FUTURE GROWTH IN GLOBAL MEAT CONSUMPTION: THREE INCOME SCENARIOS

BY

GRETCHEN KUCK

THESIS

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Adviser:

Professor Gary Schnitkey

ABSTRACT

Meat has played an increasingly important role in both the human diet and the agricultural economy over time. As it stands the global population is currently eating more beef, pork, and chicken than ever, which begs the question: can (will) consumption go up from here? This thesis models the impacts of different plausible income scenarios on future meat consumption at the global scale in context of the idea that income drives increased meat consumption until a point of saturation. Several far-reaching economic events have occurred in the past two decades, necessitating an updated understanding of the relationship between income and consumption growth. The analysis is concerned with several questions that will impact stakeholders over the next period of consumption: how much meat will be consumed by the global system, the division of the three different meat types among this total volume, and the geographical distribution and implications of expected future growth. To answer these questions, income elasticities for beef, pork, and chicken are estimated using historical price, income, and consumption data for a set of 26 countries.

Applying several different hypothetical income scenarios to the model, the resulting meat consumption projections increase understanding of the role that economic forces play in shaping global meat demand in a modern, globalized food system. The testing of different scenarios confirms that while the majority of meat consumption by volume occurs in large higher-income countries, most future consumption growth will come from middle-income countries. However, because the model finds that meat consumption income elasticities are higher at lower incomes (particularly for chicken and beef), the scenario testing is clear that negative economic events

will have a larger downward effect on global meat consumption than future increases in income will have a positive effect.

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CHAPTER 1: INTRODUCTION

Meat has traditionally served as a major source of calories and protein for much of the globe. Meat consumption has evolved past the prehistoric hunters and husbandry of prior centuries to commercial feedlots and massive poultry houses in the twenty-first. Recently, debate has arisen on what role meat consumption and livestock production should play in the global resource structure going forward. The discussion is broad, from health to environmental concerns, and some suggestions are drastic (Bill Gates made headlines in 2021 by suggesting that all developed countries should transition to only consuming synthetic beef (Temple 2021)). The ramifications of any consumption changes on a global industry with significant land, resource, nutritional, and economic implications will have pervasive consequences. Striking a balance between the sustainable use of natural resources and the need to meet growing world demands for food is no doubt a major challenge.

Livestock, meat, and dairy production uses more land than any other human activity ("Livestock and Landscapes"). In keeping with the theory of comparative advantage, large land- and resource- abundant countries such as the US, China, Brazil, and Canada are major meat producers. Other countries that consume large amounts of meat are not as rich in resources must rely on imports of feed, meat, or animals to ensure their food security. As the amount of available arable land becomes a constraint, countries that are unable to produce enough of their own food to meet domestic consumption demands are left largely reliant on those countries that can produce in excess of their needs.

The global meat industry also has large impacts on the global feed grains and oilseeds industry. In the 2021-22 marketing year, the world is expected to produce 258 million metric tons (MMT) of soybean meal and 1,502 MMT of coarse grains, the majority of which will be used for livestock feed. In addition, the globe is expected to produce 751 MMT of corn for domestic feed use alone (WASDE Report, January 2022). This volume of cultivation utilizes about a third of the planet's cropland ("Sustainability Pathways: Livestock and Landscapes"). Coupled with livestock grazing use (about a quarter of arable land), the impact of the feed and meat industries on the availability of arable land and water resources is far from inconsequential.

Growth in meat consumption typically traces an Engel curve. As income increases, the total proportion of income spend on food decreases) before plateauing at a level of saturation. Bennet's Law observes that as incomes rise along this curve, more of the income will be spent on more nutrient-dense foods. In the twenty-first century, this rapid uptake of meat consumption occurs in lower-income economies that coincidentally typically also see the highest rates of population growth. At the same time, population growth has reached a plateau in higher-income countries, even as incomes and the consumption options available to consumers have increased. The relationship between income and meat consumption is well known, but complicated by the disparities between income levels across the globe and ever-changing economic conditions.

Global meat consumption has been shocked by two major income events over the past decade alone: the 2008 Great Recession and the COVID-19 pandemic in 2020-21. Both of these events were significant enough to reduce global consumption of meat, the 2008 Recession by reducing incomes and the COVID-19 pandemic for a host of reasons including supply chain issues, decreased demand for certain cuts, and reductions in incomes. Two major shocks in ten years underscores the need for an updated understanding of how income-related changes in consumption, large or small, will impact the global meat industry.

The intent of this thesis is to assemble an analysis that allows for the presentation of the impact of potential economic scenarios on the future volume, composition, and geographical distribution of global meat consumption. The analysis is calculated with the consideration to the fact that agricultural commodities do and will continue to operate as a global system. Due to the biological nature of both meat and livestock feed production, understanding how patterns of demand for meat are and will shift will aid the decision making of commodity producers, policymakers, and others. Using an econometric model that estimates global meat consumption as a function of global commodity prices and income, the resulting projection will develop a base estimate of future consumption for years 2022-30. After this, three different economic scenarios will be applied to the model and the results will be compared to the baseline projection to establish a range for possible future meat demand outcomes.

The analysis that follows is separated into several parts. First, Chapter 2 discusses the current state of global meat consumption, provides background on the multiple forces that influence meat consumption, and identifies the need to investigate potential future scenarios. A review of existing literature presents established approaches for forecasting per capita food consumption changes at the global scale and testing them on hypothetical outcomes in Chapter 3. These chapters will be used as rationale to present a system that will then be used to explore the divergences in projected consumption until 2030 under three different economic scenarios: a five percent increase from the currently-expected income levels, a five percent decrease from expected income levels, and a split approach where high income countries see a five percent increase in expected income while all other countries incomes are decreased by five percent.

To conclude, the outcomes of each of these scenarios and their potential implications will be discussed in Chapter 5 both comprehensively and at the income classification level. In doing so, the intent is to provide a current and forward-looking understanding of the patterns and trends playing out on the plane of global meat consumption. Effects to consider include not only the total volume and makeup of meat consumed, but the demographics and long-term sustainability of the growth, potential areas of declining meat consumption, and the trade and resource needs associated with geographical shifts in consumption centers.

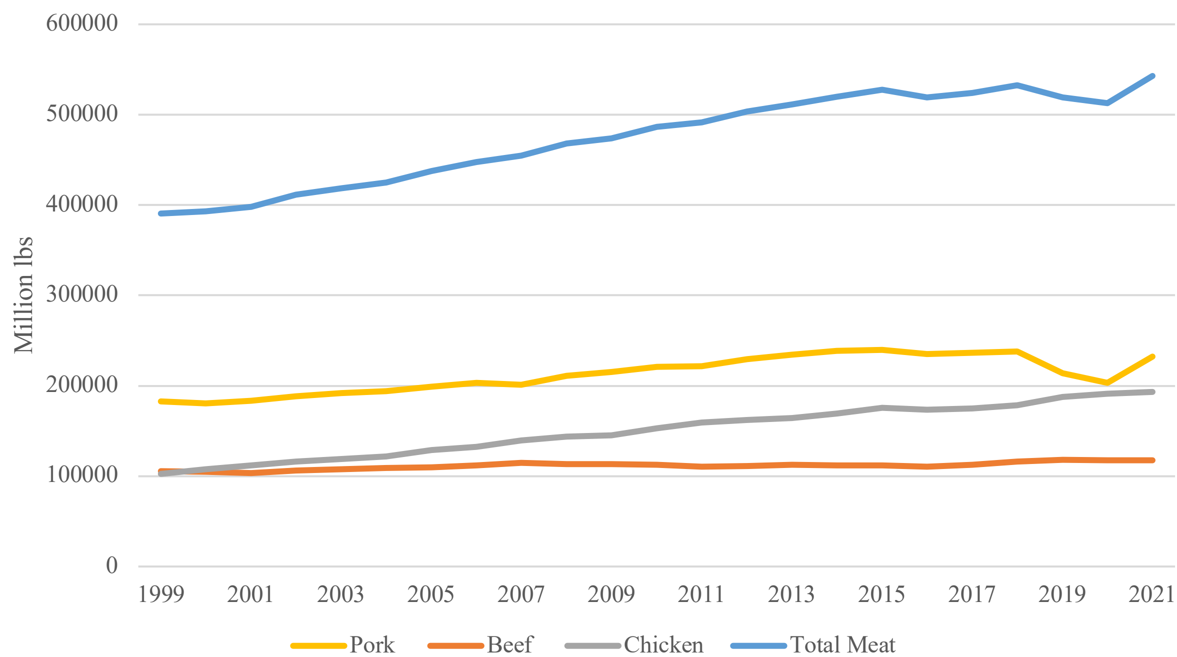
CHAPTER 2: TRENDS IN MEAT CONSUMPTION OVER TIME

The purpose for undertaking this thesis is to project and understand future meat consumption. Evaluating historical trends will provide a baseline for making projections into the future and cement the necessity of this analytical exercise. This chapter first provides data characterizing the trends in meat consumption that have occurred over the past two decades and then suggests some of the drivers behind those developments.

2.1 Current Global Meat Consumption

This thesis is concerned with observing three components of global meat consumption: changes in per capita consumption, changes in a country's consumption volume, and changes and substitutions between beef, pork, and chicken (the three most consumed meat types). This Chapter uses a dataset of 26 countries with complete consumption data for beef, pork, and chicken recorded by the United States Department of Agriculture' Foreign Agricultural Service Production, Supply, and Distribution database. These 26 countries represent 90 percent of the meat consumed in 2021 as recorded by the USDA database and will be used to make the forthcoming model projections.

Figure 1: Total Meat Consumption, Dataset Countries, Volume in Million lbs, 1999-2021



Overall, consumption of meat has trended consistently upwards, with an average annual growth rate of 1.5 percent over the 22 years. The total volume of consumption is up 40 percent (156,887 million pounds) since 1999, though consumption declined after 2018 and has only just recovered to previous levels in 2021 (Figure 1). Much of this decline can be attributed a decrease in pork consumption corresponding to the 2018 outbreak of African Swine Fever in China.

Pork is the most-consumed meat, comprising 43 percent of total meat consumption in 2021. Pork consumption increased 29 percent from 1999-2021, an average annual growth rate of 1.16 percent and a total of 54,042 million pounds. Pork consumption fell to its lowest level since 2007 in 2020, about 14 percent lower than record consumption (2018) and is currently about 3.3

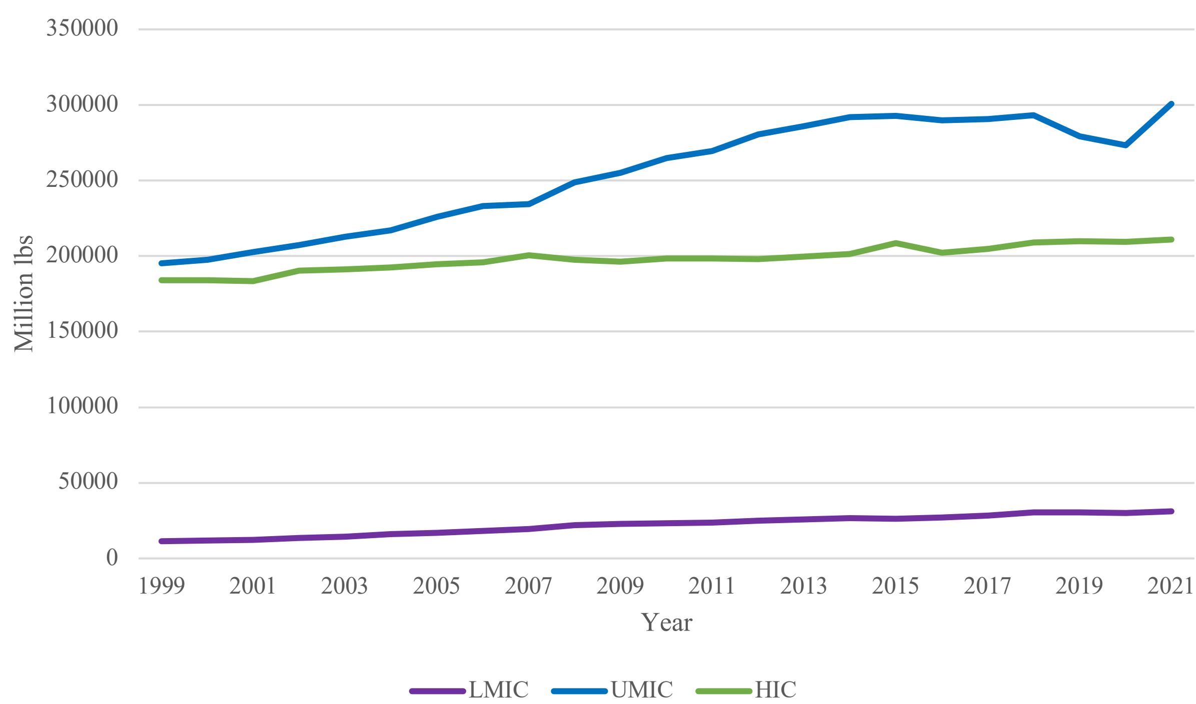
percent lower than would be expected on a linear trend. This decrease corresponds with the impact of African Swine Fever on meat production in China, the world's largest meat and pork consumer, though pork still remains the most preferred meat type by volume globally.

Chicken is the next highest-consumed meat type, with significantly faster positive consumption growth than pork or beef. Consumption of chicken increased 88 percent from 1999-2021, rivaling the global consumption of pork. 90,698 million pounds more chicken was consumed in 2021 than 1999, representing a nearly 3 percent average annual growth rate.

Likely due to its relative higher costs and more intensive resource needs, beef is the least-consumed meat type with an average annual growth rate of only 0.5 percent from 1999-2021. While beef consumption increased a little over 11.5 percent during those years, consumption only increased 12,147 million pounds by volume- less than a third of what pork or a seventh of what chicken increased.

While global meat consumption has exhibited positive and stable growth, there is substantial variation at the country consumption level. Cultural and religious diet preferences play a large role in shaping consumption patterns across borders, but countries' consumption behavior can be roughly grouped by income level. This thesis will utilize the four income brackets determined by the World Bank to make these groupings. This paper uses per capita GDP due to data availability, but the World Bank classifies countries with a per capita GNI of less than $1,045 as low-income, between $1,046 and $4,095 as lower-middle income, between $4,096 and $12,695 as upper-middle income, and greater than $12,696 as high-income. The lower-middle income countries (LMICs) are responsible for the smallest share of global meat consumption by volume but have some of the highest growth rates in per capita consumption and also see moderate-high population growth. Total meat consumption in LMICs grew 174 percent between 1999-2021. HICs have the highest per capita consumption levels though with lower rates of growth, but only moderate population growth resulting in smaller growth by volume (15 percent from 1999-2021). UMICs, however, are characterized by both large and growing populations and moderate-high per capita consumption levels and growth. The combination of the two forces leads to not only the highest (by total volume) consumption but also a potential for growth (given a 54 percent increase from 1999-2021, about 1.5 percent a year on average).

Figure 2: Total Meat Consumption by World Bank Classification, Dataset Countries, 1999-2021



*Note: Due to lack of data, low-income countries are not represented

The figures below will illustrate that total meat demand is currently driven by only a handful of countries. China, the US, the European Union, and Brazil together represented 69 percent of the meat consumed in the dataset in 2021. Each of these four countries is high or upper-middle income. These countries also represent the largest four producers of meat in the world. All of these countries have large populations and, with the exception of China, relatively high per capita consumption levels.

Table 1 describes changes in population and per capita total meat consumption between 1999 and 2021 and provides evidence for two important patterns in meat consumption. The countries included in the dataset that consume the most pounds of meat per capita include Hong Kong (322 pounds), the US (264 pounds), and Argentina (246 pounds).

