Supplementary Material

The effect of antibiotic usage on resistance in humans and food-producing animals: a longitudinal, One Health analysis using European data

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# Supplementary Figures and Tables

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## Supplementary Tables

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| Table S1: Summary Statistics of Antibiotic Usage by Class for Food-Producing Animals and Humans |
| Class | **Animal Usage in Tonnes** | **Human Usage in Tonnes** |
| **Minimum** | **Average** | **Median** | **Std. Deviation** | **Maximum** | **Minimum** | **Average** | **Median** | **Std. Deviation** | **Maximum** |
| Aminoglycosides | 0.01 | 12.46 | 2.01 | 27.37 | 204.97 | 0.00 | 0.84 | 0.22 | 2.57 | 22.18 |
| Amphenicols | 0.00 | 3.68 | 1.03 | 6.72 | 47.86 | 0.00 | 0.99 | 0.00 | 2.00 | 9.67 |
| Carbapenems | - | - | - | - |  | 0.00 | 3.86 | 2.31 | 5.81 | 35.00 |
| Cephalosporins | 0.00 | 5.77 | 1.09 | 10.73 | 60.05 | 0.00 | 3.56 | 1.21 | 4.54 | 33.53 |
| Fluoroquinolones | 0.01 | 8.97 | 1.75 | 18.71 | 99.61 | 1.89 | 81.65 | 47.20 | 90.63 | 383.53 |
| Macrolides | 0.00 | 21.70 | 4.65 | 36.73 | 180.71 | 2.43 | 138.90 | 44.49 | 261.08 | 2053.13 |
| Penicillins | 0.11 | 73.04 | 15.35 | 138.76 | 697.72 | 29.90 | 2237.31 | 652.72 | 3223.18 | 15912.65 |
| Polymyxins | 0.00 | 16.19 | 1.10 | 42.25 | 263.00 | 0.00 | 20.00 | 2.47 | 52.34 | 532.51 |
| Sulfonamides | 0.01 | 32.34 | 7.29 | 54.88 | 341.96 | 1.13 | 109.07 | 54.51 | 134.31 | 541.92 |
| Tetracyclines | 0.01 | 107.38 | 29.87 | 192.62 | 1043.12 | 0.00 | 19.11 | 0.97 | 36.94 | 178.97 |
| Trimethoprim | 0.01 | 4.77 | 0.97 | 8.95 | 66.65 | 0.23 | 37.77 | 18.04 | 55.14 | 298.51 |

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| Table S2: Summary Statistics of Antibiotic Resistance by Bacteria for Food-Producing Animals and Humans |
| Bacteria | **Animal Resistance** | **Human Resistance** |
| **Minimum** | **Average** | **Median** | **Std. Deviation** | **Maximum** | **Minimum** | **Average** | **Median** | **Std. Deviation** | **Maximum** |
| Campylobacter | 0.00 | 24.64 | 7.41 | 30.03 | 100.00 | 0.00 | 27.22 | 15.69 | 28.78 | 97.67 |
| Escherichia | 0.00 | 18.31 | 8.38 | 22.13 | 100.00 | 2.11 | 25.12 | 16.71 | 19.54 | 77.96 |
| Salmonella | 0.00 | 12.85 | 4.61 | 18.69 | 100.00 | 0.00 | 13.36 | 7.01 | 16.35 | 95.70 |

