun i begrænset omfang – tager hensyn til effekterne af klimaændringer eller klimapolitiske tiltag på husdyrrproduktion. Der er således behov for at udvikle analysemetoderne, så de også tager hensyn hertil.


Konsekvenser for human sundhed. Animalske fødevarer indeholder vigtige næringsstoffer, der for eksempel højværdiproteiner, fedtstyrer, mineraler og vitaminer, og disse fødevarer spiller derfor en
vigtig rolle i forhold til at nå FN’s bæredygtigheds mål vedrørende forebyggelse af sult og underernæring. Overforbrug af produkter som rødt kød (herunder okse- og svinekød) og forarbejdede kødprodukter er imidlertid også udført som en risikofaktor for blandt andet hjertekarsygdomme. Som konsekvens heraf har de officielle kostanbefalinger de senere år haft tendens til at opprioritere plantebaserede fødevarer frem for animalske fødevarer. Ud over de ernæringsmæssige aspekter er kød og mejeriprodukter også relateret til andre sundhedsproblemer som fødevaresikkerhed, spredning af zoonoser og antibiotikaresistens, og en række lande har foranstaltet politikker eller retningslinjer med henblik på at imødegå sådanne problemer.

Kødsektoren. Lande i det østlige og sydøstlige Asien, især Kina, Vietnam, Sydkorea og Filippinerne, forventes at være vækstmarkeder for kødeexportører i såvel EU som Nord- og Sydamerika. I løbet af det kommende årti forventes imidlertid et ændret sammensætning af kødeimporten, med især øget efterspørgsel efter fjerkrækød og til dels svinekød. Efterspørgsenl efter oksekød forventes blot at vokse i moderat omfang, og kun i Asien forventes en stagnering i oksekødimporten per indbygger. Mens kødimporten i højindkomstlande samlet set stagnerer, så efterspørgsel forbrugerne her i stigende grad forarbejdet kød som convenience- eller foodservice-produkter. Øget opmærksomhed om miljø- og sundhedsaspekter påvirker også forbrugsmønsterne i nogle lande, for eksempel i EU som observerer stigende efterspørgsel efter økologisk kød og plantebaserede alternativer. I takt med at den offentlige debat om kødforbrugets miljømæssige konsekvenser tager til, øges sandsynligheden for, at kødimporten i fremtiden bliver genstand for regulering, især i højindkomstlande.

På produktionssiden kan såvel nuværende som fremtidige divergencer i landenes miljø- og veterinærreguleringer føre til omkostningsmæssige forskelle i produktion og handel. Kødproducenter fra EU er eksempelvis underlagt relativt strenge miljøreguleringer og standarder for sundhed og fødevaresikkerhed og skal markedsføre deres produkter under disse betingelser, mens andre lande som for eksempel USA og Brasilien konkurrerer mere på priser og mængder. Sidstnævntes prisfordel kan også knyttes til disse landes direkte adgang til store indenlandske forsyninger med foder, eftersom begge lander er storproducenter og eksportører af såvel majs som sojabønner. Potentielle forskelle mellem landenes regulering af drivhusgasudledninger fra husdyrproduktionen kan ydermere påvirke produktionsomkostninger og eksportmuligheder, hvor lande med forholdsvis strenge reguleringer sandsynligvis også vil have et højere omkostningsniveau. Der er også risiko for såkaldt løkkage i den forstand, at hvis drivhusgasreguleringen bliver skærpet i lande med lav emissionsintensitet, vil lande med høj emissionsintensitet og mindre ambitiøse reduktionsmålsetninger kunne vinde markedsandelene og dermed udlede mere. Samtale på politikker rettet mod produktion kan producerenterne vælge at udflytte deres produktion til regioner med mere moderate reduktionsambitioner, og tilsvarende kan producerenterne som reaktion på politikker rettet mod forbruget omdirigere deres produkter fra hjemmemarked til eksport.

USDA) tyder på en fremtidig udvikling, som i store træk er konsistent med de udviklingstendenser, som har kunnet observeres i historiske data. En række væsentlige usikkerhedsfaktorer er dog kun i begrænset omfang indarbejdet i disse fremskrivninger, herunder især omkring landenes klimapolitikker og -tiltag som følge af Paris-aftalen, den teknologiske udvikling og udviklingen i de politiske rammevilkår for international handel. Der er behov for at indarbejde sådanne usikkerheder i fremtidige studier, ligesom der er behov for fremskrivninger med et længere tidsperspektiv end de 10 år, som typisk er tidshorisonten for de foreliggende fremskrivninger.

Mejerisektoren. Som det er tilfældet med udsigterne for kød, forventes det globale forbrag af mejeriprodukter at øge, forventes de mest forarbejdede produkter at medføre en stigende andel af forbruget af mejeriprodukter, mens forbrugere i udviklingslande fortsat især forbruger frisk mælk og melkepulver. Dette mønster forventes at vare ved, idet en række udviklingslande (især i Sydøstasien, Vestafrika og Mellemøsten/Nordafrika) forventes at stigende andel af forbruget af mejeriprodukter.
eksportører, mens Asien og Afrika er de væsentligste importregioner. For ost er Nordamerika dog også nettoimportør.

**EXECUTIVE SUMMARY**

Production and consumption of livestock and animal food products have received intensive public policy attention and media coverage in recent years, primarily due to the climate and environmental impacts attributed to their production processes and their roles in diets and food and nutrition securities. It is widely recognized that the livestock sector accounts for a significant share of the annual anthropogenic GHG emissions. At the national level, GHG emissions from the livestock sector depends on the size of the livestock sector and emission intensities per unit of outputs, which differ significantly across countries and different livestock species. About 40% of the global agricultural GDP is from the livestock sector, a testament of the importance of the sector in global agriculture. The share of livestock in agricultural GDP, however, varies significantly across countries/regions and the role of livestock production in the economy varies with respect to a country’s development stage, the production system, and the environmental characteristics, among other things.

Animal food products such as meat and dairy provide valuable nutrition such as protein, fatty acids, minerals, and vitamins and are widely regarded as an important part of the dietary choices of consumers in many countries and cultures. Increasing meat and dairy consumption has motivated numerous studies of their dietary and nutrition roles, as well as their health implications in connection with both over- and under-consumption of such products and to food safety, zoonoses, and antimicrobial resistance issues connected to their production. Per capita consumption levels of the different animal food products vary widely across and within countries, with the per capita intake of animal proteins in some of the world’s poorest countries amounting to only a small percentage of that in North America and Europe. This uneven distribution mirrors disparities of food and nutrition security situations across poor and rich countries.

While not intensively traded as some other agricultural products, significant trade flows of animal food products take place between countries with surplus production and those with insufficient domestic supply, leading to a complex trading network that is also shaped by differential trade barriers, trade agreements, food safety standards, and other regulations. In 2019, 36 million tons of meats (in carcass weight equivalents) and 76.7 million tons of dairy products (in raw milk equivalents) were traded internationally.

In the following decades, population and income growth in developing countries are expected to boost livestock production and consumption. However, the per capita consumption levels of animal food products are likely to evolve along different pathways across different countries. For instance, rising income and population is expected to push up consumption in the emerging and developing economies, whereas countries already with high consumption levels may not follow the same pattern. Likewise, the composition of animal food consumption across individual product categories (i.e. beef, pork, poultry, fluid milk, milk powder, butter and cheese) may also change, particularly due to shifting preferences and changing production patterns in connection with environmental regulations. For instance, while meat and dairy consumption is growing in much of the developing world, stagnated consumption and saturated markets have been observed in the EU. In fact, per capita beef consumption has decreased in many parts of world in the last three decades, whereas poultry consumption rises across the globe. Expected growth in meat and dairy consumptions in the developing and emerging economies in the coming decades can also stimulate rising import demand from the world’s traditional exporters of such products. In parts of the developed world, such as Western Europe, heightened attention to climate change may change their production patterns, which in turn can alter the existing trade patterns. In the case of uneven de-carbonization ambitions in agriculture across countries, particularly when countries with higher emission intensities in the livestock sector committing to lower de-carbonization targets,
countries committed to higher de-carbonization ambitions may resort to trade policy remedies such as border carbon adjustment to safeguard their production and trade positions on the global market. This discussion has emerged in the EU and more recently also in the US. However, such actions would further add to costs and barriers in animal food trade and upset the already fragile global trading system that in recent years has suffered from several major setbacks such as BREXIT, US-China tariff war, and the stalled multilateral trade liberalization process under the WTO.

As the initial output of a research project focusing on the future of the animal food sector, the purpose of this report is to provide a nuanced explanation of how these different aspects – supply drivers, demand-side determinants, trade relations, climate impacts, technological advancements and potential future regulations – interlock with each other and how they will jointly affect the future development of the global livestock and animal food market. The report provides a solid foundation from which further research and analysis can be carried out to understand the future development of the livestock and animal food markets in the long-term. This report is built upon an extensive literature review, detailed data compilation and analysis, and direct dialogues/interviews with industry experts in key decision-making roles. The report is structured as follows. Chapters 2 and 3 examine, respectively, the key demand and supply drivers, including an overview of available methodologies to understanding these drivers in the economic literature. Chapter 4 provides an overview on the implications of livestock production and animal food consumption on international trade, climate and environment, and health. Chapters 5 and 6 are devoted to detailed data analysis on the historical and current consumption, production, and trade of individual meat products (e.g. beef, pork, poultry) and dairy products (e.g. fluid milk, milk powder, cheese, and butter), respectively. A synthesis of short- and long-term market projections on these products are also offered in these chapters. Last but not the least, a number of research gaps are identified for further studying the sector’s future development, for purposes of mapping out the research priorities to be focused upon in our further research. In what follows, we provide some highlights on the main findings of the report. Readers are invited to read the main text for more details.

**Demand drivers.** In the economics literature, income and prices have long been considered the fundamental determinants of food demand, e.g. as revealed by the well-known Engel’s Law (that food consumption shares decrease with rising income) and Bennett’s Law (that shares of livestock products rise with higher per capita income). Recent evidence, however, suggests a divide between consumption patterns between developing and developed countries: while income and population changes continue to drive consumption patterns in developing countries, increasing attentions to the environment, climate and health implications of animal food consumption in many developed countries have seemingly led to shifting consumer preferences.

Studies on projecting consumer demand traditionally rely upon demand system estimations and use demand elasticities to approximate demand behaviors. Despite the fundamental role of these concepts in empirical economic analysis, estimates of income and price elasticities for animal food products in the current literature are quite fragmented or outdated in terms of coverage of product categories, geographical areas and time period, pointing to the need to conduct more systematic studies.

**Supply drivers.** The supply of animal food products concerns both the primary production (livestock sector) and processing activities. Livestock production systems range from extensive grazing-based production system to intensive “landless” production system, as determined by animal species, land and water resource availability, climatic conditions, access to feed, technologies, and proximities to demand. Regulations regarding environment, health, and animal welfare also play important role in shaping the supply and composition of animal food products. The livestock sector is directly and indirectly impacted by climate change and is also an important contributor of GHG emissions. Climate
impacts on livestock production require adaptation measures. To mitigate the burden of livestock production on climate change, technical solutions aiming at improving feed efficiencies and limiting direct emissions are considered. More direct policy interventions such as carbon tax are also proposed and debated. Both adaptation and mitigation measures are expected to be important future factors driving future national and global supply pattern in the animal food sector.

Quantitative economic models such as computable partial equilibrium (PE) and general equilibrium (GE) models are developed and applied to numerically evaluate how the development of these drivers would shape the sector’s future development, including long-term projections conducted by organizations such as the FAO, OECD, EC and USDA. Common to these modeling exercises are the exogenous assumptions on general macro-economic and demographic development and sectoral specific development concerning technological development and resource use efficiencies. A notable omission in the existing model-based projections are the insufficient characterization of climate impacts of livestock production and the role of future climate policy. This omission mandates further research.

International trade. International trade of meats and dairy products are an important part of agricultural trade worldwide but they generally faces higher trade barriers as compared to non-agriculture products. The stalled WTO multilateral trade negotiations imply that actual reductions in tariff barriers limiting the international movements of animal food products have largely been achieved in the last two decades by regional or bilateral trade agreements, thus intensifying trade flows within trade blocs and between partner countries within trade agreements. Due to the more stringent food safety and sanitary requirements and the added costs associated with cold chain transportation, trade costs are also higher for fresh/chilled/frozen animal food products. This limits the participations of countries without the necessary infrastructure. Future trade growth therefore depends not only on the demand potentials and supply capacities, respectively, in importing and exporting countries, but also relies on the elimination of trade barriers, the lowering of trade costs, and harmonization/convergence of regulations.

Environment impacts. Livestock production contributes to GHG emissions through land use, feed consumption, enteric fermentation, manure application and the associated pollutions to soil, water and air. There are different accounting methods for measuring emissions from the sector, including the production-based “territorial” approach adopted by the IPCC and the consumption-based approach that tracks emissions along the whole supply chain. The rather wide range of estimated GHG emissions from the livestock sector not only reflects the differences in emission accounting methods and statistical errors, it is also due to data issues related to livestock population, feed composition, and physiological assumptions. Despite these differences, there are general agreement on the relative emission intensities across animal food products, with cattle meat emitting the most, followed by pork, milk, and poultry. According to the FAO’s on-farm emission database, there are also very large variations of emission intensities across countries, most notable for cattle meats and pork. Multiple measures are proposed for reducing the negative environmental implications of livestock production, ranging from technical solutions directly targeting livestock production, supply side policies such as regulations and environmental standards, and demand side measures such as carbon tax, information campaigns, and dietary recommendations.

Human health implications. Animal food products contains important nutrients such as high-value proteins, fatty acids, minerals, and vitamins, positioning it for an important role in attaining health-related SDGs concerning hunger and undernourishment. However, over-consumption of products such as red meats and processed meats is identified as a risk factor of cardiovascular disease and other diseases. Thus, in recent years, dietary guidelines tend to prioritize plant-based food over animal food products. Beyond nutritional aspects, meat and dairy production is also related to other health concerns
such as food safety, the spread of zoonoses, and antimicrobial resistance. Some countries are already implementing policies or guidelines that try to deal with such concerns.

**The meat sector.** Countries in East Asia and Southeast Asia, notably China, Vietnam, South Korea, and the Philippines, are expected to be growth markets for meat exporters from the EU and the Americas. Over the next decade, changing composition of meat demand is expected, led by growing demand for poultry and followed pork demand. Aggregated beef demand is expected to increase moderately and only Asia is projected to increase its per capita beef demand. In developed countries, while per capita meat demand stagnates, consumers increasingly demand more processed meat products that are convenient and/or available from food services. Increasing environmental and health concerns are also changing the consumption patterns in some countries, for example in the EU where there are increasing demands for organic meat and plant-based alternatives. As the public debate on the environmental implications of meat consumption intensifies, future consumption of meat products may subject to policy interventions, particularly in high-income countries.

On the production side, current differences and potential future divergences in environmental and veterinarian regulations can lead to cost differentials in production and trade. For instance, meat products sourced from the EU are subject to more stringent environmental regulations and health and food safety standards and will have to continue to market their products on these terms, whereas other countries such as the US and Brazil compete more in prices and volume terms. The latter’s price advantage can also be attributed to their access to ample domestic feed supplies, as both are major producers and exporters of bulk commodities such as maize and soybean. Potential cross-country differences in regulating GHG emissions from livestock production can further influence production costs and export performance, with countries with more stringent emission regulations possibly bearing higher costs. There is also a risk of carbon leakage: if GHG regulation becomes more stringent in countries with low emission intensities, countries with high emission intensities and low emission reduction ambitions may gain market share and emit more. Responding to policies targeting production, producers may relocate production to regions with lax emission ambitions; similarly, responding to policies targeting consumption, producers can redirect their products from domestic markets to export markets.

The Covid-19 pandemic and the African Swine Fever (ASF) crisis currently affect the global meat market. The initial reaction to the Covid-19 pandemic was a decrease in meat production due to logistic bottlenecks and labor shortages. At the same time, the ASF outbreak represents a major threat to the pork industry in a number of countries in Asia, Europe, and Africa, contributing to reduced domestic supply and increased import demand in countries such as China. In the medium term, demographic patterns in developing countries are expected to be the main determinant of the meat market. Growing population and income are expected to drive the demand growth, especially in South-East Asia. A detailed analysis of the available data on the consumption, production, and trade patterns in the meat sector – disaggregated by beef, pork, poultry – corroborates the views expressed by industry members: the largest changes within the meat market will likely take place in developing and emerging economies. A detailed review of long-term market projections from several major organizations (i.e. FAO-OECD, EC, and USDA) are found to be largely consistent with the patterns already observed from the historical trends. However, major uncertainties on climate change mitigation measures in connection with the Paris Agreement, technological development, and trade agreements and trade conflicts in the coming decades are not adequately reflected in the current market projections but they may change the sector’s development trajectories. Therefore, there is a need to incorporate these uncertainties in future studies; furthermore, there is need for projections with a longer time horizon than the 10 years typically covered by the aforementioned market projections.
The dairy sector. Similar to the meat sector projection, the global consumption of dairy products is expected to increase over the coming decades, driven by population growth, changing diets, and higher purchasing power for a growing middle-class population in developing economies. Large differences in per capita dairy consumption exist across countries, with annual per capita dairy consumption (measured in milk equivalent) reaching 467 kg in Finland, 24kg in China, and only 2kg in Nigeria. In developed countries where per capita dairy consumptions are generally higher, processed dairy products have an increasingly larger share of total dairy consumption, whereas consumers in developing nations continue to consume mainly fresh milk and milk powder. This pattern is expected to persist with developing countries (particularly Southeast Asian, West African and the MENA region) consuming per capita and total dairy consumption. On the other side, having already reached market saturation for traditional dairy products, developed countries’ consumption measured in raw milk equivalents is expected to stagnate but a shift towards “sustainable” products and “to go” options is expected, driven in part by increased awareness of climate change and sustainability.

On the production side, South Asia (particularly India), North America, Europe, and Oceania are the main milk producers. For more processed dairy products, the US, the EU, New Zealand are the more important producers. The global distribution of milk and dairy production is determined by a variety of factors that influence herd size and yields, which often differ across countries and in particular between developed and developing countries. Smallholder and subsistence farming still prevail in developing nations, while large-scale intensive production dominates in developed regions. Annual raw milk yields per cow reaches the level of around 10 tons in North America and part of Europe but only a fraction of that in many other countries. Similarly, large differences in total emissions and emission intensities from milk production are also observed. While total emissions are the highest in India, the Americas, China, milk production in Africa and part of South Asia emits more on per unit basis. Such differences can be partially explained by differences in production methods and technologies, which in turn are rooted in the differences of resource endowments, national regulations, and degrees of economic and social development. Therefore, the development of these factors needs to be considered in understanding the sector’s future development, not the least in connection with the need to reduce the sector’s GHG emissions.

Perishability, the need for cold supply chain, and the high water content of fresh milk limit the tradability of fresh milk. Divergences of Sanitary and Phyto-sanitary (SPS) measures also add to trade costs. Therefore, it is not surprising that only 8% of the total world milk production is traded internationally, most of which is more processed products such as butter, cheeses and milk powder. Technology innovations and economic development have opened up trade of liquid milk and other fresh dairy products in certain new trade routes, such as the exports of liquid milk from New Zealand and the EU to China. In contrast, there is very limited access to the Indian market, the world’s largest milk producer. For milk and cream, North America, Australia, New Zealand, the EU are the major exporters, while Asia and Africa are the main importers. In the case of cheese, North America is also a net importer.

Much like the meat sector, the short-term development of the dairy sector hinges on the recovery of the world and national economies from the Covid-19 pandemic, and on the extent to which the pandemic may continue to create supply chain disruptions. In the long-term, the evolution of the dairy sector will be influenced by demand factors such as income growth, demographic shifts and potential changes in dietary patterns, as well as structural changes in production and technological innovations. Using detailed market projections conducted by FAO-OECD, EC and USDA, this report synthesizes the likely market development in the next ten years regarding production, consumption and trade patterns of milk,
milk powder, butter and cheese. Furthermore, these projections are compared and contrasted with opinions expressed by industry experts whom we interviewed for this report.
1 INTRODUCTION

The livestock sector and the consumption of animal-based foods have been receiving increased attention in recent years, giving the environmental impacts attributed to the production process. The livestock sector is related to several Sustainable Development Goals (SDGs) (UN Open Working Group, 2014), such as ending hunger and limiting climate change. Hence, the sector is at the center of policy discussions globally. For instance, Denmark – which accounts for around 6.6% of the European pig meat production (Eurostat, 2020) – recently witnessed the emergence of the first vegan party whose main goal is to abolish industrial animal agriculture and move towards a fully plant-based agricultural sector (Veganerpartiet, n.d.)\(^2\). Also in Denmark, the government follows the recommendations of the EAT-Lancet Commission (2019) and encourages limiting the consumption of animal-based food (Ministeriet for Fødevarer, 2021). At the same time, the livestock sector is a key contributor to the economies of many developing countries since it is a valuable source of livelihood in poor rural areas in those countries (Salmon et al., 2020). Thus, studying what is the state of the livestock sector at the moment and understanding its role in a global context is crucial in informing both public policy debates in accordance with the SDGs and the industry that will need to adapt to new regulations and developments.

The agricultural sector accounted for 4% of the global Gross Domestic Product (GDP) in 2018 (The World Bank, 2020). According to the FAO (2006), the world livestock sector contributes around 40% to the global agricultural GDP, amounting to 1.6% of the global GDP. However, this share varies significantly across countries/regions and depends on the number of agricultural services (e.g. the value created by the use of livestock as draught power or manure utilization) considered within the livestock sector (Salmon et al., 2020). The role of livestock in the economy varies with respect to the stage of a country’s development, the production system, and the environmental characteristics, among other things (FAO, 2018).

In the following decades, current projections suggest that population and income growth in developing countries are expected to boost livestock production (OECD & FAO, 2020). Per capita demand for poultry has been increasing in every world region in the last 30 years, while that for pork has stagnated in Europe and North America. Beef per capita consumption has decreased in every world region in the last three decades. Nonetheless, the story changes when we factor into population growth: total demand for poultry, pig, and beef are expected to increase in Asia, Latin America, and Africa (OECD & FAO, 2021).

International trade between developed countries and emerging markets also plays an important role in the livestock market’s expansion. In 2019, 36 million tons of carcass weight equivalent meat (FAO, 2020g) and 76.7 million tons of milk equivalent\(^3\) (FAO, 2020c) were traded internationally. With the ratification of the General Agreement on Tariffs and Trade (GATT), as well as the establishment of the World Trade Organization (WTO) in the 1990s, strides were taken in liberalizing trade across multiple sectors multilaterally (VanGrasstek, 2013). However, in the current context of market internationalization, multilateral trade agreements are not advancing in liberalizing agricultural trade, hence countries are developing regional agreements to facilitate trade (VanGrasstek, 2013). In fact, most trade in agricultural commodities already happens between neighboring countries given (a) the logistic requirements for the product durability and (b) the historical patterns of trade in the agrifood

\(^2\) n.d. = non dated

\(^3\) Milk equivalent is a measure for dairy products that reflects the quantity of milk used in their production.
sctors (Vitaliano, 2016). Given these limitations, it is difficult to conceive the market for some livestock products as one unified global market.

The livestock sector accounts for 14.5% of the annual anthropogenic greenhouse gas (GHG) emissions following the official guidelines for emissions accounting (Gerber et al., 2013). The estimation of the total emissions is however a challenging task due to the multiple sources of GHG emissions throughout the livestock supply chain (Gerber et al., 2013; Goodland & Anhang, 2009; Herrero et al., 2016; IPCC, 2019). One of the key methodological differences is whether the calculation of the national emissions accounts is production- or consumption-based. The choice seems to be a pragmatic or political matter, as there is no clear scientific argument tipping the balance (IPCC, 1996; Peters, 2008). Currently, international agreements are based on production-based accounts of emissions, meaning that countries with export-centered industries will have larger emissions estimates than if the calculation were consumption-based. The environmental pressures are incentivizing further regulation and monitoring of the production systems. One of the commonly accepted ways to reduce the GHG emissions is to grow intensively, i.e. increase the product yield per animal to reduce emission intensities (Herrero et al., 2016). Increases in production through increases in yields and reductions of dairy herd sizes are already occurring in Europe (EC, 2019; FAO, 2020c).

Meat and dairy provide protein, fatty acids, minerals, and vitamins; hence, they are widely regarded as an important part of the diet. Increasing meat and dairy consumption in recent decades has motivated the study of their properties and health implications. As a result, scientists identified both positive and negative aspects of consuming animal-based food. On the positive side, for instance, milk powder is the most effective way to treat malnutrition in infants (Michaelsen et al., 2009). On the negative side, an excessive intake of red or processed meat is a risk factor for cardiovascular disease, type 2 diabetes, and colorectal cancer (GBD Diet Collaborators, 2019). Conversely, vegetarian diets are inversely associated with the risk of developing type 2 diabetes (Olfert, 2018). As a result of the scientific evidence, research organizations, national government agencies, and international institutions have developed updated dietary guidelines (EAT-Lancet Commission, 2019; Harvard University, 2011; Ministeriet for Fødevarer, 2021; WHO, 2020a). Other health implications of animal-based food are related to food safety, zoonoses, and antimicrobial resistance.

The purpose of this report is to provide a nuanced explanation of how these different aspects mentioned above interlock with each other and how they jointly affect the development of the global livestock and animal food market, including the global distribution of production and consumption and the associated international trade patterns of these products. In the second and third chapters, we examine the demand and supply drivers, including an overview of available methodologies to study them. The third chapter discusses other important topics regarding the future of the sector, such as international trade development, the environmental impacts, and the health implications. The fifth and sixth chapters’ present market reviews of the meat and dairy sectors, respectively, using data to characterize the current consumption, production, and trade patterns. We also compare a range of short- and long-term market projections. Lastly, in the seventh chapter we summarize the facts presented and discuss the research gaps identified for understanding the sector’s future development.
2 DEMAND ANALYSIS

In this section, we first summarize the common demand trends of meat and dairy products. Then we present the data and methodologies used in the literature to understand consumer behaviors and to project future demand. The goal is to provide a framework before analyzing the markets separately.

2.1 DEMAND DRIVERS

Population and income are considered the main drivers for food demand in the economic literature. Average consumers in developing countries generally spend a large share of their income on food, so they are more responsive to both income and price changes (Regmi & Meade, 2013). The high responsiveness of expenditure on basic human needs to income changes is known as the Engel’s Law and is well documented in the literature (Chaudri & Timmer, 1986; Ho et al., 2020). In the next decade, projected rising income and population in low- and medium-income countries is expected to further drive the food market, particularly the meat and dairy markets (OECD & FAO, 2015b). This also corresponds to another well-known pattern called Bennett’s Law: the share of livestock products increases and the share of staple food decreases in the consumption bundle as income grows (Bennett, 1941; Ho et al., 2020). Development policies might further encourage this effect, as a thriving agricultural sector has two to four times more potential to diminish poverty compared to other economic sectors (World Bank Group, 2015). In contrast, consumers in developed countries generally spend a smaller share of their income on food and are less sensitive to income and price changes in their food purchases.

Current research on food consumption in Western countries tends to focus more on healthy and environmentally friendly food choices. It could be pointed out that this research agenda is “westernized”, because developing countries are still transitioning towards richer diets and therefore focusing on food security and food safety. Recent research suggests that population growth and dietary changes towards animal-based foods in developing countries are expected to increase greenhouse gas (GHG) emissions from food and agriculture by up to 80% by 2050 (Springmann et al., 2016). In this context, the multiple purposes of livestock (e.g. to support crop production with draught power and manure, to provide a valuable use of crop residues and other by-products, high-quality nutrition, a regular income, insurance, savings, as well as cultural and social roles) in low- and middle-income countries tend to be neglected (Salmon et al., 2020). Yet, health and environmental concerns leading to meat regulation are also expected to rise in these countries (Bonnet, Bouamra-Mechemache, Réquillart, & Treich, 2020), adding significant uncertainty to long-term projections on whether future meat and dairy consumption will continue to be determined by income and population growth.