Table 1: Changes in Per Capita Meat Consumption, Dataset Countries, 1999-2021, lbs

World Bank Income Classification		1999	2021	Percent Change
HIC	Australia	193	210	9%
HIC	Canada	208	195	-6%
HIC	Chile	134	199	49%
HIC	EU	219	205	-6%
HIC	Hong Kong	252	322	28%
HIC	Japan	98	120	23%
HIC	Korea	92	166	81%
HIC	Saudi Arabia	148	207	40%
HIC	US	255	264	4%
UMIC	Argentina	225	246	9%
UMIC	Belarus	120	196	64%
UMIC	Brazil	158	210	32%
UMIC	China	95	122	29%
UMIC	Colombia	80	129	61%
UMIC	Guatemala	47	72	51%
UMIC	Kazakhstan	69	125	81%
UMIC	Malaysia	159	260	64%
UMIC	Mexico	121	153	26%
UMIC	North Macedonia	77	94	22%
UMIC	Russia	92	150	63%
UMIC	South Africa	77	112	46%
LMIC	Angola	24	38	60%
LMIC	India	4	11	149%
LMIC	Philippines	58	72	24%
LMIC	Ukraine	73	108	47%
LMIC	Vietnam	36	102	184%

High-income, high per capita-consuming countries such as the US, the EU, and Canada, have slowed or even decreased the rate at which individuals consume meat. However, lower-middle income countries saw large percentage gains in per capita consumption. Table 1 also presents evidence for the idea that per capita growth is coming from the bottom up as the highest growth rates almost perfectly overlap with the Global South. Southeast Asia/MENA and Central Asia/Russia have been areas with significant growth at the per capita consumption level.

Of the major drivers (by volume) of global consumption, China, the US, EU, and Brazil all display modest percentage increases in per capita consumption. However, China is at a significantly lower level of per capita consumption (122 pounds compared to 264 pounds for US consumers). In light of the huge volume of meat it consumes, China differentiates itself from other high-volume consuming countries by having most of its total volume of consumption driven more heavily by population rather than high consumption at the individual scale. Given the 144 pound disparity between the US' per capita total consumption and China's, China potentially has immense room for gain. If China *did* eat at the same per capita level as the US in 2021, their volume needed would be nearly as much as the US, EU, and Brazil combined eat today. Realistically, it will take China many more years to reach that level of per capita consumption, but this hyperbole exemplifies the potential that high-population, low- per capita consumption UMI and LMI countries (China, India, Malaysia, Indonesia, Nigeria, etc) in particular have to increase the total volume of meat needed by the world.

While looking at per capita consumption growth provides some insight into how meat consumption has evolved over time, it does not provide the entire picture. Combining the per capita consumption rates with population data to yield total consumption *volume* provides a more accurate representation of where most meat is consumed (Table 3).

Table 2: Volume of Meat Consumed and Population, Dataset Countries, Three Year Average 1999-2021, Million lbs

		1999-2001			2019-2021		
		Population (1000 people)	Consumption	Share of Consumption	Population (1000 people)	Consumption	Share of Consumption
LMIC	Angola	16,403	448	0.11%	32,875	1,256	0.24%
LMIC	India	1,056,545	5,035	1.28%	1,379,944	15,026	2.86%
LMIC	Philippines	77,997	4,703	1.19%	109,582	8,020	1.53%
LMIC	Ukraine	49,171	3,296	0.84%	44,126	4,779	0.91%
LMIC	Vietnam	79,896	3,036	0.77%	97,323	9,462	1.80%
LMIC		**1,280,011**	**16,518**	**4.19%**	**1,663,850**	**38,542**	**7.34%**
UMIC	Argentina	36,871	8,177	2.08%	45,366	11,198	2.13%
UMIC	Belarus	9,978	1,121	0.28%	9,402	1,833	0.35%
UMIC	Brazil	174,768	28,700	7.28%	212,534	45,364	8.64%
UMIC	China	1,262,410	119,640	30.36%	1,402,121	155,677	29.66%
UMIC	Colombia	39,628	3,143	0.80%	50,829	6,755	1.29%
UMIC	Guatemala	11,591	567	0.14%	16,878	1,187	0.23%
UMIC	Kazakhstan	14,890	1,118	0.28%	18,746	2,293	0.44%
UMIC	Malaysia	23,188	1,827	0.46%	32,364	4,206	0.80%
UMIC	Mexico	98,894	12,329	3.13%	128,923	19,151	3.65%
UMIC	North Macedonia	2,034	148	0.04%	2,083	197	0.04%
UMIC	Russia	146,596	13,118	3.33%	144,177	21,683	4.13%
UMIC	South Africa	44,959	3,797	0.96%	59,303	6,822	1.30%
UMIC		**1,865,809**	**193,685**	**49.16%**	**2,122,728**	**276,366**	**52.65%**
HIC	Australia	19,164	3,689	0.94%	25,673	5,512	1.05%
HIC	Canada	30,703	6,338	1.61%	37,974	7,350	1.40%
HIC	Chile	15,340	2,124	0.54%	19,093	3,688	0.70%
HIC	EU	429,347	79,865	20.27%	447,527	76,640	14.60%
HIC	Hong Kong	6,662	1,568	0.40%	7,507	2,517	0.48%
HIC	Japan	12,6874	12,499	3.17%	125,800	15,030	2.86%
HIC	Korea	46,998	45,82	1.16%	51,760	8,586	1.64%
HIC	Saudi Arabia	20,687	1,641	0.42%	34,808	3,568	0.68%
HIC	US	282,057	71,497	18.15%	329,722	87,074	16.59%
HIC		**977,832**	**183,804**	**46.65%**	**1,079,864**	**209,965**	**40.00%**

Southeast Asia, China, Central Asia/the Middle East, and Africa were the key drivers of recent meat consumption growth. Looking solely at per capita or percentage growth fails to capture the enormity of outliers. The multiplier of population translates even modest increases in per capita level consumption to massive gains in total volume consumed by the country. Angola, Colombia, Guatemala, India, Kazakhstan, Korea, Malaysia, Saudi Arabia, and Vietnam all doubled their volume of meat consumed from 1999-2021.

In comparing the top-volume countries, the dichotomy between the high per capita consumption of the EU, US, and Brazil and the population-driven consumption exhibited by China and other fast-growing countries further posits the question that this thesis seeks to address. As the rate of consumption growth slows and populations are expected to plateau in high income countries, it would be expected to see consumption growth rates decline or even reverse. Eventually, a consumer, no matter how high their income, will reach the point that they no longer gain satisfaction from consuming more meat. As consumers gain more food choices, become more health conscious, or feel more passionately about animal rights or climate issues in high income countries, per capita consumption could slow or even decrease. Given the slowing gains in per capita consumption of high-income countries in the recent past, peak meat could realistically be seen in these countries in the near future. This means that gains in volume growth would come solely from population increases, which are also expected to level off in these countries (and already have in some, like Japan).

The last aspect of meat consumption to examine is the composition of the total volume between meat types: beef, pork, and chicken. As a rule, chicken is the least expensive per pound of retail cut, followed by pork and then beef. This is also usually the order of integration as consumers add meat into their diets as their purchasing power increases (OECD-FAO).

Not all meat animals require the same amounts of resources to produce. It takes significantly more land and feed to produce one pound of beef than it does one pound of chicken pork. If consumption of more resource-intensive meats is concentrated in less resource-abundant areas, the extent of feed and meat trade will need to shift to match demand.

Depending on income and consumer preference, beef, pork and chicken can be considered either complements *or* substitutes for each other. Further complicating consumption patterns are cultural and religious inclinations towards certain meat types. Several of the countries (India, Malaysia, Saudi Arabia) in this paper's dataset do not consume significant amounts of pork based on the religious (Muslim, Hindu, Buddhist) beliefs held by large majorities of their populations, but some countries (China) consume higher than average proportions of pork in their diet due to cultural preference.

Table 3: Percentage of Total Consumption Made Up by Each Meat Type, Dataset Countries, 1999-2021

		1999			2021		
		Pork	Chicken	Beef	Pork	Chicken	Beef
HIC	Australia	21%	34%	45%	24%	51%	24%
HIC	Canada	33%	32%	35%	27%	42%	31%
HIC	Chile	26%	37%	37%	28%	38%	34%
HIC	EU	57%	20%	24%	54%	28%	18%
HIC	Hong Kong	46%	43%	11%	42%	23%	35%
HIC	Japan	38%	35%	27%	40%	41%	19%
HIC	Korea	51%	21%	28%	50%	27%	23%
HIC	Saudi Arabia	50%	43%	7%	50%	44%	6%
HIC	US	27%	35%	38%	25%	43%	32%
UMIC	Argentina	8%	25%	67%	13%	42%	45%
UMIC	Belarus	48%	14%	39%	47%	41%	11%
UMIC	Brazil	14%	39%	47%	15%	51%	35%
UMIC	China	74%	16%	9%	68%	19%	13%
UMIC	Colombia	6%	44%	50%	19%	58%	23%
UMIC	Guatemala	14%	65%	21%	16%	67%	16%
UMIC	Kazakhstan	20%	7%	73%	9%	40%	51%
UMIC	Malaysia	50%	43%	7%	50%	43%	7%
UMIC	Mexico	21%	37%	42%	26%	53%	22%
UMIC	North Macedonia	25%	38%	37%	33%	49%	18%
UMIC	Russia	31%	28%	41%	36%	47%	17%
UMIC	South Africa	9%	53%	39%	9%	60%	31%
LMIC	Angola	21%	20%	59%	33%	49%	18%
LMIC	India	0%	40%	60%	0%	61%	39%
LMIC	Philippines	50%	36%	13%	40%	48%	11%
LMIC	Ukraine	47%	14%	39%	37%	49%	14%
LMIC	Vietnam	74%	20%	6%	63%	29%	8%

For the most part, the relative proportion of beef in total consumption has decreased while the fraction of total consumption made up of chicken has increased (Table 4). This implies that most of the gains in total meat consumption are attributable to increased chicken consumption. Though countries usually have individual preferences between the two, the total share of the diet composed of pork and chicken has trended upwards over time as the role of beef has decreased.

2.2 Factors Shaping Meat Consumption

As characterized by the historic pattern of meat consumption above, per capita consumption growth and population growth are the two forces driving growth in global meat demand. Having identified directional trends in past consumption, the following sections will explore in more detail these two forces and the role that each will play looking forward to 2030.

2.2.1 Global Population

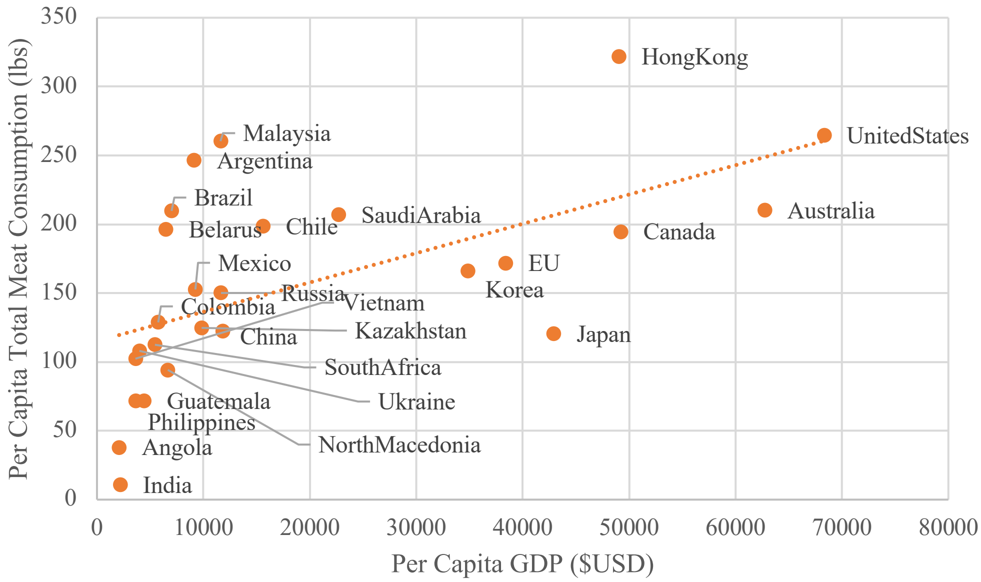
From 1999-2021, the dataset population increased 30 percent to 7.8 billion people. Future population growth is expected to continue increasing at a decreasing rate. The World Bank projections used for the analysis in this paper estimate the population rising by a little over 8.5 percent to total 8.5 billion people by 2050.

To draw meaningful conclusions about what this means for global meat consumption, consideration must not only be given to speed of total population is growth but *where* that growth is occurring. The wide disparity of diet patterns and resources between countries means that consumption patterns in countries with larger or faster-growing populations will be more heavily weighted to changes in per capita consumption. In 1999, China and India led the world in population by a large boundary; in 2021, still China and India remained a sizable margin above the rest of the world, but the distance between the two populations sizes closed significantly. By 2030, the World Bank projects India to usurp China as the most populous country in the world. The progression of the 21st century has also seen low and lower-middle income countries become relatively and absolutely more populous. Population growth rates in the Middle East-North Africa (MENA) region, Southeast Asia, and low-income Sub-Saharan Africa have already begun to rise steeply, chiefly in Pakistan, Nigeria, and the Arab World. Conversely, the slowing of growth rates in the most developed and higher income countries will occur as the actual global population approaches 10 billion by 2050.

2.3 Per Capita Consumption

As population centers expand, contract, and shift, focus shifts to individual meat consumption choices. Even small trend shifts in per capita consumption of meat will have large implications when multiplied over billions of people. Increased accessibility and relative affordability of meat has allowed per capita consumption to increase dramatically. Other factors that impact both the supply and demand for meat have shaped prior consumption patterns and will continue to do so in the coming decade, but it is accepted that income is the largest factor in determining how much meat a consumer eats (OECD/FAO 2020; Milford et al, 2019: Whitton et al, 2021; Vranken et al, 2014).

Figure 3: Relationship Between Per Capita Meat Consumption and Per Capita GDP, 2021



As a rule, meat consumption is typically seen to increase along with incomes. Figure 1 above reveals how well this assumption tracks by plotting total per capita consumption of meat on per capita GDP. As consumers are financially able to introduce variety into their diets, rational economic behavior indicates that they will choose to do so. More directly, as consumers are able they will begin to trade the starches in their diets for more expensive and nutritionally-dense foods such as fruits, vegetables, and animal proteins in particular.

In high income countries, the idea that meat consumption is nearing or has reached saturation is common (Whitton et al, 2021; OECD/FAO, 2020). 'Peak meat' could be credited to several suggested factors including ageing populations, consumer health perceptions, and consumer preference for higher-quality or different meat cuts. The OECD's Agricultural Outlook for 2020-29 suggests expected growth of 0.24 percent in per capita meat consumption in developed (defined as sustained economic growth and security) countries, less than a quarter of the rate in the preceding decade (OECD/FAO 2020). However, the same source expects to see the per capita growth rate in developing countries to double from the previous decade to 0.8 percent.

2.3.1 Urbanization

In addition to income, urbanization of populations impacts per capita consumption rates. Increased agricultural production efficiency has instigated a flow of people out of rural communities in what has been a rapid and one-way transition to cities in much of the globe. The United Nations estimates that 60 percent of the current world population lives in urban areas, up from 47 percent in 1999. A solid majority (68 percent) of the world's population is projected to live in an area classified as urban by 2050. Most of this transition is expected to come from the geopolitical regions that are also expected to see the greatest population growth rates, Asia and Africa. India, China, and Nigeria alone will be responsible for 35 percent of the urban growth and will add a combined 860 million urban inhabitants by 2050 ("World Urbanization Prospects: The 2018 Revision").

The physical redistribution of population concentrations engenders adjustments in lifestyle, caloric needs, and consumer preferences. Urbanization is associated with increased incomes, more food consumed away from home, and increased consumer options (Hawkes, Harris, and Gillespie 2017). Urbanization is also associated with a more sedentary lifestyle with a lower caloric need, but observations suggests that the transition from a rural or farming lifestyle affects the composition of the diet rather than the level of total consumption (Kearney 2010).

