How much Meat do we eat? Estimating per Capita Meat Consumption in Germany based on a Market Balance Approach

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Abstract

Meat consumption has become increasingly relevant within the greater scientific, political, and public debate due to the variety of negative effects that it has on the environment, human health, and animal welfare. In Germany, the statistical basis for "direct consumption" entails uncertainties and is based on parameters dating back to 1987. The following study deals with an updated and revised estimate of the per capita consumption of pork, beef, and poultry in Germany, focusing on the supply-side. Unlike the original approach, the estimate is based on a mass flow analysis. It includes a survey at the slaughterhouse level, adjustments to external trade statistics, and assumptions on loss and waste at five different value chain stages. An average total per capita meat consumption of 65 kg is calculated for the year 2018. Thus, meat consumption has been underestimated by 4 kg per capita based on official statistics by overestimating waste, losses, and non-food uses. Our results provide information regarding per capita and total meat consumption, enable future projections, and give an overview of the use of meat outside the food chain. The approach used is discussed against the background of international comparability and applicability. In this way the study provides important indications for political decision-makers and contributes to more objectivity in the public debate on meat consumption.

Keywords

meat consumption; Germany; food balance data; market balance approach; international comparability

1 Introduction

The general public, the political and scientific communities are critically discussing the effects of the current and projected consumption of livestock proteins: particularly the demand for meat is being controversially re-examined. This demand is associated with negative consequences for human health and adverse effects on the environment, the preservation of natural resources, and animal welfare as a result of intensive animal husbandry in industrialized countries (GODFRAY et al., 2018; SPRINGMANN et al., 2018).

Against this background, scientific studies at different national and institutional levels have indicated the necessity for demand management. In its "Special Report on Climate Change and Land Systems", the Intergovernmental Panel on Climate Change (IPCC) of the United Nations refers to the climate impact of meat-intensive diets and thus shifts the issue into the focus of current public perception at the international level (IPCC, 2019). At the European level, and in the course of the "Farm to Fork Strategy", the European Commission strives for more sustainable food consumption. It also works to counter negative external effects of red meat consumption on the environment and health (EC, 2020b). In Germany, the the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection at the Federal Ministry of Food and Agriculture (WBAE) recently indicated the necessity of reduction in the consumption of meat to design a more sustainable food system (WBAE, 2020).

However, the frequently cited German "food balance sheet data" providing regular information on meat consumption from a market-balance perspective has important limitations. Fixed coefficients are used to convert the domestically available total meat supply into average per capita consumption of different meat types expressed as carcass weight (BLE, 2021). The coefficients adjust for inedible components, losses at the slaughter-level, non-food uses, and waste at the consumer level. They were established in 1987 (DFV, 1987), and have not been changed or updated appreciably since then (BLE, 2021). The average per capita meat consumption level estimated in this manner varied between 60 and 62 kg within the years 2000 to 2018 and was 57 kg in 2020 (BLE, 2021).

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In contrast, the second representative National Nutrition Survey (NVS II), measuring food ingested by individuals, calculated a mean per capita meat intake of 43 kg among meat consumers based on dietary interviews and 24-h recalls conducted between November 2005 and January 2007 (KOCH et al., 2019). The NVS II refers to prepared meat quantities including cooking losses in the course of a demand-side approach (STRAßBURG et al., 2019), which partly explains the discrepancy with the supply-side estimates. Mismatches between consumption indicators based on "food balance sheet statistics" or dietary surveys have been reported in various studies (e.g., DOWLER and SEO, 1985; BARRETT, 2010; YU and ABLER, 2014; AMO et al., 2016; THAR et al., 2020). However, results with such high inconsistency raise questions about the accuracy of the application of the 30-year-old set of coefficients in Germany. Incorrect consideration of meat exports, over- or underestimated loss and waste ratios or changing marketing channels might be reasons for an incorrect assessment (over- or underestimation) of consumption based on the supply-side.

Nevertheless, a regular recording of average meat consumption is not only useful with regard to the evaluation of consumption levels and trends to add more objectivity to the emotionally-driven discussion on the topic in Germany. Such monitoring additionally provides information regarding the availability of meat as food, enables future projections, and gives an overview of the use of meat outside the food chain.

The purpose of this paper is two-fold: first, it describes and compares existing estimation procedures (national and international). Second, the paper uses an updated estimation approach for the German per capita consumption of beef, pork, and poultry. The calculation bases on mass flow analysis which accounts for losses and waste along the value chain. Therefore, a survey was conducted at the slaughterhouse level to determine the quantity available for domestic human consumption. Based on descriptive analysis adjustments are made for foreign trade, which are included in the total estimate. Finally, the updated estimation procedure and the results are discussed considering the intended purposes and the international comparability of the estimated meat consumption level.

2 Review of Current Procedures Estimating Meat Consumption

How is per capita food or meat consumption measured? Different types of data are collected regularly in most developed countries to monitor nutrition and the human consumption of various commodities (SERRA-MAJEM, 2001). Household budget surveys (HBSs) are based on nationally representative population samples to collect data on food availability at the household level. Individual dietary surveys (IDSs) based on representative country population samples provide information regarding the quantity of different foods ingested by the individual and for the survey period under review (RUSSO et al., 2016). An approach commonly used by the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2021a, 2021b), the European Commission (EC) (EC, 2021) and national administrations (BLE, 2021) is the estimation of average annual consumption based on food balance sheets including utilisation and loss and waste assumptions (SERRA-MAJEM, 2001; RUSSO et al., 2016).

2.1 International Approaches Estimating Meat Consumption

The FAO calculates meat and edible offal available for national human consumption (referred to as food supply) with country specific data expressed in terms of quantity, calories, protein, and fat per day and capita (FAO, 1972, 2021b). In these food balances, this information is shown conjointly for different meat types, whereas "Supply Utilization Accounts" present data separately for different products or product groups. The FAO calculates per capita supply of different meat types or products considering production, stocks, imports, and exports. In addition, losses and waste incurred in the course of storage and transport up to retail level are deducted (FAO, 2021a, 2021b). At the product level, the "Supply Utilization Accounts" show a per capita supply (inedible bones excluded) for individual product-groups. The industrial utilisation of meat is considered as an additional utilisation path, without explicitly reporting meat used for pet-food production. In principle, feed, seed, and food quantities consumed by tourists and residuals complement the specified utilisation options. Waste at the household level is not considered (FAO, 2021a, 2021c).