In other literature, food demand is also explained by the nature of the human brain. In his seminal book, Kahneman (2011) presents the concept of ego depletion as a way to explain irrational decisions. The idea is that humans have limited mental resources, so when we are tired or focusing in other demanding tasks, our self-control is impaired. At the same time, human brains have evolved to identify energy-dense food in an environment with limited food security, developing a taste for sugary, fatty and salty foods (Breslin, 2013). Hence, engineered hyper-palatable and easily accessible foods are a trigger for our brains (Gearhardt, Grilo, DiLeone, Brownell, & Potenza, 2011; Stroebel & De Castro, 2004). For example, a cheesy convenience dish seems like a perfect idea for a Friday dinner after an intense week of work. The importance of these elements should not be neglected when trying to explain demand.

* Besides income is important to consider affordability. The housing cost often represents a significant share of the household expenses, and should be taken into account while examining dietary patterns (Penne & Goedemé, 2020).
drivers; indeed, Thaler and Sunstein (2008) highlight how choice architecture influences economic outcomes due to our bounded rationality.

*Figure 2.1: A Meat Stall with the Holy Family Giving Alms by Pieter Aertsen (1551)*

Social norms, religions, and cultures also influence food consumption patterns. For instance, many religions impose dietary restrictions affecting the global distribution of meat and dairy demand. The majority of Hindus are vegetarian or do not eat beef, whereas Muslims and Jews cannot eat pork. The distribution of socio-cultural and social norms is often heterogeneous, not only across countries but also within countries.

It is interesting to study whether and when certain changes in social trends end up influencing aggregated outcomes at the country level. For instance, the French court society was the vanguard of western dietary trends still present today: that the meat cuts are not prepared at the table, that a reduced variety of meats is consumed, and that the reminders of the slaughtering are avoided (De Boer, Hoek, & Elzerman, 2006). In Figure 2.1 the Dutch painter Pieter Aertsen (Aertsen, 1551) depicted a meat stall displaying a pig and a cow head, hoofs, and birds still not unfeathered. Next to it, Figure 2.2 shows the results of Google Images for the query “meat”; the meat seems now completely dissociated from animals. De Boer et al. (2006) relate the unawareness of the meat’s origin to the lack of attention to animal welfare. Other societal aspects like gender roles also explain changes in food demand: a higher participation of women in the labor market increases the outsourcing of food services and vice versa (Raz-Yurovich & Marx, 2019; Van Der Lippe, Tijdens, & De Ruijter, 2016).

*Figure 2.2: Googling “meat” – November 2020*

Finally, it is important to consider the rise of political movements, particularly in Western countries, concerning the protection of the environment and animal welfare/rights. In 2019, the Green parties got their largest share in the European Parliament (Henley, 2019). Last August, the first Danish Vegan party was created (Euronews & AFP, 2020). Similar (but more timid) political ambitions are reaching mainstream parties. Recently, the Danish Government proposed to ban meat twice a week in state canteens (Levitt, 2020). In fact, restrictive regulatory measures on food production to attenuate environmental damage are not new; for example, overfishing regulation has been present for decades. Even consumer-oriented campaigns have been present for years. The John Hopkins Center for a Livable Future has been campaigning for meatless Mondays since 2003 (GRACE Communications Foundation, n.d.).
Figure 2.3: Google Trends – Plant-based diet, Veganism and Vegetarianism

Figure 2.3 shows the increasing interest for the terms “Plant-based diet”, “Veganism”, and “Vegetarianism” worldwide in recent years. Indeed, plant-based substitutes to dairy (e.g. soy, oat, or almond drinks) and to meat (e.g. Beyond Meat or Impossible Meat) are flourishing in the shelves of western supermarkets. Gerhardt, ZiemBen, Warschun, Donnan, and Kühnle (2019) expect that a significant change of agricultural production in the European Union (EU) over the next 10-20 years could be driven by a gradual shift towards flexitarian diets. Currently in Europe, the number of flexitarians rises across generations, while vegetarians and vegans are concentrated in the younger generation. However, the illustrations provided mainly come from developed economies. Although potential regulations on animal food consumptions due to environmental concerns may become relevant on the political agenda of developing countries (Bonnet et al., 2020), it is important to acknowledge that a global shift based on these movements is highly unlikely since income and population growth are still the main drivers of the animal food market in developing economies.

2.2 METHODOLOGICAL ASPECTS

Economists usually study demand drivers by estimating demand elasticities - the percentage change of the demand of a given product due to a 1% change in a given variable, e.g. price, income, housing price, or population characteristics. The demand function can be specified either in the products space – using quantities, prices, or other exogenous variables – or in the characteristics space – using the features defining a product. In both cases, there exists a broad variety of econometric models whose suitability depends on the data and scope of the analyses. When analyzing food demand in the product space, a number of data and modeling issues must be addressed, e.g. acquiring enough observations to estimate the parameters (the number of parameters to estimate generally grows with the number of products) and dealing with the difficulties to model new products due to the obvious lack of historical data, among other considerations.

Gallet (2010) conducted a meta-analysis on the price elasticities of meat and found that the most common model is the linearized almost ideal demand system (LAIDS) using a price index for the
linearization (Deaton & Muellbauer, 1980). Other versions of the almost ideal demand system (AIDS) also populate his sample, i.e. nonlinear AIDS, quadratic AIDS, and generalized AIDS.

Given the diversity of econometric models and data sources, conducting meta-regressions can be a useful exercise to obtain robust estimates of demand elasticities. In the context of long-run demand projections covering a wider range of countries of significantly different income levels and of varying income growth patterns, another direction is to estimate a global demand system encompassing a full range of countries along the global income spectrum (Cranfield, Preckel, Eales, & Hertel, 2002). However, such work would require a global data set as well as a demand system that satisfies global regularity properties (Yu, Hertel, Preckel, & Eales, 2004).

Once the demand elasticities are estimated using historical data, we can understand better how consumers react to price and income changes, as well as how they adjust consumption bundles by reallocating their food budget across different products. This information can then be used to perform forward-looking projections that are often model-based extrapolations built upon the estimated elasticities and additional information such as projected income growth and demographic changes. Depending on the specific functional forms used in the projection models, the estimated elasticities either remain unchanged or depend on the new income and price levels during the projection period. Ad hoc adjustments to the estimated elasticities or the parameters underlying these elasticities may also be introduced by researchers (Ho et al., 2020).

Several major international and national agencies, such as the Organisation for Economic Cooperation and Development (OECD), Food and Agriculture Organization (FAO), the European Commission (EC), and the United States Department of Agriculture (USDA) have published regularly updated projections on the agricultural and food markets. All these projections are based on quantitative models that make use of existing estimated demand elasticities. Specifically, the OECD-FAO projections are based on the Aglink-Cosimo (OECD & FAO, 2015a); the European Commission projections are drawn from the EU module of the Aglink-Cosimo model (Araujo Enciso et al., 2015); and the USDA projections are obtained from the ERS Country-Commodity Linked System (Hjort, Boussios, Seeley, & Hansen, 2018). These models characterize their demand equations using elasticities obtained from the literature or other models. In Table 2.1, we summarize relevant text from their respective documentation to reveal the sources of demand elasticities and the methods that such elasticities are derived from. As can be seen from the table, these models typically source elasticity estimates from the economic literature and then calibrate the parameters in their demand systems to these elasticities. While analyzing international markets, it is common to find data discrepancies on commodity aggregation, time intervals, and geographical coverage. Hence, modelers usually employ synthetic elasticities that are (a) theoretically consistent, (b) reasonable in terms of known supply and demand elasticities in similar economies, (c) reasonable in terms of cross-commodity comparisons, (d) representative of historical behavior, and (e) that generate credible results according to country and commodity experts (Hjort et al., 2018).
Table 2.1: Food demand elasticities used on long-term projections

<table>
<thead>
<tr>
<th>Model</th>
<th>Projections</th>
<th>Demand system and elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aglink-Cosimo</strong></td>
<td>OECD-FAO</td>
<td><strong>Source of elasticities</strong>: Cross- and own-price elasticities are sourced from literature or calculated based on historic information (OECD, 2007) and need to fulfill certain criteria (OECD &amp; FAO, 2015a).</td>
</tr>
<tr>
<td><em>(OECD &amp; FAO, 2015a)</em></td>
<td></td>
<td><strong>Demand system</strong>: Double-log equation incorporating several variables (e.g. human consumption, population and price and consumption indexes) and the cross- and own-price elasticities (OECD &amp; FAO, 2015a).</td>
</tr>
<tr>
<td><strong>EU module for Aglink-Cosimo</strong></td>
<td>European Commission</td>
<td><strong>Source of elasticities</strong>: The EU price-demand elasticities used are:</td>
</tr>
<tr>
<td><em>(Araujo Enciso et al., 2015)</em></td>
<td></td>
<td><img src="https://via.placeholder.com/150" alt="Table" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Cheese</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Fresh dairy products</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Whole milk powder</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Pork</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Sheep meat</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Demand system</strong>: Same as Aglink-Cosimo.</td>
</tr>
<tr>
<td><strong>ERS Country-Commodity</strong></td>
<td>USDA</td>
<td><strong>Source of elasticities</strong>: The “elasticities must be obtained from published studies or other means”. The own- and cross-price demand elasticities need to be consistent. Theoretical demand properties imposed on projections.</td>
</tr>
<tr>
<td><strong>Linked System - CCLS</strong></td>
<td><em>(Hjort et al., 2018)</em></td>
<td><strong>Demand system</strong>: Choice from three functional forms: linear, Cobb-Douglas, or exponential.</td>
</tr>
<tr>
<td><strong>CAPRI</strong></td>
<td></td>
<td><strong>Sources of elasticities</strong>: obtained from Aglink-Cosimo.</td>
</tr>
<tr>
<td><em>(Britz &amp; Witzke, 2014)</em></td>
<td></td>
<td><strong>Demand system</strong>: Marshallian demands based on prices and income.</td>
</tr>
<tr>
<td><strong>MAGNET</strong></td>
<td></td>
<td><strong>Source of elasticities</strong>: Income elasticities calibrated using PPP-corrected Gross Domestic Product (GDP) per capita, and the Global Trade Analysis Project (GTAP) income and price elasticities of demand.</td>
</tr>
<tr>
<td><em>(Woltjer et al., 2014)</em></td>
<td></td>
<td><strong>Demand system</strong>: same as GTAP.</td>
</tr>
<tr>
<td><strong>GTAP</strong></td>
<td></td>
<td><strong>Source of elasticities</strong>: GTAP Database 10 elasticities are estimated using GTAP data and AIDADS demand system.</td>
</tr>
<tr>
<td><em>(Hertel &amp; van der Mensbrugghe, 2019)</em></td>
<td></td>
<td><strong>Demand system</strong>: The elasticities are calibrated to the Constant Difference of Elasticities (CDE) demand system.</td>
</tr>
<tr>
<td><strong>WTO – World Trade Model</strong></td>
<td></td>
<td>Same as GTAP.</td>
</tr>
</tbody>
</table>
The data choice to estimate demand elasticities varies with the scope of the study and the model specification. Micro-data gathered from individual consumers are valuable because they gather detailed information on both the products and consumers. There are several types of micro-data for food consumption: survey consumption data, stated preference data\(^5\), and revealed preference data\(^6\) (e.g., scanner (Muth, Okrent, Zhen, & Karns, 2020) or field experiment data). However, their collection frequently lacks standardization, is costly, and is difficult to conduct in informal markets. Regarding survey and stated preference data, even within developed countries, there is a lack of standardization. In fact, currently the European Food Safety Authority (EFSA) supports surveys to collect harmonized food consumption data from the Member States (Ioannidou, Horváth, & Arcella, 2020). Since the collection of survey and stated preference data is very costly, it is frequently not available for developing countries. Moreover, in such countries food markets frequently lack scanner technologies.

Due to these limitations, it is a common practice to use macro-data when studying international markets. Aggregated standardized data allow for international comparisons but have relevant limitations on the level of detail. For instance, the best source in this case is the Food and Agriculture Organization Statistics Division (FAOSTAT) Food Balance data (FAO, 2020d) that cover a wide range of countries, particularly with regards to food supply indicators such as per capita intakes of calories, protein and fat. These indicators gather information on per capita food availability but not on the actual consumption, thereby likely systematically overestimating food consumption compared to micro-data (Kearney, 2010). Another major issue is that matching price and food expenditure information is not available, thereby making it difficult to conduct cross-country demand estimations. Alternatively, macro-data for individual countries may be available from national statistical agencies, allowing estimation of demand elasticities for individual countries of particular interest.

As an illustration, Figure 2.4 provides the income and price elasticities for meat-livestock and dairy products from the GTAP database version 10 (Aguiar, Chepiliev, Corong, McDougall, & van der Mensbrughe, 2019), a widely used global dataset in virtually all global computable general equilibrium models. In the first panel, we observe that income elasticities for meat-livestock and dairy products are in between zero and one across regions. This means that an income increase leads to a less than proportional increase in meat-livestock and dairy demand. The closest to one is meat-livestock products in Sub-Saharan Africa, where a 1% income increase leads to a 0.92% increase in meat-livestock consumption.

The next two panels show the distributions of price elasticities. The triangles indicate the own-elasticities of meats and dairy products, which measure the responsiveness of demand of these products with respect to their own price changes, whereas the circles indicate the cross-elasticities (i.e. the percentage change of meat/dairy demand in responding to a one percent change in the price of another product) that capture the substitution or complementarity patterns across different products. The GTAP database uses Marshallian elasticities that include both the income and substitution effects. In the second panel, we observe that in Oceania, North America, and EU28 a one percent increase in meat-livestock prices significantly reduces their demand, whereas the resulting decrease in demand is smaller

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\(^5\) Stated preference data refers to data gathered from surveys where the consumers state their preferences. Often they face a number of consecutive choices between different goods (e.g. meat, dairy, fish or pulses) that are defined by some salient characteristics (e.g. price, protein content and preparation time). In each subsequent choice the values of the characteristics of each type of food varies. From this information, the researcher is able to estimate what features of the good drive consumption choices. Such data is frequently used when researchers model demand in the characteristics space.

\(^6\) Revealed preference data refers to data gathered from actual consumer behavior. It has some limitations because the collection does not happen in a controlled environment, but it provides important insights on consumer behavior in real settings.
in developing regions. In general, consumers in developing countries tend to follow Engel’s Law, devoting a larger share of their income on food consumption (Chaudri & Timmer, 1986; Ho et al., 2020), and are generally more sensitive to income and food price changes (Regmi & Meade, 2013). In our illustration, however, these consumers seem to react less to an increase in the prices of animal food products. This could mean that the households in such countries are currently consuming relatively small quantity of meat-livestock and dairy products, making them less willing to give up on them. We observe the same pattern in the dairy products’ panel. With respect to the patterns implied by the cross-price elasticities, we observe complementarities (negative cross-price elasticities) across the different food products. The most significant are the complementarity of meat-livestock and dairy products with grains and crops in Sub-Saharan Africa. A 1% rise in the price of crops and grains reduces the quantity of meat and livestock consumption by 0.21% and the quantity of dairy products by 0.20%.

Figure 2.4: Income and price elasticities for meat-livestock and dairy products

Source: Authors’ elaboration from Aguiar, Chepeliev, et al. (2019).

Another well-known source of elasticities is the price and income elasticities database compiled from the literature by the USDA (2006). Table 2.2 includes some estimates for pork own-price elasticities. For the different estimates, the sample varies: some of them are from the United States (US) and others from China and the time periods of the data collection also differ. The data type can be either time series – same data points collected at different points in time – or cross sectional – different data points collected at the same point in time. More importantly, these elasticities are either defined differently or
estimated from different demand systems. First, these elasticities are either Marshallian or Hicksian elasticities, where the former simply represents the relationship between the price of a good and the quantity demanded, while the latter does so assuming that real wealth remains constant. As a result, Marshallian demands include both income effects – a price decrease can be perceived as an income increase – and substitution effects – a price decrease will make the product more attractive relative to others, whereas the Hicksian demand only includes substitution effects. Second, there are multiple functional forms used to estimate these two demand systems, e.g. the AIDS, Normalized Quadratic or Translog models. Here it is relevant to recall that the GTAP elasticities are estimated from An Implicit, Directly Additive Demand System (AIDADS) model and calibrated to the constant difference elasticity (CDE) demand system (see Table 2.1). Such combination is not present in the USDA (2006) dataset so we cannot directly compare the estimates. However, if we compare the estimates for the own-price elasticity of Meat and Livestock in Figure 2.4 and the estimates in Table 2.2 for own-price pork elasticities we see that in general the difference does not seem to be large. We also observe that there are some outliers in the USDA (2006) data. Including all the 56 observations in the dataset, the average own-price elasticity for pork is -0.583 with a standard deviation of 0.47.

Table 2.2: Extract of some pork own-price elasticities collected by USDA (2006)

<table>
<thead>
<tr>
<th>Elast.</th>
<th>Country</th>
<th>Model</th>
<th>Demand system</th>
<th>Data type</th>
<th>Data period</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.471</td>
<td>US</td>
<td>Normalized Quadratic</td>
<td>N/A</td>
<td>TS</td>
<td>1987-1999</td>
<td>(i)</td>
</tr>
<tr>
<td>-0.687</td>
<td>US</td>
<td>AIDS</td>
<td>Marshallian</td>
<td>CS</td>
<td>1987-1988</td>
<td>(ii)</td>
</tr>
<tr>
<td>-0.867</td>
<td>US</td>
<td>Mean symmetric LAIDS</td>
<td>Marshallian</td>
<td>TS</td>
<td>1958-1985</td>
<td>(iii)</td>
</tr>
<tr>
<td>-0.872</td>
<td>US</td>
<td>Translog</td>
<td>Marshallian</td>
<td>TS</td>
<td>1965-1981</td>
<td>(iv)</td>
</tr>
<tr>
<td>-0.959</td>
<td>China</td>
<td>QAIDS</td>
<td>Marshallian</td>
<td>CS</td>
<td>1998</td>
<td>(v)</td>
</tr>
<tr>
<td>-0.741</td>
<td>China</td>
<td>QAIDS</td>
<td>Hicksian</td>
<td>CS</td>
<td>1998</td>
<td></td>
</tr>
<tr>
<td>-0.924</td>
<td>China</td>
<td>Censored QAIDS</td>
<td>Marshallian</td>
<td>CS</td>
<td>1998</td>
<td></td>
</tr>
<tr>
<td>-0.722</td>
<td>China</td>
<td>Censored QAIDS</td>
<td>Hicksian</td>
<td>CS</td>
<td>1998</td>
<td></td>
</tr>
</tbody>
</table>

Note: The references for the study column are (i) Lusk, Marsh, Schroeder, and Fox (2001), (ii) Huang and Lin (2000), (iii) Chen (1998), (iv) Menkhaus, St. Clair, and Hallingbye (1985), and (v) Liu and Chern (2003). From Huang and Lin (2000) we included the estimate using all income groups and for Menkhaus et al. (1985) we took the 1975-1980 mean since both papers had included several estimates using different samples. In the data type column TS corresponds to time series and CS to cross section. N/A means not available.

As we have seen, many different factors contribute to explain the demands for animal-based food products in different parts of the world. The projection of these demands mainly depends on the developments in population, income level, and relative prices. Another element to consider would be a trend variable representing, for instance, intertemporal developments in preferences and dietary transitions to align with sustainability concerns. The demand projections simultaneously depend on the econometric model, data, and method to update the elasticities in partial and general equilibrium models. The updating methods currently used depend on marginal changes, but growing income is expected to lead to a non-marginal change on food consumption behavior. Hence, the projections based on elasticities estimated with historical data imply important uncertainties.

7 We computed these statistics after doing a correction in the original dataset. The USDA (2006) collected the QAIDS Marshallian estimate as -0.009 while in Liu and Chern (2003) that figure corresponds to the cross-price elasticity of pork with respect to fresh fruits.
3 Supply Analysis

A multitude of factors drives livestock and animal food production patterns, ranging from indirect factors related to demand-side forces (e.g. demographic transitions and income growth), and direct factors that shape livestock production systems, such as characteristics and availability of natural resources, farm decision making, new regulatory requirements, and technological advancements, among others. These supply drivers vary geographically and livestock production systems differ across the globe, resulting in uneven allocation of livestock and animal food production across countries and regions. The heterogeneity in production systems also affects the emissions intensities and the possibility to reduce them by means of technology development and best practice transfers (e.g. some regions’ production systems are already at the technological frontier whereas others lag behind). Moreover, the emissions related to livestock production are not easy to monitor and quantify. As such, analyzing the future of the livestock sector in the presence of heightened climate mitigation pressure is a challenging task, since we need to consider the uncertainties regarding the development in production systems, adoption of technology, and effects of climate change on the sector. In this section, we discuss the drivers of livestock supply and the current state of production systems, along with future prospects and potential challenges. In addition, in relation to the challenges identified, we introduce several methods commonly used to model the development of the livestock and animal food production under climate change.

There are many factors influencing outputs from the livestock sector. Some influence it indirectly and others are specifically related to the sector. The definition of a driver is broad. Hazell and Wood (2008) provide a widely accepted definition: a driver is “any natural- or human-induced factor that directly or indirectly brings about change in an agricultural production systems”. Van Zanten, Van Hal, and De Boer (2016) define direct factors as the ones that are a part of the farm decision-making process. Examples of such drivers are changes in (1) regulatory measures that determine the allowed practices, (2) current production capabilities – i.e. technology and management practice knowledge –, and (3) biophysical constraints of the livestock breeds (Hazell & Wood, 2008; Herrero et al., 2012; Millennium Ecosystem Assessment, 2005; Van Zanten et al., 2016).

Indirect drivers have less defined boundaries, as the factors tangentially influencing production are manifold (Table 3.1). When conducting projections, researchers most commonly reflect upon the macro-trends in society, such as population and income growth, which influence demand thereby indirectly leading to production growth through market forces. Culture and lifestyle changes may lead to shifts in dietary patterns, thereby also leading to production changes through market interactions (Hazell & Wood, 2008; Herrero et al., 2012; Millennium Ecosystem Assessment, 2005; Van Zanten et al., 2016). Another indirect driver is the political environment under which production is undertaken; this influences future regulation, trade relationships, as well as investment incentives. Environmental issues emerging from production and societal environmental concerns can also affect the regulation for future production and lead to demand shifts towards environmentally conscious consumption. Science and technological innovations may as well influence future production capabilities and change biophysical constraints.

The many drivers affect supply behavior to different degrees. The relative magnitude of their impact is not constant geographically or over time, but depends on the specificity of each market (Herrero et al., 2012). This is especially relevant when designing regulations to induce a certain reaction. For instance, in a demand driven market, regulation targeting consumers may be more impactful, whereas, if supply is only responding to production capabilities and resource availability, regulation targeting the producers may be more appropriate. When projecting future market movements, the drivers included
and their assumed future behaviors can significantly influence projection results. Therefore, any evidence on these relationships can improve the validity of projections and lead to comparable projections.

Table 3.1: Supply Drivers

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulation</td>
<td>Macro changes</td>
</tr>
<tr>
<td>Production capabilities</td>
<td>Political environment</td>
</tr>
<tr>
<td>Biophysical</td>
<td>Environmental issues</td>
</tr>
<tr>
<td></td>
<td>Science and technology</td>
</tr>
<tr>
<td></td>
<td>Culture and lifestyle</td>
</tr>
</tbody>
</table>

Source: Van Zanten et al. (2016)

3.1 PRODUCTION SYSTEMS

The livestock production systems differ significantly across the world with respect to factors such as resource intensity, average farm size, market orientation, and regulation standards (FAO, 2010; IFCN, 2020; OECD & FAO, 2020; Robinson et al., 2011). It ranges from extensive production systems where livestock is grazing on grassland on the one hand, to intensive “landless” systems where little land is used per animal head on the other hand. In between, there are also some mixed production systems. This idiosyncrasy has large implications for the potential to regulate the sector, for instance requirements to the use of technology, management practices restrictions, or taxation schemes based on production size or environmental impacts, which requires farm information collection. In countries where smallholder farming is prevalent, regulating the sector is more costly due to the dispersion of producers and lower data availability. More developed countries typically have production concentrated towards large producers, making regulation easier to implement. Moreover, in countries with smallholder production, the livelihoods of smallholders are closely tied to livestock production, as it is an important income for the poorest part of society. Hence, any intensification that results in consolidated production might not be optimal for society in the short run, as it may risk the livelihoods of these poorest parts of society, especially if an alternative income source is not first established. (Bingshen & Yijun, 2008; Herrero et al., 2013; Rabobank, 2013).

The differences mentioned above, together with the rising demand for environmentally friendly production in higher income countries, has led to a wide variation of livestock production regulation

Box 1: Views from the industry

In preparing this report, we have engaged in in-depth dialogues with senior managers in key decision positions (e.g. CEO, COO, Chairman of the Board of Directors, member of executive boards, etc.) from a few major meat and dairy companies based in Europe and having operations in Europe, Asia, Africa, North America, and South America. The industry representatives with whom we have spoken also recognize regulation differences across countries. They generally consider regulations (such as environmental standards, sustainability, food safety, and animal welfare) to be stricter in the European Union (EU) as compared to developing countries and other main competitors in international markets such as the United States (US) and Brazil. As such, EU producers tend to compete on the premises of better quality and food safety attributes, as opposed to prices.

8 Definitions on standard production systems classifications can be found in Seré, Steinfeld, and Groenewold (1996)
across countries (Vranken, Avermaete, Petalios, & Mathijs, 2014). In this respect, there is a dichotomy between developed and developing countries, which will likely guide the changes in production systems during the coming decades. Simply put, developed countries pursue environmental sustainability, whereas developing countries are still pursuing increasing quantities of production to meet growing demand (Thornton, 2010). One such example is that the dairy herd size of the European Union (EU) is decreasing and milk collection rises due to productivity increases, whereas the dairy herds in Asia and Africa are increasing (OECD & FAO, 2020).

Besides regulation disparities, infrastructure is also heterogeneous across countries, influencing production methods and supply chain integration. In developed countries, the historical evolution of the livestock production led to a strong vertical integration of primary producers, processors, and retailers, especially in the dairy sector (Demirbas, Kenanoglu, Uysal, & Karagozlu, 2004). Supply chain infrastructure has a role in determining the level of processing and potential for large production, and is yet to be fully developed in rural areas of developing countries (Heard & Miller, 2019). As storage is not a viable option in some countries, the production of processed goods and their integration in the international market is limited.

Over the coming decades, production growth is expected to stagnate in developed countries because their livestock markets are at a saturation point with constrained growth for a range of products. Thus, even if there may still be a change in production patterns, the aggregate level will remain somewhat stable (OECD & FAO, 2020; Thornton, 2010). In developing countries, on the other hand, demand is increasing, driven by income and population growth. It is therefore expected that the future production in these countries will be challenged by the competition uses of natural resources (Herrero et al., 2012; Thornton, 2010).

