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APPENDIX

INTENSITY OF ANTIBIOTIC USE IN U.S. LIVESTOCK PRODUCTION

2022 UPDATE

Each December, the U.S. Food and Drug Administration (FDA) releases an annual report summarizing the previous year's antibiotic sales for use in U.S. livestock production.[1] Sales data are currently available for 12 consecutive years, going back to 2009.

These are the only data pertaining to farm-level antibiotic use that the FDA collects and reports on a regular basis. Since 2018, NRDC has used these data as the basis for estimating the rate, or intensity, of antibiotic use by the U.S. livestock sector as a whole and then comparing it with the intensity of antibiotic use by livestock sectors in other countries, mostly in Europe.[2] NRDC's analysis yields a straightforward comparison of intensity of livestock use across these two regions, and especially how they have changed over time.

The methods used for this analysis are those devised and subsequently deployed by the FDA's European counterpart, the European Medicines Agency (EMA), since 2010.[3] Using antibiotic sales data as the basis for estimating actual farm use of antibiotics is an approach endorsed by the World Organization for Animal Health (WOAH) in its Terrestrial Animal Health Code.[4] The FDA's Center for Veterinary Medicine is a Collaborating Center of WOAH. In recently published studies, independent experts have used this same approach.[5]

The intensity of antibiotic use, typically for a particular year, is determined as follows:

$$\text{Intensity of antibiotic use (mg/kg)} = \frac{\text{antibiotic active ingredient sold for livestock use (mg)}}{\text{calculated livestock weight (kg, or population correction units [PCUs])}}$$

Within the EMA online database for the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project, one can find the mg/kg intensities of antibiotic use reported for up to 31 individual European countries, and as far back as 2010.[6] The EMA database contains both raw antibiotic sales (the numerator) and the calculated size of the livestock sector for each country (the denominator), by year. The EMA refers to the latter as population correction units (PCUs), which are also expressed in kilograms.

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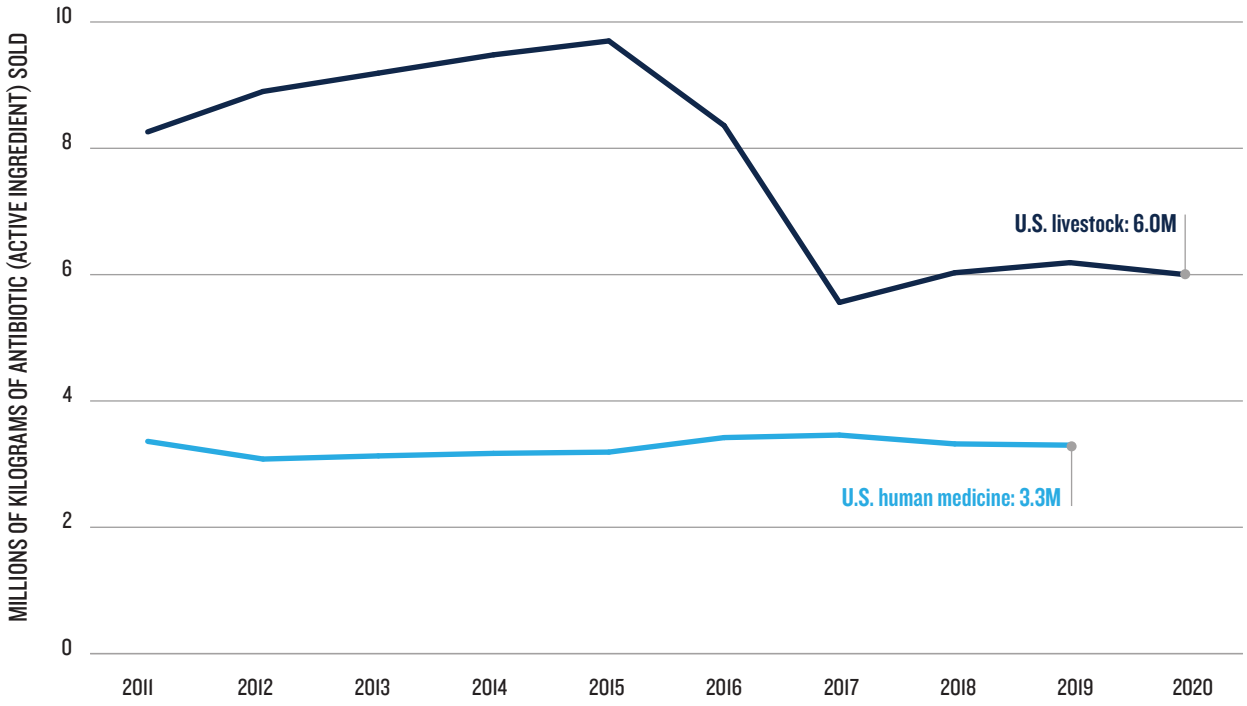
We combined the EMA-provided information with the equivalent information calculated for the United States to construct Figures 1A, 1B, and 2, as well as Tables 1 and 2 in the issue brief. This Appendix provides more details about their construction, summarizes the underlying data, and gives source information for those data. The appendix version of Table 2 is somewhat expanded, with data for more years to provide additional insights. Also lending more insights are data tables (A and B) not found in the issue brief because of space constraints.