The United States Department of Agriculture (USDA) publishes annual national data on human consumption based on supply balances. To show the available supply of a commodity or each meat category, exports, shipments to U.S. territories, and ending stocks are deducted from the sum of production, imports, and beginning stocks. The total and per capita quantities available are shown in carcass weight, retail

weight, and as a boneless quantity (USDA, 2021a, 2021c). In addition to the "Food Availability System", the USDA provides loss-adjusted data on meat availability through the "ERS Food Availability Data System". Data include deductions for the conversion of primary to (boneless) retail weight and from retail to consumer weight. The per capita availability is calculated adjusting for preparation including cooking losses and plate waste (at-home and out-of-home consumption (USDA, 2020, 2021b). Due to limited data availability, this calculation method does not include deductions for meat quantities used in the pet food and animal feed industries (USDA, 2018).

The European Commission (EC) also uses production and trade data when calculating the annual per capita consumption of different meat types. Based on net production and foreign trade, domestic supply (referred to as "total consumption") is calculated as carcass weight (EC, 2021). The EC determines the per capita consumption level, summarised for the 27 Member States of the European Union (EU) considering total population. Carcass weights are transformed into retail weight to adjust for inedible components, fat, trimmings, and further losses and waste up to the consumer level (NELSON et al., 1989; EC, 2021). The conversion factors are 0.70 for beef and veal, 0.78 for pork, 0.88 for poultry, and 0.88 for sheep and goat. Waste at the consumer level is not considered. The EC does not report consumption of edible offal and by-products separately (EC, 2021).

2.2 Current Supply-Side Approach Estimating Meat Consumption in Germany

The Federal Office for Agriculture and Food (BLE) publishes German per capita meat consumption derived from supply balances for meat, edible offal, and by-products on an annual basis. The available domestic supply expressed as carcass weight is calculated by deducting exports and adding imports of meat and meat products from and to net production, which corresponds to slaughter volume (BLE, 2021).

The total available domestic supply is primarily for human consumption, but also for other purposes since inedible components, losses, and waste are still included. These cover (1) non-food material (DFV, 1987), which is used for industrial purposes, further processed and commonly used in biodiesel production and oleo chemistry (NIEMANN, 2017); (2) meat, edible offal, and by-products used as pet-food and in aquacultures; and (3) losses and waste from the slaughter to the consumer level as well as waste at the consumption level (DFV, 1987). For this reason, a set of coefficients is used to convert total domestic supply into per capita consumption by considering population size (BLE, 2021). The German Livestock and Meat Market Association implemented the coefficients in 1987 also based on expert assessments (DFV, 1987).

The estimation concepts presented consider different deduction items. Table 1 gives an overview of the main differences and also includes our updated technique for Germany.

Table 1. Overview of the main differences of estimation methods

Institution	Deduction for inedible components	Deduction for non-food uses	Deduction for pet food production	Deduction for losses and waste during production, processing, and storage	Deduction for consumer waste
FAO	(X)	(X)		X	
USDA	X			X	X
EC	X			X	
BLE	X	X	X	(X)	X
Updated national estimation presented in this study	X	X	X	X	X

Notes: partial consideration of the deducted item in parentheses. In the case of non-selection, the corresponding item is not explicitly shown or specified within the individual estimation procedure.
Source: authors' compilation based on USDA (2018, 2020), BLE (2021), EC (2021), FAO (2021a, b)

3 Proposal for a Revision of Estimating Meat Consumption in Germany

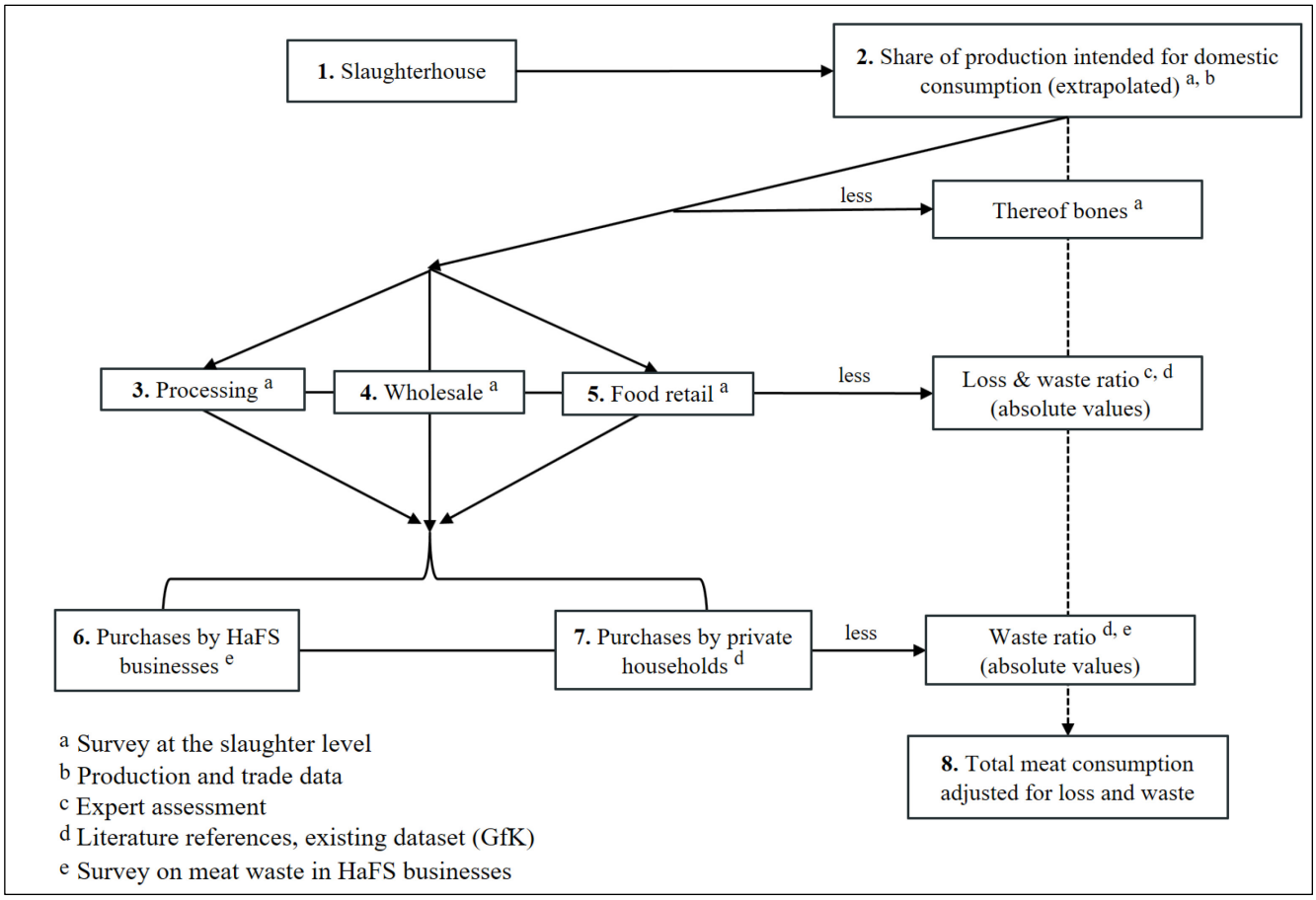
Based on a mass flow analysis we conduct an updated estimate of German per capita beef, pork, and poultry consumption. It uses results of a survey at the slaughterhouse level, official production and adjusted trade data as well as loss and waste assumptions along the value chain. The following chapter describes the methodological procedure and the data collection.