Figure 3.1 shows the distribution of global livestock production in 2006. The largest concentrations of livestock are in Europe, China, and the United States (US). For cattle, the dispersion seems to spread out more than other livestock species. This is due to two main reasons. First, cattle and dairy production are more common in grassland production systems (Table 3.2); hence, the production is relatively affordable as the capital requirements are minimal. Second, the size of the animals allows using them for a dual purpose: carrying material or powering instruments for working in fields. For other livestock such as pigs and poultry, their distributions are more concentrated around developed countries and urban centers. Placing production close to urban centers help minimize transportation costs, enabled by the possibility of producing pigs and poultry in the so-called “landless” production systems that reduce land requirements (Table 3.2) (FAO, 2006). In the next sections, we present a detailed account of the global distribution of livestock production in each sector.
Figure 3.1: Global distribution of livestock (e.g. a) cattle, b) pigs, c) chicken and d) duck)

Table 3.2: Commodities produced in each production system

<table>
<thead>
<tr>
<th></th>
<th>Cattle stock</th>
<th>Dairy cattle</th>
<th>Milk product</th>
<th>Pigmeat</th>
<th>Poultry</th>
<th>Egg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>28</td>
<td>15</td>
<td>7.9</td>
<td>1</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Mixed</td>
<td>66.9</td>
<td>85</td>
<td>92.1</td>
<td>59.8</td>
<td>24.3</td>
<td>30.8</td>
</tr>
<tr>
<td>Landless</td>
<td>5.1</td>
<td>0</td>
<td>0</td>
<td>39.3</td>
<td>73.9</td>
<td>67.9</td>
</tr>
</tbody>
</table>

Source: Author’s elaboration from Seré et al. (1996)
3.2 GLOBAL CHANGE AND FUTURE DEVELOPMENT OF THE LIVESTOCK SECTOR

Future regulation and development of livestock production will be influenced by global concerns. Global food security and environmental impacts of livestock production are both prominent examples of the sustainable development goals (UN General Assembly, 2015).

Global food security considerations under an increasingly stressed planet suggest that the food system needs to move towards the most efficient production to satisfy nutrition needs of the human population while minimizing resource use and greenhouse gas (GHG) emissions. In this regard, livestock products are problematic as their low feed conversion rate (i.e. the ratio between the input and output of human-edible nutrients) (Wilkinson, 2011). One way to mitigate this is to use innovated production methods to use feed that are non-edible for humans; however it may cause significant changes in the production structure (Ertl, Zebeli, Zollitsch, & Knaus, 2016; Karlsson, Spörndly, Lindberg, & Holtenius, 2018). To achieve global food security, increasing global cooperation is also needed, particularly during times of crisis, such as the current Covid-19 pandemic. Recent research points out the need to restructure the food system in order to have enhanced and resilient food security (Echeverría, 2020; Swinnen & McDermott, 2020). Such concerns often take on nationalistic characteristics, as countries either pursue food security by self-reliance or by increasingly engaging in trade as a coping strategy to production shortfalls (Martin & Glauber, 2020). The extent to which countries pursue these strategies will have implications for the future livestock production and the use of resources. For instance, a move towards self-reliance would increase domestic production in net importing countries, which may not be the most efficient producers. Thus, this may lead to a higher resource use in the global agricultural sector.

The environmental and climate effects of livestock production are increasingly becoming a serious concern. On the one side, livestock production leads to an increasing concentration of atmospheric GHG (to be discussed in section 4.2). On the other side, climate changes affect livestock productivity (see Figure 3.2). While the implication of livestock production on GHG emissions is widely documented, current knowledge on the climate change impact on livestock production is less detailed. Easterling and Apps (2005) point to the lack of research on this topic. Since then, more studies have been published on the impacts of global warming (Lara & Rostagno, 2013; Nienaber & Hahn, 2007), but there is still no systematic approach or analytic framework. Moreover, the increase of the so-called extreme weather events falls outside of what can be analyzed in traditional models, leading to a high degree of uncertainty of the estimated impacts (Thornton, van de Steeg, Notenbaert, & Herrero, 2009).

The scientific literature on the impacts of climate change on the food system has devoted more attention to the changes in crop production. The indirect impact that changes in crop production have on livestock production is more frequently studied than the direct impact (Rötter & Van de Geijn, 1999). Though the exact nature of the effects are unknown, some broad effects are commonly agreed upon. For instance, landless production systems are less vulnerable to indirect effects of changes in crop production, as landless farms do not themselves produce crops, and can therefore manage risk by diversifying input sources. Similarly, the direct impact of rising temperature on animals can be managed by ventilation systems in closed of stables (Rötter & Van de Geijn, 1999; Thornton et al., 2009). Thus, climate change is likely to have smaller impacts on poultry and pig production (see Table 3.2). In contrast, cattle production often uses large land areas, implying a greater connection to the surrounding environment. As mentioned above, landless systems are more widely used in developed countries and around large urban centers (FAO, 2006). Consequently, production impacts will differ depending on both geographical and species distributions.
The effects of climate change on production have already been observed. According to Sejian (2011), the rising temperature can lead to heat stress, affect feed intake and normal physiological as well as growth and reproductive processes, and induce behavioral and metabolic changes (Figure 3.2). Indirectly, other than the adverse effects on feed production and on water and land resource availability, climate change may also increase the severity and distribution of the spread of livestock diseases and parasites (see Figure 3.2 for more detail). The Avian Flu, and African Swine Fever are examples of such spreads. Furthermore, in most of the largest producing countries, there have been instances of cattle herds cut down due to adverse weather and low feed availability (Arelovich, Bravo, & Martínez, 2011; Countryman, Paarlberg, & Lee, 2016).

Figure 3.2: Effect of Climate change on productivity

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in Ambient temperature creates Heat Stress to livestock</td>
<td>Influences available feed quantity and quality</td>
</tr>
<tr>
<td>Affects feed intake and normal physiological processes</td>
<td>Water resource reduction, inducing pasture availability limitations</td>
</tr>
<tr>
<td>Induces behavioural and metabolic changes</td>
<td>Increases severity and distribution of livestock diseases and parasites</td>
</tr>
<tr>
<td>Affects growth and reproductive processes of animals</td>
<td>Vulnerable animals cause substantial economic impact</td>
</tr>
</tbody>
</table>

Source: Modified from Sejian (2011).

There exist a number of strategies for the adaptation to these changes. The most widely employed are technological innovation and adoption. Typically, advancements in breed productivity happen in countries located in temperate climates, where the production systems are capital-intensive and where there are willingness and resources for investment in such innovations. In contrast, breed productivity progresses have so far been more limited in tropical low-input environments (Van Zanten et al., 2016). For the coming decades, the developing countries – mainly Asia, but also Africa and South America – are likely to be under pressure to significantly increase their production (continuing the current trend) in order to meet their increasing demand (FAO, 2020c; OECD & FAO, 2020). In order to achieve such increases, improvements on resource efficiency will be critical. Therefore, the extent to which already existing technology is transferable and the rate of invention of new methods will be important factors to consider to optimally utilize the limited available resources.

3.3 SUPPLY MODELLING METHODOLOGY

Modelling future meat and dairy supply development under multiple considerations, as laid out above, typically requires a structural economic model to explicitly address these drivers. In what follows, we review several relevant models devoted to related issues, as summarized in Table 3.3.

These models can be broadly categorized as partial equilibrium (PE) such as Aglink-Cosimo, Common Agricultural Policy Regionalized Impact (CAPRI) and Country-Commodity Linked System (CCLS), or general equilibrium (GE) models such as the Global Trade Analysis Project (GTAP) model and many other models that have similar structure to the GTAP model. The distinction between the two types of models are concerned with sectoral inclusion and inter-sectoral linkages: PE models cover only one or
several sectors of the economic system, whereas GE models encompass the whole economy including linkages across sectors and factor markets. General equilibrium models typically feature utility maximizing consumers allocating expenditure across different goods and services and producers adopting production decisions according to cost-minimizing (or profit-maximizing) behaviors. Resource constraints and the presence of inter-mediate inputs create extensive inter-sectoral linkages. Finally, consistent macroeconomic accounting ensure the equalization of factor incomes and expenditure at the economy level. Due to the stringent accounting and behavior consistencies in the economic system and the need to maintain macro-economic aggregates (e.g. Gross Domestic Product (GDP) and employment), many applications of GE models have higher sectoral aggregation levels (i.e. lower granularity at product level). Partial equilibrium models can be specified with a higher degree of sectoral details and are therefore useful in capturing detailed changes to a sector. One such example is the interactions between feed intake and production in the case of the livestock sector. Nonetheless, the ability for PE models to capture inter-sectoral linkages are naturally limited by the sectors included in the model. Likewise, linkages between product markets and the underlying factor markets also depend on the extent to which factor markets are characterized in such models. Moreover, as consumers are only assumed to consume a subset of goods and service, consistent welfare economic analysis cannot be conducted For that reason, in any application of a PE model, the link to other sectors must be assumed to be inconsequential in magnitude (Bacchetta et al., 2012). Recent methods overcome this by linking models to account for both sectoral detail and sectoral interaction. Delzeit et al. (2020) conduct a review of such methods and finds that they require large investments of time, as model specifications and data often require harmonization. Furthermore, the authors conclude that, dependent on the research question, they might not provide significant additional knowledge.

We can also classify the models into net trade and bilateral trade models. Bilateral trade models usually follow the Armington trade structure, where imports from different sources are considered imperfect substitutes (Armington, 1969; Hertel, 1997). Net trade models have a simpler structure that equalizes the global exports with global imports (Bacchetta et al., 2012). Armington trade models are desirable where bilateral trade needs to be tracked, e.g. in situations where GHG emissions from trade need to be accounted for or where the origin country of imports needs to be identified for implementing bilateral trade policy. Furthermore, it allows for cross-hauling9 of commodities, an occurrence commonly observed in trade data, which the net trade structure does not account for (Bacchetta et al., 2012). Current climate agreements are based on within-border emissions. For the moment, the tracking of emissions embodied in trade is mainly an academic interest, but intensified discussions on carbon leakage and border carbon adjustment has attached increasing policy relevance to this issue. Models used by major organizations (e.g. the United States Department of Agriculture (USDA), Organisation for Economic Cooperation and Development (OECD), Food and Agriculture Organization (FAO), and European Commission (EC)) to project future development of the global food markets are net trade models (see Table 3.3). However, as stakeholders are increasingly interested in future bilateral trade patterns in a trading environment featuring numerous preferential trading agreements, the ability for a model to track bilateral trade becomes an important consideration.

In the structural models, functional forms and elasticities (or parameters determining such elasticities) determine the behavioral aspects of the production systems. For example, in GTAP-based models the production module is typically set up with a Leontief functional form for the combination of intermediate and a composite of value added inputs, so the two are fixed at a specific proportion. The composite value-added is further specified as an aggregate of individual primary production factors (such as land, labor, and capital) through a constant elasticity of substitution function (Hertel, 1997).

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9 The export of the same commodity by two countries to each other.
Additional to the model structures, projecting future supply requires the setup of a scenario of exogenous changes and computation of the outcomes of such changes relative to a pre-established base case that resembles the situation in the current year or in a recent year. Scenarios are built on assumptions related to the future development of market drivers, which are not always consistent in the literature. This lack of agreement sometimes makes assumptions based on expert opinions necessary. In this setting, comparing study results is problematic (Chateau et al., 2020). The establishment of the shared socioeconomic pathways (SSPs) is intended to minimize such divergences in model assumptions. SSPs include assumptions on economic, population, and technology expectations among other (O’Neill et al., 2014). Less quantifiable drivers, such as culture and lifestyle, are less common and when included the assumptions are highly inconsistent. This leaves projection results that are harder to compare and therefore strengthens the need for modelers to be transparent in their assumptions.
Table 3.3: Common computable equilibrium models

<table>
<thead>
<tr>
<th>Model</th>
<th>Model type</th>
<th>Trade modelling</th>
<th>Institution</th>
<th>Projection</th>
<th>Disaggregation of commodities</th>
<th>Countries/ regions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCLS</td>
<td>PE</td>
<td>Net trade</td>
<td>USDA (ERS)</td>
<td>USDA annual 10 year</td>
<td>Main agricultural commodities 5 dairy and 7 meats products</td>
<td>44 countries/regions representing the most important competitors and markets for the US</td>
</tr>
<tr>
<td>Aglink-Cosimo</td>
<td>PE</td>
<td>Net trade</td>
<td>OECD &amp; FAO</td>
<td>OECD &amp; FAO 2020-2029</td>
<td>Main agricultural commodities 11 dairy and 10 meats products</td>
<td>26 countries and regions of mainly the OECD countries</td>
</tr>
<tr>
<td>Aglink-Cosimo EU module</td>
<td>PE</td>
<td>Net trade</td>
<td>EC</td>
<td>EU Agricultural outlook 2019-2030</td>
<td>Main agricultural commodities</td>
<td>13</td>
</tr>
<tr>
<td>CAPRI</td>
<td>PE</td>
<td>Armington trade</td>
<td>Several research institutions</td>
<td></td>
<td>Main agricultural commodities 47 products</td>
<td>EU27, Norway, Turkey and Western Balkans, with NUTS 2 regional level (280 regions) - 77 countries in 40 trade blocks</td>
</tr>
<tr>
<td>MAGNET</td>
<td>GE</td>
<td>Armington trade</td>
<td>LEI Wageningen</td>
<td></td>
<td>68 sectors with 15 primary agricultural sectors and 15 agricultural processing sectors</td>
<td>140 regions including all 28 EU member states</td>
</tr>
<tr>
<td>WTO world trade model</td>
<td>GE</td>
<td>Armington trade</td>
<td>WTO</td>
<td></td>
<td>Entire economy</td>
<td>GTAP dimensions 121 countries, 20 aggregate regions, 65 sector (4 meat, 1 dairy)</td>
</tr>
<tr>
<td>Mirage</td>
<td>GE</td>
<td>Armington trade</td>
<td>CEPII</td>
<td></td>
<td>Entire economy</td>
<td>GTAP dimensions 121 countries, 20 aggregate regions, 65 sector (4 meat, 1 dairy)</td>
</tr>
</tbody>
</table>

4 TRADE, ENVIRONMENT AND HEALTH CONSIDERATIONS

4.1 INTERNATIONAL TRADE

As discussed in earlier chapters, demand and production patterns can develop at divergent paces at regional and country levels, often resulting in either insufficient domestic supply when domestic production falls short of domestic demand or excessive supply when domestic supply exceeds domestic demand, at a given price level. Mismatches between total consumption and domestic production of the various animal food products at country level suggests that international trade has an important role to play to reach market equilibrium at the national and global levels. Future development of demand and supply drivers in the animal food markets may create changes in the current demand and production patterns at country level and lead to changes in the size and directions of global trade pattern. Standard trade theory based on comparative advantages suggest that both importing and exporting countries can benefit from increased trade integrations and open markets, as such trade linkages ensures gains from more efficient use of resources and production specializations.

However, international trade in agricultural and food products generally faces more tariff and non-tariff barriers, as compared to other products, due to a variety of reasons, ranging from country specific concerns over food security and self-sufficiency that limit imports, underdevelopment of multinational trade agreements for agricultural products, and difficulties in transporting meat and dairy products due to their biophysical nature. In addition, sanitary and phytosanitary regulations (SPS) and other food safety standards specifically for animal-based food products can also hinder the development of trade of these products.

Food security concerns distinguish the trade of agricultural and food products from other less essential goods. Some countries have long-held self-sufficiency goals that favors domestic production while limiting the extent to which imports of such products can take place. Short-term market disruptions can also trigger adverse impacts on imports. When a market disruption (due, for example, to an economic, diplomatic, environmental, or sanitary crisis) occurs on food markets, countries can become significantly protectionist by applying measures that limit both exports and imports. Such measures took place both during the 2007-2008 crisis (Martin & Anderson, 2012), and, to a lesser extent, at the beginning of the Covid-19 pandemic with a rise in export restrictions mainly in staples markets, which affected the entire food market system Espitia, Rocha, and Ruta (2020). Hence, the concerns about food security ultimately reflect vulnerabilities for countries highly dependent on international markets.

Because of food security and other concerns, agricultural and food products have been treated quite differently within the multilateral trade agreements. The original General Agreement on Tariffs and Trade (GATT) in 1947 regulated tariffs on both agricultural and industrial products, but still allowed for non-tariff measures (i.e. export subsidies and product standards) on agricultural primary products (WTO, n.d.-a). The historical development of multilateral trade negotiations under the GATT/World Trade Organization (WTO) resulted in higher average Most-Favored Nation (MFN) tariffs on agricultural goods as compared to non-agricultural goods (WTO, 2020). The Uruguay Round negotiations had for the first time resulted in meaningful disciplines on agricultural and food trade, but still left significant trade barriers. The most recent attempt to further reduce trade barriers in agriculture and other products under the Doha Round of the WTO have failed to reach an agreement (Vitaliano, 2016). This failure can be partially attributed to the difficulties to reach consensus within the growing WTO memberships (VanGrasstek, 2013; Vitaliano, 2016). It also mirrors the general setbacks to the globalization agenda. As agricultural and food trade liberalization fails to make further inroads, a
number of countries have engaged in the negotiations of bilateral and regional trade agreements for further liberalization (Vitaliano, 2016).

Meat and dairy products often need the existence of a cold chain to enable transport in safe conditions. For instance, meats either need to be kept in frozen or chilled form. At the same time, their (often) limited durability requires supply chains to be able to rapidly transport products from producers to consumers. The most difficult product is liquid fresh milk, given that it requires speed, controlled temperatures, and the capacity to move a significant volume of liquid products (FAO, n.d.-b). Such constraints especially affect the developing countries lacking relevant infrastructure; in fact, international trade figures show that one of the most common dairy products traded to such countries is powder milk (Cox & Zhu, 2005). In connection with the perishability and food safety concerns of meats and dairy products, many countries have established their food safety regulations for different meats and dairy products. In certain cases, such regulations can act as non-tariff barriers if the enforcement of these regulations differs between imports and their domestic substitutes. In addition, the divergence of these regulations and standards across countries and the need to comply with importing countries’ specific regulations can add significant trade costs.

As a simple illustration of the limited extent of international trade of livestock products, in Figure 4.1 we compare net export shares (as percentage of domestic production; e.g. a 50% share indicates that the country/region’s net exports equal to half of its domestic production) of major animal food products and cereals at country and world region levels. Note that when a country/region has very little domestic production but imports, the net export ratio can be a large negative number. Conversely, when a country/region has large amount of exports but little domestic consumption, this ratio can approach 100%. This explains why the graphs have longer “tails” to the left side of zero. Panel A of the figure depicts the distribution of net export shares across world regions as defined in UN Statistics Division (2021) whereas panel B illustrates the same distribution at the country level. There are two key messages in Figure 4.1.First, if we look at the simple average net export share (red dashed lines), we see that trade dependency – measured as the absolute value of net export shares – is much more common for cereals compared to animal food products. This is possibly also an indication that many food-insecure developing countries tend to import cereals but do not necessarily import meats and dairy products. Second, comparing panels A and B reveals that the trade dependency seems to be more or less unchanged for cereals (except for rice), possibly indicating that cereal trade happen across world regions. Making the same comparison for livestock products, we find that trade dependency is significantly smaller across regions as compared to the same indicator measured across countries (except for poultry). This possibly implies that a large part of the animal food product trade happens within world regions.
Figure 4.1: Shares of net exports in domestic production, by countries and world regions (2018)

<table>
<thead>
<tr>
<th>Number of regions</th>
<th>Number of countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Exports – Imports)/Production (%)</td>
<td>(Exports – Imports)/Production (%)</td>
</tr>
</tbody>
</table>

Note: Some outliers have been cut out of the graphs. The average percent of net exports with respect to production is displayed in red and marked with a dashed line for each commodity.
4.2 ENVIRONMENTAL IMPLICATIONS

The livestock and animal food sectors are facing a multitude of environmental policy challenges, due to the sector’s contributions to greenhouse gas (GHG) emissions and soil, water and air pollutions, and its impacts on land use and biodiversity. Among these concerns, one major challenge facing the livestock and animal food sector arises from heightened societal attention to climate change and the role of the sector as a major GHG emitter.
There are a number of emission sources from the livestock sector. The majority of the sector’s emissions are methane (CH₄) released from enteric fermentation as well as manure management. Additionally, the livestock sector emits nitrous oxide (N₂O) and carbon dioxide (CO₂) in almost equal measures. The origin of N₂O emissions are the use of fertilizers and the application and storage of manure, whereas the majority of CO₂ emissions stems from feed production and the land-use and land-use change (LULUC) due to feed production and expansions of grazing pastures (Gerber et al., 2013; Herrero et al., 2016; IPCC, 2019). The large land footprint of animal sourced foods gives rise to relevant opportunity costs from the foregone carbon sequestration. A shift in consumption towards plant-based diets would therefore both limit the emission from the food production sector and increase carbon sequestration through the recovery of grasslands and forests (Hayek, Harwatt, Ripple, & Mueller, 2021).

Accounting for the exact level of emissions is difficult, given the land coverage of the production and the multiple emission sources. Emission accounting methods are therefore diverse. Among other aspects, the methods differ in terms of their supply chain coverage (i.e. the scope of emissions accounting), and the perspectives they take (i.e. production or consumption-based emissions accounts). Direct (or on-farm) emissions are always included in emissions accounts for the livestock sector, but the same does not apply to indirect emissions from upstream and downstream activities. An example for upstream activity is the production of feed that mainly emits CO₂ from LULUC and N₂O from fertilizer use. When included, LULUC emissions significantly increase the estimated level of CO₂ emissions. Emissions from downstream activities from the processing and distribution represent typically only a small fraction of the aggregate emissions (CONCITO, 2021; Gerber et al., 2013).

Primary sector emissions do not take into account post-production emissions, whereas food system emissions do. For example, the FAO (2020a) includes only on-farm emissions and is therefore specific to the primary sector (see Table 4.1), whereas CONCITO (2021) includes emissions from the entire supply chain and therefore emissions from the entire food sector.

National emissions accounts can be consumption or production-based. Currently, international agreements use a production-based approach, also known as territorial emissions, thus each country is responsible for the emissions generated within their territory (IPCC, 1996; Peters, 2008). A consumption-based approach tracks the emissions from each input into final consumption products. International trade complicates the tracking of emissions, as emission intensities differ across countries (i.e. the production of an input or a final product in country X can be more polluting than in country Y). The differences between the two accounting methods can be illustrated with an example. If we think about soybean, for instance, production-based emissions accounting regards exclusively producing countries accounts. With a consumer-based approach, the emissions are tracked throughout the entire supply chain – soybean is often exported and imported in multiple steps – to finally be included in the emissions account of the final consumer country. In other words, if soybean from Brazil is used to feed pigs in Denmark and a share of the Danish pork is then exported to China, with the consumption-based approach China would account for the corresponding share of soybean emissions whereas with a production-based approach Brazil would account for all the soybean emissions.

Both approaches are favored or opposed for different reasons. The consumption-based approach requires larger amounts of data, whereas the production-based approach is closely tied to the national production account and Gross Domestic Product (GDP), which are often available and therefore less uncertain (Peters, 2008). Additionally, Peters (2008) claims that assigning emissions based on consumption makes countries responsible for emissions outside their political reach. However, consumption-based approach is often regarded as more transparent about the environmental footprint of the products and is favored from a fairness viewpoint: countries should be at least partially responsible for their consumption, as it is argued that the demand is driving the supply (Caney, 2009;
The accounting method on its own will not hold countries responsible for the emissions, but simply increase transparency. In order to hold countries responsible, additional global agreements based on consumption-based emissions would have to be implemented, or if multilateral agreement cannot be found, countries would have to implement policies unilaterally.

In summary, accounting for emissions at national levels is difficult due to the presence of international trade. There is an important difference between the GHG from consumption and production. In general, producers of beef, veal, and dairy have a larger environmental footprint, however if the production is export-oriented the consumption footprint of the country might not be significantly high (EC, 2019).

The total GHG emissions from the global livestock production (including upstream and downstream emissions) in 2010 were 7.1 GT of CO₂ eq. per year, accounting for about 14.5% of all anthropogenic GHG emissions according to (Gerber et al., 2013). As the emissions from the entire agriculture, forestry and other land use sector (AFOLU) is estimated to be 21% of all anthropogenic GHG emissions (FAO, 2017), the livestock sector is therefore the main contributor to emissions. Herrero et al. (2016) estimate that 2-3.6 GT of CO₂ eq. of the total are non-CO₂ emissions, the majority being methane coming mainly from cattle’s enteric fermentation. Cattle is estimated to be the source of 65-77% of the global livestock emissions (IPCC, 2019).

The uncertainty of the emissions estimates from the livestock sector is significant, with the estimates vary in a wide range. The principal sources of uncertainty are (1) the use of different accounting methods across countries, (2) statistical errors, and (3) the lack of an accurate account of livestock population globally. Moreover, feed composition influences the release of CH₄ and different climates and soil types influence the release of N₂O (Charles et al., 2017; Fitton et al., 2017; IPCC, 2019). For example, the estimate of enteric fermentation from the sector ranges from 1.6 to 2.7 GT of CO₂ eq. per year depending on feed composition and animals’ physiology assumptions (Herrero et al., 2016). More generally, different accounting methods can generate very different estimates. For instance, the GHG protocol of World Resource Institute (World Resources Institute, n.d.) includes three scopes of emissions. Goodland and Anhang (2012) argue that the widely-cited emission calculation conducted using the IPCC (2006) guidelines by FAO (2006) does not account for World Resource Institute scope 3 emissions and other sources of emissions (such as the opportunity cost of land used in livestock production for carbon storage purposes).10

In spite of the apparent methodological differences mentioned above, there is also agreement on the relative magnitude of species-specific emission intensities. Emission footprints differ quite significantly across different animal food products and across different countries. Table 4.1 shows the on-farm emissions from FAO (2020a) for some key market players. On the product dimension, cattle meat has the highest emission intensity across all countries, followed by pig meat, milk, chicken meat, and eggs. Meanwhile, emissions from chicken meat, eggs, and cows’ milk are notably uniform across countries due to the high degree of standardization in the production systems of these products. FAO (2020a) reports on-farm emissions, so the differences are explained by the production system, use of different breeds, divergence on feed composition, and climatic conditions for the production. Generally, countries with high production levels of any given product tend to have lower on-farm emission intensities. Many countries with high production levels also have intensified production system. This could be one explanation of the low emissions level of the United States (US) cattle meat and milk production, and of the high emissions from the Indian cattle meat production. Another source of

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10 Following this alternative method, Goodland and Anhang (2009) suggest the GHG emissions of the livestock sector to be as high as 32.56 GT of CO₂ eq. per year, or about 51% of annual anthropogenic GHG emissions.
difference, apart from the intensification level, is the degree of integration of meat and dairy cattle systems. In multipurpose systems the cattle used for milk production is subsequently used to produce meat. Simultaneously, the bull calves reared to sustain dairy production are also used in the cattle meat system. Hence, differentiating the emissions from the meat and dairy industries in multipurpose systems is difficult. In some countries, the split of emissions between the two industries can be disputed (Hermansen & Kristensen, 2011).

Table 4.1: On-farm emissions intensities per production sector (kg CO2 eq./kg product)

<table>
<thead>
<tr>
<th></th>
<th>Eggs, hen, in shell</th>
<th>Meat, cattle</th>
<th>Meat, chicken</th>
<th>Meat, pig</th>
<th>Milk, whole fresh cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.3704</td>
<td>24.4651</td>
<td>0.2464</td>
<td>2.5447</td>
<td>0.5712</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.8016</td>
<td>34.5849</td>
<td>0.3337</td>
<td>2.4099</td>
<td>1.0663</td>
</tr>
<tr>
<td>Canada</td>
<td>0.4497</td>
<td>20.2916</td>
<td>0.4168</td>
<td>2.095</td>
<td>0.5066</td>
</tr>
<tr>
<td>China</td>
<td>0.5829</td>
<td>15.8116</td>
<td>0.5361</td>
<td>0.9224</td>
<td>0.8185</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.6846</td>
<td>14.3006</td>
<td>0.3269</td>
<td>1.9855</td>
<td>0.3943</td>
</tr>
<tr>
<td>France</td>
<td>0.6057</td>
<td>20.0797</td>
<td>0.3719</td>
<td>1.4302</td>
<td>0.5753</td>
</tr>
<tr>
<td>Germany</td>
<td>0.4806</td>
<td>12.9386</td>
<td>0.4539</td>
<td>1.2383</td>
<td>0.4941</td>
</tr>
<tr>
<td>India</td>
<td>0.4987</td>
<td>108.2617</td>
<td>0.4497</td>
<td>4.9718</td>
<td>1.0192</td>
</tr>
<tr>
<td>Poland</td>
<td>1.0609</td>
<td>12.6907</td>
<td>0.2314</td>
<td>1.0698</td>
<td>0.4652</td>
</tr>
<tr>
<td>Spain</td>
<td>0.5795</td>
<td>16.3289</td>
<td>0.258</td>
<td>1.9099</td>
<td>0.4641</td>
</tr>
<tr>
<td>USA</td>
<td>0.4689</td>
<td>11.924</td>
<td>0.3094</td>
<td>1.9909</td>
<td>0.4243</td>
</tr>
</tbody>
</table>

Source: FAO (2020a), accounts for only on-farm emissions, or what in emissions calculations are referred to as the farms scope 1 emissions.

