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Two pandemics: the COVID-19 pandemic's impact on future AMR collaboration in Europe

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Based on 117 responses to a web survey in 29 European countries and interviews with bureaucrats in managerial positions, this paper investigates how people working professionally with antimicrobial resistance (AMR) assess the impact of the COVID-19 pandemic on their future long-run cooperation in the struggle against AMR, both within their own country and among the European countries. We measure whether the severity level of the AMR problem, cumulative COVID-19 death rates, and the daily number of confirmed new COVID-19 cases in their own countries have affected bureaucrats' beliefs about long-run AMR collaboration. We find that around 40% of the bureaucrats believe that the cooperation will increase domestically and at the European level, indicating that global health crises such as the COVID-19 pandemic can shape future collaboration across the European countries when it comes to the equally global but more long-run health problem, AMR. However, there are considerable differences across regions: Eastern European bureaucrats are clearly the most pessimistic about future cooperation, while the Southern European and Nordic bureaucrats are the most optimistic. Neither the severity of the AMR problem nor the number of confirmed new COVID-19 cases in their own countries has a significant impact on bureaucrats' beliefs about future collaboration. Instead, it is the cumulative COVID-19 death rate that increases the perceived likelihood of future AMR collaboration, both domestically and among the European countries. Furthermore, our interviews highlight the longer-term impact of the pandemic on public health in the EU countries and the prospect of increased EU control to prevent future cross-border health hazards. The mixed methods approach details both the broader patterns of bureaucrats' perceptions of the impact of the pandemic on AMR-related work as well as the more long-term institutional changes that are likely to follow in the wake of the pandemic.

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Introduction

While the COVID-19 pandemic has demonstrated the need for international collaboration around global health challenges, the strategy chosen by many states has often been self-centered nationalism rather than cooperation for the global common good. Despite the passing of a WHO resolution on solidarity and collective action in response to the pandemic (WHO 2020), closed borders, competition over medicines and equipment, and rising vaccine nationalism have hindered the fulfillment of common objectives (Anderson et al. 2020, Bump et al. 2021). The lack of collective action raises questions about the future of European collaboration to address major global health problems more broadly. How will the non-cooperative behavior during the COVID-19 pandemic affect cooperation around other cross-border health issues?

In this paper, we study how the COVID-19 pandemic may influence the prospect for future European collaboration around the issue of antimicrobial resistance (henceforth AMR). AMR and the COVID-19 pandemic are both large-scale collective action problems threatening human health. Moreover, both are global problems since multi-resistant bacteria and viruses move quickly across continents, thus making it difficult to protect an individual country. This means that both AMR and the COVID-19 pandemic demand actions from all countries, emphasizing the importance of cooperation. However, as pointed out by Congleton (2021), the optimal pandemic policies do not need to be uniform across the countries.

Conceptually, our analysis draws on the weakest link theory, which states that each actor is responsible for one link of a chain in the provision of a public good (Hirshleifer 1983). Caparrós Gass and Finus (2020) argue that, since the contribution of the agent that contributes the least determines the outcome of all, the COVID-19 pandemic is a weakest-link public good game. Moreover, since the spread of virus and resistant bacteria is highly affected by other people's behavior and choices, both the COVID-19 pandemic and AMR are negative externalities.

However, the COVID-19 pandemic and AMR differ in one key aspect: while COVID-19 spread quickly and took most of the countries in Europe and elsewhere by surprise, AMR has been developing over several decades, although the problem has exacerbated more recently. On March 11, 2020, COVID-19 was declared a pandemic by the World Health Organization (WHO) (WHO 2020). According to Johns Hopkins University & Medicine (2022), by December 2021 there had been over 620 million confirmed global COVID-19 cases and about 6.5 million confirmed global deaths. With much less media and political attention, AMR may cause some *10 million deaths* annually by 2050 if left unchecked (O'Neill 2014), and the economic consequences may become as severe as the financial crisis of 2008/2009 (Jonas et al. 2017). In addition, antibiotics resistance is more of an intergenerational collective action problem since the overuse of antibiotics of past and current generations has led to antibiotic-resistant superbugs that threaten future generations (Sandler 2015).

An increasing number of studies investigate how the COVID-19 pandemic and the AMR problem might affect each other. Antibiotic prescribing, demographic characteristics of COVID-19 patients, and practices for infection protection and control may have changed during the COVID-19 pandemic. Interestingly, AMR could either increase or decrease as a result of the pandemic (Donà et al. 2020, Rawson et al. 2020a, Metsemakers et al. 2021, Knight et al. 2021). Knight et al. (2021) argue that the impact of the varied responses to the COVID-19 pandemic on AMR is difficult to predict and will vary in the short, medium, and long term. For example, increased hand hygiene, decreased international travel, and a decreased rate of elective hospital procedures may reduce the spread of AMR in the short term, while the opposite effects may be seen if antibiotics become more widely used as standard healthcare pathways break down. For example, Calderón-Parra et al. (2021) found that about one third of the hospitalized COVID-19 patients in Spain were inappropriately prescribed antibiotics. Hsu (2020), Bengoechea and Bamford (2020), and Clancy et al. (2020) argue that the COVID-19 pandemic will increase AMR. Clancy et al. (2020), however, argue that the extent of the increase in the AMR problem may vary, e.g., by region and the severity of the pandemic in each region. An additional problem is that several of the antibiotics used for possible secondary infections after COVID-19 have been broad-spectrum antibiotics (Rawson et al. 2020b) and/or antibiotics classified as being critically important (Miranda et al. 2020). Thus, the previous literature has so far focused on investigating medical aspects of the COVID-19 pandemic on AMR. This paper fills the existing gap of a social science perspective on the relationship between COVID-19 and AMR.