3.1 Market Balance Approach

Figure 1 shows the mass flow analysis which serves as a framework for the estimate. In a first step, the average share of production intended for domestic human consumption as well as inedible bones included are calculated based on a random survey of slaughterhouses. This information is used to extrapolate the total quantity of meat generally available for consumption, using official production and adjusted trade data. We calculate the distribution among different marketing channels (meat processing, wholesale, and food retail) in accordance with the slaughterhouse data to consider different loss and waste ratios. Following the simplified FAO definition, losses are defined as the reduction of edible food or meat quantities at the processing and wholesale level. Waste arises at the retail and consumption level (FAO, 2019). In the course of the estimate, we differentiate between consumption at-home and out-of-home. Hospitality and Food Service (HaFS) businesses are defined as final consumers in the out-of-home sector. Finally, the total loss and waste quantities are derived from the meat generally available for human consumption to calculate total or loss- and waste-adjusted consumption.

The estimate comprises three main calculation steps for each meat type. First, the total quantity of meat generally available for domestic consumption (AC) is determined by considering net-production (Q) (including edible offal and by-products), the share of meat available for domestic consumption (SD), the share of inedible bones (SB) included, as well as adjusted exports (EX) and imports (IM). In a second

Figure 1. Framework for the estimation procedure



Notes: we present value chain stages, for which we assume losses and waste within the estimation procedure (i.e., Tab. 4-5).
Source: authors' own compilation

step, total consumption is computed by deducting absolute losses and waste at the processing-, wholesale-, and retail-level, which are calculated considering the share (S) of each marketing channel (i) and the individual loss or waste ratios (LR, WR). Absolute waste at the consumption level is determined considering consumption in private households (CH), consumption out-of-home (CA), and the individual waste ratios (WR). By dividing total consumption by population size, per capita consumption is estimated.

$$Available\ for\ domestic\ consumption = (Q * SD)(1 - SB) - EX + IM \quad (1)$$

$$Absolute\ losses\ at\ processing, wholesale\ \&\ waste\ at\ retail\ level = \sum_i ((AC * S_i * LR_i) + (AC * S_i * WR_i))$$

$$Absolute\ waste\ in\ private\ households = CH * WR_{CH}$$

$$Absolute\ waste\ out\text{-}of\text{-}home = CA * WR_{CA}$$

$$Total\ consumption = AC - \sum_i((AC * S_i * LR_i) + (AC * S_i * WR_i)) - (CH * WR_{CH}) - (CA * WR_{CA}) \quad (2)$$

$$Per\ capita\ consumption = \frac{Total\ consumption}{Population} \quad (3)$$

3.2 Data Collection

Data Collection at Slaughterhouses Level

Data collection was mainly done at the slaughterhouse level. As the relevance of specific sales channels is most likely to vary between companies, we have aimed for a high market coverage in terms of the national slaughter volume. The random sample comprised six pig slaughterhouses (market coverage: 50%), four cattle slaughterhouses (market coverage: 48%), and seven poultry slaughterhouses (market coverage: 81%). Due to the relatively low number of veal slaughtered compared to young bulls, heifers, and cows (DESTATIS, 2021), the corresponding information from cattle slaughterhouses was also assumed for veal. Abattoirs provided information on the utilisation at the product or product-group level based on their Enterprise-Resource-Planning (ERP) systems (sales data) for an annual period to minimise seasonal effects and for two reference years (2017 and 2018) to recognise annual effects. Certain abattoirs provided information for one year only. The data query was conducted using a predefined Excel-Spreadsheet, which we developed with industry experts to ensure a recording in accordance with the slaughtering process and to avoid double counting (i.e., bones). We distinguished between products removed before and after determination of carcass weight and thus between edible offal, by-products, and meat. Exports, category I-III material[1] (risk material specified by Regulation (EC) No 999/2001 (EP, 2001), material intended for animal feed production or further non-food uses were indicated as possible utilisation paths. The slaughterhouses stated inedible shares (i.e., bones, tendons) and further marketing channels (processing, wholesale, retail) of meat, generally available for domestic consumption. Figure 2 displays the query scheme.