Unlike the Food and Agriculture Organization (FAO) emissions data, CONCITO (2021) compiles the consumption-based GHG emission estimates for a range of products available to Danish consumers, based on the average emissions for each type of product across the supplying countries. In this data set, the emissions from the primary sector – including agriculture and indirect land use change – are assigned to each product based on its monetary value. Moreover, CONCITO also provides estimates of the downstream emissions from processing and distribution. The majority of emissions originate from primary production, while the downstream industries weigh less in the total emissions.

The environmental implications of the meat and dairy consumption also extend to the changes in land use (IPCC, 2019) and therefore biodiversity losses (IPBES, 2020). In 2015, 37% of ice-free global land surface was used as pasture, 22% as managed/plantation forest, and 12% as cropland (IPCC, 2019). Agriculture is estimated to drive 80% of deforestation worldwide (Kissinger, Herold, & De Sy, 2012), which not only has effects on biodiversity (Alkemade, Reid, Van Den Berg, De Leeuw, & Jeuken, 2013) but also on the reduction of carbon capture (Tokimatsu, Yasuoka, & Nishio, 2017).

Livestock production accounts for about 8% of the human water use, a share that is likely to increase as temperatures rise. Nardone, Ronchi, Lacetera, Ranieri, and Bernabucci (2010) estimate that animal water consumption could increase by a factor of two to three in response to temperature increase. The authors use the data and calculation detailed in Chapagain and Hoekstra (2003), where it is estimated that a kg of livestock product needs 5 to 20 times the amount of water that a kg of plant-crop needs. This estimate varies greatly across different livestock species, as the virtual water content\(^\text{11}\) of beef is

\(^{11}\) The virtual water content is the water footprint of a product, i.e the amount of water used to produce that product.

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significantly higher than other livestock products. On average producing one kg of beef requires 22-23 tons of water, whereas the water use for one kg of pig meat, one kg of chicken, and one liter of cow milk is, respectively, 3.5-3.7, 2.3, and 0.8 tons (Chapagain & Hoekstra, 2003; Nardone et al., 2010). Water scarcity is an increasing concern in some regions, hence, the embodied virtual water and the methods to limit its use are important aspects shaping the future of the sector (Heinke et al., 2020; Rojas-Downing, Nejadhashemi, Harrigan, & Woznicki, 2017; Thornton, 2010).

Pollutions from livestock production directly concerns health. Considering atmospheric environments, sources of GHG emissions simultaneously emit co-pollutants e.g. particulate matter (West et al., 2013), and livestock is not an exception (Cambra-López, Aarmink, Zhao, Calvet, & Torres, 2010). It is widely acknowledged that such co-pollutants have direct negative implications on human health (De Rooij et al., 2019; Lovarelli, Conti, Finzi, Bacenetti, & Guarino, 2020; West et al., 2013; WHO, 2013). Beyond these, if we also consider aquatic, marine, and terrestrial environments, nutrient pollution originated from manure can also pose danger for human health (EPA, 2020).

There are many different suggestions on how the livestock and animal food sector can contribute to climate mitigations, ranging from supply side measures – such as production system transitions and technological development – to demand side measures – such as dietary transitions in favor of food products of lower emission intensities. Government policy can promote these transitions through either economic incentives, regulations, guidelines, or campaigns. Among other measures, the role of dietary transition towards a diet rich on plant-based food has received ample attention. One of the reasons is that there is a resource efficiency gain: to produce one kg of high-quality animal protein animals need to be fed with around six kg of plant protein (Pimentel & Pimentel, 2003). The IPCC (2019) and other international and national dietary guidelines (EAT-Lancet Commission, 2019; Ministeriet for Fødevarer, 2021) encourage this substitution. However, the effectiveness of dietary guidelines remains understudied. A review of the existing studies published in 2011 concludes that food-based dietary guidelines have had little effect on consumer behavior and points that possible reasons are the lack of political support, non-participation of stakeholders, and conflict with market forces (Brown et al., 2011). There are, however, evidences suggesting changes in consumer preferences of particular population segments. For instance, the number of vegetarians in the European Union (EU) is growing especially among the younger population and the number of flexitarians is also rising across all generations (EC, 2019).

In the paragraphs above, we discussed mainly the negative environmental impacts of the livestock production; however, there are also some potential environmental benefits associated with livestock production. For instance, integrating livestock in less developed farming systems limits the demand for manufactured fertilizers and pesticides, by using manure and animal grazing instead. Besides, the animals can be used as draught power, limiting the need for machines and therefore fossil fuels. Both in large scale industrialized farming systems and smallholder farms the extraction of biogases could present an opportunity. In smallholder systems, the collection of manure can replace the use of fuelwood with biogas for basic energy (Dalibard, 1995). In industrialized agriculture, the transformation of manure into biogas would both limit the methane emissions and reduce the dependence on fossil fuels (FAO, 2018).

Summing up, livestock, particularly cattle, is an important source of GHG emissions. Moreover, the livestock sector also generates biodiversity losses and deforestation, and accounts for around 8% of human water use. Accounting for the environmental implications of livestock involves a range of uncertainties. For instance, experts need to choose among different methodologies (production or consumption-based) in order to distribute the mitigation responsibility among countries, and take into account complex interactions between biological (e.g. the type of feed, or livestock breeds) and...
ecological (e.g. the type of soil or climatic conditions) aspects. Currently, there are multiple available measures to reduce the negative environmental implications of the sector. Examples of supply side policies are increased regulation and environmental standards. Examples of demand side policies are taxes (e.g. carbon tax), information campaigns, and dietary recommendations.

4.3 **HEALTH IMPLICATIONS**

Meat and dairy are widely regarded as a good source of protein and other essential nutrients, hence playing an important role in diet and human health. In recent decades, increased animal protein consumption has led to a surge of studies aiming at understanding the implications on human health, in particular regarding the quality of fats contained in these products (Valsta, Tapanainen, & Mannisto, 2005; Webb & O’Neill, 2008), their role in dietary guidelines (EAT-Lancet Commission, 2019; Harvard University, 2011; WHO, 2020a), and their relationship with some particular conditions such as colorectal cancer or diabetes (Chan et al., 2011; Olfert, 2018). For instance, excessive intake of red meat and processed meat has been identified as a risk factor for cardiovascular disease, type 2 diabetes, and colorectal cancer (GBD Diet Collaborators, 2019).

Meat and dairy provide high value protein, fatty acids, minerals, and vitamins to the diet and are commonly regarded as a resource to end hunger and all forms of malnutrition (FAO, 2018). The WHO (2020b) defines malnutrition as “deficiencies, excesses, or imbalances in a person’s intake of energy and/or nutrients”, and identifies three broad groups: undernutrition, micronutrient deficiencies or excess, and overweight, obesity, and diet-related non-communicable diseases. At the global scale, over 1.9 billion adults are overweight or obese, while 462 million are underweight. Overweight and obesity are not merely a high-income country problem, as these two conditions are now also growing in low- and middle-income countries, especially in urban areas. Many of these countries suffer the so-called double burden of malnutrition: they deal with undernutrition, at the same time they experience a rise of obesity and overweight. It is common to observe obesity and undernutrition within the same country, community, and even household (WHO, 2020c). The WHO (2020c) explains how this conjunction occurs:

*Children in low- and middle-income countries are more vulnerable to inadequate prenatal, infant, and young child nutrition. At the same time, these children are exposed to high-fat, high-sugar, high-salt, energy-dense, and micronutrient-poor foods, which tend to be lower in cost but also lower in nutrient quality. These dietary patterns, in conjunction with lower levels of physical activity, result in sharp increases in childhood obesity while undernutrition issues remain unsolved.*

Providing animal source food, particularly dairy products, to malnourished children in the first three years of their lives is widely regarded as an effective treatment associated with child growth (FAO, GDP, & IFCN, 2020). The diet used to treat severe malnutrition is based on milk powder and has low content of fibers and antinutrients mostly present in unrefined cereals and legumes (Michaelsen et al., 2009). However, the prioritization of fruits and vegetables, whole grains, and nuts is recommended to tackle other types of malnutrition such as overweight and obesity (WHO, 2020c).

Even if meat and dairy foods provide important nutrients to the diet, the dietary guidelines directed to the general population currently propose to limit meat and dairy consumption by prioritizing the consumption of fruits and vegetables, whole grains, and nuts. One of the widely used dietary guidelines nowadays is the *Harvard healthy eating plate*, which divides a plate into four food groups: one half of the plate is devoted to vegetables and fruits, one quarter to whole grains, and the remaining quarter to healthy protein. Regarding healthy protein, the diagram recommends to “choose fish, poultry, beans
and nuts; limit red meat and cheese; avoid bacon, cold cuts, and other processed meats” (Harvard University, 2011). Guidelines that are more recent emphasize both the health and environmental aspects of the diet. For instance, the EAT-Lancet Commission (2019) published a set of targets to achieve planetary health diets by 2050. Figure 4.2 shows their proposal for a planetary health plate. The role of meat and dairy products in this new guideline is rather limited; in fact, the Commission states that “a diet rich in plant-based foods and with fewer animal source foods confers both improved health and environmental benefits”. The diet suggested by the EAT-Lancet Commission (2019) has already influenced the Danish dietary guidelines which now recommend to reduce the consumption of meat and acknowledge the nutritional value of dairy products, but also their environmental impact (Jensen, 2021; Ministeriet for Fodevarer, 2021).

Figure 4.2: The planetary health plate

Lately, researchers have been studying the healthiness and sustainability of national and international food-based dietary guidelines (FBDGs), (e.g. the EAT-Lancet Commission (2019) or the WHO (2020a)). Springmann et al. (2020) find that a number of low- and middle-income countries lack national FBDGs. The authors encourage the creation of such guidelines in these countries because they are projected to switch towards Western diets as income increases, hence, raising the pressure on the healthcare system and the environment. In existing national FBDGs, Herforth et al. (2019) finds that the key messages regarding protein include: 1) use of the term “lean meat” or suggesting removing fat from meat (34%); 2) a positive message about consuming fish (27%); and 3) limiting or moderating meat consumption (23%). With respect to dairy, Springmann et al. (2020) observe that most national FBDGs recommended increasing dairy consumption and that the EAT-Lancet Commission (2019) contradicts this message by recommending to limit the dairy intake to one serving or glass a day. The latter guideline is based on the lack of “clear association between milk intake, bone health, and reduced risk of non-communicable diseases, and the existence of plant-based alternatives that have similar nutrient content and are more clearly associated with reduced risks”. The modelling exercise performed by Springmann et al. (2020) concludes that the adoption of national FBDGs on average would be associated with a 15% reduction in premature mortality and a 13% reduction on GHG. The effects of the adoption of the WHO (2020a) dietary guidelines would be similar. And the best health and environmental outcomes would come from the adoption of the EAT-Lancet Commission (2019) recommendations, which are associated with a 34% larger cutback in premature mortality and more than three times larger cutback in GHG, as compared to the FBDGs reductions.
Beyond the direct nutritional aspects covered above, animal-based food products are also associated with health risks due to transmission of bacteria, viruses, parasites, toxins etc. between animals and humans. A strategy to handle these types of health risks is the so-called One Health approach. The intention of the One Health concept is to address problems threatening global health and economic well-being, i.e. human and animal health, food security, poverty, and environmental damages (FAO, 2011). The strategy consists in promoting the interdisciplinary study of all aspects of health including humans, animals, and the environment (One Health Initiative team, 2020). According to WHO (2017), three especially relevant areas for One Health are food safety, zoonoses’ control, and antimicrobial resistance12.

Regarding food safety, developing countries face challenges due to the special characteristics of meat and dairy products and the infrastructure limitations mentioned at the end of section 4.1. In such countries, the best practice to handle food safety is risk-based farm-to-table approach focusing on cost-effective prevention. However, it has important limitations. While high-value markets (i.e. the export market) provide economic incentives to apply this practice, the same practice is not economically attractive for producers targeting low-income consumers within developing countries (Unnevehr, 2015).

Public awareness of the control of zoonoses surged with the Covid-19 pandemic. Covid-19 is a zoonotic disease: an infectious disease jumping to humans from non-human animals (MacKenzie & Smith, 2020; WHO, 2020d). The potential for the spread of zoonotic diseases rises in a context of global agribusiness relying on economies of scale, intensive agriculture, and increased commodities trade both within and between countries (Brown, 2004). Other potential causes of pandemics indirectly related to the livestock sector are land-use change, and wildlife trade and consumption (Brown, 2004; IPBES, 2020).

A continued rise in antimicrobial resistance implies substantial human costs (10 million yearly deaths) and economic costs (100 trillion US$) by 2050 (O'Neill, 2014). The main drivers of antimicrobial resistance rise from the use in humans and agriculture, and from the pollution of the environment (including the effect of minerals and nitrogen fertilizers on the selection for resistance genes, human waste processing, and pharmaceutical pollution) (Holmes et al., 2016). In animal agriculture, antibiotics are commonly employed as prophylactic or growth promotion tools (O'Neill, 2016). Bacteria that reside in skin and excrements of animals can develop antibiotic resistance and through various means be transferred to humans (Holmes et al., 2016).

Summing up, meat and dairy are a source of important nutrients such as high-value proteins, fatty acids, minerals, and vitamins and may play important role in attaining some health-related Sustainable Development Goals (SDGs) (FAO, 2018) in developing countries e.g. concerning hunger or undernourishment. Nevertheless, the role of meat and dairy is diminishing in recent dietary guidelines that are prioritizing plant-based food (excluding ultra-processed plant-based food). Beyond nutritional aspects, meat and dairy production is also related to other health concerns such as food safety, the spread of zoonoses, and antimicrobial resistance. Some countries are already implementing policies or guidelines that try to deal with such concerns. Some illustrations are the Danish government recommendation to reduce meat consumption (Ministeriet for Fødevær, 2021), and the long-term Swedish strategy to fight the growth of antimicrobial resistance (FAO, 2020i).

12 An antimicrobial is a medication employed to treat infections caused by bacteria, parasites, viruses, and fungi. The most famous are antibiotics that are antimicrobials treating infections caused by bacteria. The inadequate use of drugs eases antimicrobial resistance (WHO, 2017).
5 THE MEAT SECTOR

Growing population and income in developing countries are the major drivers for the increase in meat demand worldwide. Therefore, countries in East Asia and Southeast Asia - particularly China, Vietnam, South Korea, and the Philippines - are the hotspot for meat exporters in the European Union (EU) and the Americas, a point that both industry experts\(^\text{13}\) and results from several published projection exercises emphasize. Over the next ten years, a change in the composition of the meat demand is further expected according to several projections. Globally, both the total and the average per capita demand of poultry are expected to have the largest growth, followed by increasing demand for pork. Conversely, while aggregated cattle meat demand is expected to increase moderately, per capita demand for cattle meat will have a stable or downward trend in some countries (Henchion, McCarthy, Resconi, & Troy, 2014; OECD & FAO, 2020). Only in Asia, the consumption of cattle meat is expected to increase in per capita terms over the coming decade (OECD & FAO, 2020). In developed countries, while per capita meat demand stagnates, consumers increasingly demand more processed meat products that are convenient and/or available from food services. Increasing environmental and health concerns are also changing the consumption patterns in some countries, for example in the EU member states where there are increasing demands for organic meat and plant-based alternatives (EC, 2019).

The effect of policy recommendations from international organizations cannot be disregarded. For instance, the Danish Fat Tax implemented in 2011 can be understood as a response to the World Health Organization (WHO) recommendations on the reduction of saturated fats. As the public debate is centered on the environmental implications of meat consumption (IPCC, 2019), the effects of the fat tax (Jensen, Smed, Aarup, & Nielsen, 2016) can potentially inform the design of a possible carbon tax on meat demand or supply.\(^\text{14}\)

Another aspect that is shaping the market is the differences in regulations across countries. As pointed out by the industry experts we interviewed for this report, differences in environmental and veterinarian regulations can lead to cost differentials in production and trade. In this respect, the industry experts (mostly based in the EU) suggest that animal products sourced from the EU are subject to more stringent environmental regulations and health and food safety standards. Therefore, products sourced from the EU are marketed on the premise of higher food safety and environmental standards, whereas other countries such as the United States (US) and Brazil compete more in prices and volume terms. The latter’s price advantage can also be attributed to their access to ample domestic feed supplies, as both are major producers and exporters of bulk commodities such as maize and soybean. Potential cross-country differences in regulating greenhouse gas (GHG) emissions from livestock production can further influence production costs and export performance, with countries with more stringent emission regulations possibly bearing higher costs. There is also a risk of carbon leakage: if GHG regulation becomes more stringent in countries with low emission intensities, countries with high emission intensities and low emission reduction ambitions may gain market share and emit more. Responding to policies targeting production, producers may relocate production to regions with lax emission ambitions; similarly, responding to policies targeting consumption, producers could redirect their products from domestic markets to export markets (Herrero et al., 2016; Zech & Schneider, 2019). Zech and Schneider (2019) estimate 43\% leakage rates for policies within the EU food sector. A study analyzing the effect of unilateral actions from Denmark estimated a leakage rate of 75\% for the agricultural sector in 2019 (Det Økonomiske Råd, 2019), which in a more recent publication have been

\(^{13}\) Source: Interviews with industry experts, June-August 2020

\(^{14}\) The FAO (2020e) summarizes the latest political updates on the meat market for every member country.
revised to 25% (Det Økonomiske Råd, 2020), indicating a degree of uncertainty of these estimate. These estimates highlight the need for globally coordinated efforts in emission regulation (Matthews, 2019). The Covid-19 pandemic and the African Swine Fever (ASF) crisis currently affect the global meat market. The first reaction to the Covid-19 pandemic was a decrease in meat production due to logistic bottlenecks and labor shortages (FAO, 2020c; Kim, Kim, & Park, 2020), and the expected evolution varies according to the possible scenarios of the public health crisis. At the same time, the ASF outbreak represents a major threat to the pork industry. Some Asian, European, and African nations are currently affected by the ASF. In fact, the ASF outbreak seems to become the source of low meat output in the last two years, a shock which FAO (2020e) claims has been aggravated by the market disruptions of Covid-19.

In the near future, the meat market will be shaped by the evolution of the Covid-19 pandemic and in particular the ASF outbreaks for the pork market. In the medium term, demographic patterns in developing countries are expected to be the main determinant. Growing population and income are expected to drive the demand growth, especially in South-East Asia. In the rest of the chapter, we continue investigating the expected patterns. First, we analyze the available data on the consumption, production, and trade patterns in the meat sector. The analysis corroborates the views expressed by industry members: the largest changes within the sector will likely be the result of changes on developing markets. The section also includes a review of the published market projections and expectations. These projections are found to be consistent with the patterns already observed from the historical trends in the available data.

5.1 DATA ANALYSIS

In the following section the meat sector is described based on data obtained from UN (2020), CEPII (2020)18, FAO (2020a) (2020d), and OECD and FAO (2021) on meat demand/consumption, production and international trade. We look at multiple indicators to analyze the current and historical trends and critically assess the projections of international organizations along with the expectations of industry representatives.

5.1.1 Consumption

Across the globe, we find three distinctive patterns in per capita meat consumption (as illustrated in Figure 5.1): (1) developed economies with relatively persistent high consumption levels, (2) emerging economies with rapidly growing consumption, and (3) other developing economies with low consumption (OECD & FAO, 2020). As it is an expensive protein source, meat consumption is positively correlated with income (OECD & FAO, 2014, p. 181). Recently, dietary guidelines recommend limiting the consumption of meat products, especially red and processed meats, and favor proteins such as pulses and fish (EAT-Lancet Commission, 2019; Harvard University, 2011; Ministeriet for Fødevarer, 2021). FAO (2020d) suggests a declining per capita aggregate meat consumption in Western Europe from 2014-2017, possibly indicating limited impacts of further income growth and growing environmental/health concerns. This could be driven by an increasing income elasticity of environmental quality, which correlates with the increase in income, education levels, and information about health consequences (Vranken et al., 2014). Conversely, the per capita consumption in Central

15 China, India, Mongolia, Viet Nam, Cambodia, North Korea, Myanmar, Laos, The Philippines, South Korea, Papua New Guinea, Timor-Leste, and Indonesia. (FAO, 2020c; OIE, 2020)
16 Bulgaria, Germany, Hungary, Latvia, Moldova, Poland, Romania, Russia, Serbia, and Ukraine (OIE, 2020).
17 Namibia, Nigeria, South Africa, and Zambia (OIE, 2020).
18 Gaulier and Zignago (2010) provide the documentation of these data.
America consistently rose over the period (FAO, 2020d). However, neither of the these two patterns can be identified in other regions (FAO, 2020d). In Figure 5.2, the absolute consumption changes are illustrated for a longer time period for disaggregated meat types. The consumption level is stable in most regions, except for the consumption of poultry, for which most regions have increasing consumption levels. From Figure 5.2 it seems that consumption growth tends to slow down as income reaches very high levels, possibly implying a decrease of the income demand elasticity (Cranfield et al., 2002; Yu et al., 2004). Cole and McCoskey (2013) highlight how the stagnation of meat consumption growth as income increases is observed across multiple studies. However, the authors argue that the hypothesis that at a given income level people start consuming less meat (i.e. negative meat demand elasticity) is not consistently confirmed in the literature. The demand for meat is driven by an interplay between economic development, income growth, and several other potential influencing factors such as culture, religion, the economy, or trade connectivity. Rigorous econometric analysis is necessary to determine the individual drivers’ role in meat demand, including estimates of demand elasticities.

Figure 5.1 and Table 5.1 show that there are other factors influencing meat consumption beyond income. Of particular interest is the case of Argentina, Brazil, Chile, and Bolivia whose consumption levels are comparable to countries with significantly higher income per capita. Figure 5.1 suggests that countries with large landmasses and low population densities, where the cost of grazing and feed production is lower, consume more meat per capita (e.g. North America, Australia, Argentina, and Brazil). Meat consumption is also generally higher in the regions with higher per capita production, reflecting a higher availability and minimized transportation costs. This also explains why international trade volume of meat products remains limited, relative to total production.

**Figure 5.1: Average annual meat consumption, kg per capita, 2017**

![Image of world map showing meat consumption levels]

Source: FAO (2020d).

Note: We take as a proxy for food consumption the FAO food supply data which is estimated as the production level adjusted for net trade and waste along the supply chain. Some argue that this measure may overestimate actual consumption level (Kearney, 2010).

Regional food diversity traditionally depends both on the natural environment and human settlement (Wahlqvist, 2007). Such aspects related to food supply end up affecting regional cuisines. For instance, Eurasia is believed to be the origin continent of pigs (Giuffra et al., 2000) and today is still the region with the highest pig consumption (Table 5.1 and Figure 5.2). Bovine meats prevail in the Americas and Australia, as extensive land areas allow for ranching activities and increasing supply (FAO, 2006). On the other hand, poultry meat consumption levels are quite uniform across developed regions, since the production is highly industrialized and standardized. Similarly, lower production costs and use of land

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19 Per capita food supply from the FAO is chosen to proxy consumption due to its extensive country coverage. Some argue that this measure may overestimate actual consumption level (Kearney, 2010).
resource also make poultry meats accessible to consumers in small island nations. Globally, poultry consumption is rising in most regions. Finally, other types of meats tend to be consumed in countries with smaller populations. For instance, mutton and goat meat is widely consumed in Mongolia. The aggregate group other meats (e.g. horse, birds, camel, mule, rabbit, game, snails, rodents, etc.) are likewise not widely included in everyday diets of most countries and instead consumed mostly in Mongolia, Botswana, and Gabon according to FAO (2020d). It is possible that consumption of this last product group is under-reported, especially in countries where informal markets are important, as it also includes animals common in wild populations.

Figure 5.2: Beef and veal (a), poultry (b), and pig (c) meat consumption by regions, kg per capita

Source: OECD and FAO (2021)

Europe as a whole has a high level of per capita meat consumption (FAO, 2020d). Within Europe (Figure 5.3), Spain has the highest per capita total meat consumption at 100.25 kg per year, followed by Portugal (94.06) and Iceland (91.01). European countries also differ in the composition of their per capita meat consumptions: consumption of bovine meat is the highest in Denmark and Luxembourg, whereas pork consumption is the highest in Poland and Spain.\(^{21}\) For other products, average consumers

\(^{20}\) See detailed composition in FAO (2020d)

\(^{21}\) According to other data sources, FAO data might understate Denmark’s significantly higher level of pork consumption. (Landbrug & Fødevarer, 2018)
in the United Kingdom (UK), Russia, Spain, Portugal, Iceland, Denmark, and Poland consume more poultry; mutton and goat meats consumption are more common in Iceland, followed by Greece. Finally, other meats are consumed mainly in Malta and the Czech Republic, however at low rates.

Figure 5.3: Per capita meat consumption per capita within Europe 2017

Source: FAO (2020d)

Note: The data is obtained from the food balance sheets and measures the food supply in kg per capita and year. The figure is commonly used as a proxy for consumption.

Table 5.1: Countries with highest consumption levels per capita globally and by regions

<table>
<thead>
<tr>
<th>Meat index</th>
<th>Global</th>
<th>Europe</th>
<th>Asia + Oceania</th>
<th>Africa</th>
<th>Americas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovine</td>
<td>US, Australia, Argentina and New Zealand</td>
<td>Spain and Portugal</td>
<td>Australia, New Zealand and Israel</td>
<td>South Africa, Gabon and Mauritius</td>
<td>US and Argentina</td>
</tr>
<tr>
<td>Other meat</td>
<td>Timor-Leste, Gabon, Mongolia and Botswana</td>
<td>Malta and Czech Republic</td>
<td>Timor-Leste and Mongolia</td>
<td>Gabon, Botswana and Republic of Congo</td>
<td>Cuba and Saint Kitts and Nevis</td>
</tr>
<tr>
<td>Pig</td>
<td>Argentina, US, Brazil and Australia</td>
<td>Denmark and Luxembourg</td>
<td>Australia, Turkmenistan, Uzbekistan</td>
<td>Central African Republic, Swaziland and South Africa</td>
<td>Argentina and US</td>
</tr>
<tr>
<td>Pig</td>
<td>Poland, Spain, Germany and Hungary (High levels in both Asia and Europe)</td>
<td>Poland and Spain</td>
<td>South Korea, Vietnam and China</td>
<td>Cabo Verde, Malawi and Guinea-Bissau</td>
<td>US and Paraguay</td>
</tr>
<tr>
<td>Poultry</td>
<td>Saint Vincent and the Grenadines, Israel, Samoa and Saint Lucia</td>
<td>UK and Russia</td>
<td>Israel, Samoa and Australia</td>
<td>Mauritius, South Africa and Gabon</td>
<td>Saint Vincent and the Grenadines and Saint Lucia</td>
</tr>
<tr>
<td>Mutton and goat</td>
<td>Mongolia, Turkmenistan, Iceland and New Zealand</td>
<td>Iceland and Greece</td>
<td>Mongolia, Turkmenistan and New Zealand</td>
<td>Chad, Mauritania and Mali</td>
<td>Barbados and Bahamas</td>
</tr>
</tbody>
</table>

Source: Authors’ elaboration from FAO (2020d).

Note: In the table, we list the countries with per capita consumption levels within the 98% quantile globally, and within 95% quantile regionally.
5.1.2 Production

The world’s largest meat producers in absolute volume terms are China, US, and Brazil (see Figure 5.4), all of which hold major production shares in all meat product categories, as can be seen from Table 5.2. The EU as a whole is also a major meat (particularly pork) producer. China is the world’s largest producer of pork, but in recent years has also been a major importer, due to its even larger domestic demand and in recent years significantly weakened supply in connection with the ASF outbreak. In the rest of this section, we describe the production and supply situation for different regions.