One of the biggest changes in the composition of the diet towards more meat per capita is an increase in convenience or processed goods, particularly when women work outside the home (Knorr et al 2018), which happens more in urban areas than rural in communities. The draw of economic opportunity in urban centers incentivizes consumers to use more of their (increased) incomes on 'faster' food options rather than spending more of their time preparing a meal. Additionally, consumers in urban areas typically have access to greater variety in their food choices rather than just what can be produced by their household or local area (Knorr et al 2018).

2.3.2 Globalization and Trade Liberalization

The rate of globalization in the post- Cold War era has marked a change to how trade patterns are formed (Faini 2004). New levels of interdependency and accessibility have permeated almost every aspect of an increasingly globalized society and meat consumption is no exception. McDonald's serves American-style cheeseburgers in South Korea, cargo ships transport Certified Angus Beef from the U.S. to anywhere in the world in ten days or less, and pork prices in Germany affect the amount of Brazilian soybeans China will buy next year. In addition to widening the consumer's food options, globalization also impacts the global society's need for fuel, supply chain timeline, and ability and willingness to invest in or share technological improvements.

One of the bellwether changes that helped to usher in this era of a broader global food system is the liberalization of cross-border trade. The accension of China to the World Trade Organization in 2001 marked a staunch shift in the way that countries opened their ports, borders, and wallets to their neighbors. The percentage of the global gross domestic product made up by trade has more than doubled from 1970 to 52 percent in 2020 (World Bank WITS).

Agricultural trade has been a major driver of this growth at nearly 7 percent growth year over year on average. In the past decade alone, global meat trade of all types has increased 20 billion USD for a total value of 70 billion USD (OECD-FAO, 2020). Much of the past and future growth in international trade is attributable to developing countries. The reduction of protectionism in the form of the standardization of tariffs and sanitary and phytosanitary measures, and the removal of non-tariff barriers to trade has led to increased welfare from trade in all but the most-isolationist corners of the globe. Policy advancements in labelling, biotechnology, animal health and safety, and customs standardization has made it significantly easier to transfer goods across borders, increasing welfare and choice for global consumers.

2.3.3 Production and Processing Efficiency

The largest input to producing chicken, pork, or beef is feed. Unlike most other major food commodities, meat production requires both end-stage processing and the input of other commodities in the form of feedstuffs such as corn, soybeans, oats, sorghum. Feed is typically the largest expense a producer has in raising an animal for consumption at anywhere from 50-75 percent of input costs for commercial animals ("Farm Production Expenditures"). Consequently, the amount and cost of feed necessary to produce an animal for meat can have dramatic effects on the supply and demand of meat. The amount of feed needed to produce a pound of live gain is a measure called the feed conversion ratio (FCR). Management, genetics, and animal health maintenance can all affect this measure in meat animals. FCR can vary widely along the lifecycle of meat animals and the way it is measured. Generally accepted benchmarks for current efficient FCRs for animals intended for slaughter are 2:1 or less for chicken, about 3:1 for pigs, and between 5-8:1 for beef cattle. When considering carcass weight, the difference in feed need is even more drastic. Chicken remains roughly the same (2:1), but feed needs increases to about 5:1 for pork meat and 12-16+:1 for beef cattle (Mekonnen et al, 2019; McGee 2014; USDA ERS "Livestock and Meat Trade Conversion Factors").

Over the past two decades, there are two major divergences in FCR that have impacted the meat industry. First, an overall improvement in FCR across all meat types and secondly, an increased level of efficiency in more industrialized countries ("Global Considerations for Animal Agricultural Research" 2014). Meat production efficiency is typically highest in countries with centralized production infrastructure and large amount of feed resources such as the US, Brazil, China, and certain EU countries. Investments in genetics, biotechnology, and animal health are all reflected in lower FCRs and reduced production costs. In countries where the meat industry might be characterized by smaller individual operations, fewer land and feed resources, or less investment in agricultural research, FCRs are likely to be higher making meat relatively more expensive and less available. Chicken and swine have made improvements in FCR over time, but ruminants (cattle) have not made significant progress. This can be attributed to the way they process energy and protein, longer time to maturity, and the tendency for FCR to slow as animals grow larger ("Feed Efficiency and How It's Measured").

Big picture, improvements in feed efficiency have made meat more affordable, accessible, and sustainable. Couple these gains with improvements in cold chain infrastructure, transportation, and supply chains and distribution and the effects of improvements in production on getting meat to the tables, supermarkets, and drive-throughs of the 21st century consumer is clear.

CHAPTER 3: LITERATURE REVIEW OF PER CAPITA CONSUMPTION MODELLING

At the most basic level, consumption is a function of income and prices in a country complicated by income elasticities at varying levels of development and cross-type substitution. Income is the most relevant and widely used metric associated with per capita meat consumption- and as an interval variable it is also the most easily quantified. While summative approximations of global meat consumption are common and regularly updated, reproduceable quantitative models that would allow for testing against a single variable on a global level are scarcer. Country-level models may integrate considerations for urbanization, feed prices, trade policy, etc., though these additional variables are difficult to quantify accurately at a global scale and very difficult to predict more than a few years into the future. Most large-scale meat consumption models from authorities like the OECD-UN FAO or USDA do not release their methods or data to the degree that they could be replicated for scenario testing as this thesis intends. This literature review will focus on models that center on a few commonly utilized quantifiable variables (focused on income, the most significant driver of meat consumption) and calculated at the global scale rather than for individual countries. Several of the models identified as of interest also include scenario testing, which will be discussed where applicable.

Valin et al's comparison of existing large-scale food demand projection models "The future of food demand: understanding differences in global economic models" provides a jumping-off point for understanding strategic approaches to global-scale food demand models, as well as a frame of reference for what range of growth a consumption model might be expected to fall in. In this paper, the methods and outputs of ten large-scale food demand models are compared and contrasted. Most of the established models concur within a range of growth rates for total calories forward until 2050, but there is significantly more variation between estimates for livestock consumption. For example, the expectations for growth of animal-derived calories from 2005-2050 for the models discussed in this review is much wider-ranging (64-144 percent) than projects for overall calories, a smaller bracket of 59-98 percent. Cited reasons for this include the uncertainty of the economies and cultural consumption patterns of China and India, large population centers with rapid per capita growth and the confounding effect of crop consumption as an input for livestock-derived calories.

This paper divides consumption models into two different categories: partial equilibrium models that yield reduced-form demand as a function of (usually) income and commodity prices, or more-integrated computable general equilibrium models based on linear expenditure system utility functions. These typically utilize external price and income elasticities, which are limited in availability particularly for recent adjustments to the income-consumption relationship, with limited consideration to other drivers. For this reason, most of the models focus on recalibrating other parameters around established elasticities which leads to a very diverse collection of modelling attempts, depending on the desired outcome and inputs. Most of the models use elasticities that were established externally-typically using USDA-published data that is no longer being updated-or are endogenously calibrated or derived (price elasticities from income elasticities in the computable general equilibrium models).

While the focus of the review is on the difference between these established consumption models/predictions, it does identify some convergences that are relevant in establishing expectations for the forthcoming analysis. Almost all of the models (using a middle-of-the-road socioeconomic scenario) predict consumption of total and livestock-derived calories at levels above OECD/FAO's 2050 projections. The levels projected by the OECD/FAO are relevant as a baseline because they are the source of the oft-cited need for 60 percent greater agricultural production by 2050. Next, Valin et al notes that attempting to account for climate change or bioenergy policy increases uncertainty in the model projections compared to the inclusion of the standard population, income, and price factors, again particularly for livestock.

Other global-scale food demand prediction analyses other than those systems collected in Valin et al's evaluation also rely heavily on the income-consumption relationship. Like Bodirsky et al, most are patterned after the idea of the Engel curve, which states that as incomes (and the absolute amounts spent by a household on food) rise, the percentage of income spent on food falls. The Bodirsky et al model was created specifically for scenario testing overall calorie and animal-derived calorie demand with minimum data availability and requires only population and income data to reproduce. In order to accomplish this, two separately derived parameters (time and saturation) are imposed on historical caloric consumption data. Like most of the large-scale models mentioned in Valin et al however, livestock-derived calories (to include eggs and dairy in addition to meat) are calculated as a share of total projected caloric consumption. The assumption is that livestock calories are inferior goods after a certain break point of income, but a normal good below that point. The model uses a separate set of relationships when computing overall caloric need and determining the animal-derived proportion of consumption.

To yield the food demand/income relationship needed for prediction, this model uses World Bank population and per capita income data. Future income and population data used to construct various scenario tests comes from the Intergovernmental Panel on Climate Change (IPCC) Special Report of Emissions Scenarios (SRES), which were also used in several of the models referenced in Valin et al. The IPCC provides standardized SRES 'storylines' for future income and population dependent on varying climate change assumptions.

Komarek et al takes a slightly different approach to answering a similar question to the one at hand but integrates the use of hypothetical scenarios to test understanding of movement of future meat consumption. The third version of IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (discussed in Valin et al), a partial equilibrium model that equates global and supply and demand for agricultural commodities each year, is used for this particular consideration of theoretical meat consumption changes. The perspective in this particular model focuses on meat demand as a function of meat (and feed) supply. In predicting future consumption, the analysis takes a cyclical approach and allows the livestock commodity price to vary as an endogenous variable and engages the successive feedback effect of commodity prices on meat demand. The analysis also relies on per capita income, population, and the prices of the livestock commodity and competing livestock commodities but uses income and price elasticities obtained externally. Most similarly to the intent of this thesis, the model is employed in this particular context not to predict actual demand over the time, but rather to project shifts in demand under a range of possible scenarios between the present and an end target. To the model, several different scenarios were applied out to 2050: relative to baseline, both an optimistic and pessimistic manipulation of red meat income elasticities under 3 different income conditions (increase, base, and decrease), and increases and decreases in global population. Additional what-if conditions were applied in isolation to high-income countries. Meat consumed in each scenario was then converted to a protein equivalent and compiled to determine total demand for livestock-derived protein sources.

While there are differences in actual output between this model and that needed to accomplish the intent of this thesis, there are a few distinctive attributes to utilizing the IMPACT model for a scenario approach. The model considers meat demand as a function of supply, whereas the perspective of this thesis is moreso of demand as a determinant of supply ("how much feed will be needed to meet demand" rather than the converse) and works under the assumption that yields and markets will be able to respond to increases and decreases in demand, at least in the near future. Secondly, the scenarios of concern for this thesis will not depend on other changes that impact consumer willingness to purchase meat beyond broad changes in economic conditions. The manipulation of the income elasticities in the scenarios here could reflect forces such as environmentalism, health concerns, or the rise of plant-based meat alternatives, but the analysis of this thesis is not concerned with quantifying or explicitly addressing how income elasticities will be impacted by these consumer preferences.

Each of the models mentioned above in this chapter estimates meat or livestock calories/consumption as a proportion dependent on the total amount of food consumed. This provides little of the detail sufficient to answer the question of this thesis. The model of meat income elasticities developed by Schroeder, Barkley, and Schroeder in 1996 focuses only on meat consumption by developing a regression equation from an entire system of countries. This particular model used income, consumption, and the trade-weighted approximations of prices for beef and veal, pork, poultry, and lamb and mutton. The inclusion of cross prices allows consumers to 'trade' meat for other types as quasi-substitute goods. Unlike some of the other models mentioned, the derivation of income elasticities themselves rather than using a set from another source allows the income elasticity relationship to reflect actual and current data. This model also accounts for a phenomenon that typically complicates predicting meat consumption at a global level (when meat acts less like a normal good as income levels rise) by allowing income elasticity to vary. This income elasticity variance across a diverse group of countries allows the model to reflect meat consumption relationships at different income levels.

The form offered here is also straightforward and clearly isolates the potential effects of income changes. The potential ability of the model in its entirety to present changes in the context of an entire system is valuable. Though the paper does not utilize this model to consider changes to its input variables, nor does it attempt to predict actual levels of broad consumption, it identifies broad trends and relationships between variables and output at the global scale. Though the expectations suggested by this model are now almost 30 years out of date, the broad trends suggested by the consumption elasticities suggested by this model have been proven true over recent years. The idea of 'peak meat' is mentioned and supported by the elasticities found in the model, though slow consumption growth is still occurring today in some of the identified countries indicating that the peak was not reached between 1996 and present. Countries with lower incomes but high income growth rates identified in the paper (China, Vietnam, Thailand) did in fact exhibit the large percent growth in consumption. Reviewing in retrospect how much economic transition has taken place across the globe since these expectations were identified supports the idea of integrating income expectations and scenario tests into a similar analysis to prepare for and understand the potential impacts of economic trends that may happen over the period.

Having laid out a survey of the existing challenges and approaches to answering questions similar to the one under consideration for this thesis, the income elasticity tactic employed by Schroeder, Barkley, and Schroeder was selected for use for this analysis. This selection was made for several main reasons. First, the scope of the model (global) and focus of the regression relationship (meat types) provides both sufficient detail and breadth to identify broad trends in consumption and the patterns behind the growth. Second, the model is based on income and price variables. This is ideal as the largest determinant of per capita meat consumption is accounted for and also this information (and future projects) have data available through the COVID-19 pandemic (see Chapter 4). Lastly, as this analysis assumes that production conditions will continue to be favorable enough to meet demand and that future population growth can be assumed to be accurate as predicted by international institutions and is therefore focused on economic uncertainty, the output of income elasticities is easily manipulated into hypothetical scenarios.

CHAPTER 4: METHODOLOGY AND DATA

The goal of this thesis is first to use income to estimate future meat demand out to 2030, and then to use hypothetical economic scenarios to develop an understanding of contingencies. To accomplish this, both future per capita consumption and population levels are needed. Consumption is first separated from the population effect to derive the relationship between income growth and per capita meat consumption growth for each meat commodity. After using this relationship to project per capita meat consumption until 2030, the population factor is reintroduced to yield expectations for future volume of meat demanded. Three different economic scenarios were then applied to the projection model in order to gauge how meat consumption responds to changes in income conditions.

This chapter will first discuss how the per capita projection model was constructed and the data used to create an estimation of the income-consumption relationship. The income elasticity structure used by Schroeder, Barkley, and Schroeder (see Chapter 3) was used to quantify the relationship of per capita consumption to income and price levels. Information and examples of the data used to develop this step are provided as well as each set of regression coefficients. Limitations of the model are also addressed.

The baseline projection was created by applying the elasticity relationship from the per capita regression estimation to projected future income levels. Reintroducing the population effect using population growth estimations for the projection years returns the total volume of meat consumption for each country. Comparisons of the baseline volumes to USDA's 2022 PSD domestic consumption expectations are provided to gauge the fit of the recombined projection.

After the baseline was estimated, several different economic scenarios were developed to provide a range for possible demand. The scenarios represent optimistic, pessimistic, and deviating expectation for the global economy post COVID-19 recovery and growth in the near future.

4.1 Per Capita Consumption Model

The income elasticity derivation derived by calculating a single equation for each meat commodity from Schroeder, Barkley, and Schroeder allows flexibility between meat types when calculating projections. Since the outcome of the model is an income elasticity relationship, only estimations of future income are needed to project future per capita consumption. This minimizes issues with lack of data and simplifies the projection. Additionally, using an elasticity derivation that relies on an income input and is allowed to vary makes it possible to apply economic scenarios to the projection model.

A few changes were made to the original model as estimated by Schroeder, Barkley, and Schroeder: first, global market prices (an approximation of an 'average' price) were used rather than the import-export prices from the original model due to lack of data. Second, Schroeder, Barkley, and Schroder utilized their model to calculate meat consumption growth rates, but did not predict actual meat consumption levels. This thesis will do the same, but use the per capita projection model as part of a larger-scale projection model. To do so, the variable coefficients of the regression equation were used to calculate different income elasticities that vary by income level for each meat type. The integration of the IMF income projections allows the elasticity relationship to be used to determine expected elasticates for 2022-2030, meaning that the projections did not require forecasting commodity prices, etc.