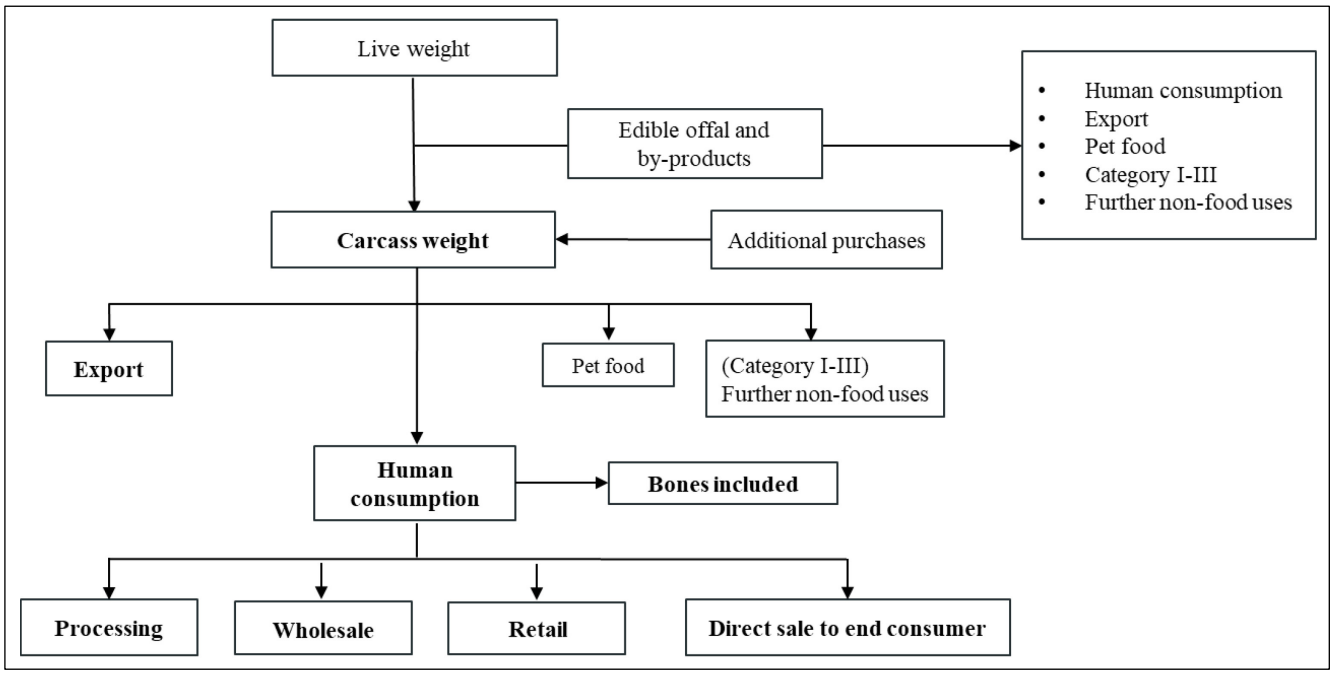
Absolute figures of all surveyed slaughterhouses were summed up to obtain the weighted percentage shares of exports, meat available for domestic consumption, and included bones in their relation to carcass weight (including additional purchases). Percentage shares of the individual marketing channels were determined in relation to the total meat available for domestic consumption, also expressed as carcass weight. In this manner, the information from the sample was extrapolated to the entire market since net production equals the total slaughter volume (expressed as carcass weight equivalent (c.w.e.)).

Data on External Trade

The German balance sheets provide a condensed overview of the meat supply for the individual species, edible offal, and by-products (BLE, 2021). In contrast to meat, the quantity of edible offal and by-products is not weighed but estimated using fixed coefficients in order to determine net production (BZL, 2019). The domestic supply is calculated considering foreign trade (BLE, 2021), where external trade statistics classify products in accordance with the Combined Nomenclature (CN) (EC, 2020a). Other than edible offal there are hardly any products in this nomenclature that do not belong to the carcass and are therefore officially classified as meat. As a result, only few products can generally be categorised as by-products. However, an analysis of the German export volume of edible offal and by-products of the past

[1] According to the negative effects on human and animal health, animal by-products are divided into three risk categories (Categories I-III) and have to be processed differently BMEL (2020).

Figure 2. Data query at slaughterhouse level



Notes: information used for the estimation procedure is indicated in bold type.
Source: authors' own compilation

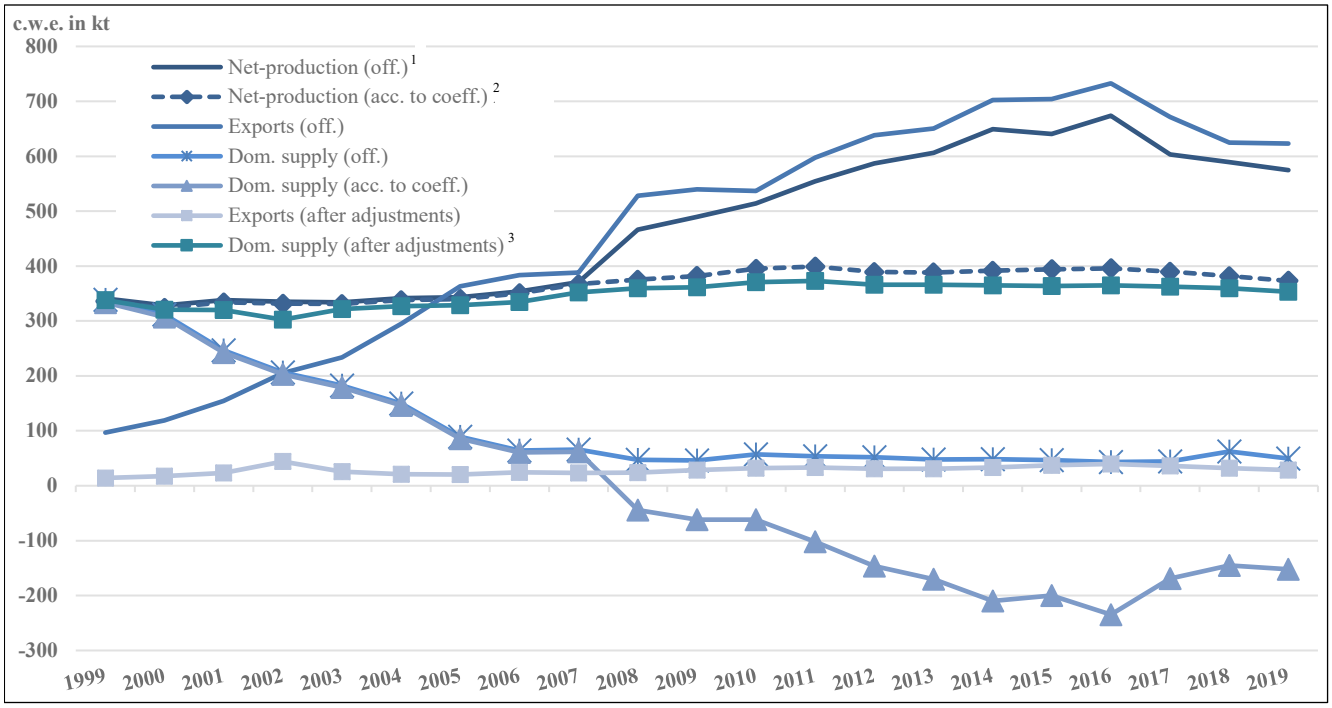
20 years showed that the majority of exports are assigned to CN-codes classified as by-products. In 2019, 89% of the total export volume of edible offal and by-products were pork by-products (EUROSTAT, 2020).