An earlier version of Figure 1A was published in November 2021 as part of a blog coauthored by NRDC and colleagues at the then-named Center for Disease Dynamics Economics and Policy (CDDEP).[7] The latter provided annual medical sales data for the U.S., which are proprietary. Medical sales data are not yet available for 2020, but the FDA has released livestock antibiotic sales for 2020, as indicated in the data table for Figure 1A.

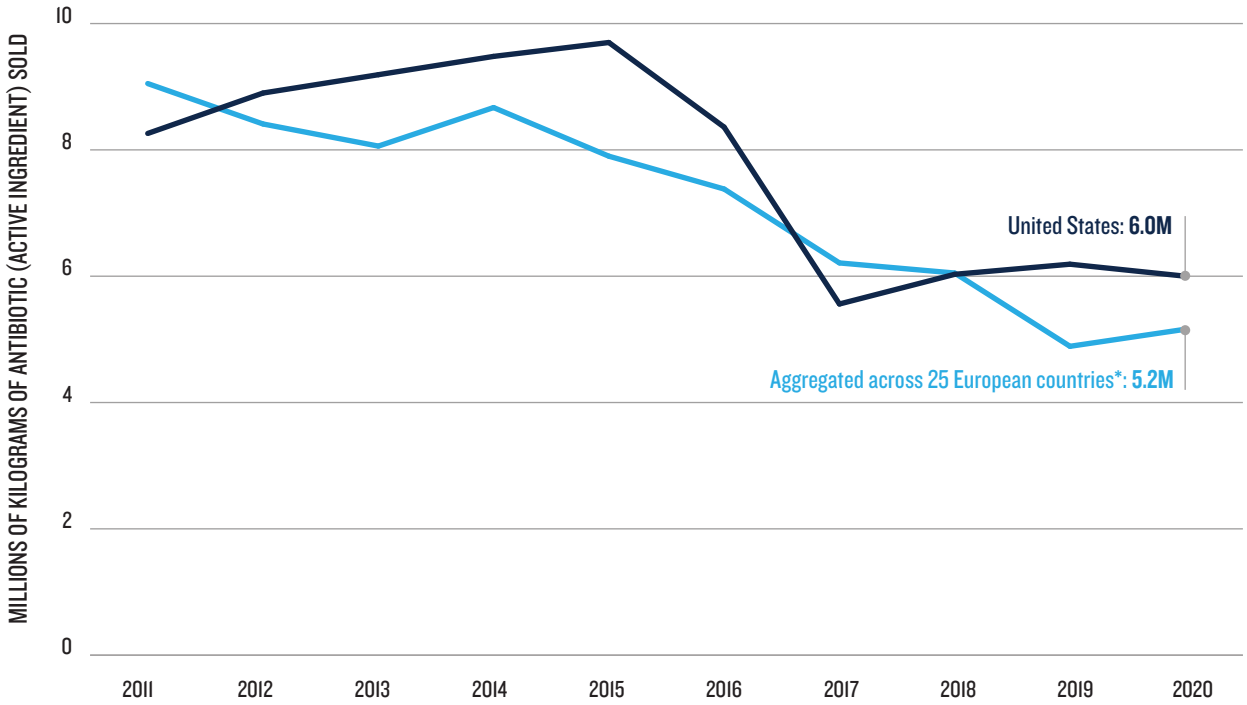
FIGURE 1A: SALES OF MEDICALLY IMPORTANT ANTIBIOTICS FOR U.S. LIVESTOCK PRODUCTION AND HUMAN MEDICINE, 2011 TO 2020