The first step in calculating the per capita projection model was to remove the effect of population on increases in meat consumption volume by converting the USDA PSD consumption data from metric tons per country to per capita consumption by dividing by population.

One equation was estimated for each of the three meat commodities using the 26 countries in the dataset. The per capita consumption-income relationship was estimated using the following equation that includes individual country per capita consumption data, the global market price for each meat type, and the income levels for each individual country for each year of the period:

$$lnQ_{ijt}= \beta_0+ \beta_1 lnP_{ijt}+\sum\beta_2 P_{hjt}+\beta_3 lnINC_{jt}+\beta_4(lnINC_{jt})^2$$

where (i ≠ h). For meat type i, Q_{ijt} is per capita consumption, P_{ijt} is global price, and INC_{jt} is per capita income in country j at time t (Schroeder, Barkley, and Schroeder). It was expected that since the regression would be run on a dataset including both high- and low-income countries, per capita consumption would vary at different points of income. In order to allow consumption to increase at a decreasing rate as higher levels of income were reached, a logged squared income variable is included in the model. A log transformation of all other variables was used.

Because the question is concerned with predicting future Q but lacks future values of P, the relationship between Q and INC can be reduced to an income elasticity by taking the derivative with respect to INC.

$$\varepsilon= \beta_3+2\beta_4(lnINC_{jt})$$

With an income elasticity for each country/meat type/year and the IMF's per capita income predictions, an approximation of future per capita meat consumption of each type for each country can be made. To construct per capita consumption estimates for each country for each meat type, the elasticity relationship calculated for each income was used to calculate the corresponding change in per capita consumption for the percent growth in income, using actual consumption in 2021 as the base.

4.2 Data Used in Model

4.2.1 Consumption Data

The US Department of Agriculture (USDA)'s Production, Supply, and Distribution (PSD) dataset was chosen for its completeness and consistency across countries. PSD data is compiled in part by USDA's Foreign Agricultural Service posts across the globe. Posts revise reported commodity balance sheets based on policy or trade changes, crop inspections, or new industry information. For the commodities tracked, estimates are typically reported and revised annually or on a more regular basis, depending on the size and volatility of the market. Post expectations are revised with input from USDA commodity analysts and compiled by the World Agricultural Outlook Board of the USDA.

The data categories selected for use were the three most consumed meat types- USDA's "Meat, Beef and Veal" (referred to as "beef" in this paper), "Meat, Swine", and "Meat, Chicken". The PSD dataset began reporting "Meat, Chicken" as its own category in 1999 and stopped reporting "Poultry, Meat, Broiler" in 2016. Because of this change in data collection, the historic time period used was determined to be 1999-2021 based on the availability of data that was consistent across collection, time, and location. Though this data is originally reported in 1,000 MT, it is converted into pounds/million pounds for this paper for ease of comparing per capita level trends (see Table 4 for an example represented by the data for the United States).

The dataset includes those countries for which data was available for each meat category for each year of the time period. While this dataset is relatively representative of the world, it is not whole. Over 90 percent of 2021 total consumption recorded by the USDA is represented by the data available, but unfortunately some influential countries were not able to be included in the model due to their lack of complete data such as Pakistan, Turkey, and Nigeria. Trade challenges, lack of domestic government statistical infrastructure, conflict, and even a country's diplomatic relations with the US can impact the ability of accurate commodity balance sheet reporting in any given year. Unfortunately, this means that the data is skewed towards more economically- and politically-stable states. Countries with less informational and trade infrastructure or enough safety and stability to host an American agricultural attaché are the ones less likely to have a complete period of consumption in the USDA dataset and are therefore less likely to be included in the model. This self-selection tends to be symptomatic of lower categories of economic development.

One additional note regards the way that the European Union is recorded and referred to. At the end of 2020, the United Kingdom severed trade ties with the EU. The USDA PSD database did not split the United Kingdom from the data label 'European Union' until December 2022, after the data for this thesis was obtained. For ease of terminology and consistency, projections past this point will continue to be calculated as the EU+ UK but referred to as the EU.

Table 4: Example of Consumption Data, United States

				Per Capita		
Year	Beef, Million lbs	Chicken, Million lbs	Pork, Million lbs	Beef, lbs	Chicken, lbs	Pork, lbs
1999	27,177	24,978	18,932	97.39	89.51	67.85
2000	27,567	25,615	18,641	97.70	90.78	66.07
2001	27,234	25,834	18,513	95.57	90.65	64.97
2002	28,085	27,483	19,148	97.64	95.55	66.57
2003	27,210	28,087	19,444	93.79	96.82	67.02
2004	27,931	29,139	19,453	95.39	99.52	66.43
2005	27,924	30,012	19,095	94.49	101.56	64.62
2006	28,297	30,504	19,058	94.83	102.23	63.87
2007	28,290	30,308	19,768	93.92	100.61	65.62
2008	27,342	30,043	19,433	89.91	98.80	63.90
2009	26,974	28,954	19,874	87.93	94.38	64.78
2010	26,517	30,134	19,082	85.73	97.42	61.69
2011	25,668	30,552	18,383	82.38	98.06	59.00
2012	25,878	29,858	18,612	82.45	95.13	59.30
2013	25,596	30,603	19,106	80.98	96.83	60.45
2014	24,786	31,384	18,840	77.85	98.57	59.17
2015	24,861	33,659	20,597	77.51	104.94	64.22
2016	25,746	34,200	20,895	79.69	105.86	64.67
2017	26,575	34,896	21,038	81.74	107.33	64.71
2018	26,859	35,688	21,492	82.18	109.19	65.76
2019	27,362	36,828	22,196	83.34	112.17	67.60
2020	27,631	37,472	22,125	83.86	113.73	67.15
2021	28,043	37,745	21,821	84.63	113.91	65.85

4.2.2 Population Data

The historic and projected population data was obtained from the World Bank. The World Bank's Development Data Hub compiles global data from internationally-recognized official sources and offers complete and consistent population data across borders. The metric used here is total population- per capita calculations included in this model give no regard to consumer age, sex, or rural/urban location. The model sample of countries is expected to grow by 4.2 percent to reach 5.0493 billion people from 2022-30, a rate slightly less than that of the entire world.

Omissions of note in the model due to lack of data include Indonesia (expected to be the fourth most-populous country in the world by 2030) and Nigeria (expected to be the fifth most-populous country by 2030 and the third by 2050), and other population growth regions Pakistan and Ethiopia.

Table 5: Example of Population Data, United States

Year	Population
1999	279,040,000
2000	282,162,411
2001	284,968,955
2002	287,625,193
2003	290,107,933
2004	292,805,298
2005	295,516,599
2006	298,379,912
2007	301,231,207
2008	304,093,966
2009	306,771,529
2010	309,327,143
2011	311,583,481
2012	313,877,662
2013	316,059,947
2014	318,386,329
2015	320,738,994
2016	323,071,755
2017	325,122,128
2018	326,838,199
2019	328,329,953
2020	329,484,123
2021	331,353,000
2022	333,207,000
2023	335,044,000
2024	336,869,000
2025	338,688,000
2026	340,500,000
2027	342,296,000
2028	344,071,000
2029	345,825,000
2030	347,562,000

4.2.3 Income Data

This model uses per capita gross domestic product (GDP) as a measure of individual incomes. GDP measures the monetary value added by all goods and services finished in a country's borders, regardless of who they are produced by. This means that this gauge can be slightly skewed for countries with large amounts of foreign investment or insulated from smaller moves in monetary distribution since it is calculated at such a high level. Since it is such a broad aggregate measure of the economy, however, it is consistent and immediately available for even the most recent years.

IMF data was used for this analysis. The source was chosen for the completeness and consistency across borders and demographics available to an international organization. In addition, since it is the IMF's function to facilitate global financial stability, it is able to provide the most up-to-date reports and projections. This was particularly relevant when considering the ongoing circumstances of the global COVID-19 pandemic. The IMF estimates per capita GDP projections in current USD until 2026 for each country. The IMF only provides projections five years out, so in order to complete longer future projections desired for the model, the remaining years were estimated using a linear regression using both historical income levels and the IMFs existing projections.

Table 6: Example of Income Data, United States

Year	GDP per capita, current prices (U.S. dollars per capita)
1999	$ 34,495
2000	$ 36,318
2001	$ 37,101
2002	$ 37,971
2003	$ 39,412
2004	$ 41,630
2005	$ 44,026
2006	$ 46,214
2007	$ 47,869
2008	$ 48,283
2009	$ 47,008
2010	$ 48,403
2011	$ 49,829
2012	$ 51,563
2013	$ 53,072
2014	$ 55,025
2015	$ 56,849
2016	$ 58,017
2017	$ 60,106
2018	$ 63,056
2019	$ 65,254
2020	$ 63,416
2021	$ 68,309
2022	$ 71,896
2023	$ 74,130
2024	$ 76,362
2025	$ 78,660
2026	$ 80,959
2027	$ 78,617
2028	$ 80,258
2029	$ 81,898
2030	$ 83,539

4.2.4 Price Data

Because the model will be built on the idea of income-related demand, it is natural to consider the inclusion of a factor to represent domestic consumer prices. Ideally, this would be reflected in the model as the average retail price that a consumer in each individual country would pay for each individual meat type each year. However, this data is sparse and difficult to come by and further complicated by differing exchange rates, food inflation rates, regional and quality differences in meat products, and the lack of incentive for countries to share these proprietary numbers. Few reputable sources attempt to report price rates for meat types and a publicly available dataset that fit the completeness and time period requirements of this model does not exist. Other attempts to model meat consumption at a global level have run into the same issue. One paper consulted (Schroeder, Barkley, and Schroeder) used trade-weighted import prices from a trade yearbook. Information that would allow an approximation of price in the same manner was not publicly available for a significant number of countries or complete through the COVID-19 pandemic (2020-21). In lieu of actual retail prices, benchmark prices for the entire globe were used here. These were determined by the largest single market of a given commodity in the most common (by volume) cut or preparation of each meat type. For beef, the US import price of CIF Australia/New Zealand 85 percent lean beef fores was used; for swine meat, the US price of 51-52 percent lean hogs; and for chicken, the US price (Georgia docks) for whole iced chickens. All prices were pulled from the IMF's Primary Commodity data system in terms of current USD.

Using prices from single (albeit large) export-import market is not wholly indicative of the prices or price changes consumers might face in their own country, but it is an approximation of larger price shocks in the global system. Two of the markets used are American so it would be expected that the U.S. would have the strongest correlation between global market prices and domestic prices. Using available retail price data for the US found a correlation of 0.53 for the pork prices, 0.94 for beef, and 0.88 for chicken. There could be differences expected for countries that do not engage with the global meat market at significant levels, have domestic protectionist or price support policies, or have tariffs levied against them.

Table 7: Meat Commodity Price Data, current $/lb

Year	Pork	Beef	Chicken
1999	0.44	0.83	0.60
2000	0.59	0.88	0.59
2001	0.61	0.97	0.64
2002	0.47	0.95	0.63
2003	0.53	0.90	0.66
2004	0.71	1.14	0.76
2005	0.68	1.19	0.74
2006	0.64	1.16	0.69
2007	0.64	1.18	0.78
2008	0.65	1.21	0.85
2009	0.56	1.20	0.86
2010	0.74	1.52	0.86
2011	0.89	1.83	0.87
2012	0.83	1.88	0.94
2013	0.87	1.84	1.04
2014	1.03	2.24	1.10
2015	0.68	2.00	1.15
2016	0.62	1.78	1.11
2017	0.68	1.92	1.26
2018	0.62	1.84	1.31
2019	0.65	2.10	1.19
2020	0.58	2.00	0.99
*2021	0.89	2.15	1.15

*Jan-October average

4.2.5 Selection of Countries for Inclusion in Model

Twenty-six countries are included in this model: Angola, Argentina, Australia, Belarus, Brazil, Canada, Chile, China, Colombia, the EU, Guatemala, Hong Kong, India, Japan, Kazakhstan, Korea, Malaysia, Mexico, North Macedonia, Philippines, Russia, Saudi Arabia, South Africa, Ukraine, the US, and Vietnam. In cases where a country did not eat any of a type of meat for religious or cultural reasons, the country was still included in the dataset but removed from the calculation in order to avoid taking the log of a zero. Malaysia, India, and Saudi Arabia were removed from the pork calculation due to their negligible consumption. The per capita consumption models for beef and chicken use 598 observations and the pork model 529.

The population of these countries represents 62 percent of the global population in 2021. There are two countries from Africa, five from South America, eleven from Asia, four from Europe (including Russia and the EU bloc as a single entity), three from North America, and Australia.

Zero low-income countries, five lower-middle income countries, 12 upper-middle income countries, and nine high income countries (the EU was considered high income for the purpose of classification here, though the World Bank only assigns classifications to its individual members) had enough recorded consumption data to be included in this model. This skews the sample slightly more towards high and upper middle-income countries and away from low-income countries (zero percent in the sample and nine percent in the global population).

4.2.6 Selection of Meat Types for Inclusion in Model

One of the difficulties of developing a meat consumption estimate at the global scale rather than by individual country is accounting for non-quantifiable differences in cultural or religious preferences for meat consumption. For this analysis, the three most consumed meat types were chosen- beef, pork, and chicken. Most other forecasts attempting to answer similar questions similarly use only three meat types. However, it is of note that the areas most affected by the omission of fish and seafood, sheep, and goat meat are Southeast Asia, South Asia, and the MENA region.

4.3 Per Capita Consumption Model Performance

Again, the model and analysis constructed in this thesis is intended to be more useful in projecting shift in demand based on income rather than actual levels of demand due to the data constraints. The model represents a trendline of possible results and does not account for additional economic movements outside of the scenario manipulations. Since lower-income countries are both more vulnerable to shocks (civil unrest, collapse or degradation of institutions, currency devaluation, recovery from large-scale natural disasters) and have higher income-consumption elasticity responses, these countries are more likely to vary from actual observation ex-post compared to more stable higher-income countries.

Table 8: Chicken Regression Coefficients

	Estimate	Standard Error	Significance
Intercept	-14.56930425	0.966692763	1.10886E-43
Price of Beef	0.197048346	0.203846187	0.334112701
Price of Pork	-0.304861344	0.149285342	0.041580393
Price of Chicken	-0.174678186	0.232516615	0.452800537
Income	3.670689236	0.215257929	2.44873E-53
Income Squared	-0.180814211	0.01201545	1.42304E-43

When estimating the chicken equation, each of the income variables and the intercept are significant with an adjusted R-squared of .64, meaning that 64 percent of the variability in chicken consumption can be explained by the model.

Table 9: Pork Regression Coefficients

	Estimate	Standard Error	Significance
Intercept	1.733136864	1.438573972	0.666707643
Price of Beef	-0.005345118	0.303351624	0.96114622
Price of Pork	-0.113910148	0.222157459	0.503651924
Price of Chicken	0.087101995	0.346017228	0.799698604
Income	0.08450591	0.320333891	0.355272603
Income Squared	0.012423264	0.01788067	0.878097839

When estimating the pork equation, none of the price or income variables are significant with an adjusted R-squared of .27, meaning that 27 percent of the variability in pork consumption can be explained by the model. This is the least fit estimation of the three meat types. Several non-income factors constrain pork consumption at the global scale. Religious and cultural preferences play a large role in pork consumption and there were large changes in supply from 2018-2021 due to the outbreak of African Swine Fever in China. Additionally, while pork is the most-preferred meat type in most countries, several high meat-consuming countries (largely the United States) have displayed stronger consumer preference for chicken over pork and the addition of pork to the diet is slower than for other meat types in several Latin/South American lower-middle income countries in the dataset compared to their near-peers in Asia.