Figure 3 shows the production, export, and domestic supply of edible offal and by-products as presented in the official supply balance from 1999 to 2019. The sharp rise in exports of pork by-products since 2008 would have effectively resulted in a negative domestic supply ("acc. to coef.") if the fixed coefficients were used to calculate net production. To avoid this situation, official net production was manually increased each year from 2008 onwards to maintain a low but positive domestic supply ("off."). This procedure ultimately would result in the creation of edible offal and by-products, which does not seem plausible given the physical composition of the carcass. However, an ongoing incorrect assignment of products and the corresponding CN-codes seems a more realistic explanation. It can therefore be assumed that meat which is attributable to the carcass by definition, is partly declared as a by-product in trade statistics.

To correct the misalignment, we only considered products which are clearly not part of the carcass in the context of external trade of edible offal and by-products. Figure 3 additionally presents the accordingly modified domestic supply.

As a consequence, the remaining CN-codes are now reflected in foreign trade for pork and beef (meat). This adjustment affects the estimation of meat consumption. Due to the increasing export volume for pork in the observation period, and a high export share of the products now allocated to the supply balance for pork (meat), the domestic supply of pork appears to be lower than the quantity shown in the official statistics. This effect is considerably lower for beef. The revised allocation of the CN-codes is included in the estimation procedure in the course of reporting updated import and export quantities for beef, pork, edible offal, and by-products (i.e., Tab. 8).

Figure 3. Adjustments for foreign trade of edible offal and by-products, 1999-2019, c.w.e. in kt (kiloton (metric tons[a]))



[a] All values expressed as kiloton refer to "metric" tons.
[1]official statistics; [2]according to the authorised coefficient; [3]according to the authorised coefficient after adjustments to external trade
Source: authors' own representation of food balance sheets BLE (2021) and author's own calculation

Assumptions on Losses and Waste

Loss and waste assumptions for the individual value chain stages were collected from published studies with applicable reference units (meat waste and loss related to the quantity originally sourced or generally available), and from expert interviews. As recent publications on food waste for out-of-home consumption rarely show specific values for meat and do not provide indicators for the calculation of a waste ratio related to the quantity purchased (LIU et al., 2019), we conducted a representative survey among HaFS businesses on meat purchases and waste (THIES et al., 2021a). Table 2 presents an overview of the individual loss and waste ratios. The values given for at-home and out-of-home consumption refer to the avoidable losses and waste (excluding inedible components). This differentiation was not possible at the other stages due to limited data availability. The waste ratio at the retail level includes the product group fish (LEBERSORGER and SCHNEIDER, 2014), which is also among the frozen products for losses in private households (GFK, 2017).

Table 2. Assumptions on losses and waste at different stages of the meat value chain

Loss and waste items	Loss and waste ratio in %	Source
Meat industry	0.10	Expert assessment, Federal Association of the German Meat Industry BVDF (2020)
Wholesale	1.00	Expert assessment, German Meat Industry Association VDF (2020)
Food retail	2.58	LEBERSORGER and SCHNEIDER (2014), author's own calculation based on unpublished raw data
At-home consumption	3.13	GFK (2017), (AMI, 2020a, b), author's own calculation based on raw data
Out-of-home consumption	6.15	THIES et al. (2021a)

Source: authors' own compilation

4 Application of the Revised Estimation Procedure of German Meat Consumption and Corresponding Implications for Supply Balances

After presenting the conceptual approach for updating the German estimation procedure, chapter 4 demonstrates the implementation of our estimation technique and the corresponding effects on meat supply balances.

4.1 Individual Estimation Steps to Determine Per Capita Pork Consumption

Per capita meat consumption is determined using results from data collection at the slaughter level, official production data, modified trade data as well as loss and waste assumptions. Tables 3 to 7 show the individual estimation steps to determine per capita pork consumption. In accordance with the survey period at the slaughterhouse level, the values shown refer to mean values of the years 2017 and 2018.

In a first step (Table 3), we calculate the quantity of meat generally available for human consumption based on net production (corresponding to the domestic slaughter volume), foreign trade and the information provided by abattoirs:

- Net production (5,438 kt) and the percentage data from slaughterhouses are used to calculate the volume of meat available for domestic human consumption (3,146 kt). Bones included content (8.09%) is deducted.
- The companies additionally reported imported and exported quantities. The total direct imports and exports of fresh meat carried out by German slaughterhouses are calculated by means of net production based on the sample's weighted export or import share. As official trade statistics additionally cover processed and canned meat, we obtain the meat available for domestic consumption by determining the difference between the calculated and the official trade volume (remaining exports and imports). The remaining exports (898 kt) are considered as boneless, as these meat products originate from a domestically produced slaughter volume, of which the share of inedible components has already been deducted as a first step of the calculation (1a). We assume that imports are comparable to domestically sold meat in terms of tissue composition and accordingly also presume a bone content of 8.09%.
- The first calculation step results in the quantity available for human consumption (3,071 kt) (boneless).

In a second step (Table 4) we obtain the absolute losses and waste quantities from the processing to the retail-level by extrapolation.

- The information given by abattoirs serves to determine absolute sales volumes in the various marketing channels (meat processing industry; wholesale; food retail). Applying the ratios results in absolute loss and waste quantities.
- In addition to the direct selling from slaughterhouse to processing, wholesale and retail, we con-

Table 3. Estimate of per capita pork consumption Step 1

1. Calculation of the quantity of pork available for domestic consumption (boneless)					
1a. Net production in kt	Weighted share for dom. cons. acc. to SH[1] data in %	For domestic consumption in kt	Weighted share of bones included acc. to SH data in %	Bones included in kt	Boneless domestic consumption in kt
5,437.76	57.86[2]	3,146.41	8.09	255.65	2,891.76
1b. Exports in kt	Weighted export share acc. to SH data in %	Projected for total market in kt	Remaining exports in kt	Weighted share of bones included, acc. to SH data in %	Boneless remaining exports in kt
3,003.88	38.72[2]	2,105.74	898.14	0.00	898.14
1c. Imports in kt	Weighted import share acc. to SH data in %	Projected for total market in kt	Remaining imports in kt	Weighted share of bones included, acc. to SH data in %	Boneless remaining imports in kt
1,188.06	0.29[2]	15.64	1,172.42	8.09	1,077.53
1d. Available for domestic consumption (boneless) in kt					***3,071.15***