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| Table S3: Simultaneous effects of lagged antibiotic usage on animal and human resistance excluding certain antibiotic classes. |
| Excluding Penicillin |
|  | (1) | (2) | (3) | (4) |
| Variables | ln (Animal Resistance) | ln (Human Resistance) |
| ln (Animal Usage) | 0.185\*\*\*(0.0195) | 0.444\*\*\*(0.0230) | 0.0375(0.0198) | 0.387\*\*\*(0.0303) |
| ln (Human Usage) | 0.0623\*\*\*(0.0118) | 0.171\*\*\* (0.0143) | 0.0395\*\*(0.0133) | 0.159\*\*\*(0.0168) |
| Constant | 1.704\*\*(0.581)  | 26.61(34.60) | 0.981(0.502) | 77.66\*(37.46) |
| Observations | 2078 | 2728 | 1061 | 1314 |
| R-squared | 0.603 | 0.271 | 0.690 | 0.224 |
| Excluding Aminoglycosides |
| ln (Animal Usage) | 0.168\*\*\*(0.0185) | 0.417\*\*\*(0.0220) | 0.0449\*\*(0.0171) | 0.411\*\*\*(0.0250) |
| ln (Human Usage) | 0.0475\*\*\*(0.00912) | 0.140\*\*\*(0.0105) | 0.0214\*\*(0.00780) | 0.130\*\*\*(0.0106) |
| Constant | 1.221\*(0.553) | 39.26(34.84) | 1.350\*\*(0.446) | 86.07\*(38.02) |
| Observations | 2013 | 2638 | 1041 | 1279 |
| R-squared | 0.643 | 0.306 | 0.745 | 0.336 |
| Excluding Amphenicols |
| ln (Animal Usage) | 0.190\*\*\*(0.0181) | 0.431\*\*\*(0.0220) | 0.0378\*(0.0162) | 0.401\*\*\*(0.0259) |
| ln (Human Usage) | 0.0643\*\*\*(0.00872) | 0.156\*\*\*(0.00967) | 0.0422\*\*\*(0.00760) | 0.164\*\*\*(0.00983) |
| Constant | 1.829\*\*\*(0.545) | 34.75(32.28) | 1.062\*(0.420) | 89.03\*\*(33.32) |
| Observations | 2227 | 2920 | 1245 | 1534 |
| R-squared | 0.618 | 0.317 | 0.756 | 0.363 |
| Year FE | YES | YES | YES | YES |
| Country FE | NO | YES | NO | YES |
| Lagged Dependent Variable | YES | NO | YES | NO |
| Usage Variables Lagged 1 Year | YES | YES | YES | YES |
| Standard errors in parentheses \* p<0.05, \*\* p<0.01, \*\*\* p<0.001 |

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| Table S4: Simultaneous effects of lagged antibiotic usage on animal and human resistance for individual bacteria. |
| *For Salmonella* |
|  | (1) | (2) | (3) | (4) |
| Variables | ln (Animal Resistance) | ln (Human Resistance) |
| ln (Animal Usage) | 0.237\*\*\*(0.0305) | 0.441\*\*\*(0.0298) | 0.183\*\*\*(0.0339) | 0.534\*\*\*(0.0294) |
| ln (Human Usage) | 0.0732\*\*\*(0.0137) | 0.146\*\*\*(0.0138) | 0.0813\*\*\*(0.0129) | 0.140\*\*\*(0.0123) |
| Constant | 1.523(0.887) | 65.45(46.34) | 2.990\*\*\*(0.683) | 67.90(47.54) |
| Observations | 960 | 1288 | 599 | 737 |
| R-squared | 0.541 | 0.366 | 0.637 | 0.495 |
| *For Campylobacter* |
| ln (Animal Usage) | 0.261\*\*\*(0.0632) | 0.427\*\*\*(0.0649) | -0.0565(0.0494) | 0.394\*\*\*(0.116) |
| ln (Human Usage) | 0.0375(0.0356) | 0.0916\*\*(0.0322) | -0.0330(0.0317) | 0.187\*\*\*(0.0513) |
| Constant | -0.747(1.885) | 57.77(110.1) | -1.876(1.577) | -71.80(186.3) |
| Observations | 282 | 412 | 182 | 232 |
| R-squared | 0.610 | 0.408 | 0.838 | 0.212 |
| *For Escherichia* |
| ln (Animal Usage) | 0.137\*\*\*(0.0210) | 0.342\*\*\*(0.0288) | 0.0139(0.00735) | 0.166\*\*\*(0.0159)  |
| ln (Human Usage) | 0.0644\*\*\*(0.0106) | 0.184\*\*\*(0.0122) | 0.0218\*\*\*(0.00344) | 0.195\*\*\*(0.00407) |
| Constant | 1.273\*(0.583) | -13.56(46.35) | 0.542\*\*(0.167) | -12.61(21.51) |
| Observations | 1083 | 1346 | 496 | 603 |
| R-squared | 0.746 | 0.415 | 0.974 | 0.895 |
| Year FE | YES | YES | YES | YES |
| Country FE | NO | YES | NO | YES |
| Lagged Dependent Variable | YES | NO | YES | NO |
| Usage Variables Lagged 1 Year | YES | YES | YES | YES |
| Standard errors in parentheses \* p<0.05, \*\* p<0.01, \*\*\* p<0.001 |