DATA TABLE FOR FIGURE IA. U.S. ANTIBIOTICS SALES, MILLIONS OF KILOGRAMS OF ACTIVE INGREDIENT

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
U.S. livestock	7.69	8.24	8.26	8.90	9.19	9.48	9.70	8.36	5.56	6.03	6.19	6.00
U.S. human medicine	3.49	3.40	3.36	3.08	3.13	3.17	3.19	3.42	3.46	3.32	3.30	N/A
Livestock as % of all sales	68.8%	70.8%	71.1%	74.3%	74.6%	74.9%	75.3%	71.0%	61.6%	64.5%	65.2%	

FIGURE 1B: SALES OF MEDICALLY IMPORTANT ANTIBIOTICS FOR U.S. AND EUROPEAN LIVESTOCK PRODUCTION, 2011 TO 2020



* The 25 countries providing national sales data to the European Medicines Agency for this time period were Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Under 2008 amendments to the federal Animal Drug User Fee Act, Congress required the FDA to collect veterinary antibiotic sales information from manufacturers and feed distributors and publish annual summaries of those data.[8] The FDA's initial report covering 2009 sales appeared in December 2010.

Similarly, the EMA launched the ESVAC project in 2009, as directed by the European Commission. In 2011, ESVAC issued a report covering veterinary antibiotic sales in nine European countries from 2005 to 2009.[9] It then began issuing annual sales reports, starting with 2010. The 2010 report contained national sales data from 19 countries: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Hungary, Iceland, Ireland, Latvia, Lithuania, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, and the United Kingdom.[10] An additional six countries—Bulgaria, Cyprus, Germany, Italy, Poland, and Slovakia—provided data from 2011 onward.[11] By 2017, six more countries had been added for a total of 31: Luxembourg (in 2012); Croatia, Romania, and Switzerland (in 2014); Greece (in 2015); and Malta (in 2017).[12] Of the 31 countries, 27 are members of the European Union, three are part of the European Economic Area, or EEA (Iceland, Lichtenstein, and Norway); and Switzerland is unaffiliated.

Figure 1B provides no information about the relative size of the livestock sectors in the United States and Europe, and too little context for determining the public health importance of changes in sales. However, the EMA database makes available both raw sales figures and the calculated size of the livestock population, expressed in kilograms or PCUs, for each year that participating countries provided data.

Data Table A (page 4) summarizes the EMA's 2020 information for Europe's nine top livestock-producing countries, as well as the summed total of raw antibiotic sales and PCUs for the 25 countries providing EMA with national information since 2011. In addition, Data Table A incorporates the latest raw U.S. antibiotics sales information reported by the FDA. It also indicates the total livestock weight calculated that same year for the United States, using the EMA's methodology.