[1]Slaughterhouse (SH); [2]Share of production used for pet-food production or non-food uses corresponds to the difference to 100 percent points, i.e. 57.86% added to 38.72% minus 0.29% equals 96.29%; thus 3.71% are used as pet-food or non-food.
Notes: net production, exports, and imports correspond to mean values of the years 2017 and 2018.
Source: BLE (2021), authors' own calculation

Table 4. Estimate of per capita pork consumption Step 2

2. Calculation of total losses & waste at processing-, wholesale-, & retail-level				
Marketing channel	**Data acc. to SH surveyed in %**	**Calculated in kt**	**Loss & waste ratio in %**	**Calculated loss & waste in kt**
2a. Processing	54.31	1,668.06	0.10	1.67
2b. Wholesale	9.39	288.46	1.00	2.88
2c. Retail	27.24	836.50	2.58	21.56
2d. Processing to retail = (3b ∗ 1.0258) − 2c, i.e. 1,255.26 = (2,039.20 ∗ 1.0258) – 836.50		1,255.26	2.58	32.35
2e. Direct sale to customer	9.06	278.13	0.00	0.00
2f. Total loss & waste at processing-, wholesale- & retail-level in kt				***58.46***

Source: LEBERSORGER and SCHNEIDER (2014), GFK (2017), AMI (2020a, b), BVDF (2020), VDF (2020), authors' own calculation

sider a product flow between processing and food retail. The corresponding sales volume complies with the residual figure comparing (boneless) purchases of private households (purchases of meat, meat products, and sliced cold meat according to data of the "Gesellschaft für Konsumforschung", GfK) without losses at the retail level to meat quantities directly delivered to retailers by the slaughterhouses (837 kt). We accordingly also assume a waste ratio of 2.58% for this meat quantity, sold via retail.

- Further marketing levels that serve direct sales to end customers (e.g., shops on the slaughterhouse premises) are calculated as residual value (278 kt).

Step three (Table 5) involves calculating the share of purchases of HaFS businesses and private households.

- We calculate the share of purchases by HaFS businesses as the remaining quantity (974 kt) after deducting purchases of private households (2,039 kt) from the total boneless consumption (3,013 kt).

To calculate absolute consumer waste, waste ratios described in Table 2 are applied to the purchases by HaFS businesses (974 kt) and private households (2,039 kt) in a fourth step (Table 6).

Table 6. Estimate of per capita pork consumption Step 4

4. Calculation of total waste at the consumption level			
Consumption level	**Quantity in kt**	**Waste in %**	**Calculated waste in kt**
4a. At-home consumption	2,039.20	3.13	63.76
4b. Out-of-home consumption	973.49	6.15	59.89
4c. Total waste at consumption level			***123.65***

Source: GFK (2017), AMI (2020a, b), authors' own calculation

Finally, total meat loss and waste is deducted from the available quantity for human consumption and then divided by population size to show average per capita consumption of pork (34.9 kg). We obtain the coefficient for the derivation of the total quantity consumed by dividing total consumption after losses and waste (2,889 kt) by domestic supply (3,622 kt) (Table 7).

Table 5. Estimate of per capita pork consumption Step 3

3. Calculation of the out-of-home consumption		
3a. Consumption after losses and waste = 1d − 2f, i.e. 3,012.69 = 3,071.15 – 58.46	3,012.69	Calculated in kt
3b. Purchases of private households without bones	2,039.20	According to GfK-Data, without bones, product weight[1] in kt
3c. Purchases of HaFS businesses (3a-3b)	***973.49***	*Calculated as a residual value in kt*

[1]According to expert information, the market coverage of the GfK household panel is between 75% and 90% for meat, meat products, and meat comprising convenience products due to unrecorded quantities or lacking sales data from e. g., weekly markets. Based on the experts' recommendations, 25% were, therefore, added to the stated meat purchases of private households. Bones included were deducted according to GfK (2017).
Source: AMI (2020a, b), authors' own calculation

Table 7. Estimate of per capita pork consumption Step 5

5. Calculation of per capita consumption	
Domestically available for consumption (boneless) (1d) in kt	3,071.15
5a. Total loss and waste (2a-2e, 4a-b) in kt	182.11
5b. Total consumption after losses and waste (1d-5a) in kt	2,889.04
Population size in million	82.78
5c. Per capita consumption in kg	***34.90***
Domestic supply; including adjustments to external trade in kt	3,621.94
5d. Coefficient for the derivation of consumption from domestic supply in %	***79.77***

Notes: domestic supply and population size correspond to mean values of the years 2017 and 2018.
Source: BLE (2021), authors' own calculation

4.2 Corresponding Implications for Meat Supply Balances

Based on the previously determined coefficients (i.e., Table 7), Table 8 shows the estimated supply balance for the year 2018. Estimated values are printed in bold type. The remaining values correspond to the officially published statistics (BLE, 2021) and thus to the results of DFV (1987) regarding the consumption of sheep and goat, horse meat, and further meat types. An average total per capita meat consumption of 64.7 kg is calculated for the year 2018 based on the updated estimation procedure. The average per capita consumption level of beef is 11.5 kg. Pork consumption is 34.8 kg/capita and per capita poultry consumption totals 15.8 kg.

Table 9 shows the estimated consumption levels for pork, beef, and poultry compared to the results of DFV (1987). Additionally, the corresponding coefficients for the derivation of consumption from domestic supply are presented. The comparison results in an increased overall per capita meat consumption of 3.6 kg determined by the updated procedure. With view on the specific meat types, we find an underestimation of beef consumption by 16% and an underrated poultry consumption of 14%. The per capita consumption of pork is overestimated by 3%. The adjustment in external trade in particular exhibits a measurable effect in this regard and accordingly leads to an increase in consumption of edible offal and by-products compared to the official statistics (BLE, 2021).