Table 10: Beef Regression Coefficients

	Estimate	Standard Error	Significance
Intercept	-10.77221308	1.460378237	5.52352E-13
Price of Beef	-0.389249195	0.307949482	0.20672627
Price of Pork	-0.143151007	0.225524669	0.525838951
Price of Chicken	-0.389784364	0.351261763	0.267592141
Income	2.674869339	0.325189147	1.23691E-15
Income Squared	-0.120697706	0.018151685	6.69738E-11

When estimating the beef equation, each of the income variables and the intercept are significant with an adjusted R-squared of .44, meaning that 44 percent of the variability in beef consumption can be explained by the model. Beef is the least-consumed meat type and consumed mostly in North and South America and at higher income levels. While the fit of this estimation is not as good as that of the chicken regression, beef consumption is still responsive to changes in incomes and meat commodity prices.

Because the scenario comparisons are interested in future expectations, when comparisons are made across the entire period, forecasts are built off of the last year of available consumption (2021). However, it is worth noting that because a forecast based on elasticities will depend heavily on the previous year that errors will permeate in a single direction as time progresses.

Table 11: Percent Difference in Model Projections from USDA PSD Estimations, 2022

	Chicken	Pork	Beef
Angola	-0.58%	-4.32%	-2.68%
China	3.62%	0.70%	3.17%
European Union	-1.18%	0.64%	0.40%
US	-1.65%	1.19%	-2.25%
Vietnam	-1.23%	-0.50%	0.20%

The model is constrained from predicting meat consumption for the entire globe due to lack of data. Although the intent of this thesis is not necessarily to precisely predict demand over the time but rather to project shifts in demand under certain income conditions, Table 10 above provides a glimpse at the alignment of the projection model with USDA's domestic consumption expectations (as of March 2022) for the year 2022. This table uses the volume of each meat type calculated after the per capita consumption projections are recombined with population data (see below) for comparison. USDA numbers are adjusted throughout the year in response to current events (see "Consumption Data" in the previous chapter) so this is not a perfect comparison, but this table demonstrates that model projections fall within in a reasonable threshold.

4.4 Limitations of Income Elasticity

Table 12: Income Elasticities at Various Income Levels

	Chicken	Pork	Beef
$ 3,181.60	.75	.34	.73
$ 7,428.40	.45	.34	.52
$ 13,964.02	.22	.35	.37
$ 41,743.87	-.27	.35	.11
$ 83,538.52	-.42	.36	-.06

The model allows income elasticity to vary by income level. Table 11 shows the income elasticity for each meat type for each of the quartile breaks for 2030 expected income levels. The model does not account for any other consumer preference in meat consumption beyond the relationship with income. As decreasing income elasticities for each meat type suggest, there are limits or constraints to meat consumption at higher incomes. These are likely to vary between countries and over time and are very difficult to quantify.

In this model, income elasticities for chicken and beef begin to shift negative at the highest levels of income. Using the United States (the highest per capita GDP country in the dataset) as an example, chicken, beef, and total meat consumption all peak in 2021, declining incrementally afterwards. As described above, the relationship between pork consumption and income is the weakest of the three meat types due to unquantifiable factors such as religion or animal health-related supply issues. However, consumer preference in the US is more likely to favor poultry over pork unlike much of the world (Haley, 2001; Mitchell, 2004; Zeng et al, 2019). The trend before 2021 in the United States slightly favored replacing beef with chicken- rather than pork- in the makeup of the diet, though this was as total meat consumption continued to increase.

The deviation from historic consumer preferences conveys some of the limitations of using income elasticity and indicates other non-income factors in the mix, especially at high income levels. Given the impetus behind this thesis as noted in Chapter 1, these factors could be health or environmental, or even pandemic-related in the immediate past/future. Although Table 10 shows that the income elasticity relationship is a fairly accurate fit to the USDA PSD's 2022 expectations, there are no doubt additional confounding non-income variables that will likely increase over both time and income levels.

4.5 Projection Model

The per capita consumption model described above produces an estimation of per capita consumption based on per capita income using an income elasticity. Based on the projected changes in income each year, the corresponding changes in per capita meat consumption were calculated (using actual consumption in 2021 as the base year) for years 2022-30. To get the most accurate picture of the impacts of both population and income growth on meat demand, the projections for per capita consumption were then multiplied by the projected population for each year/country. The output is the total volume of each meat type demanded by a country for each year 2022-30.

4.6 Scenario Selection

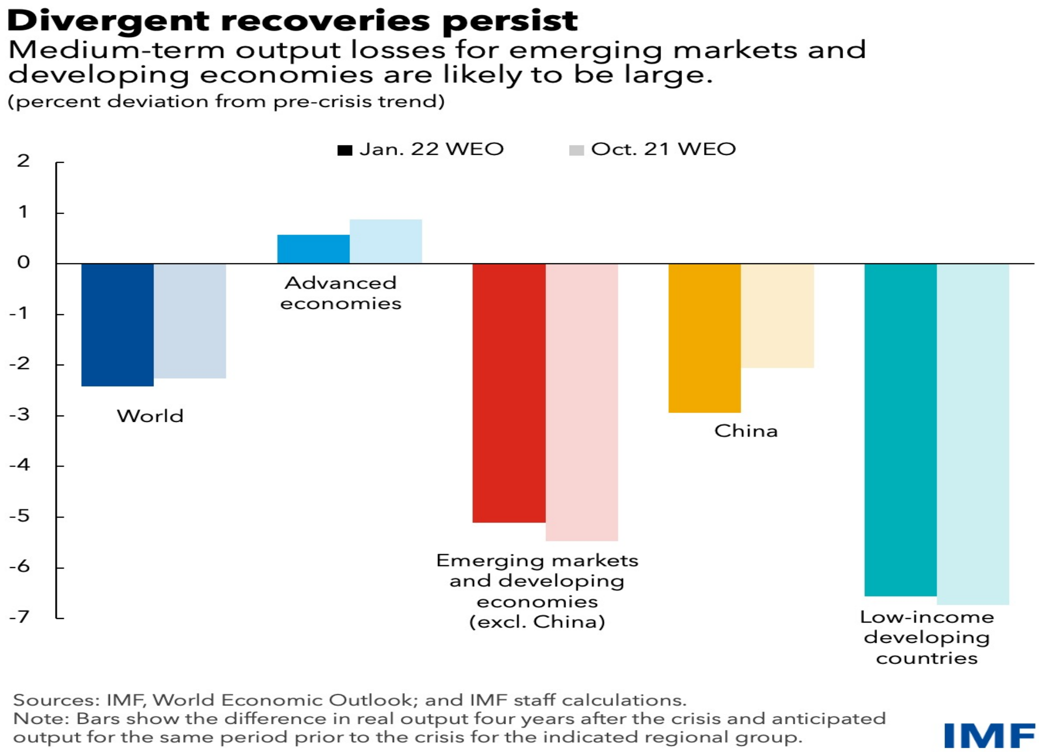
Having developed a baseline projection of the volume of meat demanded for each of the 26 countries for years 2022-30, the next objective of this thesis is to use the model to explore the impacts of different possible income scenarios on meat demand in the next decade. The scenarios included in this analysis use the projection model to understand how changes in income level could alter the volume, location, and composition of meat demand from 2022-2030. Several of the papers mentioned in the literature review that consider multiple scenarios utilized the United Nations Intergovernmental Panel on Climate Change's (IPCC) long-term Shared Socioeconomic Pathways that lay out possible global population, income, and greenhouse gas emissions to 2050. Ostensibly, the IPCC storylines delineate different socioeconomic outcomes in 2050 based on how aggressively climate policy is adopted. However, since the analysis here is concerned with a much shorter window and will not take into consideration changes in population or supply, employing these storylines was not appropriate. Instead, simple situations were chosen based on current events to reflect realistic potential economic situations. Each scenario was selected to represent a pattern of potential recovery that the world could face as the economic constraints of the COVID-19 pandemic lockdowns begin to recede. The scenarios are applied at the global level and represent large-scale economic shifts.

Scenario 1 was designed to represent a "best case" for global economic conditions. A five percent increase of income was applied as an estimate of greater and quicker than expected recovery for all years in the projection period (2022-30) and all countries. In real terms, five percent is a higher than average expectation for a country's annual total GDP growth for 2022, though 2021 was an admittedly low baseline for increase ("Global Economic Prospects" 2022). As economic recovery from lower levels in 2020-21 decelerates, 5 percent increases would represent very strong global economic conditions. The output of this scenario will help reveal where 'room for growth' in global meat consumption originates and the extent that increased incomes will impact the total volume of meat demanded by the world. Since the model allows income elasticities to vary across income levels, this scenario will help model the disparity between established high-income, high-per capita consumers and high-income growth, low-per capita consumers and help identify which will be dominant in driving meat demand in the near future. Since the income elasticities derived by the per capita consumption model are also allowed to decrease at higher incomes, this scenario will be the best illustration of any countries approaching peak meat if meat consumption decreases even as incomes rise to higher levels.

Scenario 2 hypothesizes the converse of Scenario 1. A negative outlook is applied in the form of a five percent decrease in income from the baseline level for all countries from 2022-2030. This represents a pessimistic view of economic recovery and will illustrate how a decline will affect the countries with the highest income elasticities, and what role high income countries will play in total meat demand as their per capita consumption becomes less responsive to increases in income.

Scenario 3 imagines a slightly more complicated global economy. After the initial data collection for this thesis, the IMF released revised global GDP expectations for 2022. While it did not revise per capita projections in time for inclusion in this analysis, the organization did release details about why it was revising its economic expectations and why the need for the update is cause for concern. In late January 2022, the IMF cited pandemic-related reimposed mobility restrictions, high inflation, energy costs, and (specifically) retrenchment in China's property sector. While the IMF cited adjustments in the world's two largest economies (China and the US) in its half-point revision of growth down to 4.4 percent, it notes one additional dynamic that is not captured by either of the previous economic scenarios.

Figure 4: IMF Expected Divergence in Post-Downturn Economic Recovery



A deviation in economic expectations occurs between developed and developing countries. As seen in the IMF-published figure included above, while percentage growth is expected to be positive, global economic output is still expected to be lower in the medium-term than before 2020 ("A Disrupted Global Recovery"). Particularly relevant to this analysis is that emerging and developing economic recovery is significantly lagged behind that of developed economies. At present, this is due to lower vaccination rates and less aggressive monetary policy support in these countries. In order to reflect this shift and add some differentiation to the system-wide model approach, Scenario 3 was designed to split economic trends between developed and developing economies. The conditions applied increase HICs income by five percent while decreasing upper-middle and lower-middle countries' income expectations by 5 percent at the same time. For the purpose of this analysis, upper-middle income countries were included in the downward expectations in order to more cleanly divide similarly-consuming countries by high volume per capita consumption and high per capita consumption growth.

4.7 Summary

This chapter details the quantitative approach selected to answer the research question of this thesis. By determining the income-consumption relationship for each meat commodity at the per capita level and then reintroducing the population effect at the global scale, the model can be employed to understand the potential impacts of economic changes at the same level. The extent to which the income-based model can be used to accurately reflect changes in per capita consumption is also discussed. The next chapter will present the results of the projection model and the application of the income scenarios.

CHAPTER 5: RESULTS

In order to test how global meat consumption might respond to potential income scenarios in the next decade, various conditions were applied to the projection model. The baseline scenario presented will use the post-pandemic recovery income growth rates from the IMF. This represents how meat consumption patterns could realistically be expected to behave in response to income until 2030 using the information available in 2022. Given that the historical time period used to develop the elasticities includes at least two major income shocks, it is reasonable to expect some continued uncertainty in the global economy over the next decade. To consider what economic developments at the global scale might imply for the future of meat consumption, three different scenarios representing optimistic, pessimistic, and diverging growth rates for per capita income are applied.

This section will be organized by providing a brief overview of total meat consumption response to each scenario and a description of how the global meat consumption system reacts to change. A more detailed breakdown by meat type and income classification for the baseline and each scenario will be provided next.

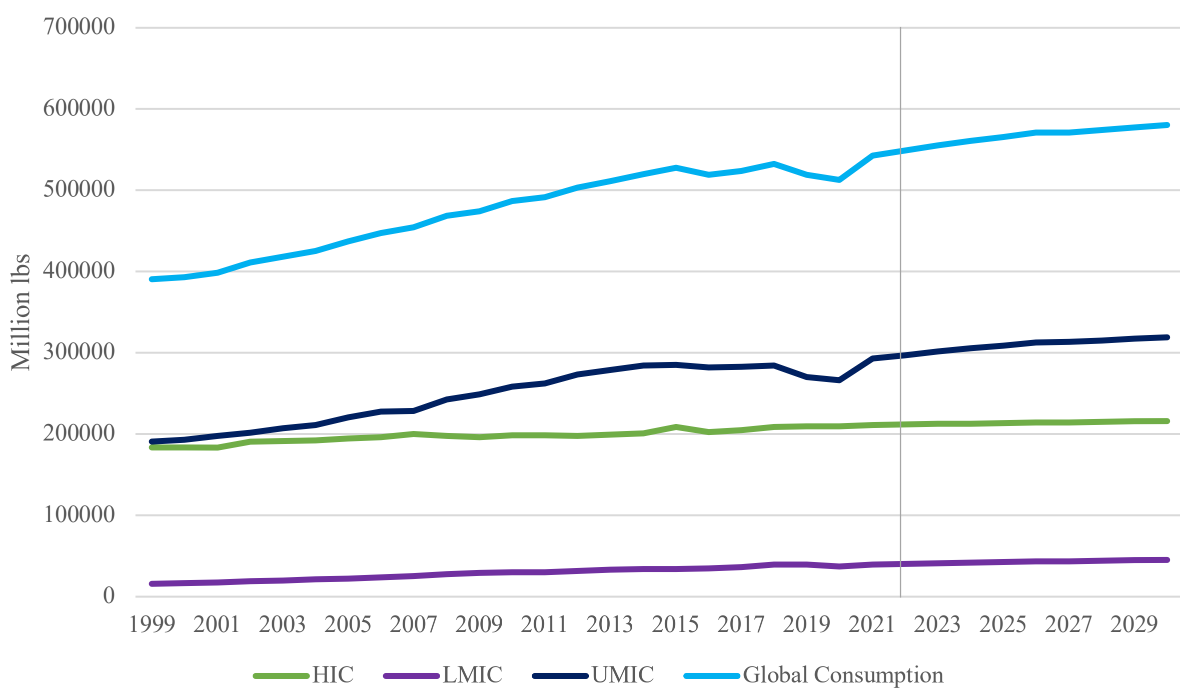
The goal of producing these results is to provide information to stakeholders about how and where demand is evolving. Accordingly, the presentation of the baseline projection and resulting scenarios will include growth rates, characterization of strong trends, information about how consumption shares are distributed between income levels over time, and brief discussion of outliers and growth hotspots. As the top consumers by volume, the US, EU, Brazil, and China will be mentioned specifically where relevant. As the low per capita consumption/high population/high income growth 'wildcard' of the top four meat consuming countries, China

represents the most uncertainty and is also the largest consumer. Accordingly, attention will be paid to China at the country level and its role in total consumption when important.

5.1 Baseline Projection

Using the elasticities developed from the historical income-per capita consumption relationship and the predicted income levels for each country, calculations would expect 6.91 percent (37,534 million pounds) more meat consumed by the world in 2030 than in 2021.

Figure 5: Historic and Projected Total Meat Consumption



Breaking growth down into income categories (Table 13), it is clear that LMICs and UMICs will dominate growth in meat consumption over the next decade. The large population and per capita consumption growth expected in lower-middle income countries results in 15.51 percent more meat consumed in 2030 than in 2021. Though not quite as drastic, upper-middle income countries are projected to consume 9.01 percent more meat in 2030 compared to their 2021 levels of consumption. High-income countries see much slower growth, only 2.41 percent.