Data Table B (page 4) shows how the U.S. figure of 35.1 billion kilograms (PCUs) was determined for 2020, summarizing the USDA livestock slaughter data and other publicly available figures. Calculations for the years from 2009 to 2019 proceeded in the same way. The data sources for each category are given below Table B; while they are specific to 2020 data, the sources for previous years' data are nearly identical.

DATA TABLE A: MEDICALLY IMPORTANT ANTIBIOTIC SALES IN 2020 AND THE CALCULATED WEIGHT OF THE LIVESTOCK POPULATION RECEIVING THEM, BY COUNTRY

		Antibiotic Sales[a] (kilograms of active ingredient	Calculated Livestock[b] Weight (kilograms)
Europe	Denmark	88,750	2,385,000,000
	Romania	173,730	3,004,000,000
	Netherlands	156,380	3,115,000,000
	Italy	689,290	3,790,000,000
	Poland	853,230	4,542,000,000
	France	394,370	6,965,000,000
	United Kingdom	215,160	7,115,000,000
	Spain	1,244,520	8,068,000,000
	Germany	684,590	8,173,000,000
	25 European countries, aggregated	***5,155,650***	***56,529,000,000***
US	**United States**	**6,002,056**	**35,126,944,634**

a EMA collects sales of pharmaceuticals in tablet and other forms; the values indicated exclude tablets, which are almost exclusively for companion animals. The aggregated figure was obtained by summing national sales for the 25 countries providing those data from 2011 to 2020. FDA reporting is specific to sales of antibiotics in food-producing animals.

b EMA's reporting of total PCUs for food-producing animals includes not only cattle, pigs, and poultry but also sheep and goats, fish, rabbits, and horses. 2020 national figures were obtained from the aforementioned ESVAC online database; the aggregated figure was obtained by summing data for the 25 countries providing PCU information from 2011 to 2020. U.S. calculations include calculated weights of only cattle, pig, chicken, and turkey populations.

DATA TABLE B: CALCULATION OF TOTAL LIVESTOCK WEIGHT, OR PCUS (KILOGRAMS), FOR THE UNITED STATES, 2020

COWS	**Number x Average weight (kg)**	**Calculated weight (kg), or PCU**
Number of slaughtered cows[a]	6,331,400 x 425	2,690,845,000
Number of slaughtered heifers[a]	9,445,400 x 200	1,889,080,000
Number of slaughtered bulls[a]	518,400 x 425	220,320,000
Number of slaughtered steers[a]	15,856,300 x 425	6,738,927,500
Number of slaughtered calves[a]	446,800 x 140	62,552,000
Number of live dairy cows[b]	9,392,000 x 425	3,991,600,000
Imported slaughter cows[c]	532,425 x −425	(226,280,625)
Imported fattening cows[c]	1,570,963 x −140	(219,934,820)
Exported fattening cows[c]	320,763 x 140	44,906,820
	Subtotal	*15,192,015,875*
PIGS		
Number of slaughtered pigs[a]	131,563,000 x 65	8,551,595,000
Imported fattening pigs[d]	4,453,626 x −25	(111,340,650)
Exported fattening pigs[e]	28,635 x 25	715,8755
Imported slaughter pigs[f]	802,862 x −65	(52,186,030)
Exported slaughter pigs[g]	10,935 x 65	710,775
Livestock sows (sows farrowed)[h]	3,164,000 x 240	759,360,000
	Subtotal	*9,148,854,970*
CHICKENS		
Slaughtered chickens[i]	9,346,660,000 x 1	9,346,660,000
Imported chickens[j]	33,516 x −1	(33,516)
Exported chickens[k]	847,805 x 1	847,805
	Subtotal	*9,347,474,289*
TURKEYS		
Slaughtered young turkeys[l]	221,323,000 x 6.5	1,438,599,500
	Subtotal	1,438,599,500
	TOTAL PCUs	***35,126,944,634***