Based on a web survey and series of interviews among experts and public servants working professionally with AMR in 29 European countries, this paper investigates how experts and bureaucrats assess the impacts of the COVID-19 pandemic and of the severity of AMR in their respective countries on their future long-run cooperation on AMR domestically and among the European countries. We investigate these questions for the whole sample, i.e., at European level, but we also divide our sample into four geographical regions to look for heterogeneity in the bureaucrats' beliefs based on geographical region. The reason we do not analyze the data at country level is that the actual number of people who work professionally with AMR is very low in some of the countries or that we received too few responses per country. In those cases, we could not guarantee the anonymity of the bureaucrats who answered our survey.

We use two different measures of the COVID-19 pandemic: cumulative death rates per million people and country and the daily number of confirmed new COVID-19 cases per million people and country. Both measures correspond to the situation in each bureaucrat's own country on the day the bureaucrat submitted our survey. The reason for including both cumulative death rates and new confirmed COVID-19 cases is that they capture two different aspects of the severity of the pandemic and that they might affect the bureaucrats' beliefs about future long-run AMR collaboration differently. The cumulative death rate continues to increase in all countries over time. This is simply the inevitable nature of this variable. In contrast, the number of confirmed new infection cases goes up *or down* every day and therefore provides a more informative picture of the current COVID-19 situation in a country. For example, while the cumulative death rate in a country of course was higher in February 2021 than in October 2020, the number of new COVID-19 cases may have been much lower. Both measures are expressed per million people to account for differences in country size, and the new cases are 7-day smoothed to handle anomalies in reporting. It is widely discussed that the reported COVID-related death rates and numbers of new COVID cases might be both under- and overestimations (see, e.g., Richterich 2020, Wu et al. 2020, Kung et al. 2021). Yet, regardless of their accuracy, they constitute the information that public servants had at the time of our survey period. Note that, since we conducted our study over 20 weeks (October 8, 2020–March 5, 2021), our analyses can utilize the fact that the ongoing COVID-19 pandemic was unevenly severe at different times in different European countries. Moreover, since we have several observations from almost all countries, we can also use the variation in death rates and new cases within a country. To measure the severity of the AMR

situation in a country, we use both our survey data regarding bureaucrats' subjective opinions about the severity of the AMR problem and the actual daily antibiotics dosages (DDDs) administered per 1000 inhabitants per day and country (ECDC 2020).

We find that around 40% of the whole sample of bureaucrats believe that AMR cooperation will increase both within their own countries and at the European level, and one fifth believe that the COVID-19 pandemic will lead to decreasing collaboration. There are however considerable differences in preferences based on the geographical region a bureaucrat works in. For example, 45% of bureaucrats working in Eastern European countries believe that the COVID-19 pandemic will decrease AMR collaboration in their own countries. Neither the severity of the AMR problem nor confirmed new COVID-19 cases in one's own country has a significant impact on bureaucrats' beliefs about future collaboration. Instead, it is the cumulative COVID-19 death rates that increase the perceived likelihood of future domestic and European collaboration on AMR. When looking at the heterogeneity among the geographical regions, we find that increasing COVID-19 death rates domestically increases optimism about future AMR collaboration the most in Western European countries.

The remainder of the paper is organized as follows. In "Method, sample, and survey design", we describe the sample and the survey design. "Results" presents the results and "Interviews with senior bureaucrats: Long-term institutional consequences of theCOVID-19 pandemic" provides quotes from interviews with senior AMR bureaucrats in managerial positions to put the results from the web survey into the context of how EU health policy will develop in the future. In "Conclusions and discussion", we discuss our findings and their implications.

Method, sample, and survey design

Method and Sample. The survey was conducted October 2020–March 2021. The sample included both bureaucrats and professional experts working with AMR at government agencies and organizations involved in work to combat antimicrobial resistance (AMR) in all 27 EU member states plus the UK and Norway. The number of bureaucrats varied significantly across the countries and not all countries had expert groups supporting the domestic and international AMR work. We took the following steps to reach the AMR bureaucrats and experts:

1. We identified national authorities and organizations responsible for AMR work in the target countries by examining EU documents about ongoing AMR work and collaborations, by asking country experts in our networks, and by carefully searching the internet for bureaucrats and experts professionally working with AMR.
2. After identifying the correct organizations, we contacted the officials in charge via e-mail and informed them about the research project and the survey. We requested that they provide us with e-mail addresses to all the AMR bureaucrats and experts employed in their respective organizations. If they were unwilling to provide us with e-mail addresses, we gave them the option to assist us by distributing a survey link to the AMR employees in their organizations.
3. The procedure resulted in 205 e-mail addresses of bureaucrats and experts working with AMR in 21 countries[1]. People in 17 countries[2] accepted forwarding the survey to AMR employees in their respective agency. (i.e., for nine countries, we obtained both e-mail addresses of some experts and assistance in distributing the survey to other officials). We sent direct surveys to the bureaucrats we were able to receive e-mail addresses for, and otherwise we sent out an e-mail with a "shareable" link to the contact persons who had agreed to forward the survey. Hence, the possibility of potential survey mode effects cannot be excluded, and we will therefore control for this later in our analysis.