Table 13: Projected Growth in Meat Consumption by Country, 2021-2030

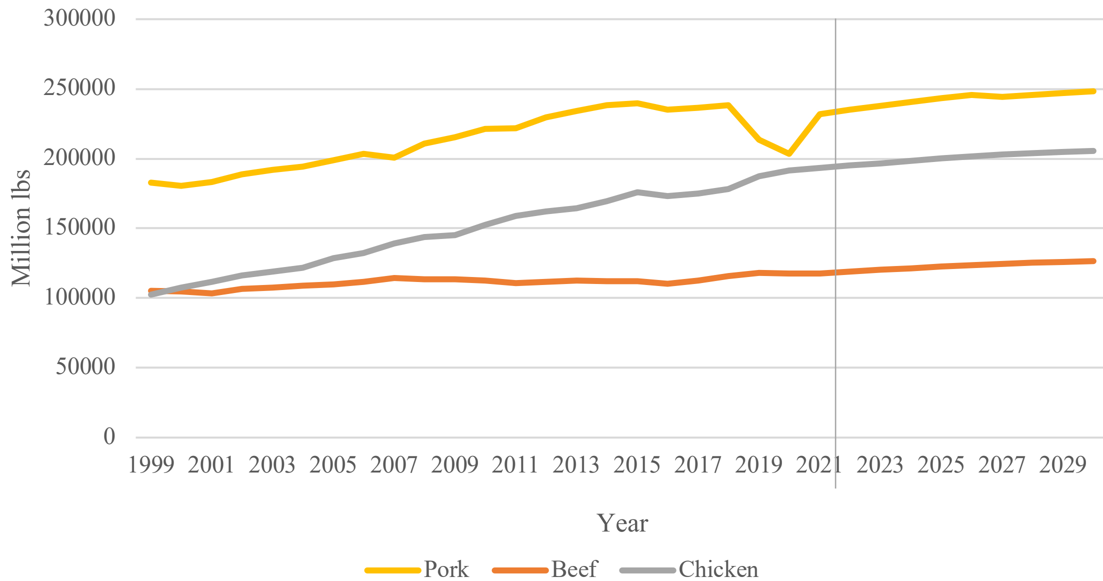
		2021	2030	Percent Change 2021-2030
HIC	Australia	5,460	5,870	7.51%
HIC	Canada	7,455	7,960	6.77%
HIC	Chile	3,815	3,995	4.73%
HIC	EU	76,866	77,347	0.63%
HIC	Hong Kong	2,423	2,602	7.36%
HIC	Japan	15,089	14,404	-4.54%
HIC	Korea	8,591	8,701	1.28%
HIC	Saudi Arabia	3,654	4,066	11.28%
HIC	United States	87,609	91,109	3.99%
HIC		**210,961**	**216,052**	**2.41%**
UMIC	Argentina	11,276	12,907	14.46%
UMIC	Belarus	1,841	1,937	5.22%
UMIC	Brazil	44,874	51,770	15.37%
UMIC	China	171,864	183,570	6.81%
UMIC	Colombia	6,600	7,447	12.85%
UMIC	Guatemala	1,230	1,521	23.60%
UMIC	Kazakhstan	2,366	2,731	15.41%
UMIC	Malaysia	4,267	4,870	14.14%
UMIC	Mexico	19,882	22,161	11.46%
UMIC	North Macedonia	196	204	3.70%
UMIC	Russia	21,616	22,150	2.47%
UMIC	South Africa	6,754	7,870	16.53%
UMIC		**292,767**	**319,139**	**9.01%**
LMIC	Angola	1,286	1,835	42.76%
LMIC	India	15,098	17,398	15.24%
LMIC	Philippines	7,967	9,532	19.65%
LMIC	Ukraine	4,739	4,870	2.78%
LMIC	Vietnam	10,048	11,572	15.17%
LMIC		**39,137**	**45,208**	**15.51%**
Total		**542,864**	**580,399**	**6.91%**

Table 14: Share of Total Meat Consumption by Country: 2021 and 2030

	2021		2030	
	Volume (million lbs)	Share of Total consumption	Volume (million lbs)	Share of Total Consumption
HIC	210,961	38.86%	216,052	37.22%
UMIC	292,767	53.93%	319,139	54.99%
LMIC	39,137	7.21%	45,208	7.79%

High income countries see a decrease in consumption share from 2021-2030 that is transferred to upper middle- and lower middle-income countries (Table 13). By percentage, the fastest rates of new growth will come from LMIC and UMIC countries in the MENA, South and Central America, Africa, and Southeast Asia regions (see Appendix A). The drivers of consumption by volume, however, will continue to come from UMICs and HICs like China, Brazil, the EU, and the US, followed by populous, relatively politically and economically stable countries: the Philippines, Mexico, Vietnam, and India. 31.18 percent of new growth from 2022-2030 will come from China. China will consume a slightly larger percentage of total meat consumption-still around 30 percent- but the US and the EU will consume relatively smaller shares of the world's meat. Under the baseline China consumes 2.01 times more meat than the United States, the next highest consumer.

Figure 6: Historic and Projected Meat Consumption by Type



The projection suggests that chicken consumption will increase 6.38 percent by 2030, while pork will increase 7.02 percent and beef will increase 7.58 percent. This scenario suggests that overall, the global diet composition of meat consumption between beef, pork, and chicken will remain consistent between 2021 and 2030, with slight increases in the share of pork consumption (<1 percent) eroding the roles of beef and chicken in the global diet (Table 14).

Table 15: Meat Type Share of Total Consumption, 2021 (Actual) and 2030 (Baseline Projection)

	2021	2030
Beef	21.63%	21.80%
Pork	42.91%	42.78%
Chicken	35.46%	35.41%

Table 16: Share of Meat Type Consumption by Income Category, 2021 and 2030

	Beef		**Pork**		**Chicken**	
	2021	2030	2021	2030	2021	2030
HIC	45.30%	43.36%	33.99%	33.08%	40.80%	38.46%
UMIC	47.56%	49.06%	60.96%	61.55%	49.37%	50.70%
LMIC	7.14%	7.58%	5.06%	5.37%	9.84%	10.84%

New consumption of chicken is the most widely distributed across the globe compared to the other meat types. Unsurprisingly, the top four consumers of chicken will continue to be the US, China, Brazil, and the EU. Brazil, India, China, and the Philippines will display the largest changes by volume in the amount of chicken consumed between 2021-2030, with the largest changes by percentage coming from Angola (43.66), the Philippines (21.68), Guatemala (24.39), and South Africa (16.77) (Appendix A).

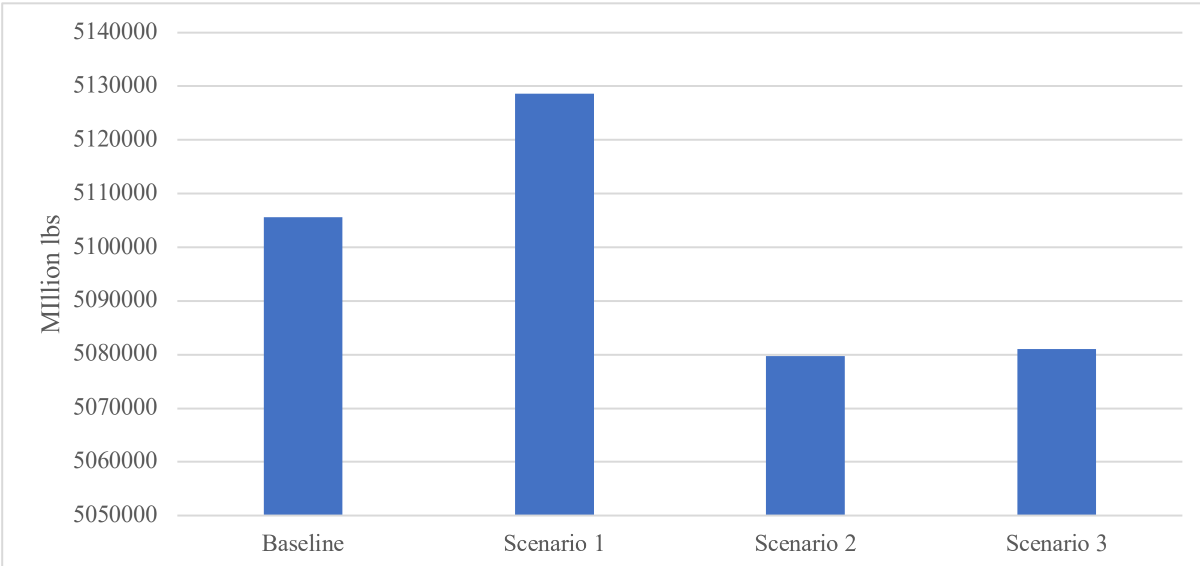
The pattern of pork consumption differs from the pattern of overall consumption, in part because of the role that religion and culture play in the different geopolitical regions. In the baseline scenario, China, the EU, US, and Russia will be the largest consumers of pork by 2030.

By percentage, the largest increases in growth will come from Angola (36.40), the Philippines (16.89), Guatemala (19.43), and Vietnam (14.10) and by volume, China, the EU, Vietnam, and the US. Notably, fewer of the newer/high growth rate markets for pork will come from MENA or Africa than for the other meat types, likely due to the strong influence of religious and cultural preferences. From a global perspective, the proportion of total pork consumed by the top four countries and the rest of the world will remain remarkably similar, although total pork consumption increases.

In 2030 the US, China, Brazil, and the EU will consume the most beef, but the largest changes in consumption by volume will come from Brazil, the US, China, and Argentina. By percentage, Angola (47.89), Guatemala (22.02), the Philippines (17.86), and Kazakhstan (17.10) will increase their consumption of beef the most from 2021 (Appendix A). The shares of total beef consumption comprised by each country will stay roughly the same, but with incremental decreases in the share of beef consumed by the currently top-consuming countries. This would indicate countries that don't currently consume large shares of beef will play a larger role moving towards 2030 and beyond.

5.2 Scenario Overview

Figure 7: Comparison of Global Meat Consumption, Total Meat Consumed 2022-30



Compared to the baseline, total meat consumption saw the greatest change under Scenario 2 (decreased incomes), suggesting that economic downturns will have a larger effect on global meat consumption than will additional growth. This could also be described as decreasing income elasticities at higher income levels. Pork saw the largest movements for any scenario and- having the largest change between 2021 and 2030 under the baseline- contributed most to the overall growth in total meat consumption. Because the model allows elasticities/consumption to vary over time, it is useful to compare total volume consumed over the entire period in order to best understand the role each income bracket will play over the next eight years (Figure 6). All following comparisons of Scenarios to the baseline will be in terms of meat consumed over the entire period 2022-30.

From a total global consumption perspective, it is clear that while HICs will continue to make up a large portion of global meat consumption by volume, they will be responsible for very little growth in consumption in the future. As incomes continue to rise, income elasticities fall or turn negative. The larger change under the decreased income conditions in Scenario 2 than for increasing incomes under Scenario 1 implies that at least some of the HICs are at or nearing peak meat consumption. Upper-middle income countries (including China) do make up most of the population in the dataset, but are disproportionately responsible for future meat consumption growth. As seen in Figure 6, they are also very responsive to changes in income conditions. This suggests that much of the future uncertainty in global meat demand as it relates to income will originate from the UMIC category. Lower-middle income countries are also very responsive to changes in income, but do not yet have the per capita consumption or population levels necessary to contribute to shifts as much as the upper-middle countries.

Figure 8: Change from Baseline by Income Classification, Total Meat Consumed 2022-30

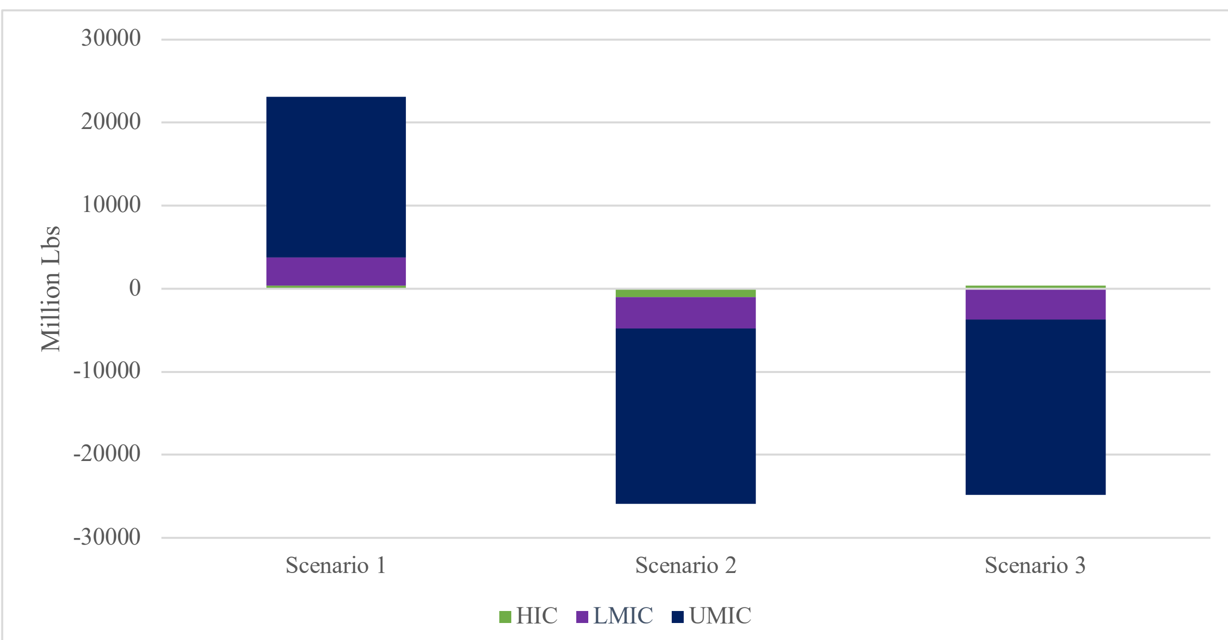


Table 17: Comparison of Volume of Meat Consumed, Baseline and Projected Scenarios, (Percent Change from Baseline) 2022- 30, Million lbs

	Baseline	Scenario 1	Scenario 2	Scenario 3
Total Meat Consumption	5,105,568	5,128,665	5,079,702	5,081,092
		(0.45%)	(-0.51%)	(-0.48%)
Chicken Consumption	1,808,644	1,810,857	1,805,029	1,795,942
		(0.12%)	(-0.20%)	(-0.70%)
Pork Consumption	2,187,889	2,204,350	2,170,746	2,181,250
		(0.75%)	(-0.78%)	(-0.30%)
Beef Consumption	1,109,036	1,113,458	1,103,927	1,103,901
		(0.40%)	(-0.46%)	(-0.46%)

More detail can be provided by looking at each meat commodity separately. The largest changes by percent are seen as consumers transition between meat types, especially to/from pork. Though some meat types begin to behave differently at higher income levels, all meat types increased and decreased overall respective to the according shifts in income conditions. This indicates that the income-consumption relationship will continue to be relevant in the future. Pork sees the largest changes in each direction while chicken sees the smallest for Scenarios 1 and 2.

5.3 Scenario 1: Increase in Income

In order to investigate the impacts of an increase in income, the incomes for the projected years were multiplied by 105%. Global meat consumption increases 7.36 percent from 2022 to 2030. Compared to the baseline, 0.45 percent (23,096 million pounds) more meat was consumed in total from 2022-2030 in this scenario.

Table 18: Comparing Scenario 1 to Baseline, 2022-30, Total Meat Consumption, lbs

	Baseline		Scenario 1		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	1,926,905	37.74%	1,927,260	0.02%	37.58%
UMIC	2,791,353	54.67%	2,810,641	0.69%	54.80%
LMIC	387,310	7.59%	390,765	0.89%	7.62%

Because income elasticity was allowed to vary at differing income levels, it would be logical to potentially see declining or lower per capita consumption levels for HICs compared to the baseline scenario. Under the assumptions that the model was created under, most of the gains would be expected to come from LMICs and UMICs in this scenario. This holds true; while most countries saw growth increase from the baseline scenario, other countries saw only minimal or negative gains from the baseline (see Appendix B for country-specific detail). Further corroborating the trends seen under this scenario is the breakdown of the share of global consumption. When incomes increase, the share of meat consumed by HICs can be expected to decrease. China extends its outlier status, consuming .64 percent more from 2022-2030 under the increased income scenario than the baseline, a difference of 10,444 million pounds. Under this scenario, China consumes 2.03 times more meat in 2030 than the US, the next highest consumer. This is a slightly larger margin than under the baseline.