DATA TABLE B FOOTNOTES

a USDA, National Agriculture Statistics Service (NASS*), Livestock Slaughter: 2021 Summary*, "Federally Inspected Slaughter and Percent by Classification and Month—United States: 2021 and 2020 Total," April 2022, https://downloads.usda.library.cornell.edu/usda-esmis/files/r207tp32d/pg15cj85z/hd76t466z/lsan0422.pdf.

b NASS Quick Stats, https://quickstats.nass.usda.gov/results/E0CFD1BD-790D-341C-853F-A5727C3EC03D.

c Economic Research Service (ERS), Cattle: Annual and Cumulative Year-to-Date U.S. Trade—All Years and Countries, "Cattle Imports, Cattle and Calves for Feeding," "Cattle Imports for Slaughter," and "Cattle Exports, Total," https://www.ers.usda.gov/data-products/livestock-and-meat-international-trade-data/.

d ERS, *Livestock and Meat International Trade Data*, "Hogs: Annual and Cumulative Year-to-Date U.S. Trade (head)," "Hog Imports, Less Than 7kg," "Hog Imports, 7–Less Than 23 kg," and "Hog Imports, 23 to Less Than 50 kg," https://www.ers.usda.gov/data-products/livestock-and-meat-international-trade-data/.

e Ibid., "Hog Exports, Less Than 50 kg."

f Ibid., "Hog Imports, 50 kg or More for Immediate Slaughter."

g Ibid. "Hog Exports, 50 kg or More."

h USDA, NASS, *United States and Canadian Hogs*, Table 3: "Hogs and Pigs Inventory, Sows Farrowed, and Pig Crop—United States: 2015–2020, December 1 Inventory, Sows Farrowed," March 2021, https://downloads.usda.library.cornell.edu/usdaesmis/files/7h149p85x/dr26zr477/kk91gd87k/usch0321.pdf.

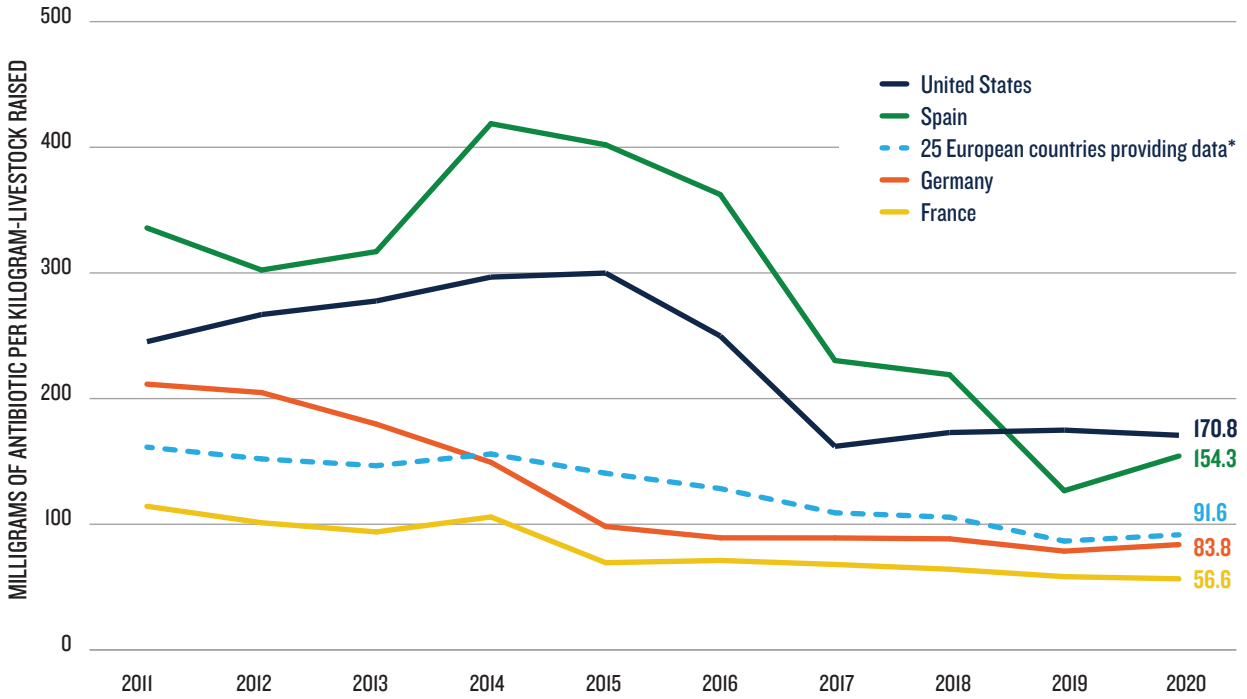
i USDA, NASS, *Poultry Slaughter: Annual Summary*, "Poultry Slaughtered, Total Live Weight, and Average Live Weight by Type and Month—United States: 2020 and 2019 Totals," page 5, https://www.nass.usda.gov/Publications/Todays_Reports/reports/psla0120.pdf.