Figure 5.4: Aggregate meat production level in tons (2017)

![Aggregate meat production level in tons (2017)](image)

Source: FAO (2020d)

Figure 5.5: Global share (a) beef, (b) poultry, and (c) pig meat production in 2017

![Global share (a) beef, (b) poultry, and (c) pig meat production in 2017](image)

Source: FAO (2020d).

Note: The countries belonging to each regional aggregation can be found in this link (UN Statistics Division, 2021).
Table 5.2: Countries with the highest production levels globally and by regions

<table>
<thead>
<tr>
<th>Meat index</th>
<th>Global</th>
<th>Europe</th>
<th>Asia + Oceania</th>
<th>Africa</th>
<th>Americas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat index</td>
<td>China, US, Brazil and Russia</td>
<td>Russia and Germany</td>
<td>China, India and Vietnam</td>
<td>South Africa, Egypt and Nigeria</td>
<td>US and Brazil</td>
</tr>
<tr>
<td>Other meat</td>
<td>China, Russia and US</td>
<td>Russia and Germany</td>
<td>China and North Korea</td>
<td>Nigeria and Ivory Coast</td>
<td>US</td>
</tr>
<tr>
<td>Bovine</td>
<td>US, Brazil, China and Argentina</td>
<td>Russia and France</td>
<td>China, India and Australia</td>
<td>South Africa, Egypt and Kenya</td>
<td>US and Brazil</td>
</tr>
<tr>
<td>Pig</td>
<td>China, US and Germany</td>
<td>Germany and Spain</td>
<td>China and Vietnam</td>
<td>Nigeria and South Africa (no data for most North African countries)</td>
<td>US and Brazil</td>
</tr>
<tr>
<td>Poultry</td>
<td>US, China, Brazil and Russia</td>
<td>Russia and Poland</td>
<td>China, India and Indonesia</td>
<td>South Africa, Egypt and Morocco</td>
<td>US and Brazil</td>
</tr>
<tr>
<td>Mutton and goat</td>
<td>China, India and Australia</td>
<td>UK and Russia</td>
<td>China and India</td>
<td>Nigeria, Sudan and Algeria</td>
<td>Brazil</td>
</tr>
</tbody>
</table>

Source: Authors’ elaboration from FAO (2020d).

Note: In the table, we list countries with production levels within the 98% quantile globally, and within the 95% quantile regionally.

Within Europe, Russia is the largest meat producing country, as can be seen in Table 5.2. For the rest of Europe, there are clear differences in concentration of production. Germany, Spain, France, and Poland have some of the highest meat production sectors in the region, aided by factors such as the size of national market and the access to labor force. Looking at the different types of meat, France stands out in the production of bovine meats, the UK in mutton and goat meats, Germany and Spain in pig meats, Poland and other large European countries in poultry (FAO, 2020d). Some smaller EU member states such as Denmark and the Netherlands have substantial per capita meat production levels, but given their limited size, they do not stand out when comparing absolute production levels.

Figure 5.6: Production of aggregate meat within Europe (2017)

Source: FAO (2020d).

Note: Russia is not depicted, however has the largest production level within the region.
In the African region (Figure 5.7), there are clear differences in production across countries and meat types. In aggregated terms, South Africa, Egypt and Nigeria have the largest production of meat. Large quantities of bovine meats are produced in South Africa and Egypt, followed by Kenya. Mutton and goat meats are primarily produced in Nigeria, Sudan, and Algeria. The predominance of Islam over other religions in North African countries explains a negligible pig meat production in this region. In Sub-Saharan Africa, South Africa and Nigeria are the main pig producers. Poultry meat production is concentrated in South Africa, Egypt and Morocco. The “other meats” category encompasses several products, some of which are considered low cost and thus also consumed and produced in countries with lower income, such as Nigeria, Sudan, Côte d’Ivoire, Egypt, Ethiopia, and Kenya.

*Figure 5.7: Production of meat within Africa (2017)*

Within the Asia and Oceania regions, China is by far the largest producing country, mostly to meet domestic demand from a large population with rising income level. In contrast, the world’s second most populated country, India, has much lower meat production even though it still ranks as the second largest meat producer in the region. Besides a relatively low per capita income level, another possible explanation is that around 30-40% of the Indian population is estimated to be vegetarian, which is about 4-8 times larger than other countries (Leahy, Lyons, & Tol, 2010). Australia is another major meat producing country in the region since it is a high-income country with a very low population density. As seen from Table 5.2 and Figure 5.8, China is the region’s largest producer across all meat types. In addition, India, Australia, Vietnam, Japan, Iran, and Turkey are the main producers of bovine meats. Major pig meat producers also include Vietnam. India, Indonesia, Japan, Iran and Turkey lead poultry production. The main producers of mutton and goat meat are India, Australia, and Pakistan. Lastly, the aggregate group of other meats is mainly produced in North Korea, Mongolia, and Saudi Arabia.
Within the Americas, the US is the largest producing country, aided by the availability of feed which represents about 16% of the global feed production (IFIF, n.d.), and its large land mass. Brazil is another large meat producing country, enjoying similar production advantages in terms of feed access and land resource. As shown in Table 5.2, the US and Brazil are major producers of all the major meat products. Mexico and Argentina are the other major producers in the region, although their production levels in 2017 were about a quarter of the Brazilian production. Their main production is bovine meat and poultry meat, whereas Canada is the third largest producer of pig meat in the region, after the US and Brazil (FAO, 2020d).

**Emissions from the meat sector**

A large share of the global GHG emissions from the agricultural sector, as well as of overall anthropogenic GHG emissions, originates from livestock production (Gerber et al., 2013). In life-cycle assessment (which include emissions from the entire supply chain), most of the emissions from the livestock sector relate to feed production and enteric fermentation, representing, respectively, 45 and 39% of the sector’s emissions (Gerber et al., 2013). Additionally, a smaller share of emissions (10%) come from manure handling (Gerber et al., 2013). The emissions vary by species. Ruminants’ supply chains produce 80% of emissions from the livestock sector, of which 35-41% are due to cattle production (Gerber et al., 2013; Opio et al., 2013). The emissions from pig and poultry production are much lower: 9% and 8%-11% of the livestock sectors emissions, respectively (Gerber et al., 2013; Mottet & Tempio, 2017). Figure 5.10 illustrates the distribution of absolute on-farm emissions across regions. Asia and America generate the majority of on-farm emissions. Particularly, China, Brazil, and...
the US are the main contributors as these countries have the largest production levels (Table 5.2). The following paragraphs present a more detailed description of the emissions from different meat types. As can be seen from Figure 5.11, Figure 5.12 and Figure 5.13, emission intensities (measured in direct emissions relative to output level) vary significantly across countries in the cattle and pig sectors but they are more homogeneous in the poultry sector.

*Figure 5.10: Global shares of absolute on-farm emissions, a) beef, b) poultry and c) pork production in 2017*

Source: FAO (2020a)

Note: BR=Brazil, CN=China, DE=Germany, ES=Spain, FR=France, PL=Poland, RU=Russian Federation, US=United States, VN=Vietnam. The countries belonging to each regional aggregation can be found in this link (UN Statistics Division, 2021).

**Beef**

Beef is the meat type with the highest absolute GHG emissions and the highest GHG emission intensity and this holds for on-farm emissions and supply chain emissions (FAO, 2020a; Gerber, Mottet, Opio, Falcucci, & Teillard, 2015; Gerber et al., 2013). According to life-cycle assessments, the primary source of GHG emissions from cattle meat is methane released from enteric fermentation, which represents 42.6 to 46.5% of the emissions depending whether it originates from dairy cattle (that also supply meats) or meat cattle. The secondary source is the release of nitrous oxide from the application and deposition of manure for feed production (17-18%). The tertiary source stems from land use in pasture expansion (or from land use in feed production for dairy production), as beef cattle is typically produced using large land areas (Gerber et al., 2013).

Within beef production, there are large regional disparities concerning cattle types or geographical/climatic and socioeconomic conditions, as reflected in significant differences in production systems and emission intensities across countries (FAO, 2020g; Gerber et al., 2015). Low-intensity productions tend to have higher emission intensities, while gains in production efficiency through intensification are typically associated with lower GHG emissions per unit of output (Gerber et al., 2013). Furthermore, in low intensity production systems in less developed countries, cattle fulfills other purposes, e.g. as working animals in fields, leading to higher emission intensities from wasted
energy that is not accounted for in emissions intensity calculations. This leads to an over-estimation of the meat emissions intensity since the working animals substitute machinery and, thus, they indirectly reduce emissions from machinery use. As shown in Figure 5.11, the less developed African countries generally have higher emission intensities; hence, there is a potential to improve emission efficiencies in these countries. Nevertheless, the region may still have certain climatic disadvantages leading to higher emissions intensities, irrespective of the production system adopted (Opio et al., 2013). It should be noted that while emission intensities are higher in African countries, total emissions from the cattle sector in Africa are smaller than several other regions/countries (Figure 5.10). The global share of Africa’s on-farm emissions from beef production is 18.5%, whereas the share of the largest producing region, South America, is 32%. The share of the global total on-farm emissions of Brazil and the US are 19.54% and 8.4% respectively.

Figure 5.11: Emission Intensities from on-farm activities cattle (2017)

Source: FAO (2020a)

Poultry
Life-cycle assessment models estimate that poultry has the lowest emission intensity per unit of protein and per kg of product across meat types (Gerber et al., 2013; Mottet & Tempio, 2017). Life-cycle assessments also show that the largest share of emissions for global poultry production relates to feed production. The CO₂ generated from land use change related to feed and soybean production represents 25 and 21% of global poultry production emissions, respectively, followed by the emissions of nitrous oxide from the application and deposition of manure which represent 22.5% of the total (Gerber et al., 2013). Looking at the on-farm emissions exclusively, emission intensities from chicken production are by far the most uniform across countries (Figure 5.12), due to standardized intensive production systems (Mottet & Tempio, 2017). Small-scale backyard production is still common in rural areas of developing countries; however, with urbanization, its share is decreasing and the intensive system is delivering the vast majority of poultry outputs. Due to the relatively low direct emission intensities in poultry production, there is a limited emission reduction potential from technological innovation in feeding practices (FAO, 2008). The Asian regions combined emit 51.5% of the on-farm emissions from poultry production, with contributions from poultry production in South-Eastern and Eastern Asia, and more specifically China, Indonesia, Myanmar, and Vietnam (FAO, 2020a).
Pig

Emission intensities from pig production are generally lower than those from ruminants; however, as Figure 5.13 shows, there are also considerable regional differences. Since Mideast countries are not pig producers, Figure 5.13 shows these territories in grey. Similar to cattle, the areas with higher emission intensities are a few African countries. However, given the low production level within Africa (Figure 5.5), the absolute emissions are still below other regions. As illustrated in Figure 5.10, the continent is responsible for around 6% of the global total on-farm pig production emissions (FAO, 2020a). Europe contributes significantly more to pig production emissions than to beef or poultry emissions; its on-farm emissions share for pig production is 25%. The largest contributor to on-farm emissions, however, is East Asia (30.8%) and more specifically China (29.2%)\(^2\). Given that pigs are monogastric, the enteric fermentation does not occur to the same extent and the release of methane is therefore less significant. In life-cycle assessments, the most significant GHG emission source is therefore CO\(_2\) from land use expansions in feed and soybean production, representing 27 and 13% respectively. The second comes from the management of manure, which generates methane and accounts for 19% of the GHG emissions in CO\(_2\) eq. (Gerber et al., 2013).

\(^{22}\) Note here that these emission shares are based on the production in 2017. Currently ASF has significantly reduced the production level of China, and therefore diminished its emission share.
5.1.3 Trade patterns

The aggregated meat trade patterns in 2019\textsuperscript{23} indicate that the net exporters are South America, Australia and New Zealand, North America, Southern Asia and Europe, whereas the net importers are Eastern Asia, Western Asia, and South-Eastern Asia, Central Asia, Melanesia, Central America, and the whole African continent. However, Figure 5.14 shows that there is significant heterogeneity within each region. As discussed in the previous section, even though China is the largest producing country, it is still the largest net importer of meat across all meat types. In addition, Brazil is the largest net exporter of meat as a whole, and mainly exports to the Chinese market.

Given meat perishability and refrigeration requirements and higher external trade barriers for countries outside of regional trade blocs, much of meat trade occurs at the regional level and the global meat market is \textit{de facto} split into smaller markets (see illustration of this in Figure 4.1). Technological advancements in shipping have, however, lessened this restrictive factor. As Most-Favored Nation (MFN) tariffs committed under the WTO are higher on agricultural products (FAO, 2003; Matthews, 2020; WTO, 2020), so countries have incentives to engage in preferential trade agreements which are traditionally regionalized or dependent on historical connections (Fulponi, Shearer, & Almeida, 2011). This also contributes to the regionalized meat trade pattern.

\textit{Figure 5.14: Country level trade balances in meat and edible meat offal (2019)

Source: Authors’ elaboration from UN (2020)

Beef

Beef exports are largely sourced from the largest producing countries such as Australia, the US, Canada, Brazil and Argentina, for the main destinations located in Eastern and Northern Asia, Western and Southern Europe, along with Africa and the Middle East, according to trade data for 2019 (UN, 2020). Some differences exist between fresh and chilled beef trade and that of frozen beef. The largest net exporter of fresh and chilled beef is Australia, whereas Brazil has the highest trade surplus in frozen beef. According to some researchers, this likely relates to differences in the perceived quality: while Brazilian meat is competitive on prices, the Australian producers are delivering higher valued cuts (Coronel, Procópio, & Lírio, 2013). The price differentials between fresh/chilled beef and frozen beef also reflect the extra transportation cost associated with transporting fresh and chilled products (Leygonie, Britz, & Hoffman, 2012).

\textsuperscript{23} Note that at the time the data were collected, not all countries had released trade data for 2019. For countries not reported data, we rely on trade data reported by their trading partners.
Poultry

The main poultry exporters are again South and North America, in particular Brazil and the US. East Europe is also a major exporter. China has been a major importer of Brazilian poultry exports, whereas the exports from the US are mostly sold to its neighboring countries Mexico and Canada. East Europe’s poultry production is spearheaded by Poland and mainly supplies the European market.

Pork

Before the Covid-19 pandemic hit pork exports, the ASF outbreak was already disrupting the market. The ASF has mainly affected China’s swine production along with other Asian countries, making the region even more dependent on pork imports and leading to higher pork prices. In 2019, the pig meat output dropped 21% in China and 15% in Vietnam, the largest world producers (FAO, 2020g). The steep drops in swine/pork prices might also be due to overstated prices in 2019 driven by the negative effect of ASF on global supply.

Covid-19 and meat trade patterns

As a result of Covid-19 trade volume decreased relative to the expected trade levels for 2020, driven by weakened demand and disruptions to supply chains such as transport bottlenecks (FAO, 2020f, 2020h). On the demand side, income falls had a disproportionate larger impact on meat demand compared to other food items. Delays and disruptions to the supply chain also increased the uncertainty faced by importers, further inhibiting trade (FAO, 2020h). On the supply side, net exporting countries faced the reduction of sales to domestic food services, since prime cuts usually supply caterings and restaurants and are not part of most household food bundles. Decreased sales to food services increased the availability of meat products to the export market. The excess supply had a negative effect on prices, as the meat price index fell by 10.4% over the first 7 months of 2020 (FAO, 2020h).

Table 5.3: Percent price changes in 2020 compared to 2019 price average

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>1.3</td>
<td>-1.3</td>
<td>-8.3</td>
<td>-6.8</td>
<td>2.5</td>
<td>-2.9</td>
<td>-5.0</td>
<td>-4.4</td>
<td>-5.7</td>
<td>-9.4</td>
<td>-9.0</td>
<td>-9.8</td>
</tr>
<tr>
<td>Lamb</td>
<td>16.6</td>
<td>11.1</td>
<td>1.4</td>
<td>-3.2</td>
<td>-4.7</td>
<td>-4.4</td>
<td>-4.5</td>
<td>-2.1</td>
<td>-1.5</td>
<td>-0.3</td>
<td>-2.5</td>
<td>-2.4</td>
</tr>
<tr>
<td>Swine</td>
<td>-9.5</td>
<td>-15.4</td>
<td>-9.4</td>
<td>-25.9</td>
<td>-3.2</td>
<td>-28.2</td>
<td>-28.8</td>
<td>-19.2</td>
<td>1.2</td>
<td>16.6</td>
<td>5.1</td>
<td>-4.0</td>
</tr>
<tr>
<td>Meat Index</td>
<td>-0.5</td>
<td>-5.9</td>
<td>-8.0</td>
<td>-17.8</td>
<td>-3.6</td>
<td>-10.5</td>
<td>-14.9</td>
<td>-12.6</td>
<td>-7.8</td>
<td>-4.0</td>
<td>-5.1</td>
<td>-7.0</td>
</tr>
</tbody>
</table>

Source: IMF (2020)(last updated 28/04-2021)

The evolution of prices during 2020 (see Table 5.3), shows that beef price changes have been moderate compared to the changes on poultry and pork. Since beef is usually more costly than poultry and pork and, therefore, consumed by wealthier individuals with relatively inelastic demand, it is understandable that the demand is less affected by the crisis. Some potential reasons explaining why the pandemic affected more the price of poultry are: recently scaled up production as consumers are substituting towards poultry consumption, as well as the loss of pig herds in China leading to a drastic increase of poultry production (OECD & FAO, 2020). Increased poultry production thus exacerbated the effect of Covid-19 on price drops. During the first months of 2020 (Jan.-May) the main poultry exporters scaled

24 -14.2% for poultry, -12.3% pig, -8% bovine, slight increase price of ovine 0.4% (FAO, 2020h)
down their production slightly, given high feed costs because of higher maize prices, and increased competition on the Chinese market (FAO, 2020h).

### 5.2 Expected Evolution

Further development of the meat sector is expected to be driven by several important drivers, such as income growth, demographic changes, changes in dietary guidelines and related public policy, and preference shifts on the demand side, and technological development and attention to climate change on the supply side. In this section, we review the current body of knowledge on both the short- and long-term development of the meat sector, drawing from the available literature and the insights gained from the interviews we conducted.

Projections of the world food market, including that of the meat market, are regularly conducted by several major international/national organizations, mostly based on structural economic models. These projections are built on a set of exogenous assumptions on important market drivers that are identified in the economic literature. Likewise, practitioners in the relevant industries also closely track market developments. Industry representatives that participated in our interviews state that decisions within the meat industry are mostly driven by the short-term evolution of the market due to its high volatility. For instance, the Covid-19 crisis has caused major disruptions to the global meat market, resulting in large changes in market prices (Table 5.3). At the same time, they also acknowledge that most of the major investment decisions are also influenced by long-term drivers. For instance, the ongoing major investment in large-scale modern pig production facilities in China are likely to play a key role in the future development of the Chinese market. This can affect export opportunities of the European pork industry. For longer term projections, important demand and supply drivers must be explicitly modeled.

#### 5.2.1 Short-term

The Covid-19 pandemic and the ASF outbreaks are considered to be major events affecting the meat consumption and production in the short-term. The Covid-19 crisis decreased purchasing power of certain population segments, restricted labor in meat processing and slaughterhouse facilities, and generated intermittent disruptions on the activity of the food-service sector (Kim et al., 2020). During the first months of the pandemic, meat prices evolved negatively and the volumes of unsold products increased due to logistical bottlenecks and depressed demand (FAO, 2020e). The crisis has also highlighted the increasing importance of e-commerce depicted by the South Korean example (Statista Research Departement, 2020), where the shift towards e-commerce has dampened the effects of Covid-19 on the sector.

The economic hardships caused by the pandemic have decreased meat demand in traditional exporting countries such as the EU, the US, and Brazil; hence, the production excess is expected to be diverted towards foreign markets (FAO, 2020e). Countries in East Asia and Southeast Asia have so far better weathered the pandemic, thereby opening up possibilities to import more. In the case of China, the production of pig meat would fall by 20% in 2020, following the 21% decrease observed in 2019, due to the ASF outbreak (FAO, 2020e). This supply shortage makes the country an attractive destination of pork and also poultry exports. While China will drive the trade growth in the short term, major pork exporting countries are not expected to benefit equally in the short run. For example, due to the ASF outbreak in Europe, China has banned pork imports originated from a number of countries including Germany and Poland (FAO, 2020f). Small import increases are also expected in Canada, Japan,

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25 In this report short-term refers to up to one year projections into the future.
Singapore, and the Philippines. Other countries - the US, South Korea, Russia, South Africa, Viet Nam, Cuba, and Saudi Arabia - are expected to experience a contraction in their imports (FAO, 2020e).

Short-term market development varies significantly across different meat products. During the first wave of the Covid-19 pandemic, beef and poultry were affected most severely. While the global meat production is still recovering from the ASF shock, particularly reduced pork supply, poultry production is expected to increase at half of the growth rate observed in 2019, which is insufficient to offset the drop in pig and cattle meat outputs (FAO, 2020e). China is forecast to increase poultry supply as a strategy to overcome animal protein shortages (OECD & FAO, 2020). The FAO (2020e), projects the EU to increase production as well. At the same time, the US is expected to gain market share in the poultry market at the expense of Brazil and to compete with the EU on the Chinese pork market, with the help of its “first-stage” trade agreement with China, following the tariff war between the two countries (Yu, 2020).

Table 5.4: FAO’s short-term market outlook in 2020

<table>
<thead>
<tr>
<th>Poultry</th>
<th>Bovine</th>
<th>Pork</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Higher Production</strong></td>
<td>China, the EU, the UK, Brazil, and Mexico</td>
<td>China and Brazil</td>
</tr>
<tr>
<td><strong>Lower Production</strong></td>
<td>India, Thailand, Turkey, and the US</td>
<td>The US, Australia, India, South Africa, the EU, the UK, and New Zealand</td>
</tr>
<tr>
<td><strong>Higher Import</strong></td>
<td>China and Japan</td>
<td>China, Viet Nam, Philippines, Chile, and Ukraine</td>
</tr>
<tr>
<td><strong>Lower Import</strong></td>
<td>Viet Nam, the US, Russia, Mexico, the Philippines, and South Korea</td>
<td>Import decrease is expected to outweigh the increase</td>
</tr>
</tbody>
</table>

Source: FAO (2020e)

Looking ahead, the Covid-19 pandemic and the ASF outbreak will likely continue their influence on the global meat markets. Table 5.5 summarizes the short-term outlook for the meat market from several sources. These outlooks are highly dependent on the expected evolution of the pandemic and the ASF outbreak, the effects of which are not expected to be equally distributed across countries. For instance, meat products sold to food services in the EU will be affected due to Covid-19 restrictions (EC, 2020b), whereas in Australia such effect is not expected to be as significant due to the fact that the Covid-19 has largely been under control (ABARES, 2020b). For the EU and the UK, the changing trade relationship as a result of BREXIT adds further uncertainties to the bilateral trade flows between the two sides (EC, 2020b). In the following paragraphs, we explore the short-term outlook by product categories.
<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Pork</th>
<th>Poultry</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China</strong></td>
<td>Imports rise by 4%</td>
<td>Expected recovery from ASF – increased supply: production to rise by 9%, still 25% less than prior to ASF</td>
<td>• Imports decrease by 6% • Rise in production</td>
<td>1</td>
</tr>
<tr>
<td><strong>US</strong></td>
<td>Increase in production by 1%; 6% expansion of exports</td>
<td>Production to rise 1% Constant exports; previously to China, redirected to Mexico and Japan</td>
<td>• 1% rise in production • Stable exports</td>
<td>1</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td>Increase in production</td>
<td>Slight production increase due to productivity growth. Restricted exports from Germany likely to oversupply the EU market, leading to price drop</td>
<td>Rise in production</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>lowered production from the previous year continues due to disrupted food services and feed deficiency due to dry spring (resulting in lower carcass weight)</td>
<td>1% fall in production. 10% drop in exports (ASF recovery China)</td>
<td>1% production growth</td>
<td>3</td>
</tr>
<tr>
<td><strong>Australia</strong></td>
<td>Decrease in production</td>
<td>Value of exports expected to decrease by 27%, driven by a 23% volume loss and a 5% price decrease (2020-21)</td>
<td>Value of exports expected to decrease by 27%, driven by a 23% volume loss and a 5% price decrease (2020-21)</td>
<td>1</td>
</tr>
<tr>
<td><strong>India</strong></td>
<td>Increase in production</td>
<td>4% production growth</td>
<td>Rise in production</td>
<td>1</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>Increase in production</td>
<td>1.6% production growth</td>
<td>Rise in production</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3.8% export growth</td>
<td>2.4% production growth</td>
<td>4.9% production growth</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4% production growth</td>
<td>3.7% export growth</td>
<td>4.7% export growth</td>
<td>5</td>
</tr>
<tr>
<td><strong>Argentina</strong></td>
<td>Decrease in production</td>
<td>Production to rise by 4%</td>
<td>Production to rise by 2% Global exports rise by 2%, 1/3 from Brazil’s exports expansion in the Mid-east and Sub-Saharan Africa due to price competitiveness</td>
<td>1</td>
</tr>
<tr>
<td><strong>Global</strong></td>
<td>Production to rise by 2% Global exports to rise by 3%</td>
<td>Production to rise by 4%</td>
<td>Production to rise by 2% Global exports rise by 2%, 1/3 from Brazil’s exports expansion in the Mid-east and Sub-Saharan Africa due to price competitiveness</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: (1) USDA (2020b), (2) ABARES (2020b), (3) EC (2020b), (4) Ministério da Agricultura (2020), (5) USDA (2020c). Note: We use red font to highlight differences in the projections from different sources.
Beef

In 2021, the output of Australia and Argentina is expected to be lower, since both countries are expanding their herds and therefore reserve a larger amount of animals for breeding purposes. Meanwhile, the US production is forecasted to increase by 1%. Australian production is expected to be less competitive on the East Asian markets, resulting in a 6% expansion of the US exports, and a reduction of Australian exports by 23% in 2020-21 (ABARES, 2020b). This will place the US as the second largest exporter of beef next to Brazil (USDA, 2020b). In 2020, the European beef production has been negatively impacted by the pandemic and by a very dry spring leading to feed deficiency issues, which reduced the carcass weight of slaughtered animals. Reductions in the French, German, and Irish herd sizes during 2020 might translate into a further drop in EU production (EC, 2020b). Elsewhere, Cano (2019) acknowledges the weight of China in Argentinian production and observes a drop on domestic consumption from 2017, with the main driver of the market being the exports to China. In total, global beef exports are projected to expand by 3%, driven by the recovery of food services and supplied by the major producing regions apart from Australia and Argentina (USDA, 2020b). On the import side, total beef imports are expected to increase by 4% in China in 2021, the slowest growth rate over the last 5 years due to the rebound of domestic pig production (USDA, 2020b). After a 10% reduction during 2020, EU beef imports are expected to return to their normal level in 2021 (EC, 2020b).

Poultry

Global poultry production is expected to rise by 2%, led by production in China. In 2021, the recovery of its pig production and the increase in its poultry production are expected to lower China’s poultry imports by 6%. Other major market players will also expand their production, but a large share is expected to be absorbed by increased domestic demands (USDA, 2020b). During 2020, decreases in EU poultry imports due to the restrictions in the food service industry affected its main supplier, Brazil, which redirected its exports to China. The EU is expected to recover its import levels in 2021 as food service is expected to re-open (EC, 2020b). Hence, the reductions in imports from China and South Africa will be offset by increases in the EU and Saudi Arabia. Thus, global exports are expected to have a 2% growth, one-third of which is expected from Brazil’s export expansions in the Middle East and Sub-Saharan Africa due to its price competitiveness (USDA, 2020b).