As described in chapter 4.1, the updated estimation procedure corresponds to a stepwise calculation in which losses and waste are calculated considering total meat quantities at each of the subsequent value chain stages (slaughterhouse, wholesale, meat processing, retail, and at the consumption stages). On this basis, we determine a set of coefficients for the derivation of consumption from domestic supply. The

Table 8. Estimated supply balance for the year 2018

Meat type	Gross production	Imports live animals	Exports live animals	Net production	Import Meat	Export Meat	Domestic supply		Consumption	
	in kt	in kt	in kt	in kt	in kt	in kt	in kt	Per capita in kg	in kt	Per capita in kg
Beef	1,161.5	17.9	55.9	1,123.5	***523.0***	***470.9***	***1,178.0***	***14.2***	***951.6***	***11.5***
Pork	4,926.7	518.2	75.0	5,369.9	***1,191.0***	***2,941.2***	***3,619.7***	***43.7***	***2,887.3***	***34.8***
Poultry	1,821.7	164.7	392.7	1,593.7	994.7	665.9	1,922.5	23.2	***1,307.4***	***15.8***
Edible offal & by-products	553.5	49.1	13.1	***381.6***	***10.2***	***32.3***	***359.5***	***4.3***	***93.5***	***1.1***
Sheep & goat	31.4	3.2	0.1	34.5	56.3	8.1	82.7	1.0	55.0	0.7
Horse	2.7	0.4	1.3	1.8	1.8	0.3	3.3	0.0	2.2	0.0
Further meat types	53.6	0.5	0.3	53.8	55.3	15.8	93.3	1.1	63.0	0.8
Meat total	8,551,0	754.0	538.4	8,558.8	2,832.3	4,134.6	7,259.1	87.6	***5,359.9***	***64.7***
Population size in million										82.89

Source: authors' own representation of food balance sheets BLE (2021) and authors' own calculation (printed in bold type)

Table 9. Comparison with the original estimate and coefficients for the year 2018

Meat type	Estimation by DFV (1987) acc. to BLE (2021)		Updated Estimation	
	Consumption per capita in kg	Coefficient in %	Consumption per capita in kg	Coefficient in %
Beef	9.9	68.6	11.5	80.8
Pork	35.7	72.1	34.8	79.8
Poultry	13.8	59.5	15.8	68.0
Edible offal and by-products	0.2		1.1	
Further meat types	1.5		1.5	
Meat total	***61.1***		***64.7***	

Source: authors' own representation of food balance sheets based on BLE (2021) and authors' own calculation

original estimation procedure accumulates overall utilisation and loss and waste factors, which are then deducted from domestic meat supply, without considering actual meat quantities at the individual value chain stages. Despite these methodological differences, results of both estimation approaches lie in a comparable range.

4.3 Evaluation of Sensitive Parameters estimating per Capita Meat Consumption

However, the revised estimate contains uncertainties: the share of meat available for domestic consumption and the export share vary between the slaughterhouses surveyed. Both parameters are related to the meat quantity available for domestic consumption, which is calculated within the first step of the estimation procedure. Since we achieve a market coverage of 55%, considering the total slaughter volume of pig, cattle, and poultry, the sample size may influence the estimated per capita meat consumption level. Imports played a minor role for all slaughterhouses and, therefore, have a negligible influence on the result.

The quantity of meat, edible offal, and by-products sold to pet food producers by slaughterhouses is lower than initially assumed when the lucrative nature of this sales channel is considered (THIES et al., 2019). Since the quantity of (raw) meat, edible offal, and by-products used for pet food production has not been recorded so far, a verification of the information provided by slaughterhouses is nearly impossible. In the context of the estimation procedure, however, underestimating the share of production sold to pet food producers is reflected in an overestimation of the meat available for domestic consumption, since the sum of sales in different marketing channels corresponds to the total production in carcass weight.

A sensitivity analysis illustrates the potential influence of the above-mentioned parameters (i.e., Tab. 10). According to the standard deviation of the reported export shares for the specific meat types, we reduce the weighted overall export share for pork, e.g., by 17 percent points and increase the share intended for domestic consumption, respectively.

Additionally, we increase the share of meat sold to the pet food industry by approximately seven percent points for beef, pork, and poultry each. As a result, the projected total quantity intended for pet food production (including meat, edible offal, and by-products), is close to the total production volume of pet food shown in official statistics, which is not specified according to individual meat types (DESTATIS, 2019). Moreover, this quantity is not expressed as carcass weight and may include additional components (e.g., grains, vegetables).

We further adopt waste assumptions at the consumer level (at-home and out-of-home) used within the USDA loss-adjusted meat availability dataset. These waste ratios are reported on a species-specific basis (20% for beef and veal, 29% for pork, 18% poultry), include cooking losses and refer to edible meat quantities available at the consumption level (USDA, 2021b). They can, therefore, be applied in our estimation procedure. Since the consumption stage accounts for a large share of the total waste and loss in food value chains (HERZBERG et al., 2020) and as the USDA waste ratios are substantially higher than waste assumptions applied in this study, they are suitable for assessing the uncertainty range of our results.

The results of the sensitivity analyses (Table 10) show that there are considerable uncertainty ranges regarding the parameters used. In particular, higher waste assumptions and cooking losses lead to 20% lower per capita meat consumption resulting in an average per capita consumption level of 52 kg, which

Table 10. Results of the sensitivity analysis for the year 2018

Meat type	Meat consumption per capita in kg	Meat consumption per capita in kg decreased for exports	Meat consumption per capita in kg increased for pet food	Meat consumption per capita in kg increased for waste ratios and cooking losses
Beef	11.5	11.4	10.7	9.6
Pork	34.8	34.0	30.9	25.8
Poultry	15.8	15.3	14.7	13.6
Edible offal and by-products	1.1	1.1	1.1	1.1
Further meat types	1.5	1.5	1.5	1.5
Total	***64.7***	***63.3***	***58.9***	***51.6***

Source: authors' own calculation

still exceeds average meat intake according to NVS II based on self-reported meat quantities (KOCH et al., 2019). Results of this study are, thus, also in line with recently published literature, which identified inconsistencies between per capita consumption levels based on a market-balance approach and those indicated by individual dietary surveys (AMO et al., 2016; THAR et al., 2020).

5 Discussion

Based on a revised estimation procedure, this study determined an average per capita meat consumption of 65 kg for the year 2018, comprising of 35 kg pork, 12 kg beef, and 16 kg poultry. Accordingly, we found an underestimation of total per capita meat consumption by 3.6 kg compared to official statistics (BLE, 2021) and confirmed the deviation of consumption indications based on supply balances and dietary surveys (AMO et al., 2016; THAR et al., 2020).