j International Trade Centre, *ITC Trade Map*, search for United States imports from the world, product code #010511, "Live fowls of the species *Gallus domesticus*, weighing >185, imported by the US" (i.e., chickens), https://www.trademap.org/Index.aspx.

k International Trade Centre, *ITC Trade Map*, search for United States exports to the world of Product Code #010511, "Live fowls of the species *Gallus domesticus*, weighing >185, exported by the US" (i.e., chickens), https://www.trademap.org/Index.aspx.

l USDA, NASS, Poultry Slaughter: Annual Summary, "Poultry Slaughtered, Total Live Weight, and Average Live Weight by Type and Month—United States: 2020 and 2019 Totals," page 5, https://www.nass.usda.gov/Publications/Todays_Reports/reports/psla0120.pdf.

FIGURE 2: INTENSITY OF MEDICALLY IMPORTANT ANTIBIOTICS USED IN U.S. AND EUROPEAN LIVESTOCK PRODUCTION (MILLIGRAMS OF ANTIBIOTIC ACTIVE INGREDIENT PER KILOGRAM OF LIVESTOCK RAISED), 2011 TO 2020



* The 25 countries providing national sales data to the European Medicines Agency for this time period were Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Figure 2 graphically depicts by how much the intensity, or rate, of antibiotic use declined from 2011 to 2020 in the United States and Europe. As previously noted, the EMA online database reports the mg/kg intensities of antibiotic use calculated for all countries providing data for a particular year. This includes the 25 countries mentioned above. Figure 2 would be too chaotic if it included information for all 25 countries, or even for the top 9 livestock-producing countries. As a result, the figure depicts the intensity of use for the United States and for continental Europe's top three livestock-producing countries, as well as for livestock production aggregated across the 25 countries.

The following data table, however, provides intensities across the same period for eight of the top nine European livestock producers today (the exception is Romania, which didn't report sales for the entire period). The 2020 ranking of the European producers is according to the total number of PCUs reported in the EMA database. In addition, the table provides some countries' rates of use calculated for 2010, both because the EMA database already includes this information, and because it falls within the span of time, 2009 to 2020, for which our analysis calculates intensities of use for the U.S. livestock sector. For those countries, the 2010 data clearly show that work to improve veterinary antibiotic stewardship and to decrease antibiotic overuse began prior to 2011. The table's second-to-last column therefore captures the overall decline in the intensity of antibiotic use as measured from 2010.