After three reminders, our final sample consisted of 136 bureaucrats from 29 European countries working with AMR professionally. The number of observations per country ranges from 1 to 21 with a mean value of 4.03. Due to missing observations, 117 observations are available for analysis.

Survey design. We started the survey by asking whether the bureaucrat worked with AMR in the human or the animal/agricultural sector. In the "Introduction" section of the survey, we asked general questions about the severity of AMR and how the bureaucrats experienced that the AMR problem was managed in their respective countries and in Europe overall. In the second section, we asked questions about collaboration in AMR work across the European countries and about possible problems that prohibit such cooperation. The third section included questions about which European country (or countries) should take the lead in combatting AMR. We also asked how well various actors (e.g., national politicians, EU, WHO, and physicians) are suited to take a lead role in coordinating the AMR work in Europe. The third section ended with the two questions that are of main interest in this study. The first question was asked to capture beliefs about the impact of the COVID-19 pandemic on the future long-run AMR collaboration in their own countries, i.e., domestically, and the second concerned long-run AMR collaboration between European countries. The respondents were asked to choose the alternative that best described their beliefs on a scale from 1 to 5, where 1 = decrease significantly and 5 = increase significantly. They were also allowed to choose the alternative "Don't know." The questions are shown below.

Question 1. Question about collaboration domestically.

In the long run, what impact do you think the COVID-19 pandemic will have on the collaboration between different actors *in your own country* working with AMR? The collaboration will…

Question 2. Question about collaboration between European countries.

In the long run, what impact do you think the COVID-19 pandemic will have on the collaboration between *European countries* concerning AMR? The collaboration will…

The fourth (and final) section of the survey consisted of questions related to the bureaucrats and their work. We asked them to answer questions about their education, what type of organization they worked for, and how large of a share of their worktime was devoted to AMR-related work.

Interviews with AMR bureaucrats in managerial positions. In addition to the web survey responses measuring public health professionals' views on the impact of the COVID-19 pandemic on future collaboration among the EU member states in the area of AMR, we also conducted a series of interviews with senior public servants in the public health sector. One difference compared with the web survey sample was that the interviews were conducted with bureaucrats in managerial positions in their respective organizations.

Because of COVID-19 travel restrictions, the interviews were carried out digitally (video). All interviews were recorded and transcribed. They followed an interview guide consisting of around 20 questions concerning AMR, including questions about whether there is a need for a more formal authority to create coordinated and sustainable action to address the AMR problem in Europe. To put the results from the web survey in the context

Table 1 Distributions for the AMR collaboration questions in the whole sample and in the four geographical regions.

Domestic cooperation will……						Cooperation among European countries will……				
	The whole sample	Western European countries	Eastern European countries	Southern European countries	Nordic countries	The whole sample	Western European countries	Eastern European countries	Southern European countries	Nordic countries
Decrease significantly	4%	6%	4%	15.3%	0%	0%	0%	0%	0%	0%
Decrease	16%	10%	41%	15.3%	7%	19.5%	16%	41%	23%	9%
Either decrease or increase	33%	23%	33%	31%	41%	25%	19%	26%	8%	33%
Increase	31%	35%	11%	15.3%	43%	36%	36%	18%	54%	41%
Increase significantly	8%	16%	4%	15.3%	2%	6%	13%	0%	7.5%	4%
Do not know	8%	10%	7%	8%	7%	13.5%	16%	15%	7.5%	13%
Mean (1-5)	3.2	3.5	2.6	3.1	3.4	3.3	3.5	2.6	3.4	3.5
No. of obs.	117	31	27	13	46	117	31	27	13	46

of the future of EU health policy integration, the paper uses illustrative quotes from interviews with senior bureaucrats from the Nordic and Southern European regions. The interviews place the web survey responses into a larger analytical context: the EU's intention to take a higher profile on public health issues in the wake of the COVID-19 pandemic.

Results

Descriptive results, cooperation. We now turn to our descriptive analyses at individual bureaucrat level to investigate the impact of the COVID-19 pandemic on the long-term AMR work. Thus, we pool all responses and study the complete sample. We also investigate whether the beliefs about cooperation differ among the bureaucrats based on the geographical location of their respective countries. Table 1 shows the distributions for the AMR collaboration questions for the whole sample and for the four geographical regions separately. The geographical regions are Western Europe, Eastern Europe, Southern Europe, and the Nordic countries. Supplementary online material Table S1 shows which countries belong to each region. We also report, per region, the mean values of actual DDDs per 1000 inhabitants and day (ECDC 2020) and how severe each country group perceives the AMR situation to be domestically and in the other European countries in general. In addition, we report the shares of GDP used for health care expenditures (Eurostat 2021, Cooper et al. 2020) and the mean COVID-19 death rates (Our World in Data 2021). We find that the four regions differ in most of these aspects. For example, the highest mean value of daily doses of antibiotics per 1000 inhabitants and day is found in the Southern European region (about 28 DDDs per 1000/day), while the lowest mean value is found in the Nordic countries (about 14 DDDs per 1000/day), indicating a twice as high antibiotics consumption in the southern parts of Europe. The subjectively perceived seriousness of the AMR problem domestically follows that same pattern. Interestingly, the four country groups perceive the AMR problem to be about equally serious in the European countries in general: all mean values are slightly below six on the 1–7 scale. The countries in the Eastern European region use the lowest share of their GDP for health care expenditures (Eurostat 2021, Cooper et al. 2020).