Table 19: Comparing Scenario 1 to Baseline, 2022-30, Chicken

	Baseline		Scenario 1		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	708,833	39.19%	704,164	-0.66%	38.89%
UMIC	909,627	50.29%	914,514	0.54%	50.50%
LMIC	190,184	10.52%	192,179	1.05%	10.61%

0.12 percent more chicken was consumed by the world from 2022-2030 in this scenario compared to the baseline, or a difference of 2,213 million pounds. The US, China, Brazil, and the EU are still the top four chicken consuming countries in 2030, with the largest changes in volume between 2022 and 2030 coming from Brazil, India, China, and Mexico. Relative to the baseline, UMICs and LMICs are responsible for a larger share of the world's chicken consumption in 2030.

Table 20: Comparing Scenario 1 to Baseline, 2022-30, Pork

	Baseline		Scenario 1		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	730,098	33.37%	735,242	0.70%	33.35%
UMIC	1,342,941	61.38%	1,353,372	0.78%	61.40%
LMIC	114,850	5.25%	115,736	0.77%	5.25%

Pork consumption was 0.75 percent higher over the period 2022-2030 under this scenario compared to the baseline. This is a 16,460 million lb difference over 8 years. China, the EU, the

US, and Russia will be the largest consumers of pork in the world by 2030, similar to the baseline. Interesting, the shares of consumption remain fairly consistent, indicating that gains are widely distributed across the globe. The impacts of increased incomes (as determined by deviation from the baseline) will be most apparent by increased consumption in Belarus, China, Korea, and Vietnam. By volume, China, the EU, the US, Brazil, and Vietnam will see the largest increases in pork meat consumed from 2022-2030. Under this scenario, China remains the clearly dominant consumer and extends its lead even further. Under the baseline scenario, China consumes 2.93 times as much pork as the next closest country (in this case, a bloc: the EU)- a very significant gap of 739,780 million pounds between the two countries.

Table 21: Comparing Scenario 1 to Baseline, 2022-30, Beef

	Baseline		Scenario 1		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	487,974	44.00%	487,853	-0.02%	43.81%
UMIC	538,786	48.58%	542,755	0.74%	48.74%
LMIC	82,276	7.42%	82,849	0.70%	7.44%

Total beef consumption from 2022-2030 will increase 0.4 percent (4,442 million pounds) from the baseline under this scenario. Positive changes are, for the most part, incremental and occur outside the top four consumers (the US, China, Brazil, and the EU). These changes are offset by negative income/consumption relationships at very high incomes, which see beef consumption begin to decrease. This scenario supports the idea of 'peak meat' for beef, as consumption begins to decrease incrementally after 2021 for very high-income countries such as the US. Countries at higher incomes are also more likely to see decreasing population growth rates, implying overall decreases in volume consumed. From 2022-2030, this scenario predicts that lower middle- and upper middle-income countries will consume more of the world's beef, gains made up from decreases in the shares of the US and EU.

5.4 Scenario 2: Decrease in Income

Table 22: Comparing Scenario 2 to Baseline, 2022-30, Total Meat Consumption

	Baseline		Scenario 2		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	1,926,905	37.74%	1,925,870	-0.05%	37.91%
UMIC	2,791,353	54.67%	2,770,260	-0.76%	54.54%
LMIC	387,310	7.59%	383,573	-0.96%	7.55%

In this scenario, a five percent reduction was applied to all incomes. Total meat consumed from 2022-2030 is 0.51 percent less than in the baseline scenario. Every single country except the US and Australia decreased the total amount of meat consumed under this scenario relative to the baseline, though some more drastically than others. The largest negative responses to the decrease in income from the baseline to this scenario occur in countries that are just beginning to eat larger amounts of meat per capita. Angola, Colombia, Guatemala, the Philippines, South Africa, and Ukraine all see more than a 1 percent decrease in volume of meat consumed over the 2022-30 period in this scenario relative to the baseline (Appendix B). Several other countries see more than a .9 percent decline, in addition. The meat type that will be the most affected under this scenario will be the next most-telling metric as to how economic trends affect modern meat consumption. China's outlier status is eroded slightly (compared to both the baseline and Scenario 1) to consuming only 1.99 times more meat than the United States.

Table 23: Comparing Scenario 2 to Baseline, 2022-30, Chicken

	Baseline		Scenario 2		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	708,833	39.19%	713,252	0.62%	39.51%
UMIC	909,627	50.29%	903,788	-0.64%	50.07%
LMIC	190,184	10.52%	187,990	-1.15%	10.41%

0.20 percent less chicken was consumed from 2022-30 under the reduced-income scenario than the baseline. Considering that chicken meat is generally regarded as the most common and least expensive meat type for lower-income countries, it is not surprising that it sees less drastic changes than other meat types under reduced income conditions. There is also an interesting divergence present among consumers under this scenario. The chicken-income relationship inverts slightly at high levels of income. In this global model, chicken acts like a normal good at lower incomes and an inferior good at higher incomes: the EU and US actually see an increase in chicken consumed when incomes are reduced, likely due to substitution for more-expensive pork or beef. However, lower income countries such as Angola are likely not replacing their chicken consumption with a different type of meat but rather eating less meat altogether. As a rule, Southeast Asian, South/Central American, and African countries see the largest percent declines from the baseline. The four top consumers of chicken remain the same:

the US, China, Brazil, and the EU. In this scenario, the HICs (driven by the US and the EU) gain higher shares of consumption than they do in the baseline in 2030, with the redistribution coming from the rest of the world.

Table 24: Comparing Scenario 2 to Baseline, 2022-30, Pork

	Baseline		Scenario 2		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	730,098	33.37%	724,738	-0.73%	33.39%
UMIC	1,342,941	61.38%	1,332,079	-0.81%	61.37%
LMIC	114,850	5.25%	113,928	-0.80%	5.25%

In Scenario 2, 0.78 percent (17,142 million pounds) less pork was consumed by the system from 2022-2030 than under the baseline scenario. Every single country experienced a decrease in the amount of pork consumed under the imposed condition, with many countries seeing more than a 0.8 percent decrease from the baseline, including Belarus (0.90), China (0.83), Hong Kong (0.82), and Vietnam (0.88) (Appendix C). China still consumes the most pork by far and the gap between the next consumers is maintained under this scenario. The EU and the US, which saw increases in chicken consumption under this scenario, see decreases in pork consumption commensurate with the other countries. While lower- and middle-income countries also consume less pork than at the baseline, there are still large inconsistencies in the per capita amount of pork consumed at similar income levels between countries. This illustrates the large role that consumer preferences play in understanding pork consumption in particular.

Table 25: Comparing Scenario 2 to Baseline, 2022-30, Beef, Million lbs

	Baseline		Scenario 2		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	487,974	44.00%	487,879	-0.02%	44.19%
UMIC	538,786	48.58%	534,392	-0.82%	48.41%
LMIC	82,276	7.42%	81,655	-0.75%	7.40%

The conditions of Scenario 2 bring a 0.46 percent decrease in beef consumption compared to the baseline. This is less than the decrease seen in pork consumption, but still a larger percent reduction than is seen in chicken consumption. The United States and Australia (both around $80,000 per capita GDP) are the only countries to see an increase in beef consumption under more-pessimistic economic conditions, indicating that the income level for peak beef consumption is somewhere in that range. Beef is consumed more (by volume and per capita) by higher income countries, meaning that the average elasticity response per person is less than for other meat types. This follows the assumptions established in the background chapter of this work; beef, as the most expensive meat type, has consistently the highest income elasticity. Accordingly, the shifts in share of market are minor, with HICs gaining some market share due to the more-drastic consumption decreases in LMICs and UMICs. The four top-consuming countries remain the US, China, Brazil, and the EU.

5.5 Scenario 3: Deviation in Income Growth

Scenario 3 provides a bit more nuance than applications of a blanket increase and decrease. The IMF reports that it expects much of global income growth in the years immediately following COVID-19 recovery in 2021 to come from advanced economies, while developing and lesser-developed countries will continue to lag. In this scenario, a 5 percent reduction is applied to the baseline per capita incomes for LMICs and UMICs. However, the 5 percent increase seen in Scenario 2 is applied only to HICs in Scenario 3 to represent the gains in the countries where meat consumption is more insulated by shocks to income (given lower elasticities).

Table 26: Comparing Scenario 3 to Baseline, 2022-30, Total Meat Consumption

	Baseline		Scenario 3		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	1,926,905	37.74%	1,927,260	0.02%	37.93%
UMIC	2,791,353	54.67%	2,770,260	-0.76%	54.52%
LMIC	387,310	7.59%	383,573	-0.96%	7.55%

Meat consumption decreased 0.48 percent from the baseline in Scenario 3. Under the scenario conditions, the balance of global meat consumption shifts. Though Scenarios 1 & 2 demonstrate the changes in meat consumption corresponding to increases and decreases in expected income, Scenario 3 presents a system-wide approach to non-congruent economic environments. Under this split scenario, meat consumption across the system is 0.03 percent more than Scenario 2 and 0.93 percent less than Scenario 1 over the period 2022-30. The resulting dynamics indicate the role that the major large, developed consumers have yet to play in future meat consumption patterns. It is clear that a divergence of economic storylines will have the large impacts on the physical distribution of meat consumption/trade. China consumes 2.00 times as much meat as the next top-consuming country (the US) under Scenario 3.

Table 27: Comparing Scenario 3 to Baseline, Chicken, 2022-30, Million lbs

	Baseline		Scenario 3		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	708,833	39.19%	704,164	-0.66%	39.21%
UMIC	909,627	50.29%	903,788	-0.64%	50.32%
LMIC	190,184	10.52%	187,990	-1.15%	10.47%

In the model, chicken consumption decreases overall 0.70 percent (12, 701 million pounds) from the baseline, the largest change from the baseline for chicken between all three scenarios. This again confirms that chicken behaves differently in response to income in HICs compared to UMICs and LMICs. Minor gains in consumption share are shifted away from LMICs towards UMICs and HICs, despite overall decreases in chicken consumption.

Table 28: Comparing Scenario 3 to Baseline, 2022-30, Pork

	Baseline		Scenario 3		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	730,098	33.37%	735,242	0.70%	33.71%
UMIC	1,342,941	61.38%	1,332,079	-0.81%	61.07%
LMIC	114,850	5.25%	113,928	-0.80%	5.22%

Pork consumption sees a smaller percentage decline than chicken at only 0.3 percent (6,639 million pounds) less consumption from 2022-30 under Scenario 3 than the baseline. The difference in movement between pork and chicken under this scenario comes from increased consumption of pork in HICs when incomes rise, signifying that there is still room for per capita pork consumption growth among these countries. However, these gains are not large enough to offset the decrease in pork consumption under reduced income conditions in LMIC, and UMIC countries. In terms of market share advanced economies gain slightly. The top-consuming countries under the baseline retain their spots, but the distance between them narrows. Although China remains the largest consumer of pork by a large margin, that margin narrows under this Scenario.

Table 29: Comparing Scenario 3 to Baseline, 2022-30, Beef

	Baseline		Scenario 3		
	Volume, 2022-2030	Share of Consumption, 2030	Volume, 2022-2030	Change from Baseline	Share of Consumption, 2030
HIC	487,974	44.00%	487,853	-0.02%	44.19%
UMIC	538,786	48.58%	534,392	-0.82%	48.41%
LMIC	82,276	7.42%	81,655	-0.75%	7.40%

Consumption of beef over the period decreased .46 percent from the baseline under the diverging economic scenarios of Scenario 3. This results in the most negative scenario yet for beef consumption subject to decreases from both decreased incomes for consumers that treat beef like a normal good and increased incomes those that treat it like an inferior good. Scenario 3 sees less than a 0.01 percent decrease beef consumption than in Scenario 2 (all incomes decrease), but .86 percent less beef consumption than under Scenario 1. Shares of consumption still stay relatively constant with only small gains awarded to HICs. The top four beef-consuming countries (the US, China, Brazil, and the EU) stay the same as under the baseline scenario.

CHAPTER 6: DISCUSSION

The scenario-testing of the model implies several broad ideas about the future of meat demand. First, as is expected by most other projections, meat consumption will continue to increase over the immediate future, slightly less than 1 percent a year. This is in line with other global meat consumption projections for the entire globe (OECD/FAO, 2020). The application of the optimistic and pessimistic income scenarios shows that most of the global growth will come from a combination of per capita growth and population growth in lower-middle and upper-middle income countries, but also that these countries are the most impacted by changes in incomes. Economic fluctuations are inevitable, from conflict to currency devaluation. However, LMICs (and some of the UMICs, to a lesser extent) are most susceptible to both increases and decreases in incomes due to their higher income elasticities. There is also another factor dually impacting changes in consumption growth in these countries; as centers of rapid population growth and the largest shares of the global population, even minor changes permeate across a very large issue. China continues to be the dominant player in both growth and absolute volume. Again, even minor changes will play out in the largest population to massive results. Though the increases and decreases resulting from the manipulation of China's income are small in percentage, they represent millions of pounds of meat and the resources need to produce it. Countries such as China (India, the Philippines, Angola) with lower per-capita consumption levels but large or growing populations will be the 'wildcards' of future meat consumption. Though they each see significant growth in consumption under the scenarios in the model (either by volume or percentage), each still has markedly lower per capita consumption levels than those attained by high income, high per capita consumption countries like the US or EU. While the model indicates that the response to income changes in the lower per capita/income countries is substantial, the incredibly vast potential for growth in these countries and complicated economic and political systems in some of these countries leaves much room for uncertainty. The amount of market share these countries can (would) hold and the absolutely enormous resource allocations it would take to supply the demand for meat from these countries at levels similar to those of HICs would have to engender radical changes in the way the world allocates resources. Though the model was designed with the assumption of 'peak meat' and the results and elasticity patterns support it, whether every country in the world can reach a peak as high as that seen in the US is very uncertain. In the future, additional factors (resource constraints, diet, culture in some major countries) is likely to play more of a role in determining when other countries' per capita consumption has peaked.

Another characterization of future meat consumption illustrated by the model is the lack of growth share of HICs as meat begins to act more like an inferior good at higher income levels. Again, this is evidence of the peak meat assumption and is illustrated in the model results as lower chicken and beef consumption under the increased income conditions (Scenario 1, 3). Until 2030 in the model, consumption in HICs are still growing and responsible for much of the total volume consumed under each scenario, but their moderate-to-small growth rates indicate that this will not always be the case. As developing economies increase their per capita incomes, per capita meat consumption, and volume of meat demanded they will play a much larger role in meat demand as HICs begin to play a smaller role in future growth.

Meat consumption is changing, and accordingly meat production, imports, and exports will need to change too. The biological nature of agricultural production makes it even more necessary (and difficult) to anticipate shifts in supply and demand in advance. Though the percentage changes identified in the results chapter may seem minor, the changes in volume demanded and corresponding resource needs are anything but minimal or trivial. For example, the 0.75 percent increase in pork consumption under Scenario 1 means that 16,460 million pounds more pork will be needed, and, using a (very conservative) carcass-yield FCR estimate of 5:1, at least 82,450 million pounds more feed over the 8-year period (in addition to the baseline scenario) will be needed to support increased pork consumption. For most countries, producing significantly more livestock or feed to support their growing consumption habits is simply not a competitive use of limited resources, meaning that they will turn to trade.