DATA TABLE FOR FIGURE 2: CHANGING INTENSITY OF MEDICALLY IMPORTANT ANTIBIOTICS (% INCREASE [RED] OR DECREASE [GREEN]) USED IN U.S. AND EUROPEAN LIVESTOCK PRODUCTION (IN MILLIGRAMS OF ANTIBIOTIC ACTIVE INGREDIENT PER KILOGRAM OF LIVESTOCK)

	2020 rank in PCUs	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	% change in intensity of use, 2010–2020	% change in intensity of use, 2011–2020
United States		244.6	245.3	266.9	277.7	296.7	299.9	249.8	162.0	173.0	174.9	170.8	–30.2%	–30.4%
Germany	1		211.5	204.8	179.7	149.3	98.2	89.2	89.1	88.4	78.6	83.8		–60.4%
Spain	2		335.8	302.3	317.0	418.8	402.0	362.4	230.3	219.0	126.7	154.3		–54.1%
United Kingdom	3	67.8	51.0	66.2	62.5	62.3	56.5	39.0	32.1	29.0	30.4	30.2	–55.4%	–40.8%
France	4	133.6	114.3	101.2	93.9	105.8	69.4	71.2	68.0	64.2	58.3	56.6	–57.6%	–50.5%
Poland	5		126.3	134.1	150.3	139.5	137.9	128.4	163.9	168.3	185.2	187.9		+48.8%
Italy	6	421.2	371.0	340.9	301.5	332.3	321.9	294.7	273.7	244.0	191.0	181.8	–56.8%	–51.0%
Netherlands	7	146.0	113.7	74.8	69.9	68.4	64.4	52.7	56.2	57.4	48.2	50.2	–65.6%	–55.8%
Denmark	9	47.1	42.1	43.7	44.5	43.8	41.8	40.4	38.9	37.8	37.1	37.2	–21.1%	–11.6%
25 European countries providing data*			161.4	152.0	146.6	155.9	140.6	128.4	109.1	105.6	86.6	91.6		–43.2%

Sources: U.S. Food and Drug Administration, Annual summary reports on antimicrobials sold or distributed for use in food-producing animals, https://www.fda.gov/industry/animal-drug-user-fee-act-adufa/adufa-reports; European Medicines Agency, *European Database of Sales of Veterinary Antimicrobial Agents*, https://esvacbi.ema.europa.eu/analytics/saw.dll?Dashboard.

TABLE 2. CHANGING INTENSITY (% INCREASE [RED] OR DECREASE [GREEN]) OF U.S. ANTIBIOTIC USE OVERALL AND BY SPECIES, 2016 TO 2020
(IN MILLIGRAMS OF ANTIBIOTIC ACTIVE INGREDIENT PER KILOGRAM OF LIVESTOCK)

	2016	2017	2018	2019	2020	% change 2016–2020	% change 2017–2020
Chicken	55.5	29.6	24.2	20.7	15.2	–72.7%	–48.8%
Cattle	232.6	153.1	162.8	163.1	161.3	–30.7%	5.3%
Swine	380.2	239.0	272.9	285.1	267.9	–29.5%	12.1%
Turkey	478.5	427.0	435.9	435.8	476.6	–0.4%	11.6%
Overall	249.8	162.0	173.0	174.9	170.8	–31.6%	5.5%

Sources: NRDC analysis, reproduced from David Wallinga, et al., "A Review of the Effectiveness of Current US Policies on Antimicrobial Use in Meat and Poultry Production," *Current Environmental Health Reports*, 9, no. 2 (June 2022): 339-354, https://doi.org/10.1007/s40572-022-00351-x.

Table 2 captures the intensity of antibiotic use by species over the four-year period from 2016 to 2020, measuring the change in intensity both before and after the FDA made it illegal for medically important antibiotics to be prescribed or marketed for growth promotion purposes, which occurred at the start of 2017.

The values in Table 2 reflect the application of the same EMA methods and metrics used in the rest of the analysis to the FDA's published estimates of raw U.S. antibiotic sales by livestock species since 2016, when the agency first began to ask pharmaceutical companies for them. These species-specific estimates provide the numerator in the mg/kg expression of the intensity of antibiotic use for each year; the denominator was calculated using the same set of data pertaining to calculation of the size of that particular livestock population as shown in Data Table B.

ENDNOTES

1 Food and Drug Administration (hereinafter FDA), Center for Veterinary Medicine, *2020 Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals*, December 2021, https://www.fda.gov/media/154820/download.