We first look at the whole sample. According to the Wilcoxon signed rank test, there is a statistically significant difference between the distributions of responses to the questions about collaboration (p value 0.038). The bureaucrats are slightly more optimistic about future AMR collaboration at the European level than within their own respective countries: 39% of the bureaucrats and experts believe that cooperation will increase within their own countries, while the corresponding share for the European level collaboration is 42%. The mean scores (1–5, a higher number equals more cooperation) show the same pattern: 3.2 for within-country cooperation and 3.3 for European cooperation. However, one fifth believe that the COVID-19 pandemic will decrease the AMR collaboration in the future. The share of unsure bureaucrats was larger when we asked about European cooperation (13.5%) than when we asked about domestic cooperation (8%).

When looking at the different geographical regions, we find that there are considerable differences in preferences. While the largest shares of bureaucrats in the Nordic and Western European countries believe that the AMR collaboration will increase in their own country (45% and 51%, respectively), the largest shares of their colleagues in the Eastern European countries (45%) believe that the domestic collaboration of this type will instead decrease. When it comes to European collaboration, the Eastern European bureaucrats are clearly the most pessimistic and the Southern

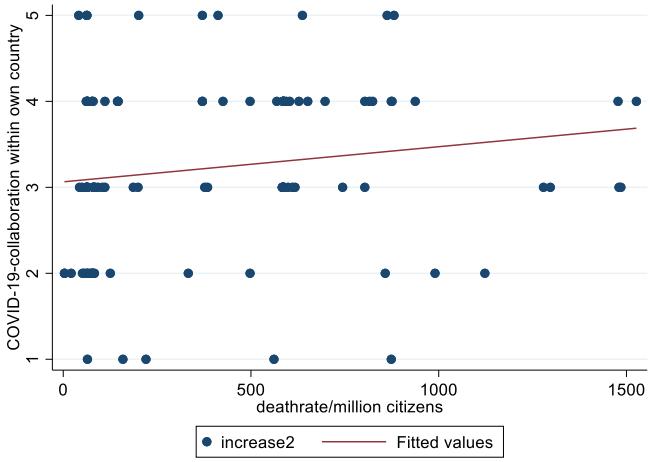

Fig. 1 Relationship between COVID-19 death rate/million and beliefs about domestic AMR collaboration. Figure 1 shows that when the death rate increases, bureaucrats' beliefs slowly become more optimistic about future domestic collaboration.

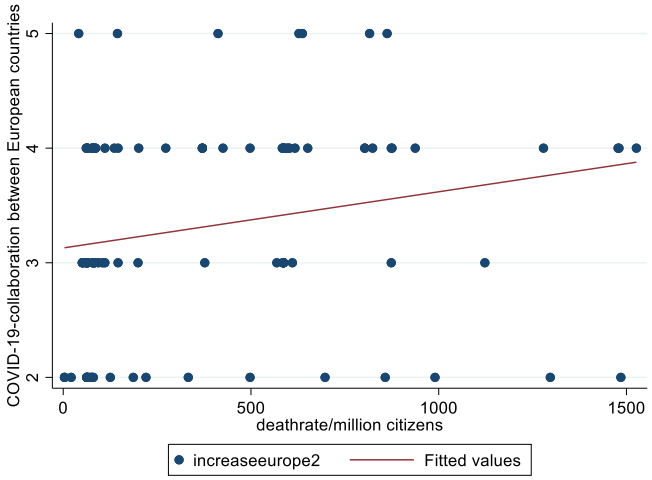

Fig. 2 Relationship between COVID-19 death rate/million and beliefs about European AMR collaboration. Figure 2 shows a steeper line compared to the Fig. 1, i.e., the bureaucrats are more optimistic about future European than domestic long-run collaboration when the death rate increases.

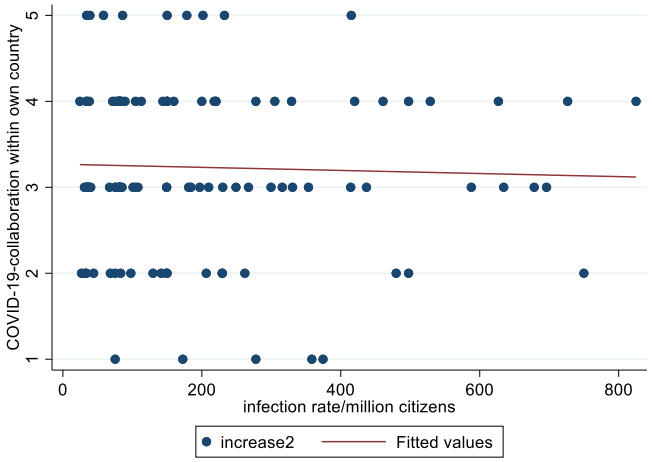

Fig. 3 Relationship between confirmed new COVID-19 cases/million and beliefs about domestic AMR collaboration. Figure 3 shows a flat and slightly decreasing line. Thus, if anything, increasing daily numbers of new COVID-19 cases decreases the expectations of increased domestic cooperation.