Pork

China’s total meat imports were unusually high in 2020 due to the ASF outbreak. During 2021, China is expected to regain its production and reduce its imports as compared to the previous year. Pork prices are subsequently expected to lower, allowing a reorientation of exports towards less developed economies with low-income consumers. Overall, global exports are expected to remain stable during 2021, as the reduction in exports to China will be offset by an increase in countries recovering from the Covid-19 crisis (USDA, 2020b). In the first half of 2020, European exports were up 15% compared to 2019. In September 2020 ASF cases were discovered in the German wild boar population, impeding exports of German pork towards large destination markets: China, South Korea, and Japan. So the increase of European exports has been revised to 2% in 2020 (EC, 2020b). Given the situation, the EC (2020a) expects the outflow of pig meat to standstill in 2021. Following USDA (2020b), the ASF-related exports restrictions will lead to lower prices in the EU market oversupplied by pork from Germany. However in 2021, the USDA still expects the EU production to increase slightly due to productivity growth. According to EC (2020b), total production in the EU would decrease in 2020, with a 0.9% year-on-year reduction already observed for the first half of 2020. However, such reductions are unevenly distributed across EU member states, as pork production actually increased in Denmark and Spain. For 2021, the EC expects EU production to drop by 1% (EC, 2020b). In the US, pork production
is expected to increase by 1% and exports will be diverted from China to Mexico and Japan (USDA, 2020b). Brazil on the contrary is expected to hold to the Chinese market (USDA, 2020c) and to experience an increase in its own domestic consumption (USDA, 2020b), which will translate into a production rise of 2.4-4.5% depending on the source consulted (see Table 5.5).

5.2.2 Long-term

In the long-term, income growth and demographic changes are expected to be the main demand drivers of animal products. Thus, most of the long-term growth of the sector is expected in developing countries where income and population grow more rapidly (USDA, 2020c). In particular, demand for poultry products is expected to experience disproportionately larger growth. Moreover, the change in per capita consumption is expected to vary significantly across countries and different meat categories. For instance, processed meats and convenience foods are expected to become more important on developed markets (OECD & FAO, 2020), whereas average consumers from emerging and developing economies may simply consume more meat products. This not only reflects across-country differences in the current meat consumption patterns, but also the expected divergences of future meat demand patterns across countries of different income levels and demographic characteristics. More specifically, in high-income countries already with higher level of per capita consumption, further increases will likely be limited; at the same time, compliance with health and environmentally friendly diet guidelines may lead to shrinking per capita consumption. Changing consumption patterns are expected to be accompanied by increases in the level of trade, particularly if countries with expected high demand growth have limited possibility to meet their own demand. Continued innovation in transportation and logistics and digitalization may further reduce trade costs, thereby having the potential to further promote trade (OECD & FAO, 2020). On the flip side, the proliferation of regional trade agreements and the stalling multilateral trade liberalization process can restrict further trade growth while regionalizing trade along particular trade routes.

Other driving forces behind long-term meat demand are environmental and health concerns. Heightened attention to climate change may also elicit consumption behavior changes and consumers may change their consumption to comply with dietary guidelines such as EAT-Lancet Commission (2019) or WHO (2020a). For example, younger consumers have a large representation among vegetarians in the EU (EC, 2019), possibly suggesting that the share of vegetarians may rise in the future if the current trend further develops and expands in other parts of the world. Stringent climate regulation in the form of GHG emissions taxation has also been proposed to account for externalities in meat production (Bonnet et al., 2020). Such measures can potentially change the global meat market and the effects would depend on the ambition level of its implementation. For example, the EC (2019) suggests that environmental policies will constrain meat production growth in the majority of the EU Member States, thereby limiting future EU exports. Conversely, the EC expects that Brazilian exports will experience a much higher relative growth given the differences in regulation. Moreover, after the pandemic, there may be an increased focus on the biosecurity risks associated with interactions between humans and animals in terms of disease transmission (IPBES, 2020), which could speed up some of the tendencies already occurring in the expansion of vegetarianism. Finally, it is important to notice that the transition in high-income countries is not only expected to be towards plant-based protein, but also away from red meat and towards poultry and fish (OECD & FAO, 2020).

Existing long-term projections have been regularly conducted by several international and national organizations, including the OECD, FAO, European Commission, and the USDA. These projections often contain extrapolations up to a decade and have been updated annually, built upon current projections of income and population growth, other macro-economic drivers, and also factors specific
to the agricultural and livestock sectors. However, dietary guidelines, possible shifts of consumer preferences, and attention to climate change and other environment concerns typically receive insufficient attention in such projections. We summarize the main findings from the latest projections from these agencies below, with a focus on the joint OECD-FAO projections due to its global coverage.

Figure 5.15: Beef and veal (a), poultry (b), and pork (c) consumption by regions, 1,000 tons

Source: OECD and FAO (2021)

The OECD and FAO project the average annual growth of total meat consumption to be 1.1% from 2020 to 2029, lower than the 2% observed from 2009 to 2019 (EC, 2019). Figure 5.15 depicts the evolution of regional beef, poultry and pork consumption over the last three decades and the projections for 2020 to 2029. In the three panels, we observe that the total demand of meat grew worldwide in the last three decades. Asia has been and will continue to be in the next decade the main driver of worldwide meat demand growth. This growth is expected to be mostly covered by domestic productions. The other regions that have been developing rapidly in the last three decades, namely Latin America and Africa, show a convergence, particularly in poultry and pork consumption. Latin America’s total consumption of beef and veal, and poultry is now higher than in North America. However, per capita consumption is still significantly lower in Latin America (OECD & FAO, 2021). In the case of Europe and North America, the growth is mainly due to the increase of the consumption of poultry meat. Europe even experienced a decrease in total beef and veal consumption. Lastly, the absolute consumption of meat in Oceania does not change much due to the small population. The projections into the next decade for
every meat type seem to follow the trend observed in the last decade. Developing countries are expected to continue converging towards developed countries’ per capita consumption levels. The projections for pork in Asia also reflect the drop in demand due to the ASF outbreak and the expected rapid recovery thereafter.

In developing regions, imports are projected to increase because demand is expected to grow faster than production (EC, 2019). Figure 5.16 shows that Asia is the major importer in every meat type. Its net imports has increased over the last three decades and is expected to follow the same trend in the next one. Africa is also a net importer of all three types of meats. However, the import of pork is almost negligible. This might be due to some of the richest African countries have a strong influence of Islam, constraining the demand of pork. The import of poultry, however, has been significantly growing in the last three decades and this trend is expected to continue. Latin America is a net exporter of beef and poultry, with the growing trend from the early 2000s expected to continue in the coming decade. North America is a net importer of poultry and pork, with its net export position mirroring the growing net import position in the Asian market. Europe is, as well, a net exporter of pork and has recently (around 2014) become a net exporter of poultry. As for North America, the European positive trade balance of pork mirrors the Asian negative trade balance. Finally, Oceania is a major exporter of beef and veal.

Overall, international trade in the meat market has been growing significantly from 1990 to 2019 and is expected to continue growing in the next decade.

*Figure 5.16: Beef and veal (a), poultry (b), and pork (c) net exports by regions, 1,000 tons*

Source: OECD and FAO (2021)
Box 3: Views from the industry

When analyzing meat market development, industry experts we interviewed tend to have different focus from international organizations such as the OECD and FAO. From the perspective of OECD and FAO (2020), the development of the market is mainly driven by the changes to supply, reflecting these organizations’ concern about the natural resource base upon which livestock stock production is conducted. This contrasts with the view of industry representatives we interviewed, who look upon these markets as consumer driven, an indication of the industry’s focus on markets. Another possible explanation behind these different perspectives is due to their focuses in different markets. Highly competitive mature markets may have a tendency to be consumer driven, as their choice within differentiated products make their preferences more salient to producers, whereas on less developed markets varieties might be narrower, granting the suppliers the power to drive the consumption choices.

Beef

Figure 5.15 shows that beef is the meat category with lowest worldwide demand (measured in tons consumed), reflecting the high costs and prices for producing beef. However, the international trade of beef has been growing in the last three decades and is expected to continue growing in the next one (see Figure 5.16). The consumption growth is driven by the Asian and African markets, but international trade growth of beef is mainly driven by the Asian market (see Figure 5.15 and Figure 5.16). In the EU, the cattle herd from both the beef and dairy industry is expected to decrease by 5% by 2030, causing a reduction in beef production of 9.3% from 2019 to 2030 (EC, 2019). In the US, the production of beef is expected to increase but at a lower rate than pig and poultry, as the output to feed price ratio is projected to decrease over the next ten years (USDA, 2020e). In Brazil, a similar projection to that for the US is expected: beef production is projected to increase by 16.2% from 2020 to 2030, allowing Brazil to serve domestic demand and exports (Ministério da Agricultura, 2020). In terms of exports, Brazil is expected to be the leading exporter of beef, holding approximately a third of total worldwide exports (Zia, Hansen, Hjort, & Valdes, 2019). The US total beef exports are expected to increase but its market share is expected to diminish, as China and other price-sensitive markets will increase imports of beef from Brazil (USDA, 2020e). In the EU, both exports and imports are expected to grow due to the development of its various trade agreements (EC, 2019).

In the following decade, the concerns about animal welfare, ethical production, and sustainability are expected to further divide the market in quality segments. This would benefit certain producers (e.g. Australian (ACIL Allen Consulting, 2019) or European (EC, 2019)) more than others. However, the shift in consumption patterns seems to be heterogeneous within regions and countries. For instance, the expected reduction in beef consumption in the EU is mainly originated in the EU-15 – i.e. North-Western Europe (EC, 2019).

Poultry

The pattern in the last three decades shows that poultry demand grew steadily in every world region, while this did not happen with beef and pork (see Figure 5.15). Moreover, imports are not only driven by Asia but also Africa, which became a major importer around the year 2010 (see Figure 5.16). OECD and FAO (2020) project the market for poultry meat to grow faster than for other types of meat over the next decade, with expected production growth at 16%, of which 60% is expected to come from the rise in production in Asia Pacific and Latin America. The largest exporter over the next decade is expected to be Brazil, followed by the US, EU and Thailand (there is a considerable difference between the
second largest exporter (the US) and the third (the EU)). These four countries supply 84% of all exports (USDA, 2020e). The Brazilian production of poultry is expected to increase 28.1% from 2020 to 2030. The principal importers from Brazil are Saudi Arabia, Sub-Saharan Africa, China, Hong Kong, Japan, and the EU (Ministério da Agricultura, 2020).

**Pork**

Figure 5.15 shows that the fast growth in pork demand is driven by the Asian region, while in other world regions the consumption growth has been slower. The consumption in Latin America is also growing fast relative to their consumption level at the beginning of the 1990s. International trade of pork is rather limited in Latin America, Africa, and Oceania. The international market is driven by the Asian demand, which is fulfilled by European and North American exports (see Figure 5.16).

The pork markets are the most uncertain at current times given the ASF outbreak. In fact, the ASF outbreak in China has induced spillover effects on the entire meat sector, as it is the largest pork-producing region. The crisis has resulted in significant increases in Chinese pork imports, but also of other meats to cover the meat protein gap. It is uncertain when China will be able to reach its pre-ASF production level. For the moment, as the disease is still present, investing in the sector is considered rather risky (EC, 2020a). However, in the interviews we conducted, members of the pig industry suggested that Chinese producers have been investing in very modern farms with close to carbon neutral technology and such capacity will enter into production soon.

The EC (2020a) projects that by 2030 the EU exports might be moderately higher than in 2018, given that other Asian partners other than China might not be able to fully recover from ASF by this time. The EC also predicts that the EU will remain as the main pig meat exporter by having 38% of the market by 2030. The USDA (2020e) expects that by 2029 a third of the US production will be exported, as domestic consumption is slightly decreasing. The USDA expects this export expansion to be rapid, overtaking the EU as main exporter by 2025, because other US competitors are expected to be impacted by ASF.

**Business as usual projections and the climate agenda**

Although potential cross-country differences in regulating GHG emissions from livestock production can influence global meat production and trade patterns, the projections we summarized above refer to the so-called “business-as-usual” estimates, where the establishment of potential future policies are not considered unless such changes have already been politically decided. Therefore, the projections do not capture the potential impact of new climate change mitigation and adaptation policies. At the regional level, the European Commission does perform projections with environmental impacts being calculated (EC, 2019, 2020a). However, such estimates do not cover the global livestock production. OECD and FAO (2020) acknowledge the potential impact of growing concerns about climate change and climate regulation in the future of global meat markets. However, they also argue that there is not sufficient evidence yet to support the market projections under such scenarios. Moreover, they claim that market price is still the primary concern within the developing regions. The USDA (2020e) in contrast makes no reference to the environment or climate change. Therefore, in future projections of the global market, it is necessary to explicitly consider the impacts of climate mitigation policies.
6 THE DAIRY SECTOR

The global consumption of dairy products is expected to increase over the coming decades, driven by population growth, changing diets, and higher purchasing power for a growing middle-class population in developing economies (Kharas, 2010; OECD & FAO, 2020; Vitaliano, 2016). However, differences in dairy consumption patterns exist and are expected to continue in the next decades. In developed countries where per capita dairy consumptions are generally higher, processed dairy products are having an increasingly larger share of total dairy consumption, whereas consumers in developing nations continue to consume mainly fresh dairy products and milk powder (OECD & FAO, 2020). Over the coming decades, this pattern is expected to persist with developing countries (particularly Southeast Asian, West African and the Middle East and North Africa (MENA) region) increasing per capita and total dairy consumption. On the other side, having already reached market saturation for traditional dairy products, developed countries’ consumption measured in raw milk equivalents is expected to stagnate. However, the demand composition is expected to shift towards sustainable branded products and “to go” options, similar to the shift in the meat sector. This shift was already pinpointed in the early 2000’s (Delgado, Rosegrant, Steinfeld, Ehui, & Courbois, 2001); therefore, it can be regarded as a long-term development that is receiving more media attention in recent years due to the increased awareness of the linkages between climate change and animal based products.

On the production side, a major determinant is the need to mitigate the climate impacts of milk production. As a large contributor to greenhouse gas (GHG) emissions, further growth of the dairy sector may pose a challenge to global emissions reduction goals (Opio et al., 2013). National climate change mitigation strategies may effectively impose restrictions on milk and dairy production, particularly in developed countries, where climate goals such as net-zero emissions are a focus of public debates. In this regard, differences in production methods and technology can partially explain observed variations in emission intensities across countries (FAO & GDP, 2018). Such differences suggest that there are varying emission reduction potentials stemming from improving technology and best practice. More fundamentally, the divergences on production systems across the world are rooted in the differences of resource endowments, national regulations, and degrees of economic and social development (FAO, 2020d; IFCN, 2014; OECD & FAO, 2020). Therefore, the development of these factors needs to be considered in understanding the sector’s future development.

Mismatches between dairy production and consumption across countries are eliminated by international trade flows. Challenges to enhance trade linkages to better connect surplus and deficit countries include tariff and non-tariff barriers. The proliferation of regional trade agreements may also have favored trade flows along particular trade routes over others. Moreover, logistic requirements influence the tradability of different dairy products. For instance, international trade for fresh dairy products is constrained by the need of well-developed cold supply chains (Heard & Miller, 2019); however, such requirement is absent for milk powders, allowing the latter to occupy a large share of traded dairy products. Overall, the logistical difficulties and high transportation cost associated with fluid milk result in only approximately 8% of milk equivalent dairy production being traded internationally (FAO, n.d.-b). At the moment, dairy is a sector characterized by consumption of mainly domestically produced varieties. In the next decades, the demand in growing markets is expected to expand faster than the domestic production levels, thereby promoting more dairy trade flows (OECD & FAO, 2020).

6.1 DATA ANALYSIS

In this section we use data from UN (2020), CEPII (2020), FAO (2020a); (2020d), and OECD and FAO (2021) to analyze the current and historical situation in the dairy markets. This provides the basis
for understanding current projections on the sector’s future development available from several major international and national organizations, and the expectations from the industry representatives we interviewed for this report.

6.1.1 Consumption

Per capita consumption of dairy products varies greatly across countries, according to the Food and Agriculture Organization (FAO) Food Balances (FAO, 2020d). As illustrated in Figure 6.1, per capita consumption of dairy products (measured in kilogram milk equivalent in 2017) is much higher in highly developed regions (such as the European Union (EU), North America and Australia) than in many developing countries in Asia and Africa. For example, the average per capita consumption of milk equivalent dairy products in Finland was 469 kg in 2017, whereas in Nigeria and Côte d’Ivoire per capita consumption was only around 2 kg in the same year. Within Africa, per capita consumption levels vary significantly across countries. For example, Algeria has the highest per capita consumption of 122 kg in 2017, far higher than many other African countries. Similarly, in Asia, the East and South-East regions have low per capita dairy consumption (e.g. 24 kg in China), while the consumption is more prominent in South Asia, particularly in Pakistan where on average each person consumed 185 kg of dairy products. India, despite of being the largest producer worldwide, had a per capita consumption level of 106 kg. Additionally to the information regarding the quantities consumed, the Food Balances of the FAO also include information on nutritional intakes from the dairy sector, including protein (in grams), fat (grams), and calorie (in kcal per capita per day). Such measures are also generally higher in developed regions. In fact, developed regions tend to derive more of their nutritional needs from livestock products, relative to developing countries where the contribution of starches tends to be of higher importance (Muehlhoff, Bennett, & McMahon, 2013). In Asia and Africa, dairy products supply 3 to 4% of dietary energy, while in Europe and Oceania this is 9%. Similarly, the share of proteins and fats supplied by dairy in Asia and Africa is about half of that in Europe, Oceania, and the Americas (FAO, n.d.-a). The consumption levels also vary across countries/regions, with respect to specific dairy products, as summarized in Table 6.1.

Figure 6.1: Food supply of dairy products in kg per capita (2017)

Source: FAO (2020d).

Note: Dairy products are aggregated using primary commodity equivalents for all the dairy commodities available in the FAO food balances.
Table 6.1: Largest per capita consumers globally and in each region in 2017

<table>
<thead>
<tr>
<th>Dairy products (Milk – Excluding Butter)</th>
<th>Global</th>
<th>Europe</th>
<th>Asia + Oceania</th>
<th>Africa</th>
<th>Americas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland, Albania, Montenegro and Estonia</td>
<td>Finland, Albania</td>
<td>Kazakhstan, Australia and Uzbekistan</td>
<td>Algeria, Botswana and Tunisia</td>
<td>US and Uruguay</td>
<td></td>
</tr>
<tr>
<td>Latvia, Slovenia</td>
<td>Latvia, Slovenia</td>
<td>Iran and Kazakhstan</td>
<td>Botswana</td>
<td>Canada</td>
<td></td>
</tr>
<tr>
<td>New Zealand, France and Sweden</td>
<td>France, Sweden</td>
<td>New Zealand, Australia and Azerbaijan</td>
<td>Morocco, Tunisia</td>
<td>Canada and US</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ elaboration from FAO (2020d).

Note: In the table, we mention countries within the 98% quantile at the global level, and countries within the 95% quantile at the regional levels. The composition of the three dairy groups can be found in FAO (2020d).

Table 6.2: Dairy consumptions by product categories and regions/countries in cow milk equivalent 1,000 tons (2019)

<table>
<thead>
<tr>
<th>Product</th>
<th>World</th>
<th>OECD Countries</th>
<th>Africa</th>
<th>Asia</th>
<th>Europe</th>
<th>Latin America</th>
<th>North America</th>
<th>Oceania</th>
<th>China</th>
<th>European Union</th>
<th>India</th>
<th>New Zealand</th>
<th>Nigeria</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter</td>
<td>11,570</td>
<td>4,199</td>
<td>389</td>
<td>6,643</td>
<td>2,908</td>
<td>466</td>
<td>1,013</td>
<td>152</td>
<td>222</td>
<td>2,112</td>
<td>4,491</td>
<td>43</td>
<td>24</td>
<td>880</td>
</tr>
<tr>
<td>Casein</td>
<td>283</td>
<td>18,448</td>
<td>892</td>
<td>2,625</td>
<td>111</td>
<td>0</td>
<td>140</td>
<td>19</td>
<td>391</td>
<td>111</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>140</td>
</tr>
<tr>
<td>Cheese</td>
<td>23,802</td>
<td>103,904</td>
<td>34,388</td>
<td>256,992</td>
<td>11,355</td>
<td>2,336</td>
<td>6,234</td>
<td>359</td>
<td>27,600</td>
<td>9239</td>
<td>3,729</td>
<td>48</td>
<td>48</td>
<td>5,720</td>
</tr>
<tr>
<td>Fresh dairy products</td>
<td>430,276</td>
<td>103,904</td>
<td>34,388</td>
<td>256,992</td>
<td>11,355</td>
<td>2,336</td>
<td>6,234</td>
<td>359</td>
<td>27,600</td>
<td>9239</td>
<td>3,729</td>
<td>48</td>
<td>48</td>
<td>5,720</td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>4,578</td>
<td>2,025</td>
<td>384</td>
<td>1,831</td>
<td>1,187</td>
<td>621</td>
<td>500</td>
<td>56</td>
<td>299</td>
<td>819</td>
<td>193</td>
<td>7</td>
<td>4</td>
<td>441</td>
</tr>
<tr>
<td>Whey powder</td>
<td>2,798</td>
<td>1,951</td>
<td>384</td>
<td>720</td>
<td>1,539</td>
<td>621</td>
<td>500</td>
<td>56</td>
<td>607</td>
<td>819</td>
<td>17</td>
<td>4</td>
<td>8</td>
<td>258</td>
</tr>
<tr>
<td>Whole milk powder</td>
<td>4,947</td>
<td>928</td>
<td>625</td>
<td>2,364</td>
<td>582</td>
<td>1,297</td>
<td>54</td>
<td>35</td>
<td>1,513</td>
<td>398</td>
<td>4</td>
<td>17</td>
<td>371</td>
<td>43</td>
</tr>
<tr>
<td>Total Dairy</td>
<td>47,253</td>
<td>131,738</td>
<td>36,702</td>
<td>271,188</td>
<td>93,407</td>
<td>39,832</td>
<td>33,558</td>
<td>3,568</td>
<td>30,632</td>
<td>50,679</td>
<td>137,168</td>
<td>371</td>
<td>371</td>
<td>30,001</td>
</tr>
</tbody>
</table>


Note: The quantities are expressed as cow milk equivalent.

Table 6.2 summarizes the total consumption of dairy products for world regions, as well as several countries, in 2019. Although not providing full disaggregation at country level, these most recent data are used in OECD and FAO (2020) to characterize the latest global market situation. In 2019, 478.253 million tons of cow milk equivalent dairy products were consumed, 66% of which in developing countries (OECD & FAO, 2021). India is the largest dairy consuming country and consumed 137.168...
million tons (cow milk equivalent) of dairy products in 2019, representing almost 29% of the global consumption and just above half of the total consumption in Asia. The consumption share of Asia is 57%, followed by Europe (19.5%) and Latin America (8.3%).

In Table 6.3 we summarize the yearly growth rate by decades for dairy consumption based on OECD and FAO (2021) data. The table shows that developing countries have higher growth rate on dairy consumption across all decades. From 2020 to 2029, annual growth in developing countries is expected to be 2.5%, compared to a rate of 0.4% for developed countries. From 1990 to 2020, Asia consistently experienced high growth rates, whereas the growth rates in Africa and Latin America have decreased in the past three decades. From 1990 to 2010, the total dairy consumption grew across all regions. From 2010, North America and Africa experienced a decrease in total and per capita dairy consumption. The growth of per capita dairy consumption in Europe, North America, and Oceania decreased over the last three decades, even reached negative growth in some of the decades, suggesting that the dairy market has saturated for some developed countries.

Table 6.3: Average annual changes (%) of dairy consumption (1990-2029)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absolute</td>
<td>Per cap.</td>
<td>Absolute</td>
<td>Per cap.</td>
<td>Absolute</td>
<td>Per cap.</td>
<td>Absolute</td>
<td>Per cap.</td>
</tr>
<tr>
<td>World</td>
<td>8.46</td>
<td>6.64</td>
<td>2.56</td>
<td>1.30</td>
<td>2.07</td>
<td>0.92</td>
<td>1.84</td>
<td>0.90</td>
</tr>
<tr>
<td>Developing countries</td>
<td>3.93</td>
<td>2.01</td>
<td>4.06</td>
<td>2.55</td>
<td>3.07</td>
<td>1.74</td>
<td>2.47</td>
<td>1.37</td>
</tr>
<tr>
<td>Developed countries</td>
<td>2.17</td>
<td>0.58</td>
<td>0.62</td>
<td>0.21</td>
<td>0.33</td>
<td>-0.11</td>
<td>0.44</td>
<td>0.23</td>
</tr>
<tr>
<td>Asia</td>
<td>4.32</td>
<td>2.56</td>
<td>4.38</td>
<td>3.14</td>
<td>4.01</td>
<td>3.01</td>
<td>2.48</td>
<td>1.77</td>
</tr>
<tr>
<td>North America</td>
<td>0.51</td>
<td>-0.66</td>
<td>0.55</td>
<td>-0.26</td>
<td>-0.74</td>
<td>-1.45</td>
<td>-0.02</td>
<td>-0.60</td>
</tr>
<tr>
<td>Latin America</td>
<td>2.38</td>
<td>0.62</td>
<td>1.57</td>
<td>0.28</td>
<td>0.46</td>
<td>-0.58</td>
<td>1.68</td>
<td>0.89</td>
</tr>
<tr>
<td>Oceania</td>
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</tbody>
</table>

Source: Authors elaboration from OECD and FAO (2021)

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26 The consumption shares in the rest of the world: Africa 7.7%, North America 7%, and Oceania 1%.
27 The countries belonging to the developing and developed groups are defined in the section “Abbreviations and acronyms” of OECD and FAO (2020).
The majority of dairy products consumed belong to the fresh products category that corresponds to 90% of global consumption; however, there are large regional differences. For instance, in Europe the share of fresh dairy products is 72% due to a large cheese consumption share, meanwhile in India fresh dairy products account for 97% of total consumption. Following fresh dairy products, cheese is the second most consumed dairy product, with five percent of global consumption, although within the European Union (EU) and North America the share of cheese is around 18%. The other dairy products have much lower global consumption shares: 2.4% for butter, 1% for skim milk powder (SMP) and whole milk powder (WMP). Nevertheless, milk powder consumption shares are much larger in certain less developed countries. For example, WMP corresponds to 23% of the Nigerian dairy consumption, and SMP amounts to 63% and 55% of dairy consumption in the Philippines and Malaysia, respectively.

Figure 6.2 shows the development of per capita consumption in the last 30 years across specific dairy product groups and the expected trend from 2020 to 2029. Overall, developing countries have had higher growth in the consumption of fresh dairy products and such trend is expected to continue in the next decade. However, within the developing world, Africa’s per capita consumption has decreased from 2010 to 2020, while per capita consumption in Asia have increased across all decades and product types. By 2029 the per capita consumption of fresh dairy products is expected to be higher in Asia than in all other regions excluding Europe (Figure 6.2) (FAO, 2020d; OECD & FAO, 2021), while North America and Oceania expect a decreasing per capita consumption trend for the fresh dairy products.

Beyond fresh dairy products, we examine the evolution on the consumption of butter, cheese, and powder milks. Butter per capita consumption is roughly stable over time for most regions. In Oceania, which has one of the highest consumption per capita, there have been significant fluctuations. In other regions, per capita consumption is stable or slightly increasing over time in per capita terms. Cheese is the only product where the largest per capita consumption increases are occurring in Europe and North America, helping stabilizing aggregated dairy consumption levels in these regions by countering, as consumers are shifting their demand from fresh dairy products to cheese. Per capita consumption of cheese is more stable within other regions. The whole milk powder per capita consumption, similarly to butter, has been quite volatile and generally in a downward trend in Oceania. It is the only dairy product in Figure 6.2 where North American has the lowest per capita consumption.