2 David Wallinga, "Antibiotic Consumption in U.S. Pork, Beef, and Turkey Industries Vastly Outstrips Comparable Industries in Europe, and the U.S. Chicken Industry," NRDC, February 4, 2020 (updating the earlier November 2018 issue brief), https://www.nrdc.org/resources/antibiotic-consumption-us-pork-beef-and-turkey-industries-vastly-outstrips-comparable.

3 The measure divides the total sales of antibiotics, in milligrams of active ingredient, by a calculated amount in kilograms representing the weight of all animals at the time(s) they are most likely to receive antibiotics. The European Medicines Agency (EMA) describes this calculated weight as the population correction unit, or PCU, and refers to the overall metric as milligrams of antibiotic per PCU. See EMA, *Trends in the Sales of Veterinary Antimicrobial Agents in Nine European Countries (2005–2009)*, September 2011, Appendix 2, http://www.ema.europa.eu/docs/en_GB/document library/Report/2011/09/WC500112309.pdf.

4 World Organization of Animal Health (formerly the Office International des Epizooties, or OIE), "*Terrestrial Animal Health Code*, Chapter 6.9, "Monitoring the Quantities and Usage Patterns of Antimicrobial Agents Used in Food-Producing Animals," adopted 2003, last updated 2018, https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/?id=169&L=1&htmfile=chapitre_antibio_monitoring.htm.

5 Thomas Van Boeckel et al., "Reducing Antimicrobial Use in Food Animals," *Science* 357, no. 6358 (September 2017): 1350–52, https://doi.org/10.1126/science.aao1495; Katie Tiseo et al., "Global Trends in Antimicrobial Use in Food Animals From 2017 to 2030," *Antibiotics* 9, no. 12 (2020): 918, https://doi.org/10.3390/antibiotics9120918; Daniel Schar et al., "Global Trends in Antimicrobial Use in Aquaculture," *Science Reports* 10, no. 1 (December 2020): 21878, https://doi.org/10.1038/s41598-020-78849-3.

6 European Medicines Agency (hereinafter EMA), *European Surveillance of Veterinary Antimicrobial Consumption (ESVAC)*, "Interactive ESVAC Database," accessed September 27, 2022, https://www.ema.europa.eu/en/veterinary-regulatory/overview/antimicrobial-resistance/european-surveillance-veterinary-antimicrobial-consumption-esvac.

7 David Wallinga, Eili Klein, and Alisa Hamilton, "U.S. Livestock Antibiotic Use Is Rising, Medical Use Falls," NRDC Expert Blog, November 18, 2021, https://www.nrdc.org/experts/david-wallinga-md/us-livestock-antibiotic-use-rising-medical-use-falls-0.

8 FDA, Center for Veterinary Medicine, "Questions and Answers: Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals," accessed September 27, 2022, https://www.fda.gov/industry/animal-drug-user-fee-act-adufa/questions-and-answers-summary-report-antimicrobials-sold-or-distributed-use-food-producing-animals.

9 EMA, *Trends in the Sales of Veterinary Antimicrobial Agents*.

10 EMA, *Sales of Veterinary Antimicrobial Agents in 19 EU/EEA Countries in 2010*, Second ESVAC Report, October 15, 2012, https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-19-european-union/european-economic-area-countries-2010-second-european-surveillance-veterinary-antimicrobial_en.pdf.

11 EMA, *Sales of Veterinary Antimicrobial Agents in 25 EU/EEA Countries in 2011*, Third ESVAC Report, October 15, 2013, https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-25-european-union/european-economic-area-countries-2011-third-european-surveillance-veterinary-antimicrobial_en.pdf.

12 EMA, *Sales of Veterinary Antimicrobial Agents in 31 European Countries in 2017*, Ninth ESVAC Report, 2019, https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-31-european-countries-2017_en.pdf.