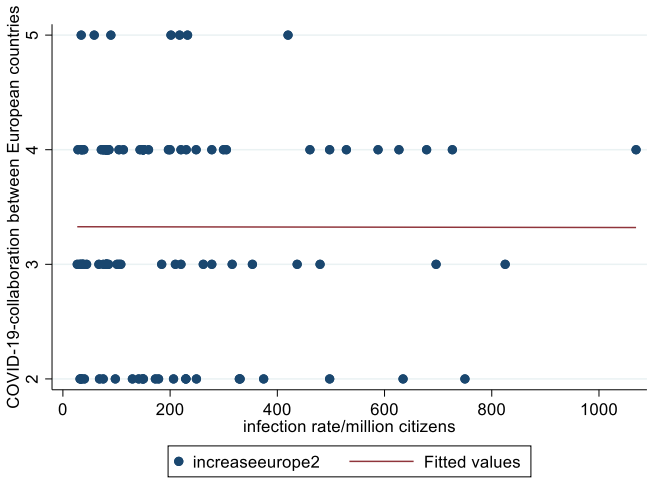

Fig. 4 Relationship between confirmed new COVID-19 cases/million and beliefs about European AMR collaboration. Figure 4 shows a very flat line indicating no relationship between the daily number of new COVID-19 cases and expectations about long-run AMR collaboration between European countries.

European bureaucrats the most optimistic: about 62% of the latter group believe that the COVID-19 pandemic will increase or significantly increase collaboration between European countries on AMR-related issues. This difference is also clear from a comparison of mean scores: The mean for Eastern European countries (2.6) is much lower than those for the Nordic (3.5), Western (3.5), and Southern European (3.4) countries.

Descriptive results, relationship between COVID-19 and cooperation. Figure 1 below shows the relationship between the number of COVID-19 deaths per million people and the answer to the first question, i.e., belief about how the COVID-19 pandemic will affect the domestic AMR collaboration in the long run. Figure 2 shows the same relationship but now for the second question, about the long-run collaboration between European countries. Figure 3 shows the relationship between confirmed new COVID-19 cases per million people and the beliefs regarding domestic AMR collaboration, while Fig. 4 shows the same for the long-run collaboration between European countries. The answers for both questions are measured on a scale from 1 to 5, where 1 = decrease significantly and 5 = increase significantly. All graphs include the whole sample of bureaucrats, but those who chose the do-not-know alternative are excluded.

Figure 1 shows that on average, when the death rate is close to zero, bureaucrats are slightly more optimistic than neutral or pessimistic in their expectations about future domestic AMR cooperation: the mean value is just above three (3.23) on the scale from 1 to 5. However, as the death rate increases, their beliefs slowly become more optimistic. When looking at Fig. 2, we find that also here, at a death rate of zero, the average expectation is again slightly above three (3.33). The slope of the line is however a bit steeper in Fig. 2 than in Fig. 1. When it comes to confirmed new COVID-19 cases, the line is flat but slightly decreasing in Fig. 3. Thus, if anything, increasing daily numbers of new COVID-19 cases decreases the expectations of increased domestic cooperation. Figure 4 shows a very flat line indicating no relationship between the daily number of new COVID-19 cases

Table 2 Descriptive statistics of the bureaucrats working with AMR.

Variable	Description	Mean value	Std. dev.
	Dependent variables:		
Increase, own country	=1 if a bureaucrat answered that the COVID-19 pandemic will increase or significantly increase domestic AMR collaboration.	0.385	0.489
Increase, European countries	=1 if a bureaucrat answered that the COVID-19 pandemic will increase or significantly increase AMR cooperation between European countries.	0.419	0.495
	Independent variables:		
Prescription level, antibiotics/country	Prescription level of antibiotics measured as DDD/1,000 inhabitants/day[a]	17.129	6.079
COVID-19 death rate/million/country[b]	Cumulative COVID-19 death rate per million people domestically on the day a bureaucrat submitted the survey.	410.222	401.525
New COVID-19 cases smoothed per million[b]	New confirmed cases of COVID-19 (7-day smoothed) per million people	211.625	204.703
Human	= 1 if a bureaucrat worked primarily in the human sector	0.470	
Animal	= 1 if a bureaucrat worked primarily in the animal sector	0.530	
Nordic countries	=1 if a bureaucrat worked in Sweden, Finland, Norway, or Denmark.	0.393	
Western European countries	=1 if a bureaucrat worked in Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, or UK.	0.265	
Southern European countries	=1 if a bureaucrat worked in Cyprus, Greece, Italy, Malta, Portugal, or Spain	0.111	
Seriousness of AMR, own country (1= not serious at all, 7= very serious)	= the level of how serious a bureaucrat experienced AMR level in own country	4.530	1.387
Direct web survey	= 1 if a bureaucrat received the web survey personally	0.547	
Agency	=1 if a bureaucrat worked with AMR at government agency level	0.581	
Ministry	=1 if a bureaucrat worked with AMR at ministry level	0.197	
Other workplace	=1 if a bureaucrat worked with AMR elsewhere	0.222	
Fulltime	=1 if a bureaucrat worked full time with AMR	0.145	
Halftime	=1 if a bureaucrat worked 50–75% of full time with AMR	0.368	
Time trend	2-week intervals from Oct. 8, 2020 to Feb. 22, 2021 (10 Dummy variables)		
No. of obs.	117		

[a]source= ECDC (2020).
[b]source= Our World in Data (2021).

and expectations about long-run AMR collaboration between European countries.

In the supplementary material (Appendix B, Figs. S1–S8), we show that there is large heterogeneity among the different geographical regions when it comes to correlation between expectations about future collaboration and death rates per million. We find that the Eastern and South European regions and the Nordic countries all show quite flat lines when it comes to domestic collaboration, while the line for Western Europe is steeper. An increasing number of COVID-19 deaths increases the collaboration from level 3 to clearly over 4, on the scale from 1 to 5. When it comes to the between-country collaboration, the line is again steepest for the Western region, but now followed by the Southern European region.