Box 4: Views from the industry

The industry representatives we interviewed discussed the maturity of the markets in Western Europe and North America, a fact that is confirmed by the data compiled in this section. Indeed, the per capita food supply of dairy products in these regions is very stable over the 1980-2017 period. In contrast, South Asia including particularly India, shows a consistent increase in per capita milk supply during the same period (FAO, 2020g).
Figure 6.2: Butter (a), fresh dairy products (b), cheese (c), and whole powder milk (d) per capita consumption in kg by regions.


Note: The consumption is expressed in cow milk equivalents. Europe’s consumption data for butter prior to 2003 is not included due to a lack of data from the EU.
These trends suggest converging consumption levels of fresh dairy products across a number of world regions. Overall, the global average per capita consumption of fresh dairy products is projected to increase by 1% per year over the coming decade (2020-2029), faster than the growth observed during the past ten years. The growth is expected to be especially high in India (the largest milk producing country). In the EU and North America, the per capita demand for fresh dairy products is either stagnating or declining, due to the shift towards dairy fats (OECD & FAO, 2019). The projections show that the consumption of highly processed dairy products, such as cheese, will continue to rise in developed regions. Hence, their market share is going to increase in EU and North America, creating an even larger difference on the dairy products shares across world regions in the near future (OECD & FAO, 2020).

Unlike their counterparts in developed countries, many consumers in developing countries do not purchase dairy products from formal market channels, 80% of milk marketed in developing countries is estimated to go through informal markets (FAO, n.d-b). In African countries, a large share of the dairy consumption stems from smallholder farming in the form of fresh dairy products with low processing levels (IFCN, 2014) (Table 6.2). This pattern is also present in India: 48% of the dairy production is non-marketed and is either used on farm or supplied to neighboring non-farmers in rural communities. For the remaining 52%, 60% is marketed through the unorganized sector, as shown by data for the 2015-16 period (Department of Animal Husbandry, 2018). Producing other highly processed dairy varieties is not possible for most subsistence farmers, as the transportation of milk to and from processing facilities requires a cold supply chain yet to be established on a large scale, especially in rural regions, requiring large investments (Department of Animal Husbandry, 2018; Heard & Miller, 2019). This is also one of the reasons as suggested by industry representatives for explaining the current low trade of fresh food products to the African countries. Moreover, fresh dairy products are subject to higher prices and considered higher quality goods in developing regions compared to powder milk alternatives. Hence, per capita income still needs to grow for average consumers to include dairy products produced outside the smallholder farming in their consumption basket.

6.1.2 Production

At the primary stage, production of dairy products is related to herd size and yields. The global distribution of milk and dairy production is therefore determined by a variety of factors that influence herd size and yields, which often differ across countries and in particular between developed and developing countries. Different milk yields across countries/regions reflect diversity in production forms28 (OECD & FAO, 2020; Seré et al., 1996). The average size of farms is one distinctive element of production forms. Smallholder and subsistence farming still prevail in developing nations, while large-scale intensive production dominates in developed regions (FAO, 2010; IFCN, 2014). Therefore, most of the production growth in developing countries can be expected from the adoption of best practices and from the increase of herd sizes in developing regions (OECD & FAO, 2020). It is worth noting that although production growth driven by yields improvement imply less resource use per unit of outputs and possibly lower emission intensities, expanded overall production can very well increase resource use (e.g. land and water use) and result in rising total GHG emissions, due to overall increments in herd sizes (Alkemade et al., 2013; IPBES, 2020). Divergences in environmental standards and animal welfare requirements also influence dairy production, and such regulations are usually more stringent in developed countries and lax in some developing countries. As Herrero et al. (2013) pinpoint, the expanding markets – i.e. Latin America, South East Asia, South Asia and Africa – not only exhibit

28 Milk is produced by ruminant animals, globally 81% being cattle, and 15% buffalos (OECD & FAO, 2020). Therefore, it is closely linked to the production of cattle meat (discussed in the livestock section).
growing population, improving living standards, high demand for livestock products, relatively good market access, but also have lower levels of regulation. The production of milk and dairy products is expected to grow over the coming decades and the majority of the growth is expected in developing regions. Therefore, if the regulation gaps do not converge, the global average environmental and animal welfare production standards will be loosened.

**Figure 6.3: Global dairy production shares by regions (2017)**

![Image of Figure 6.3: Global dairy production shares by regions (2017)](image)

Source: FAO (2020d)

Note: The countries belonging to each regional aggregation can be found in this link (UN Statistics Division, 2021).

As illustrated in Figure 6.3, global dairy production is unevenly distributed, with the largest production shares in 2017 belonging to South Asia, West Europe and North America, followed by East Europe, South America, and East Asia. In South Asia, India is the main dairy producer (as also illustrated in Figure 6.4); however, due to its population size, India’s per capita milk consumption is not as high as in West Europe or North America. Hence, India is still considered a market with growth potential (Landes, Cessna, Kuberka, & Jones, 2017; Salois, 2016). In 2017, India produced 176,279,000 cow milk equivalent tons of dairy products, far exceeding the outputs of the United States (US), which was the second largest producer with 98,651,000 tons. Within Europe, dairy production is led by Germany, which produced a third of the US production, closely followed by Russia and France. In 2017, Brazil had a dairy production of similar to the German or the Chinese, making it the largest producer in Latin America. Far behind other regions, the largest producing country in Africa, Kenya, produced 4,838,000 cow milk equivalent tons of dairy products. The production also varies across different types of dairy product. Table 6.4 shows that except for the US, the top milk producers are located in Asia, including India, Pakistan and China. At the regional level, Germany and Russia are the leading producers in Europe; Kenya and Egypt are the main producers in Africa, and the US and Brazil are the main ones in the Americas. The main cream producers include Germany and Poland at the global level. For butter and cheese, the US and New Zealand are the top global producers, followed major regional producers such as Germany and France in Europe.
Table 6.4: Major milk, cream and butter producers by region (2017)

<table>
<thead>
<tr>
<th></th>
<th>Global</th>
<th>Europe</th>
<th>Asia + Oceania</th>
<th>Africa</th>
<th>Americas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Milk – Excluding butter</strong></td>
<td>India, US, Pakistan and China</td>
<td>Germany and Russia</td>
<td>India, Pakistan and China</td>
<td>Kenya, Egypt and Sudan</td>
<td>US and Brazil</td>
</tr>
<tr>
<td><strong>Cream</strong></td>
<td>Germany, Poland</td>
<td>Germany, Poland</td>
<td>Iran</td>
<td>Egypt</td>
<td>Canada</td>
</tr>
<tr>
<td><strong>Butter, Ghee</strong></td>
<td>US, New Zealand</td>
<td>Germany, France</td>
<td>New Zealand and Turkey</td>
<td>Morocco</td>
<td>US</td>
</tr>
</tbody>
</table>

Source: Authors’ elaboration from FAO (2020d).
Note: In the table we list countries within the 98% quantile globally, and within 95% quantile of each region.

Figure 6.4: Global dairy production, cow milk equivalent tons (2017)

Source: FAO (2020d).
Note: dairy products are aggregated using primary equivalents.

Figure 6.5 explores the distribution of dairy production within Europe. The production in Europe is characterized by relatively large herd sizes and high production yields (IFCN, 2014). The current projections point to production growth through improving yields, as the herd size in the EU is expected to continue shrinking (EC, 2020a). Within the largest producers in the EU such as Germany and France, the majority of production is processed by a few large dairy companies, which are among the largest companies globally, such as DMK in Germany, Lactalis and Danone in France. Some smaller countries such as Denmark (mainly Arla Foods) and the Netherlands (mainly Friesland Campina) also have disproportionately high production relative to their population and large exports.
The scale of the major producers worldwide in Figure 6.4 overshadows the heterogeneity in regions with lower production levels. Figure 6.6 illustrates the different production pattern across the African continent, where the main dairy producers are concentrated in the east part of the continent. The product disaggregation in Table 6.4 reveals that Kenya, Egypt, and Sudan are the main producers of dairy products excluding butter and cream, followed by Ethiopia. Bingi and Tondel (2015) provide a further explanation of the recent regional developments. Since the beginning of the century, dairy production in East Africa has undergone important transformation from an industry heavily controlled by the state to ensure the coverage of domestic food consumption to a private-sector-driven industry. Private investment in dairy processing and production intensification led to improvements in husbandry, breeds, and feed systems. Other larger producers are some of the MENA countries and South Africa. The production systems vary widely across African countries. There are countries dominated by smallholder dairy farms and countries with intensified production system. Dairy production in Kenya, the most important producer in Africa, is mostly smallholder farming: in 2011 it was estimated that there were more than 1 million smallholder dairy farmers. Moreover, only 55% of the milk produced in Kenya entered the market. The milk that entered the market was mostly (more than 75%) sold through informal channels (Muriuki, 2011). On the other side, South Africa reaches a similar level as Australia and New Zealand in terms of average dairy farm size (250 cows per farm) in 2014 (IFCN, 2014).
In Asia and Oceania, India is the largest dairy producer with more than 176 million tons of cow milk equivalent production in 2017. To better illustrate the production in the rest of region, Figure 6.10 presents production data without that of India. Following India, the main Asian producers are Pakistan with 44, China with 35 and Turkey with 21 million tons. Existing projection studies suggest that the consistently rising production level in South Asia will continue in the next decade (OECD & FAO, 2020). This growth is accompanied by high levels of population growth, which increases the pressure on domestic supply. In the interviews we conducted for this report, several members of the industry identify India as an appealing export destination if existing import barriers are addressed. Unlike other regions with high dairy production levels, the production growth in India has been the result of an increase in smallholder productions, as the majority of the producers have less than 10 cows (IFCN, 2014). More intensive production featuring large herd size seen elsewhere has not yet happened in India (IFCN, 2014; Landes et al., 2017). Asia’s other large market, China, has pushed towards structural changes favoring larger scaled production, in particular following the melamine scandal of 2008, as it resulted in the use of more regulating measures placed on the sector, the compliance to which requires a large scale production (Gooch, Hoskin, & Law, 2017; Tao, Luckstead, Zhao, & Xie, 2016; Vitaliano, 2016). In Oceania, the main producer is New Zealand with 21,947,000 tons of cow milk equivalent in dairy products in 2017. New Zealand is the second largest world producer of butter (see Table 6.4) and also the second largest dairy exporting country (OECD & FAO, 2020).
Figure 6.7: Dairy products production within Asia and Oceania in cow milk equivalent tons, (2017)

Source: FAO (2020d).

Note: India is excluded from this graph for better illustrating other countries’ production scale.

Figure 6.8: Dairy products production within the Americas in cow milk equivalent tons (2017)

Source: FAO (2020d)
In the Americas, the main dairy producers are the US (98.6 million tons of cow equivalent milk in 2017) and Brazil (34.1 million), followed by Mexico (12 million) and Argentina (10.1 million). North America has the world’s highest number of cows per farm at around 1,300, but the variation is very large, ranging from 50 to 5,000 cows. In South America, the variation is also large, from a few to 2,000, but the average per farm number is around 300. Milk yields in the US dairy farms are among the highest in the world, reaching almost 10 tons per cow per year (IFCN, 2014).

In contrast to the expected growth in India and China, the three major exporting regions (i.e. the EU, New Zealand and the US) are expected to grow at a slower rate. The dairy herds of these regions are not expected to expand significantly (OECD & FAO, 2020). In fact, the size of the European dairy herd has been decreasing over the past 5 years, however at such a slow pace that increasing yields have actually led to growth in milk collection (Eurostat, 2021). This is also the trend expected in New Zealand in the next decade. European producers are expected to slightly decrease production over the coming decade, given that a significant share of consumers is moving away from traditional dairy products to plant based substitutes, and that the dairy herd size will continue to shrink (OECD & FAO, 2020). The use of technology in the major exporting regions is already at the forefront of technological advancement for the most productive producers, thus gains are only achievable by new inventions and practice changes yet to be discovered for the frontier producers (Salois, 2016).

6.1.3 Emissions from the sector

Much like the meat sector, the dairy sector is also a major contributor to GHG emissions, as ruminants in the dairy sector account for approximately 30% of the emissions from the livestock sector (Opio et al., 2013). As shown in Figure 6.9, cattle’s direct emissions from production, similarly to other ruminant animals, mainly consist of methane (CH₄) due to enteric fermentation. In 2015, on average 58.5% of the sector’s emissions came from enteric fermentation, 29.4% from feed, and 9.5% from manure management (FAO & GDP, 2018). Several technical solutions are suggested to reduce methane emissions, for example by using more digestible feed (IPCC, 2006). Furthermore, as cows with higher milk yields emit more due to their higher energy intake, increasing the feed conversion ratio can be another solution to reduce emissions from dairy cows.

*Figure 6.9: GHG emission sources from dairy production (2015)*

Source: Author’s elaboration from FAO and GDP (2018)

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29 Raw milk production is mainly from dairy cow, followed by buffalo, and to a lesser extent goat, sheep, camel, yak, and mare. (Nuñez, 2016)
From 2005 to 2015 total GHG emissions increased by 18% in global milk production while milk output increased by 30%. During that period, the increase in production efficiency lowered the average emission intensity (FAO & GDP, 2018). Even if the sector is moving towards lower emissions per unit of output, total emissions is still increasing. The difference between the rate of production growth and emission intensity improvement is therefore highly relevant for assessing the sector’s ability to reduce GHG emissions, as the emissions intensity reduction has to outweigh the production growth for there to be an emission decrease in absolute terms.

Significant differences exist across regions and countries, in terms of both total emissions from the dairy sector and emission intensities. Total emissions are tied to the scale of milk production underpinned by the number of animals as well as on their bio-physical traits. As can be seen from Figure 6.10, India is by far the largest emitter from dairy cows, followed by Brazil, the US, China, and Russia, as well as New Zealand, Australia, and EU member states such as Germany and France. Therefore, there appears to be potentials for these major emitting countries to reduce their emissions. However, if we look at emission intensities (i.e. emissions per unit of output, as shown in Figure 6.11), developing countries with smaller amounts of milk productions in Africa and South Asia emit more on a per unit basis. FAO and GDP (2018) compiles emission intensity data measured as the CO2 eq. per kg fat and protein corrected milk (FPCM), using a life cycle assessment (LCA) model that accounts for feed production emissions, on farm emissions, and the emission from transportation to retailers. In 2015, developed regions on average emitted 1.3-1.4, compared to 4.1-6.7 CO2 eq. per kg FCPM in developing regions. At country level, variations in emission intensities are even larger, exceeding the aforementioned regional range by a wider margin. The variation is significant, particularly across the latter countries. This observation is coherent, given that developed countries typically have more efficient production methods that also reduce per unit emissions, as compared to many developing countries (Figure 6.11). Thus, there appears to be emission reduction potentials in the developing countries where the emission intensity is currently high, by adopting better technology, upgrading production methods, and receiving best practice transfers. However, the transition to technologically advanced production systems would require large investments (Janssen & Swinnen, 2019). Moreover, there may be conflicting policy goals since the role of livestock in such countries, particularly owned by smallholders, frequently serve multiple purposes, e.g. dairy production for self-consumption, working animals, and cash income sources (Herrero et al., 2013; Thornton, 2010). Therefore, a restructuring of production systems away from smallholder production may come at a significant risk to the livelihoods of small producers.

Figure 6.10: Absolute emissions from cows milk production in 2017

Source: FAO (2020a)
Another pertinent factor contributing to regional emission disparities is the animal species used for milk production. On the global scale, 81\% of all milk is produced by cattle; however, 40\% and 25\% of the milk in Asia and Africa is produced by bovine animals other than cattle (FAO, n.d.-a; OECD & FAO, 2020). This is especially the case in the world's largest milk producing country, India, where the majority of the milk is produced by water buffalos (Landes et al., 2017).

Different production systems have different intensities in resource and inputs use. These systemic features are also relevant for emission reductions. First, concentrated feed systems emit less GHGs than grazing production. Furthermore, according to Wirsenius et al. (2020) they require less land, implying a lower carbon cost associated with land-use. Second, emissions from feed production and processing depend on the use of fertilizer in crop production, which emits nitrous oxide (N\textsubscript{2}O) that accounts for 20\% of the total CO\textsubscript{2} eq. emissions in milk production (see Figure 6.9). Besides, feed handling processes emit CO\textsubscript{2} from transportation and processing. Finally, accounting for 8.9\%, manure management is a relatively modest contributor to the emissions from ruminant animals in general, compared to monogastric animals due to the large emissions share of enteric fermentation. However, manure management emissions are slightly higher for dairy cattle and account for 9.5\% of the dairy sector’s emissions. The exact magnitude of these emissions depends on the manure handling system and on regional climatic characteristics, as warmer temperatures increase the release of GHGs (FAO & GDP, 2018; Wirsenius et al., 2020).

### 6.1.4 Trade patterns

Perishability of fresh milk and dairy products and the required cold supply chain (which is absent in many developing countries) and the high water content of fresh milk limit the tradability of these products (Heard & Miller, 2019). Divergences of Sanitary and Phyto-sanitary (SPS) measures\textsuperscript{31} also require compliance costs. When such measures are used in a discriminating manner, SPS measures can become a non-tariff barrier to trade. Vitaliano (2016) argues that the SPS measures are often misused as a market protectionist measure, rather than as a consumer protection measure, as the rules established are not strictly followed on domestic markets. Last but not the least, similar to many other agricultural commodities, the tariff level on dairy products is higher than on non-agricultural goods (Vitaliano, \textit{Papau New Guinea} was removed, as its high emission intensity distorts the map and its production is very small in the global scale.\textsuperscript{30})
Therefore, it is not surprising that only 8% of the total world milk production is traded internationally, most of which is more processed commodities such as butter, cheeses and milk powder (Davis & Hahn, 2016; FAO, n.d.-b; OECD & FAO, 2020).

On the other side, technology innovations and economic development have opened up trade of liquid milk and other fresh dairy products in certain new trade routes, such as the exports of liquid milk from New Zealand and the EU to China. The growing middle class in China also prefers to consume milk from regions with high food safety standards (OECD & FAO, 2020). The perception of foreign dairy products being of higher quality on the Chinese market stems from a scandal in 2008, where milk used for baby formula was found to be contaminated (Tao et al., 2016). Since then, significant efforts have gone into reestablishing the domestic dairy sector in China, focusing on a shift from small-scale production to large-scale production that is easier to regulate, and increasing SPS measures (Rabobank, 2013; Tao et al., 2016; Vitaliano, 2016). As of 2013, 80% of the dairy products consumed in China were domestically produced. However, given the large size of the country and the low level of trade on the dairy market, a 20% reliance on foreign products has turned China into the largest dairy importing country in the world32 (Rabobank, 2013; Salois, 2016).

Among major milk-producing regions/countries, South Asia is the largest milk producing region (Figure 6.4), spearheaded by the production in India. However, despite its large production, India is not a key global exporter, as most of its production serves its domestic consumers (CEPII, 2020; Salois, 2016;UN, 2020). In contrast, the other large producing regions/countries (Northern/Western Europe, Australia and New Zealand and North America) maintain significant exports. This is likely a result of a higher production per capita, and the historical development of international trade. These countries had been established exporters even prior to the conclusion of the Uruguay Round multilateral trade negotiations. For instance, the EU was already using export subsidies, making it possible for producers to export excessive production at low prices (Vitaliano, 2016). These old supply networks might still benefit traditional exporting countries to this day. Asia’s emergence as a large dairy producing region is quite recent, the per capita production there remains low and therefore the domestic demand there is not yet saturated.

Depending on the specific dairy product, the countries in the South Asian region (mainly India and Pakistan) are either net importers or exporters (Figure 6.12 and Figure 6.13). West Europe (as a group)33, North America, and Australia and New Zealand, on the other hand, are consistent net exporters across all varieties and are the home to 16 of the world’s top 20 dairy companies. The other four top dairy companies are domestically-oriented firms serving their respective domestic markets, including China’s Yili and Mengniu, Gujarat Cooperative Milk Marketing Federation in India, and Meiji in Japan. These four companies have been growing at a rapid pace (Rabobank, 2020). Ten years ago, only the two Chinese companies entered the top-20 list, but at significantly lower ranks as compared to their current positions (Rabobank, 2010).

The population levels in Europe and North America are stable and their high income levels have led to a saturated market. Hence, increases in production are more likely to be directed to export markets. Additionally, these regions have more developed processing facilities, implying that they can produce products that are easier to transport (e.g. milk powder, cheese, and butter) and more frequently traded, which also partially explains why 82% of the world’s dairy trade is produced by developed countries (FAO, n.d.-b).

32 Measured in volumes in 2010 and 2015 (Salois, 2016)
33It is important to acknowledge significant heterogeneities within the group of countries. Not every country in the group is consistently a net exporter.
Figure 6.12: Net exports of concentrated milk and cream, million US $) (2019)

Source: Authors’ elaboration from UN (2020).

Note: Data illustrated in this graph are for HS group 0402, which include concentrated milk and cream and sweetened milk and cream that are widely traded.

Figure 6.12 and Figure 6.13 depict the differences of trade patterns across concentrated milk & cream and cheese & curd. The main importing regions of concentrated milk and cream are Asia, Africa, Micronesia, the South of Europe and Central America, whereas the main exporters are Oceania, Europe (North, East, and West), and North and South America. In the case of cheese and curd, the main exporters are much more concentrated in West Europe, Oceania, and South and North Europe, where the rest of world are net importers.

Figure 6.13: Net exports of cheese and curd, million US $ (2019)

Source: Authors’ elaboration from UN (2020).

6.2 IMPACT OF COVID-19 ON THE DAIRY MARKET

The Covid-19 pandemic has affected the international dairy markets; however, the duration and significance of the impact is still unfolding (OECD & FAO, 2020). Although the agricultural and food sector is believed to be less disturbed by the pandemic than other sectors, products requiring longer operational supply chains, such as perishable dairy products, have suffered from disruptions (EC, 2020b; OECD & FAO, 2020), as evidenced by large fluctuations of prices of various milk and dairy
products (Table 6.5). The largest price decreases, relative to the previous year, are observed in butter and whole milk powder.

Table 6.5: Annualized changes in international prices of traded dairy products, % from 2019 level to 2020

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
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<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<tbody>
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<td><strong>Butter</strong></td>
<td>-9.0</td>
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<td>-11.8</td>
<td>-9.5</td>
</tr>
<tr>
<td><strong>Cheddar Cheese</strong></td>
<td>-1.3</td>
<td>-0.7</td>
<td>0.9</td>
<td>-1.6</td>
<td>-2.1</td>
<td>0.4</td>
<td>2.9</td>
<td>2.0</td>
<td>2.3</td>
<td>4.8</td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Skim milk powder</strong></td>
<td>20.0</td>
<td>17.9</td>
<td>8.1</td>
<td>-6.6</td>
<td>-6.3</td>
<td>1.3</td>
<td>3.3</td>
<td>6.2</td>
<td>7.5</td>
<td>10.0</td>
<td>7.9</td>
</tr>
<tr>
<td><strong>Whole milk powder</strong></td>
<td>1.7</td>
<td>-2.4</td>
<td>-6.2</td>
<td>-11.4</td>
<td>-13.4</td>
<td>-9.2</td>
<td>-1.8</td>
<td>-2.5</td>
<td>-4.5</td>
<td>-2.8</td>
<td>-3.0</td>
</tr>
<tr>
<td><strong>Dairy price index</strong></td>
<td>1.0</td>
<td>0.0</td>
<td>-1.3</td>
<td>-6.9</td>
<td>-8.2</td>
<td>-4.4</td>
<td>-0.8</td>
<td>-0.7</td>
<td>-0.6</td>
<td>1.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Source: FAO (2020b)

The containment measures implemented during the first weeks of the pandemic reduced the demand for food services, a sector reliant on dairy products, especially cheese (OECD & FAO, 2020). The reduced demand has harmed the US and EU markets. It is expected that this effect will continue until the food service industry recovers. The drop in demand is also expected to diminish exports of dairy products, exerting significant pressure in the three major exporting regions – i.e. EU, New Zealand, and North America – (FAO, 2020e). While the share of dairy products in total global merchandise trade seems to be quite small, the impact on countries heavily depending on dairy exports can be quite significant. For example, New Zealand exports the majority of its dairy production and reduced demand and lowered prices affects the New Zealand economy more than other exporting countries with more diversified export portfolios (OECD & FAO, 2020; Vitaliano, 2016). In the interviews conducted, members of the industry pointed out the importance of the Chinese market for the future development of the sector and a faster recovery there indeed happened.

The pandemic has led to decreasing demand for all dairy products to varying extents. Given that fresh dairy products are perishable and cannot be stored, producers initially limited their milk collection to avoid over-supply and maintain the market prices. Given the short-term nature of the shock, changes in farms sizes are not feasible so excess milk supply goes to waste. At the same time, an increase in the production of durable processed dairy products is expected. In the major markets, the production of solid dairy fats and skim milk powder (SMP) is estimated to rise year-on-year by 0.3% and 1.4%, respectively, in 2020 mainly as a result of increases in EU production. The increase in production is expected to mirror consumers’ increasing purchase of more storable dairy products, such as butter, cheese and UHT milk (FAO, 2020e). On balance, however, reduced demand has led to decreased milk prices on the world market during March-September, 2020.
### 6.6 The Global Dairy Market in 2020

<table>
<thead>
<tr>
<th>Production</th>
<th>Milk</th>
<th>Cheese</th>
<th>Butter</th>
<th>Milk powder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increase</strong></td>
<td>Asia (India, Pakistan &amp; China) North America</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Decrease</strong></td>
<td>Moderate: Central America, the Caribbean, Oceania and Africa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Import</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Increase</strong></td>
<td>Russia, China and South Korea: continued rising demand by affluent consumers</td>
<td>China and Japan.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Decrease</strong></td>
<td>Saudi Arabia, US, United Arab Emirates, EU, UK and Australia</td>
<td>Mexico, Iran, Russia, Saudi Arabia, US, and United Arab Emirates</td>
<td>China (significant decline), Algeria, Philippines, Malaysia, Russia, Mexico and Viet Nam</td>
<td></td>
</tr>
<tr>
<td><strong>Export</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Increase</strong></td>
<td>Belarus, New Zealand, Australia, Argentina, EU, UK, and US</td>
<td>EU, UK, India, New Zealand, and Belarus.</td>
<td>China, Algeria, United Arab Emirates, and Saudi Arabia. EU, UK, New Zealand and Australia (SMP)</td>
<td></td>
</tr>
<tr>
<td><strong>Decrease</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Trade expected to rise Food-service sales absorb an important share of the butter demand.

**Source:** FAO (2020f)

### 6.3 Evolution of the Sector

Similar to the meat sector, the evolution of the dairy sector in the long run will be influenced by demand factors – income growth, demographic shifts and potential changes in dietary patterns – and supply side structural changes and technological innovations. Several national and international organizations regularly conduct market projections using scenarios based on the expected changes in demand and supply drivers. We use these projections to examine the short and long-term projections of the dairy market. Currently, any short-term projection hinges on assumptions on the recovery from the Covid-19 pandemic, which is inherently very uncertain. The uncertainty is especially large regarding the impact of the Covid-19 crisis on the purchasing power, and therefore on consumption. The production of dairy is not flexible, thus it is less sensitive to short-term shocks. For long-term projections, the importance of the Covid-19 shock diminishes and expectations on macroeconomic variables, population shifts, and technological changes become more influential.

#### 6.3.1 Short term

The short-term development of the dairy sector in 2021 hinges on the recovery of the world and national economies from the Covid-19 pandemic, and on the extent to which the pandemic may continue to create supply chain disruptions. Table 6.5 shows that the price index for traded dairy products has

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34 For further detail see the discussion on demand and supply drivers in sections 2.1 and 3.1
rebounded modestly since October 2020, possibly suggesting a recovery from the demand shock that had drastically reduced price levels in April and May 2020. Despite the pandemic, the FAO actually expected a 1.4% increase of global milk production during 2020. Similarly, dairy exports in 2020 was expected to grow by 1.5%, especially whey powder (11%) and cheese (3%) (FAO, 2020b). This expectation represents a more optimistic update of the projections conducted in June 2020 that predicted a contraction of dairy exports due to the significant demand shock (FAO, 2020c). Another potential source of disruptions to the dairy market in 2021 is BREXIT, particularly in relation to exports from the EU. Historically, the UK has been a net importer of dairy products, with most of its dairy imports sourced from the EU (EC, n. d.); However, the UK became a net exporter in volume terms in 2019 and has maintained this surplus in 2020. In value terms, the UK remains a net importer due to imports of high-value dairy products from the EU, e.g. cheeses (AHDB, 2020). The UK’s overall trade patterns including dairy trade will be reshaped by the specific terms of the recent trade agreement with the EU and its future trade agreements with countries outside of the EU.