The updated estimate presented considered various marketing channels differentiated by meat types and the corresponding specific loss and waste assumptions. The original approach, however, applied accumulated utilisation and loss and waste factors without distinguishing between different sales outlets. Consequently, losses and waste quantities were overestimated and per capita figures have tended to be underestimated in the past.

Food balance sheets are an important database to monitor long-term trends, as meat production is recorded on a regular and comprehensive basis (German Act on Agricultural Statistics ((§ 59 AgrStatG (German Act on Agricultural Statistics))). The updated meat type specific coefficients identified in this study allow for the derivation of nutritional trends with regard to meat consumption.

An analysis of foreign trade in edible offal and by-products revealed difficulties with the allocation and definition of CN-codes in official trade statistics. In this context, there is a need for further research, as incorrect allocations of CN-codes are most likely not only to be found in German foreign trade in meat. Indeed, both domestic supply and the consumption level calculated are influenced by incorrect assignment.

Our analysis additionally provided insights into the relevance of the different species-specific sales outlets, the meat production share sold to pet food producers as well as the distribution of at-home and out-of-home meat consumption, on which there is nearly no data to date. The calculation of species-specific meat quantities at the individual value chain stages provided indications regarding the main sources of loss and waste. Minimising lost and wasted meat is particularly important against the background of the resource-intensive production of this food product group and the associated negative external effects on environmental sustainability (THIES et al., 2021b).

Besides the sensitive parameters already mentioned (export share, meat sold for pet-food production and waste assumptions), further limitations of the presented results have to be considered.

One important limitation of the study is the sample size. The sensitivity of the requested information kept several slaughterhouses from participating. Although a high market concentration is usually reflected by a small number of reporting companies, specific marketing strategies of individual companies might have been overrepresented. Marketing channels of rather small and regional slaughterhouses might deviate from the sample. In view of their correspondingly low market share, this is likely to have a minor effect on the estimated consumption level. The sensitivity

analysis indicated that the share of domestic and foreign sales has little influence on the result.

Participating slaughterhouses reported that marketing shares are volatile and can change even in the course of a single year. This is the reason why the results of the survey provide a transitory picture. At the same time, changes in domestic meat supply are gradual with view on meat types and quantity (BLE, 2021), we assume that profound shifts between marketing channels or at the consumption level (at-home and out-of-home) also occur rather successively. We, therefore, also assume a temporary validity of the estimated coefficients.

Nevertheless, a regular data collection at slaughterhouse level would be desirable in terms of precise monitoring, also because meat products are increasingly produced tailored to specific customer needs (BVDF, 2020) and off-cuts as well as inedible components might increasingly be utilised at early value chain stages. The implementation of regular surveys will depend on the cooperative willingness of stakeholders. However, the aggregation of the required data (i.e., bones included in product-based sales) was perceived as challenging, as the required information is not relevant for marketing purposes of slaughterhouses.

The findings of this study contribute to more objectivity in the public debate on meat consumption in Germany. On the one hand, the gap between domestically available supply and consumption was described in detail. On the other hand, remaining uncertainties and limitations have been outlined. Political decision-makers should consider both aspects in the course of interpretation and communication.

At the same time, the average annual per capita meat consumption found, considering the uncertainty range (including cooking losses), was above the recommendations of the German Nutrition Society (DGE) regarding a balanced diet (maximum of 31 kg/capita) (DGE, 2020) and a level consistent with "planetary health" according to the EAT-Lancet Commission (approximately 16 kg/capita) (WILLETT et al., 2019). Also, against the background of these distinct consumption recommendations, consideration should be given to the purpose for which the results of this study are used. We calculated an average consumption level, that comprises children, adults and elderly, intensive meat consumers, and vegetarians. Dietary behaviour is influenced by a variety of internal and external factors (BROMBACH and BARTSCH, 2014) and varies within a society (CORDTS et al., 2014). Therefore, no conclusions about meat demand behaviour of individual consumer groups can be drawn from the results. Consequently, they cannot serve as a basis for evaluating targeted demand-sided measures to curb meat consumption and aiming to reduce health risks of individual consumer groups. In the course of national monitoring, regularly conducted individual or household nutrition surveys, which comprise at-home and out-of-home meat consumption, should be used in a complementary way together with food balance data to comprehensively address nutritional issues (RODRIGUES et al., 2007; AMO et al., 2016).

With regard to international comparability, a differentiation of the "consumption term" would be target-oriented, clarifying whether official statistics or studies refer to the actually ingested meat quantity or the quantity to be allocated to human consumption. The presentation of different approaches based on food balance data demonstrated that a comparison of meat consumption levels between countries focussing on the supply-side is hardly possible due to different utilisation as well as loss and waste assumptions. In this context, there has not yet been any international agreement on standardisation, which however might be challenging in view of the various market structures. Nevertheless, consultations on the consistent calculation of domestic meat supply within food balances would be a starting point. In particular, the allocation of CN-codes to the different animal species, edible offal and by-products should be more precisely defined and harmonised across countries and in official trade statistics. A supportable approach in this context has been provided by the announcement of the United Nations Economic Commission for Europe (UNECE) Specialised Section on Meat to align the UNECE meat cut codes according to the UNECE meat standards with the Harmonized Commodity Description and Coding System (HS) (UNECE, 2020).

6 Concluding Remarks

This paper introduced a revised estimation procedure of human meat consumption using a market balance approach and following a mass flow analysis to update the official German statistical basis for "direct consumption" and contributes to a more comprehensive national nutrition monitoring. In order to convert the domestically available meat supply into average per capita consumption, a set of coefficients was de-

rived which also allows us to continuously report future meat consumption levels and to identify nutritional trends.

A meat consumption level of 65 kg per capita on average is not compatible with national health (DGE, 2020) and international environmental goals (WILLETT et al., 2019). Therefore, there is a need for further political debate and scientific research that first of all identifies consumer groups to enable the development of targeted reduction measures. Although there is a common understanding that a reduction in meat consumption can significantly contribute to the achievement of sustainability goals (WBAE, 2020), a specific desirable consumption level in relation to a given time frame is not yet on the political agenda. As the "diet-environment-health trilemma" is a challenge at the global level (CLARK et al., 2018), consistent calculations of food balances would at least allow for a comparison of domestic meat supply levels. There also is a need for further action in this matter.

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