Descriptive statistics. In Table 2, we report the descriptive statistics of both the dependent and independent variables used in our regression analysis. Table 2 shows that a small majority of our bureaucrats and experts work in the animal sector (53%), 58% work at a government agency, 20% at the ministry level, and 22% elsewhere. Fifty-five percent of the bureaucrats who submitted the survey received our survey directly from us, while the rest received it as a snowball survey. As for the experienced seriousness of the AMR situation in the respondents' own countries, the mean value is 4.5 on a scale from 1 to 7 (1 = not serious at all, 7 = very serious). In the sample, the cumulative mean COVID-19 death rate per million people is 410.222 individuals, but the standard deviation is very large, indicating clear heterogeneity across the European countries. Finally, the 7-day smoothed number of confirmed new COVID-19 cases per million people is about 212, and again the standard deviation is large, in fact almost twice as large as the sample mean value.

The country-specific mean values for death rate/million and new COVID-19 cases/million are shown in Supplementary Table S2 online. Table S2 shows that bureaucrats and experts working in Belgium and Hungary had experienced the highest death rates, over 1100 deaths per million, at the time of our survey. At the other end of the distribution, Croatia, Cyprus, Estonia, Latvia, and Norway had the lowest death rates when we conducted our study, i.e., below 100/million. Luxembourg had the highest level of new COVID-19 cases at the time of our study, followed by Spain, Czech Republic, France, Lithuania, and Slovenia.

Results, what influences expectations about future AMR collaboration? Since we have several observations per country, we will use a panel data model, namely the random parameter logit model. The p-value of the Hausman specification test (Hausman 1978) of the regression concerning the impact on domestic/European AMR cooperation is 0.080/0.630, respectively. The panel data indicator is the variable *country*, which ranges from 1 to 21 depending on the number of observations per country. In the first regression, the dependent variable is a dummy that equals 1 if the bureaucrat expected the COVID-19 pandemic to increase or substantially increase the long-run AMR collaboration in their own country. In the second regression analysis, the dependent variable equals 1 if a bureaucrat expected the COVID-19 pandemic to increase or significantly increase long-run AMR collaboration between European countries. In Model 1, we only include our main independent variables, i.e., COVID-19 death rate based on number of cumulative deaths/million per country on the day the bureaucrat submitted our survey and the variable

measuring the number of new confirmed new COVID-19 cases per million,[3] a variable capturing how serious a bureaucrat experienced the current AMR situation in their own country, and a control for the sector in which a bureaucrat works (human versus animal). Moreover, the COVID-19 death rate is in our model measured in hundreds of deaths and the variable measuring the number of new confirmed COVID-19 infections is 7-day smoothed. In Model 2, to be able to investigate heterogeneity in expectations among the countries, we created four geographically determined country groups capturing whether a bureaucrat worked in one of the Nordic countries, a Southern European country, a Western European country, or an Eastern European country (the latter is the reference category). We also add controls for work-related background information and whether a bureaucrat answered the direct personal survey or the snowball survey. Since the death rate variable is a cumulative variable that is always increasing, we also control for the time trend in all regressions. The unit of the time trend variable is two weeks and the reference category is the first two weeks of the survey period, i.e., starting October 8, 2020. A weakness of this study is the limited study period of 20 weeks. However, as shown in Table S2, the study period was long enough to capture heterogeneity in both new COVID-19 cases and cumulative death rates across the 29 countries. In Table 3, we show the marginal effects from our random parameter logit model. Since we can assume that bureaucrats within the same country have unobservable similarities, the robust standard errors are clustered at country level.

Model 1 shows that the variable capturing the cumulative number of COVID-19 deaths per million in the respondent's own country on the day they submitted the survey is positive and significant at a 1% significance level. Thus, the higher the death rate, the more likely it is that a bureaucrat expects increased AMR collaboration in their own country due to the COVID-19 pandemic. For each 100 COVID-19 deaths per million people, the likelihood increases by about four percentage points. Thus, since the sample mean death rate per one million citizens is 410.2, the marginal effect of the average death rate/million in the sample is sizeable, about 17 percentage points. The marginal effects of the variable capturing number of new COVID-19 cases and of the seriousness of the AMR situation in their own respective countries are negative but statistically insignificant. When we replaced the variable capturing a subjective opinion about the severity of the AMR problem with a variable measuring actual daily antibiotics doses per country (ECDC 2020), also that variable was insignificant. Results are available on request.

In Model 2, the results of the death rate variable remain statistically significant also after all the controls. As expected, the impact of the sector in which a bureaucrat works is large: the likelihood of expecting increasing domestic collaboration increases by about 30 percentage points if a bureaucrat works in a human sector vs. an animal sector. We also find that the large heterogeneity in preferences based on geographical location of a country we found in the descriptive analysis earlier holds for regression analyses with various controls. The bureaucrats working in the Western European countries are about 24 percentage points more likely than their Eastern European colleagues to believe in future collaboration, but bureaucrats from the Nordic countries are clearly the most optimistic concerning future domestic AMR cooperation, and the difference compared with the bureaucrats from Eastern European countries is sizeable: 44 percentage points. The marginal effect for Southern Europe is insignificant in Model 2, indicating more similar beliefs among bureaucrats working in Southern and Eastern Europe, i.e., they are significantly less likely to expect increased domestic AMR cooperation.