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| Table S5: Effects of antibiotic usage on animal and human resistance, including additional covariates (Gross Domestic Product, Health Expenditure per capita and Corruption Perception Index). |
| *For Combined Usage* |
|  | (1) | (2) | (3) | (4) |
| Variables | ln (Animal Resistance) | ln (Human Resistance) |
| ln (Combined Usage) | 0.145\*\*\*(0.0123) | 0.297\*\*\*(0.0111) | 0.0472\*\*\*(0.0877) | 0.295\*\*\*(0.0103) |
| Constant | 3.695\*\*\*(0.951) | 56.93(36.86) | 1.422\*(0.674) | 50.86(36.13) |
| Observations | 2528 | 2993 | 1211 | 1347 |
| R-squared | 0.503 | 0.257 | 0.790 | 0.362 |
| *For Simultaneous Usage* |
| ln (Animal Usage) | 0.191\*\*\*(0.0197) | 0.418\*\*\*(0.0235) | 0.0295\*(0.0143) | 0.369\*\*\*(0.0280) |
| ln (Human Usage) | 0.0762\*\*\*(0.00960) | 0.147\*\*\*(0.0104) | 0.0345\*\*\*(0.00686) | 0.165\*\*\*(0.0107) |
| Constant | 4.214\*\*\*(0.947) | 51.08(36.80) | 1.608\*(0.680) | 52.48(37.52) |
| Observations | 2528 | 2993 | 1211 | 1347 |
| R-squared | 0.505 | 0.252 | 0.789 | 0.351 |
| Year FE | YES | YES | YES | YES |
| Country FE | NO | YES | NO | YES |
| Lagged Dependent Variable | YES | NO | YES | NO |
| Additional Controls | YES | YES | YES | YES |
| Standard errors in parentheses \* p<0.05, \*\* p<0.01, \*\*\* p<0.001 |

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| Table S6: Effects of antibiotic usage on animal and human resistance, excluding countries with a population less than 6 million people. |
| *For Combined Usage* |
|  | (1) | (2) | (3) | (4) |
| Variables | ln (Animal Resistance) | ln (Human Resistance) |
| ln (Combined Usage) | 0.139\*\*\*(0.0134) | 0.310\*\*\*(0.0122) | 0.0566\*\*\*(0.0115) | 0.334\*\*\*(0.0107) |
| Constant | 2.358\*\*(0.766) | -108.3\*\*(35.34) | 1.636\*(0.640) | -91.57(49.37) |
| Observations | 2032 | 2594 | 929 | 1094 |
| R-squared | 0.539 | 0.269 | 0.804 | 0.401 |
| *For Simultaneous Usage* |
| ln (Animal Usage) | 0.179\*\*\*(0.0191) | 0.382\*\*\*(0.0213) | 0.0439\*\*(0.0144) | 0.376\*\*\*(0.0252) |
| ln (Human Usage) | 0.0558\*\*\*(0.00921) | 0.122\*\*\*(0.0101) | 0.0291\*\*\*(0.00737) | 0.144\*\*\*(0.0101) |
| Constant | 2.923\*\*\*(0.780) | -125.5\*\*\*(35.01) | 1.724\*\*(0.642) | -109.0\*(48.39) |
| Observations | 2032 | 2594 | 929 | 1094 |
| R-squared | 0.543 | 0.269 | 0.803 | 0.391 |
| Year FE | YES | YES | YES | YES |
| Country FE | NO | YES | NO | YES |
| Lagged Dependent Variable | YES | NO | YES | NO |
| Standard errors in parentheses \* p<0.05, \*\* p<0.01, \*\*\* p<0.001 |

## Supplementary Figures

**Figure S1:** Frequency distribution of Usage in Tonnes and Resistance in % for food-producing animals and humans.

**Figure S2:** Frequency distribution of log transformed Usage in Tonnes and Resistance in % for food-producing animals and humans.



**Figure S3:** Box plots using raw values of usage and resistance variables shows the variables vary widely.



**Figure S4:** Showing log normalized box plots for Usage and Resistance Variables.