Table 6.7: Short-term expectation for most important dairy markets in 2021

<table>
<thead>
<tr>
<th></th>
<th>Fresh dairy products</th>
<th>Dairy fats/and cheese</th>
<th>Dairy powders</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EU</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk collection</td>
<td>+0.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow milk</td>
<td>+0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh dairy prod.</td>
<td>-0.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size</td>
<td>-(0.3-0.8)%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yields</td>
<td>+1.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>US</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk collection</td>
<td>+(1.6-2)%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size</td>
<td>+0.21%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yields</td>
<td>+1.41%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>India</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow Herd</td>
<td>+2.75%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National plan aims at 9.2% milk increase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>Fluid milk +2.47%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>China</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow Herd</td>
<td>+0.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>Fluid milk +8.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Table 6.7**:** Short-term expectation for most important dairy markets in 2021**

<table>
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<tr>
<th></th>
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<th>Dairy fats/and cheese</th>
<th>Dairy powders</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EU</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>+0.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow milk</td>
<td>+0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh dairy prod.</td>
<td>-0.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size</td>
<td>-(0.3-0.8)%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yields</td>
<td>+1.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>US</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk collection</td>
<td>+(1.6-2)%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size</td>
<td>+0.21%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yields</td>
<td>+1.41%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>India</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>National plan aims at 9.2% milk increase</td>
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<td></td>
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<td></td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow Herd</td>
<td>+0.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>Fluid milk +8.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Imports</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td>+3.17%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butter</td>
<td>+13.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

89
Table 6.7 summarizes the market changes expected for some of the largest dairy producing and trading regions/countries, sourced from several major national agencies and the FAO. These projections are highly dependent on the development of the pandemic and its persisting effects, which are not equally distributed. For instance, the early demand drop in dairy products has reversed for Australia, which experiences a strong import demand from the Asian market (Singapore, China, and Thailand) because of a consumer preference shift towards countries with a better reputation for food safety following the Covid-19 outbreak (ABARES, 2020a). In the following paragraphs, we summarize the main findings regarding primary production, product categories, and overall trade movements from these projections.

### Milk collection and herd size developments

Herd size and yields are the main determinants of short-term raw milk supply. Despite the shrinking herd size in the EU, the production of dairy products has not diminished in comparison with previous years and is not expected to do so in the short-term. In fact, the growth of milk collection during 2020 is estimated to be 1.4%, and is expected by the European Commission to rise by 0.8% during 2021 (EC, 2020b).
However, the United States Department of Agriculture (USDA) expects the milk production growth for the EU to be only 0.4% over 2021, as the loss in herd size by their estimates will partially offset expected yield growth (USDA, 2020a). In 2021, the USDA expects the US to expand its milk collection by 1.6-2% through an increase in yields, and the herd size (see Table 6.7).

In the other large producing regions, milk collection and production growth is also expected (Table 6.7), due to either increasing herd size or rising yield. Whereas the majority of the EU and the US growth is expected from rising yields (EC, 2020b; FAO, 2020b; USDA, 2020a), herd expansions will drive higher milk collection in other regions such as India. For India, the extensive growth fits with the structure of the current livestock system with a majority of small scale producers (IFCN, 2020).

However, even with the relatively high increase in cow milk production, India is expected to fall behind its 9.2% annual growth goal (Department of Animal Husbandry, 2018). In the case of China, the herd size is expected to expand modestly (0.8%) while the output is expected to rise significantly (4.5%) (USDA, 2020a). These projections indicate a significant rise in the production yield, which may be a result of the investments in the sector’s restructuring following the melamine scandal of 2008 (Gooch et al 2017). Australia does not follow the logic mentioned above. The Australian dairy sector is fairly well developed but the drought during 2019 led to a decrease in the dairy herd from which the country is still recovering; hence, its dairy herd is expected to expand in 2021 (ABARES, 2020a; USDA, 2020a). The main dairy exporter in the Oceanian region, New Zealand, follows the same pattern as the EU with slight herd decreases (-0.3%) which are then outweighed by productivity increases. Its production is expected to rise a 0.9%. Overall, the global dairy herd is expected to expand by 1.2% in 2021 (USDA, 2020a) 35.

**Fresh dairy products**

In 2021, the drop in EU production of fresh dairy products is expected to continue, as a larger share of raw milk collected will be utilized for more processed dairy products (EC, 2020b). This falls in line with the observed demand shifts away from the traditional dairy products within the EU. 36 India and China are actively pursuing structural development plans in the dairy sector. In 2021, both countries are forecast to increase their milk supply, driven by large increases in liquid milk consumption (Department of Animal Husbandry, 2018; Gooch et al., 2017). At the global level, fresh dairy production is expected to rise by 1.4%, slightly exceeding the expansion of the global herd size.

**Dairy fats and cheese**

According to the forecast by the USDA (2020a), cheese consumption will increase in all the markets they report on except for Ukraine 37. This is due to the overall increase on dairy intake in developing countries and the shift towards food services and ready-to-eat meals typically high in cheese content in developed countries (OECD & FAO, 2020). The USDA (2020a) expects that the EU production will increase by 1%, as 60% of the milk production growth will be channeled into cheese production, while the European Commission (EC) estimates the increase to be 0.5% (EC, 2020b). Elsewhere in the world, larger increases in cheese production are expected in Australia, New Zealand, and also China. At the global level, cheese production is expected to rise by on average 2.2% across the different projections (USDA, 2020a) 38. Butter consumption is likewise increasing in most markets, and only in a few markets

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35 The growth rate is computed using the total row of the cow number table in page 10 USDA (2020a).
36 This trend was temporarily reversed during 2020 when liquid milk consumption increased.
37 The Ukrainian dairy production and consumption has been falling, as their dairy herd is contracting, and have been for the past several years, following the loss of the access to the Russian market, which previously accounted for the majority of Ukraine exports (Gereles & Szőllösi, 2019).
38 The growth rate is computed using the total row of the production tables in page 11 of USDA (2020a).
held constant. India is expected to lead the consumption increase in absolute terms, and Taiwan, China, and Japan in percent terms (USDA, 2020a). Butter hence has large growth potential in the Asian markets in the coming years.

Comparing the butter and cheese markets, the USDA (2020a, p. 11 & 13) shows that on average both butter and cheese production are expected to grow at 2.2% worldwide in 2021. However, growth will not be homogenous across countries. Particularly, New Zealand’s production of butter is expected to slightly decrease (-0.95%), whereas it has one of the highest growth rates in cheese production (4.3%) (see Table 6.7). Similarily, cheese production in China is expected to outpace that of butter by a wide margin. This pattern is reversed in Australia where butter production is expected to increase three times faster than cheese production. For the US and EU, production growth is expected to be more balanced between the two dairy products.

For both the US and EU, the USDA (2020a) forecasts that the exports of cheese will increase by 2-3% and that butter exports will remain constant. The increase for the US is driven by Mexican import demand, whereas the EU expands its shipments primarily to Japan, South Korea, and Ukraine. The difference between the two products is even more striking for Australia, where cheese exports are projected to increase 9.7%. New Zealand will lead the export increase of cheese and butter in absolute values as its initial exports are about twice as large as the Australian exports (USDA, 2020a). New Zealand’s cheese exports will rise by 9.2%, driven by increasing import demand in China, Australia, and South Korea. Especially for China, one can observe a large difference between expected production growth and consumption growth (Table 6.7), indicating a significant increase in the dependence on imports to supply the domestic market. Conversely, for India the expectation is that the growth in production and consumption will follow each other, indicating a self-sufficient market whose domestic consumption does not rely on imports. In fact, in the interviews we conducted, members of the industry acknowledged the difficulties of entering the dairy market in India.

**Dairy Powders**

Dairy powders are highly traded dairy products, given their easier transportability and low cost. Price sensitive markets in many low- and medium-income countries are viable export destinations of milk powders sourced from major dairy producing countries. These products are also used in the growing markets of processed meals in developed regions. Rising production and increasing trade of dairy powders is expected in 2021 (USDA, 2020a). However, projected increases in production differ across different types of dairy powders. EC (2020b) forecast a 3% increase in the production of SMP within the EU, whereas the increase of nonfat dry matter (NFDM) is at 1% according to the USDA (2020a). For WMP, a 0.5% reduction is forecast in the EU (EC, 2020b), as the milk components used for WMP can alternatively be used in the production of cheese, which has a higher market value, but the USDA (2020a) forecasts this change to a 1.3% increase. The expected growth is explained by the expansion of the EU milk collection. As domestic markets are saturated, any increases in production are used primarily for tradeable products (EC, 2020b). Within the US market, the USDA (2020a) expects a 10.4% increase in the domestic consumption of NFDM, the largest percentage increase across the analyzed countries. At the same time, the USDA expects a significant fall in the domestic consumption of WMP, exports of which are forecasted to rise by 13.9% but only corresponding to five thousand tons. This forecast falls in line with the increasing pattern that has been observed during the past five years. The US’ initial WMP exports in 2020 were quite small compared to the other large dairy producers

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39 The growth rate is computed using the total row of the production tables in pages 11 and 13 of USDA (2020a).
40 SMP is a broader category which includes NFDM, but also other powder with additional additives (ADPI, n.d.).
such as New Zealand, whose WMP exports are projected to rise a 1% corresponding to 15 thousand tons. Australia is forecasted to have the highest growth rate in WMP exports at 43% year on year to 2021. Nevertheless, this is connected to the rebuilding of the herd and follows a consistent significant reduction in the exports since 2016. One of the largest import markets for dairy powder is China and it is forecast to increase its imports (USDA, 2020a).

**Trade orientation of producers**

Cheese and milk powders are the most traded dairy products (FAO, n.d.-b). The largest dairy trading region is currently the EU. The EU is expected to keep that position as the majority of its dairy exports are increasing (Table 6.7). The tendency is similar for the US and New Zealand, as these markets are also saturated and a growing share of the dairy being produced is being channeled towards export markets. The growth in exports is mainly directed to supplying Asian countries, particularly China, followed by Japan, South Korea, and Thailand (USDA, 2020a).

### 6.3.2 Long term

Similar to the projection of meat, a few well-understood drivers are also shaping future demand and supply of dairy markets. The key elements on the demand side are population and income growth and potential changes in demand patterns due to health or environmental concerns. The key elements on the supply side are technological developments and restructuring of the production methods (typically heading towards more intensive production systems). Hence, the long-term evolution of the market rests on these macro trends. Quantifying these future trends are necessary but can be inherently uncertain; however, recent research efforts towards understanding long-term social economic development provide a rich set of long-term macro projections. For instance, in some relevant aspects such as population and income growth there seem to be some generally accepted projections based on time series data and economic models. Other changes such as future switches in dietary preferences are much more difficult to model. Overall, the interpretation of long-term projections should always be mindful of the models’ assumptions and data constraints. In the case of dairy, there are some consistent findings from the long run projections compiled by organizations such as the Organization for Economic Cooperation and Development (OECD), FAO, EC and the USDA that are worthy to notice. For instance, projections show the dairy sector is expanding, particularly in developing regions (Table 6.8), due to an overall increase of purchasing power and a high potential of production growth through improvements in productivity. For developed regions, the sector is expected to shift towards high value products and more environmentally friendly production practices in response to both public pressure as well as increased environmental regulation (EC, 2020a; OECD & FAO, 2020). In the following, we discuss the expected production, consumption, and trade development in the dairy sector, drawn from the latest projections and from our interviews with industry experts.

**Production**

The OECD and FAO (2020) project the global production of milk to grow by 1.6% each year until 2029 (OECD & FAO, 2020). For most countries, this growth is mainly due to yield growth. Nevertheless, herd expansions are expected in African and Asian countries that currently have low milk yields. The growth of the global average yield will therefore be limited to 0.7% a year, compared to a 0.8% average annual increase of herds (OECD & FAO, 2020).
Table 6.8: Changes in the dairy sector production on most influential markets by 2030

<table>
<thead>
<tr>
<th>Production</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk</td>
<td>0.6% 0.37%</td>
</tr>
<tr>
<td>Most growth in milk expected to go towards increased cheese production</td>
<td>(1)</td>
</tr>
<tr>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk</td>
<td>0.8% 0.88% 1.4%</td>
</tr>
<tr>
<td>Farm consolidation expected to lead to economies of scale</td>
<td>(3)</td>
</tr>
<tr>
<td>New Zealand</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk</td>
<td>0.4% 0.27%</td>
</tr>
<tr>
<td>Sustainability will be a key driver for the future developments of the New Zealand dairy sector</td>
<td>(1)</td>
</tr>
<tr>
<td>India</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk</td>
<td>3% 2.87%</td>
</tr>
<tr>
<td>This below the common growth rate in Indian milk production, according to their own historical estimates of 4.8% growth rate from 2005-2015. And below the growth envisioned in the sectoral development plan</td>
<td>(4)</td>
</tr>
<tr>
<td>China</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk</td>
<td>0.7% 0.5%</td>
</tr>
<tr>
<td>China is the largest dairy importer, however restructuring plan for the dairy sector is being implement to obtain consumer trust for domestically produced dairy products</td>
<td>(5)</td>
</tr>
<tr>
<td>Africa</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk production</td>
<td>2.7% 2.43%</td>
</tr>
<tr>
<td>The African growth rate projection is very high, note that given the current low production, the absolute increase is minor in volume terms, compared to other regions, such as India.</td>
<td>(1)</td>
</tr>
<tr>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>Annual growth in milk production</td>
<td>1.6%</td>
</tr>
<tr>
<td>The growth is expected to primarily be driven by expansion in developing markets, in particular India</td>
<td>(2)</td>
</tr>
</tbody>
</table>

Sources: (1) EC (2020a); (2) OECD and FAO (2020); (3) USDA (2020e); (4) Department of Animal Husbandry (2018); (5) Tao et al. (2016).

Note: the time range for the OECD & FAO projection: 2020-2029; for the EC projection: 2020-2030; for the USDA projection: 2020-2029.

Within the EU, production growth is projected to slow down over the next decade compared to the previous one. The EC (2020a) estimates that milk production in the EU will increase at 0.6% annually, slightly higher than the OECD and FAO (2020) projection of 0.37% (Table 6.8). About 30% of the projected rise in milk production within the EU is expected to feed the expansion of cheese production (EC, 2020a). Whey is a by-product of cheese production and therefore is expected to expand as well. Food industry is increasingly using whey, which raises its value and consequently boosts production.
incentives (EC, 2020a). Additionally, the EC (2020a) expects a production system shift to more segmented products within the EU, because of differentiated consumer demand patterns. For example, they estimate EU organic milk production to represent 10% of EU milk production in 2030, compared to 3.5% in 2018. GM-free, pasture and hay-based, high animal welfare regulated, and other certified milk production systems should also gain market shares (EC, 2020a). This could lead to a slowdown of the yield growth, and keep the size of the dairy herd from falling drastically (EC, 2020a). The USDA (2020c) similarly projects increases in the production for the US; however, as their dairy herd is not expected to decrease, the expansion of the US production is forecast to 1.4% annually from 2020 to 2029. This increase is expected to be driven by the rising demand for dairy products on both the domestic and global markets. Additionally, the USDA projects that upward trending prices will incentivize more production. In contrast to the EU, a farm consolidation process leading to economies of scale is expected within the US (USDA, 2020c). For New Zealand, both the OECD and FAO (2020) expect, similar to the EU, that the production of milk will increase at a slowing rate, the growth stemming primarily from yield growth.

Within the Asian market, China and India are actively pursuing structural improvement plans of their dairy sectors (Department of Animal Husbandry, 2018; Gooch et al., 2017). The average herd size and productivity are still far below the other large dairy producing countries, namely the EU, New Zealand, and the US. This is explained by the persistence of smallholder productions and the use of dairy cattle as draught animals, which implies a higher energy use and therefore feed requirement. Furthermore, particularly India still has a high reliance on buffalos, which have a lower milk output with a higher fat content compared to crossbred cattle breeds (IFCN, 2014, 2020; Landes et al., 2017; Salois, 2016). In these countries, the informal market structures are being challenged by the outbreaks of livestock diseases and contamination issues. For instance, the Chinese dairy sector needed to rebuild consumer trust after the melamine incidence in 2008 (Tao et al., 2016). This rebranding has involved increasing control measures, which requires the establishment of a more regulated dairy sector.

In terms of shifts in market power, the growth in production size is accelerating in India. India is currently the largest dairy producing country, in the coming decade it is expected to provide an even larger share of the world production and keep its leading position (EC, 2020a; OECD & FAO, 2020; Salois, 2016). Moreover, dairy production in African regions is expected to grow at a high pace. However, given the current low production, it will remain as a relatively small producing region in the next decade (OECD & FAO, 2020).

Consumption

In developed nations, the OECD and FAO (2020) and EC (2020a) expect a potential shift away from traditional dairy products, especially fresh milk that will be replaced by plant-based alternatives, however these projections do not quantify the effect as there are still significant uncertainties related to this expectation and the consumption of the plant-based alternatives is still at relatively low level. Looking at fresh dairy products globally, its consumption is expected to increase by a rate of 1% annually (OECD & FAO, 2020). On the other hand, demand for more processed dairy products, such as cheese (which is a key ingredient in convenience food and some vegetarian diets) is still expected to grow (EC, 2020a; OECD & FAO, 2020; USDA, 2020e).

From Figure 6.14 (based on projections from OECD and FAO), one can observe that consumption is projected to increase in Asia for all dairy products in the coming decade, continuing a generally sustained growth from the preceding decades. Looking specifically at fresh dairy products, consumption growth is expected to continue for both Asia and Africa. However, the absolute increase in tons is significantly smaller for Africa. The OECD and FAO (2020) expect the consumption of cheese to increase worldwide (Figure 6.14). It is one of the only dairy products that is currentlymostly consumed
in Europe and North America. For other products, Asia has by far the largest absolute consumption, though in per capita terms Europeans and North Americans will continue to consume more (OECD & FAO, 2021). The consumption of milk powders is similarly rising in most regions, particularly in Asia, Latin America, and Africa. In developing countries located in Asia and Africa, milk powders are used as a milk substitute; however, elsewhere in the world the majority of milk powder is used in the food processing industry for dietary formula and bakery items among others (OECD & FAO, 2020).

Figure 6.14: Butter (a), fresh dairy products (b), cheese (c), and whole powder milk (d) consumption in thousand tons by regions

Note: Europe’s consumption data for butter prior to 2003 is not included due to a lack of data from the EU.
Dairy products are mainly consumed domestically, with only eight percent of global production being traded internationally (OECD and FAO, 2020). Nonetheless, the demand growth in Africa, South East Asia, and MENA is expected to outweigh their respective domestic production expansion, making these regions more dependent on imported powder milk and other dairy products and therefore increasing the amount of global trade (OECD & FAO, 2020). However, the EC (2020a) expects the global dairy trade growth to occur at a slower pace than in the recent decade and not for all product types, partly due to increasing production of less processed products in developing countries, which is likely to increase their self-sufficiency. Trade growth will therefore mainly be due to rising demand for raw products or increasing exports of higher value-added products (e.g. cheese), reflecting increasingly westernized diet in other parts of the world. The EU is expected to remain the largest exporter by 2030, although exports coming from South America are expected to grow and compete especially on the milk powder markets (EC, 2020a). The three main dairy exporters (the EU, New Zealand, and the US) are expected to dominate the market for butter and cheese (Figure 6.15). Europe, New Zealand and the US account for more than half of the exports of all dairy products. A large share of their export is going towards Asia, in particular China, which is currently the largest dairy importing country (OECD & FAO, 2020). Conversely, the Indian dairy market is almost inaccessible to foreign suppliers and, therefore, fairly independent from international markets, despite being the largest dairy producing country. Only in recent years India has become a small net exporter to the world market (Gooch et al., 2017; Landes et al., 2017).
Figure 6.15: Net exports of tradable dairy products in thousand tons: (a) butter, (b) cheese, and (c) whole powder milk

Note: Europe’s exports data for butter prior to 2003 is not included due to a lack of data from the EU.

Box 5: Perspectives of industry experts

The expected development on the dairy market according to the referenced projections is largely agreeable with the industry representatives’ views. However, in addition to the Asian growth highlighted in these projections, the interviewees also place significance on the West African dairy markets, particularly Nigeria, as a focus growing dairy market.

Another important insight gained from the interviews is that the competition on dairy markets is not by country, but by brands and companies behind these brands. Particularly within developed countries, larger dairy corporations span over multiple countries, with subsidiaries in multiple markets.

More detailed findings from the industry interviews are summarized in Box 6.
### Box 6: Industry perspectives: summary of interviews with experts from the meat and dairy industries

**Market developments:**

<table>
<thead>
<tr>
<th>Demand</th>
<th>Current market</th>
<th>Supply</th>
<th>Growth potential</th>
<th>Supply</th>
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</thead>
<tbody>
<tr>
<td><strong>Meat</strong></td>
<td>Among our interview group, the respondents mainly supply the EU+UK markets, where different countries demand specific cuts (e.g. bacon in the UK and processed meat for Denmark). Other relevant markets are North America and Asia. Asian demand is mainly for lower cost cuts and by-products. However, there are exceptions such as Japan, which is a high-price market.</td>
<td>Major European competitors are Spain, Germany, Poland, Netherlands, and Denmark. Outside Europe, the main competitors are Brazil, the US, and Canada. The competition is marked by different production costs and veterinary practices (e.g. use of antibiotics).</td>
<td>The main growth potential is in Asian markets due to rising purchasing power, particularly in China, Korea, Viet Nam, and the Philippines. Japan is also considered a growing market, as its weakened domestic supply implies that part of the stagnated demand (due to shrinking population) needs to be satisfied with imports. India and Mideast: poultry meat. EU: switch towards processed meats and plant-based substitutes. Africa: some see potentials in South Africa; in general, lack of infrastructure hinders the growth potential. Americas: growth potential in Latin America, particularly Brazil.</td>
<td>China: rising demand may be satisfied by domestic production, with ongoing investment in close to carbon neutral facilities. Vietnam, the Philippines and Korea: also developing their own production, particularly Vietnam in pork production. The relevance of the climate agenda in shaping the future competition of the market and the importance of having standardized methods to report emissions is recognized.</td>
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| **Dairy** | The interviewees’ organizations mainly supply the EU+UK market. But they also serve China and Southeast Asia, the MENA, and West Africa (mainly Nigeria). In the Americas they also serve the US and Canada. | In the EU, competitions are within large multilaterals in the EU. Other competitors are the US and New Zealand. Outside of Europe: some markets are difficult to enter due to local competitors (e.g. MENA countries and China). In China, local companies are growing and realizing economies of scale. Segmented competitions: low priced, food safety, organic production, and climate friendly production. | Growing markets: China and Southeast Asia (Indonesia, Philippines, Malaysia, and Bangladesh) due to demographic shifts and income development. Also growing demand in India but currently foreign supply is not able to enter that market. Access to India market may be possible if domestic supply lags behind domestic demand. Other markets: the West Africa (Nigeria) and the MENA countries are potential markets. | Rising domestic production likely improves self-sufficient in Asia. Increased competition from local producers and imports is also expected in Africa. Demand in the Western world is expected to decrease. In the EU: dairy alternatives pressure dairy consumption. Moreover, global FMCGs (fast moving consumer goods) may become competitors within the EU on new product groups, such as ready meals, and to-go branded (e.g. Dairy Farmers of America, Nestle, Coca-Cola, and PepsiCo). |


7 CONCLUDING DISCUSSION

The purpose of this study is to provide an overview of the global livestock sector and the animal food markets including past and prospective market evolutions. As part of the process, we review and document the important aspects characterizing animal food demand and supply, such as the main demand and supply drivers, the health and environmental concerns related to animal food production and consumption, the role of international trade and global markets, as well as the economic modeling tools used to study these factors. These learnings help us identify several research gaps on the current literature, which are discussed in this chapter, whereas the summary of the main findings of the report are provided in the executive summary.

Further development of the livestock and animal food sector in the next decades will be influenced by a host of fundamental drivers, as reviewed in details in this report and illustrated in Figure 7.1. These drivers include demand-side factors such as income growth, demographic changes, dietary and health considerations, and supply-side drivers such as changes in regulations, production capacities and technological advancement, and biophysical constraints, as well as climate change and climate change mitigation measures. Domestic regulations and development strategies can also influence consumer behavior and producer incentives. At the global level, the pursuit for national food security goals, trade negotiations and trade conflicts, will continue to drive global trade patterns, along with the fundamental demand and supply conditions at country levels.

Figure 7.1: Drivers of the global animal food market

Current projections suggest that in the coming decades the livestock sector is expected to continue growing with likely changes in the geographic distribution of production and demand. Production is expected to increase proportionately more in developing countries. The expansion of per capita income and population occurring in developing economies, particularly in Asia and Africa, are driving a growing demand for livestock products. Therefore, many developing countries may become more dependent on imported animal food products. Some developing countries may also seek to greatly expand their livestock production through increasing herd size, upgrading technology, and improving
production efficiencies. These changes will likely re-draw the global trade patterns that we are seeing today.

Concerning the understanding of the future movement of demand behavior, there is a lack of recent harmonized cross-country estimation of income and price elasticities for the main market-players at a disaggregated product level. These elasticities can be used to approximate changes in consumption behavior due to marginal changes in income or prices. Additionally, the methods for updating such elasticities in partial and general equilibrium models to produce long-term projections are often based on *ad hoc* rules. In long-term projections, large income growth may imply non-marginal changes in consumption behavior, thus adding significant uncertainties to extrapolations of demand patterns using elasticities estimated from historical data. Furthermore, consumer behavior can be influenced by shifts in culture and the society. Currently, consumer research in developed countries grants special focus to environmentally friendly consumption. The extent to which environmentally sensitive and healthy dietary recommendations will be promoted by governments (e.g. through taxation and other policies) and adopted by consumers is uncertain, thereby adding further uncertainty to long-term demand patterns. To mitigate these uncertainties, a systematic review of the demand parameters published in the literature is needed, together with updated estimates of worldwide animal food demand elasticities and estimates of within country heterogeneities for some key market players.

On the supply modelling side, there are also great unknowns in the literature: the extent to which countries will impose restrictions on the livestock sector and the likely impacts of such restrictions will have on the sector at national and global levels. Indeed, a major deficiency of the current projections lies in the inadequate formulation of future climate mitigation scenarios, particularly in the agriculture and livestock sectors. While the reduction of GHG emissions and other negative environmental implications of the livestock sector is increasingly recognized in the academic literature and in fact considered in policy debates, concrete commitments are largely absent in many countries’ nationally determined contributions to the Paris Agreement. It is reasonable to expect that within the developed world, some countries may further regulate the livestock sector with the intention of reducing the emissions from the sector. There have already been proposals of taxation schemes or technology requirements in several countries. The extent to which such schemes will be applied will have implications for the future production patterns. Even within developing regions, it is expected that the awareness about the environmental implications of the sector will mitigate its growth (Bonnet et al., 2020). This leaves undefined the reduction distribution among sectors, adding significant uncertainty to supply modelling. Furthermore, data on the current production systems throughout the world is scarce, as global datasets on production systems are rarely updated. This is especially troublesome for the emerging regions that are expanding their livestock sectors because old observations become obsolete. Finally, concerns also emerge about modelling methods to characterize the complexities of livestock markets. These methods require a better link to the resource base, emissions footprint accounts, and technologies used across countries. Since the degree of uncertainty is significant, modelling several likely development scenarios seems to be the best approach to tackle the research gaps identified.
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