In the second regression, we investigate the likelihood of stating that the European AMR collaboration will increase in the long run. In both Models 3 and 4, the actual COVID-19 death rate is positively and significantly correlated with the beliefs about

Table 3 Marginal effects after random effects logistic regression.

Variable	Model 1 Impact in own country	Model 2 Impact in own country	Model 3 Impact between European countries	Model 4 Impact between European countries
COVID-19 death rate/100/million	0.036**	0.029*	0.032**	0.028*
people/country	(0.012)	(0.013)	(0.011)	(0.012)
New COVID-19 cases/100/million	−0.023	−0.010	−0.002	0.033
people/country	(0.025)	(0.029)	(0.024)	(0.025)
Severity of AMR, own country	−0.013	0.019	−0.029	−0.010
	(0.026)	(0.028)	(0.031)	(0.032)
Human	0.212***	0.295***	0.167**	0.199***
	(0.052)	(0.060)	(0.051)	(0.048)
Nordic countries		0.436**		0.350*
		(0.136)		(0.152)
Western European countries		0.244*		0.099
		(0.113)		(0.132)
Southern European countries		0.230		0.512***
		(0.140)		(0.134)
Control for the survey type	No	Yes	No	Yes
Controls for occupational variables	No	Yes	No	Yes
Controls for time trend	Yes	Yes	Yes	Yes
No. of countries	29	29	29	29
No. of obs.	116	116	114	114
AIC	161.288	151.688	159.433	154.048

Time trend: 2-week intervals between the period October 8, 2020–February 22, 2021.
Occupational variables: other workplace, working full time, and working half time.
Survey type: direct web survey vs. snowball survey.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.
Standard deviations in parentheses. Dependent variable is impact in own country will increase and impact between European countries will increase, respectively. Robust standard errors clustered at country level.

future AMR collaboration. Severity of the AMR problem has no statistically significant impact on the likelihood of expecting increasing collaboration in any of the models. Interestingly, the geographical pattern is partly different when investigating expected future AMR collaboration at the European level: Now it is actually the bureaucrats from Southern European countries who are the most likely to expect increased collaboration, compared with their Eastern European counterparts. In fact, the probability is 51 percentage points higher that a Southern European bureaucrat expects increased European AMR collaboration than that an Eastern European bureaucrat does so. Again, public servants in the Nordic countries are significantly more likely than their Eastern European colleagues to believe in increased future collaboration. Thus, we conclude that geographical location matters. One possible reason for the geographical differences we find in this study might be, as shown in Supplementary Table S1 online, that bureaucrats working in e.g., Eastern European countries perceive their antibiotics situation as more serious than the sample average. Another reason might be that the share of GDP used for the health sector is lowest in the Eastern European region.

Interviews with senior bureaucrats: long-term institutional consequences of the COVID-19 pandemic

The results from the web survey are interesting in light of an ongoing academic and policy debate about how the COVID-19 pandemic will influence the future of European Union health policy integration. Scholars point to COVID-19 as a health crisis potentially opening a window of opportunity for increasing European integration in the area of health (Brooks and Geyer 2020, Brooks et al. 2020). According to the EU, the member states' responses to the COVID-19 pandemic highlight the difficulties in voluntary coordinated action in the EU and the need for an upper-level authority. Whether in line with Sir Winston Churchill's idea of "never letting a good crisis go to waste" and an opportunity to increase Brussel's control over the member states or as a recognition of the devastating effects of pandemics, the EU Commission has adopted a new €5.3 billion health program—EU4Health (2021–2027)—with a focus on cross-border threats, availability of medicines, and improvements in health systems (European Commission 2020).

National senior public servants in the public health sectors have rather differing views on the EU's strategy to reduce "national competence" and give Union institutions more leverage over the member states. Even the critics of the proposal, who tend to be found mainly in Northern Europe, admit, however, that this might benefit the struggle against AMR:

> "It could be that the EU in the wake of the COVID pandemic will define AMR as a cross-border health threat, a move which would give the EU more leverage. This might push those countries that have not done very much to reduce AMR." (Scandinavian senior public servant, public health)

Another Scandinavian public health expert largely agrees:

> "The COVID-19 pandemic has probably made many countries see the need for an EU agency that tells them what to do. If the EU can come up with specific targets and rules and demand that the member states meet those targets, no matter how, it should have an impact." (Scandinavian senior public servant, public health)

A Southern European public health expert makes a similar point, only more articulated:

> "Health is a subsidiarity issue, but microbes do not recognize national borders. It is one thing to talk about national competence in areas such as cardiac surgery. It is a different story when you are talking about the rise of microbes in a country as a result of the lack of initiatives or strategies against AMR, and those microbes are then transmitted to other countries. If that is a legacy of COVID, it is a good legacy."

Despite many examples of brief spells of non-cooperative behavior among the EU member states during the initial stages of the pandemic, the long-term consequences may still be quite the opposite: more coordination, collective action, and an institutionalized mechanism for mutual help and solidarity in relation to cross-border health threats.

The threat posed by COVID-19 seems to have influenced the perceptions of the future of AMR collaboration among the bureaucrats. While it is not obvious how the bureaucrats responding to the web survey interpreted *collaboration* (for example, do they think of voluntary arrangements or formally enforced collaboration?), the web survey and the quotes from the interviews with bureaucrats in managerial positions seem to point in the same direction. COVID-19 mortality drives expectations of more collaboration, and the pandemic makes senior bureaucrats envision an institutional structure with leverage to enforce policy to combat cross-border health threats.