Table 30: Imports as a Percentage of Meat Consumption, 2021

	Chicken	Pork	Beef
Angola	89.2%	23.7%	11.2%
Argentina	0.5%	5.8%	0.4%
Australia	0.1%	33.9%	4.1%
Belarus	2.9%	11.4%	10.5%
Brazil	0.0%	0.1%	0.8%
Canada	13.1%	28.4%	19.9%
Chile	21.1%	36.5%	64.7%
China	5.2%	8.3%	30.2%
Colombia	5.7%	20.2%	1.2%
European Union	6.4%	0.5%	4.7%
Guatemala	39.9%	30.8%	27.5%
Hong Kong	97.2%	84.2%	98.7%
India	37.2%	--	0.0%
Japan	43.8%	51.8%	64.4%
Kazakhstan	--	--	--
Korea, South	16.4%	29.3%	66.1%
Malaysia	5.7%	--	93.0%
Mexico	19.6%	49.9%	10.1%
North Macedonia	--	--	--
Philippines	24.0%	31.5%	55.7%
Russia	5.0%	0.4%	19.3%
Saudi Arabia	41.0%	--	80.7%
South Africa	20.8%	10.3%	1.1%
Ukraine	11.8%	5.7%	1.0%
US	0.4%	5.5%	12.0%
Vietnam	12.8%	10.4%	29.2%

Table 24 above provides the percentage of consumption that each country imported in 2021 by meat type. Countries with overlaps of large rates of imports and the potential for large volume growth will likely have the largest impacts on trade flows. Beef sees the highest rates of import, no doubt because of its more significant land and feed needs and its smaller relative role in the diet. For example, Southeast Asian countries have some of the highest meat consumption growth rates but also the highest import rates. Trade flows will no doubt gravitate towards this area (including China), which could be complicated if adverse economic conditions arise since these countries have the most responsive income elasticities.

One other consideration that knowing the characterizations of countries that will not be able to meet meat demand with domestic consumption is to roughly speculate on whether that demand will be for inputs or finished animals/meat products themselves. Producing meat requires space, infrastructure and processing capacity, labor, and research and technology. Countries that lack one or more of these factors of production (though arable land and infrastructure are likely the most restrictive barriers for most countries) may import meat as a finished product, while others may choose to import feed ingredients to support domestic production. Countries with established production capacity are able to produce both meat and feed grains more efficiently and less expensively than those without. Based on the growth projected by the model (and especially under Scenario 1), countries with less land mass, higher per capita growth rates, and large populations or population growth rates would be expected to not only increase consumption but to increase and make up a larger share of global meat imports (particularly pork and beef) in the future. Examples include the Philippines, Hong Kong, Guatemala, Vietnam, and Saudi Arabia.

Consider Vietnam, which has been driving consumption growth in Southeast Asia with an overall 253 percent increase in volume of consumption and a 364 percent increase in the volume of beef consumed over the 1999-2021 period. Vietnam lacks sufficient grassland or the requisite infrastructure to support domestic production at this consumption level. Instead, it turns to the rest of the world, importing 70 percent of its feed ingredients and about 20 percent of its meat supply (and about a third of its beef) ("Vietnam Grain and Feed Annual 2019"). Land and feed resources will become more scarce as population increases and urbanizes, pressuring countries like Vietnam or the Philippines to consider the comparative disadvantage of producing their own meat supply and turn away from domestic production and towards the global trade field.

Equally, someone will need to supply the imports to these countries. The export market is much more concentrated to a few countries with identifiable characteristics. Large-landmass countries Brazil, the EU, India, and the US far and away make up the majority of beef, pork, and chicken exports.

Table 31: Share of Global Meat Exports by Country, 2021

	Chicken	Pork	Beef
Angola	0.0%	0.0%	0.0%
Argentina	0.3%	1.3%	7.5%
Australia	0.3%	0.3%	13.6%
Belarus	0.1%	1.4%	2.1%
Brazil	10.7%	36.3%	23.8%
Canada	11.9%	1.1%	6.2%
Chile	2.3%	1.1%	0.2%
China	0.8%	3.9%	0.2%
Colombia	0.0%	0.0%	0.7%
European Union	40.7%	15.3%	7.1%
Guatemala	0.0%	0.1%	0.1%
Hong Kong	0.0%	0.0%	0.0%
India	--	--	15.9%
Japan	0.0%	0.0%	0.1%
Kazakhstan	--	0.2%	--
Korea, South	0.1%	0.3%	0.0%
Malaysia	--	0.2%	0.1%
Mexico	2.7%	0.1%	3.5%
North Macedonia	--	--	--
Philippines	0.0%	0.0%	0.0%
Russia	1.5%	1.8%	0.5%
Saudi Arabia	--	0.4%	0.0%
South Africa	0.2%	0.4%	0.5%
Ukraine	0.0%	3.7%	0.3%
United Kingdom	2.4%	3.0%	1.4%
US	25.9%	28.9%	16.1%
Vietnam	0.0%	0.2%	0.0%

The projection model results reveal some very interesting potential dynamics in terms of exports. Several of the largest meat-exporting countries (Australia, the EU, and US) show signs of slowing or negative growth as incomes rise. Though they will continue to be key countries due to their large consumption volumes, the growth rates seen by these countries will not keep up with those seen by the rest of the world. Assuming that production trends and yields continue to increase at trend, the EU and US will likely be increasing exports of the meat (or feed) that is not demanded by their domestic markets. Other high-volume consumption growth countries will accordingly increase their reliance on the top exporting countries or be forced to invest in their own production capacities. While meat and feed importing countries are likely to further diversify, the trends suggested by the income model lend themselves to suggest further global dependence on large-scale exporters. While there are no doubt pros and cons to concentration and increased trade, this transition could have other implications for domestic agricultural policy, international relations and trade policy, and the way that producers market commodities.

CHAPTER 7: CONCLUSION

Meat consumption is one of the largest drivers of global agricultural trends; it is also an issue that is nuanced, complicated, and varies extensively across borders. This analysis aimed to provide broad ideas of global meat consumption's response to economic trends. The income-based model develop suggests continued growth over the next eight years. By volume, the current key players (China, the EU, the US, and Brazil) will continue to have the largest influences on global meat consumption. However, in terms of new growth, low-income and lower-middle income countries will see the largest gains in per capita meat consumption by percent. Coupled with the increasing population growth rates and higher income elasticities that characterize these countries, this category offers the most uncertainty and the most potential for new growth of consumption. Regions with the largest potential for growth include Southeast Asia, Central Asia and the Middle East, Central America, and Africa. Of the three meat types, pork continues to be (and further establishes itself) as the most-consumed meat in the world. Pork grows the most in the baseline model as the preferred meat of most of the world's population. The projection model results reflect the idea meat can become an inferior good at higher incomes, particularly for beef and chicken.

Under Scenario 1 (increased incomes), chicken, pork, and beef consumption each increase, and total meat consumption rises over that of the baseline (expected income) scenario. The most significant high-income high-consuming countries (the EU and the US) begin to see meat act as an inferior good and start to stagnate or decline. Total meat consumption in Scenario 2 falls by more than it rises in Scenario 1, emphasizing the role that countries with higher income elasticities (lower and lower-middle income countries) can potentially play in the total meat needed to meet demand in the next decade. Scenario 3 presents mixed-case economic conditions. Compared to the baseline and Scenario 1, less meat is consumed under the split conditions. There is still some growth in the high-income countries at increased income levels however, as more meat is consumed over the period than would be in the lowered income expectations scenario. HICs are remain significant consumers of meat over the period, even though their high levels of consumption do not outweigh the rapid population growth and rate of increasing meat consumption expected in LMICs and UMICs.

Under the baseline and each scenario, resource requirements and trade flows will also shift from current demands as income increases or decreases. Countries that import their meat or feed inputs will likely become more reliant on other countries as their demand for meat increases. In addition, high income major exporters will likely see larger-than-trend increases in exports as their domestic consumption growth slows or declines as their production becomes more efficient.

There are limitations to this modeling project, like with any forecast. First, the lack of available country, country-specific retail price, and projected per capita income data limits the use of the model to reflect actual consumption levels for the entire world. The categorization of countries by income level helps draw generalizations about how countries that would fall into each income bracket would be expected to behave, however. Representation of African and Central American countries is lower than is ideal, and countries that have large populations and population growth rates such as Indonesia, Nigeria, and Pakistan are not included due to lack of data. There is also a lack of available data for low-income countries whose role in scenarios is not represented. Higher income countries are more represented in the data sample in the real world.

It should be kept in mind that recent consumption data includes substantial anomalies attributable to ASF and COVID-19 and that 2021-a relatively unusual year for meat consumption- is used for the base of the changes suggested by the income elasticities.

While income is certainly the most significant factor in determining meat consumption, it is not the only one. Non-income consumer preferences for meat are not directly accounted for in this model but will likely grow in importance in future years and at higher incomes. There are irregular years for income included within this period, so updated results with post-COVID data would be interesting to see. It would also be expected to see further decreased meat consumption in future years. While this trend in the data is currently slight (and likely complicated by reductions in consumption related to the pandemic) recalculating the income elasticity relationship in several years when more of this trend has occurred would no doubt change the scenario responses, but could also be utilized to identify the specific peak of income-related meat consumption growth.

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Appendix A: Percent Change in Meat Consumption, Baseline Scenario, 2021-2030

	Total Meat	Chicken	Pork	Beef
Angola	42.76%	43.66%	36.40%	47.89%
Argentina	14.46%	13.13%	12.69%	16.08%
Australia	7.51%	4.39%	12.81%	8.70%
Belarus	5.22%	5.91%	4.70%	4.74%
Brazil	15.37%	14.75%	11.87%	17.19%
Canada	6.77%	3.79%	10.71%	7.33%
Chile	4.73%	2.93%	6.11%	5.62%
China	6.81%	3.80%	7.92%	5.37%
Colombia	12.85%	13.66%	9.47%	12.96%
EU	0.63%	-2.57%	2.58%	-0.25%
Guatemala	23.60%	24.39%	19.43%	22.02%
Hong Kong	7.36%	3.00%	10.55%	6.44%
India	15.24%	15.77%	--	13.76%
Japan	-4.54%	-6.06%	-3.03%	-4.56%
Kazakhstan	15.41%	13.57%	12.89%	17.10%
Korea	1.28%	-2.20%	3.56%	0.50%
Malaysia	14.14%	13.83%	--	14.30%
Mexico	11.46%	11.30%	11.12%	11.78%
North Macedonia	3.70%	4.26%	2.77%	3.66%
Philippines	19.65%	21.68%	16.89%	17.86%
Russia	2.47%	1.59%	3.52%	2.70%
Saudi Arabia	11.28%	10.92%	--	12.81%
South Africa	16.53%	16.77%	12.57%	16.64%
Ukraine	2.78%	4.87%	0.09%	1.97%
United States	3.99%	1.41%	7.76%	4.55%
Vietnam	15.17%	17.40%	14.10%	13.34%

Appendix B: Percent Change from Baseline, Scenario 1

	Total Meat	Chicken	Pork	Beef
Angola	1.11%	1.56%	0.54%	0.91%
Argentina	0.82%	0.67%	0.65%	1.01%
Australia	-0.29%	-0.84%	0.62%	-0.09%
Belarus	0.89%	0.95%	0.86%	0.83%
Brazil	0.82%	0.75%	0.65%	0.99%
Canada	-0.10%	-0.67%	0.64%	-0.01%
Chile	0.45%	0.15%	0.71%	0.57%
China	0.64%	0.22%	0.80%	0.44%
Colombia	0.92%	1.00%	0.62%	0.95%
EU	0.30%	-0.44%	0.74%	0.09%
Guatemala	1.05%	1.23%	0.49%	0.84%
Hong Kong	0.19%	-0.64%	0.79%	0.00%
India	0.81%	0.90%	--	0.66%
Japan	0.07%	-0.48%	0.63%	0.06%
Kazakhstan	0.64%	0.46%	0.44%	0.82%
Korea	0.30%	-0.36%	0.73%	0.14%
Malaysia	0.40%	0.39%	--	0.49%
Mexico	0.69%	0.66%	0.68%	0.78%
North Macedonia	0.72%	0.76%	0.65%	0.73%
Philippines	0.95%	1.22%	0.68%	0.75%
Russia	0.55%	0.40%	0.72%	0.58%
Saudi Arabia	-0.01%	-0.05%	--	0.25%
South Africa	1.06%	1.14%	0.46%	1.09%
Ukraine	0.96%	1.14%	0.74%	0.88%
United States	-0.26%	-0.90%	0.66%	-0.13%
Vietnam	0.91%	1.10%	0.84%	0.71%

Appendix C: Percent Change from Baseline, Scenario 2

	Total Meat	Chicken	Pork	Beef
Angola	-1.20%	-1.69%	-0.56%	-0.98%
Argentina	-0.92%	-0.79%	-0.67%	-1.12%
Australia	0.26%	0.81%	-0.65%	0.05%
Belarus	-0.97%	-1.08%	-0.90%	-0.91%
Brazil	-0.92%	-0.88%	-0.68%	-1.09%
Canada	0.06%	0.63%	-0.66%	-0.04%
Chile	-0.52%	-0.24%	-0.74%	-0.65%
China	-0.69%	-0.29%	-0.83%	-0.50%
Colombia	-1.02%	-1.13%	-0.64%	-1.04%
EU	-0.34%	0.39%	-0.77%	-0.14%
Guatemala	-1.15%	-1.36%	-0.51%	-0.91%
Hong Kong	-0.23%	0.60%	-0.82%	-0.06%
India	-0.88%	-0.98%	--	-0.71%
Japan	-0.11%	0.44%	-0.66%	-0.10%
Kazakhstan	-0.73%	-0.56%	-0.46%	-0.91%
Korea	-0.34%	0.32%	-0.76%	-0.19%
Malaysia	-0.50%	-0.50%	--	-0.55%
Mexico	-0.78%	-0.78%	-0.71%	-0.86%
North Macedonia	-0.80%	-0.88%	-0.68%	-0.80%
Philippines	-1.03%	-1.34%	-0.71%	-0.82%
Russia	-0.62%	-0.50%	-0.75%	-0.65%
Saudi Arabia	-0.06%	-0.03%	--	-0.29%
South Africa	-1.17%	-1.27%	-0.48%	-1.19%
Ukraine	-1.05%	-1.27%	-0.77%	-0.96%
United States	0.23%	0.88%	-0.69%	0.09%
Vietnam	-0.97%	-1.22%	-0.88%	-0.78%

Appendix D: Percent Change from Baseline, Scenario 3

	Total Meat	Chicken	Pork	Beef
Angola	-1.20%	-1.69%	-0.56%	-0.98%
Argentina	-0.92%	-0.79%	-0.67%	-1.12%
Australia	-0.29%	-0.84%	0.62%	-0.09%
Belarus	-0.97%	-1.08%	-0.90%	-0.91%
Brazil	-0.92%	-0.88%	-0.68%	-1.09%
Canada	-0.10%	-0.67%	0.64%	-0.01%
Chile	0.45%	0.15%	0.71%	0.57%
China	-0.69%	-0.29%	-0.83%	-0.50%
Colombia	-1.02%	-1.13%	-0.64%	-1.04%
EU	0.30%	-0.44%	0.74%	0.09%
Guatemala	-1.15%	-1.36%	-0.51%	-0.91%
Hong Kong	0.19%	-0.64%	0.79%	0.00%
India	-0.88%	-0.98%	--	-0.71%
Japan	0.07%	-0.48%	0.63%	0.06%
Kazakhstan	-0.73%	-0.56%	-0.46%	-0.91%
Korea	0.30%	-0.36%	0.73%	0.14%
Malaysia	-0.50%	-0.50%	--	-0.55%
Mexico	-0.78%	-0.78%	-0.71%	-0.86%
North Macedonia	-0.80%	-0.88%	-0.68%	-0.80%
Philippines	-1.03%	-1.34%	-0.71%	-0.82%
Russia	-0.62%	-0.50%	-0.75%	-0.65%
Saudi Arabia	-0.01%	-0.05%	--	0.25%
South Africa	-1.17%	-1.27%	-0.48%	-1.19%
Ukraine	-1.05%	-1.27%	-0.77%	-0.96%
United States	-0.26%	-0.90%	0.66%	-0.13%
Vietnam	-0.97%	-1.22%	-0.88%	-0.78%