Conclusions and discussion

The response to the COVID-19 pandemic has brought the prospect for international health collaboration into question (Bump et al. 2021), but it has also been held as an opportunity to strengthen the future global preparedness for pandemics (Ekström et al. 2021). This paper explores how the experience of the COVID-19 pandemic connects to the future response of the "silent" pandemic—AMR. Despite the severity of AMR and the relevance of a social science approach to this evolving problem, the social science research on these issues remains limited (Frid-Nielsen et al. 2019), in particular when it comes to the link between the COVID-19 pandemic and AMR. Based on a survey among public servants working on AMR in 29 European countries, this paper investigates how these bureaucrats expect the COVID-19 pandemic to affect their future long-run AMR cooperation both within their own countries and between the European countries. In addition, we investigate whether cumulative COVID-19 death rates and the number of new confirmed coronavirus cases have impacted bureaucrats' subjective beliefs about long-run AMR collaboration.

Our results show that the bureaucrats are slightly more optimistic about future AMR collaboration at the European level than domestically: 39% of the bureaucrats and experts believe that cooperation will increase within their own countries, while the corresponding share for European-level collaboration is 42%. One fifth of them believe, however, that the COVID-19 pandemic will decrease the future AMR collaboration both within their own countries and between the European countries. Moreover, we find large heterogeneity in preferences based on the geographical location of a country. The Nordic countries are clearly the most optimistic about increased future cooperation domestically, and the difference compared with the Eastern European countries is sizeable: 44 percentage points.

Bureaucrats working in Southern and Eastern Europe are significantly less likely to believe in increased AMR cooperation within their own countries. The geographical pattern differs partly when investigating thoughts about future AMR collaboration at the European level. The probability is 51 percentage points higher that a Southern European bureaucrat expects increased European AMR collaboration than that an Eastern European bureaucrat does so. The Nordic countries are again significantly more likely than their

Eastern European colleagues to believe in increased future collaboration. This does not seem to be caused by differences in the sample of bureaucrats between the regions. The regional variation persists when controlling for individual-level factors related to their work engagement in AMR. It is difficult to tell why bureaucrats in Eastern Europe are less likely to believe in increased collaboration. But since both AMR and the COVID-19 pandemic are weakest-link problems, successful management of these problems demand every country's engagement.

We also find that neither the severity of the AMR problem nor the rate of confirmed new COVID-19 cases in the home country has a significant impact on bureaucrats' beliefs about future collaboration. However, the cumulative death rates in the respective countries have a significant and stable impact. This result holds when adding various controls. It seems that the cumulative death rates capture the severity of the pandemic and make the bureaucrats believe in increased collaboration in the AMR field both domestically and between the European countries.

Despite the fact that the response to the pandemic has been characterized by closed borders, competition over medicine, and vaccine nationalism rather than collaboration for the common good, the results from the web survey paint a weakly positive picture of the future of AMR collaboration. The interviews with AMR bureaucrats in managerial positions point in the same direction: the pandemic may result in more European collaboration to combat cross-border health threats. This result opens for several different interpretations. As pointed out before, the COVID-19 pandemic and AMR share several features. They are both major global health challenges and weakest-link problems since successful management of them demands every country's engagement as well as intersectoral and international cooperation. But they have also some differences. The rapid spread of COVID-19 puts immense pressure on national politicians and bureaucrats to act timely and forcefully. If they do not, both the epidemiological and political consequences will be severe. AMR is not a politically salient issue. Elections are not likely to be lost if the governments underperform in limiting AMR. The slow development of AMR is more compatible with the complicated and time-consuming processes often characterizing intersectoral and international cooperation.

In summary, our first main result is that a larger share of the bureaucrats and experts working professionally with AMR in Europe are optimistic rather than pessimistic about post-pandemic AMR collaboration, indicating that global health crises such as the COVID-19 pandemic can shape future collaboration across the European countries when it comes to the equally global but more long-run health problem AMR. Moreover, the optimism is slightly stronger for the collaboration at the European level than for the collaboration within the respondents' own countries. Thus, it is possible that the COVID-19 pandemic reminds AMR bureaucrats about the value of collaboration around pressing health issues, and that the EU can provide solutions to public health threats that domestic public health policy cannot respond effectively to (Greer and Jarman 2021). However, to be able to really receive cooperation across the European countries, policy makers should consider our second main result, i.e., that there are large geographical differences in bureaucrats' expectations on collaboration. We find that bureaucrats from especially the Eastern European countries are much less likely to believe that the COVID-19 pandemic will increase long-run collaboration between European countries in the field of combatting AMR.

Data availability

The dataset generated during and analyzed during the current study is available in the Mendeley Data: V1, https://doi.org/10.17632/8rkgh823ch.1. The data comes from our own survey conducted among experts working with AMR in 29 European countries.

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Notes

1 Belgium (13), Bulgaria (7), Estonia (4), Finland (59), France (27), Greece (16), Ireland (7), Italy (9), Latvia (1), Lithuania (6), Luxemburg (10), Poland (7), Portugal (2), Romania (2), Slovenia (5), Spain (3), Sweden (3), Czech Republic (3), Germany (3), the UK (6), and Austria (3).

2 Cyprus, Denmark, Greece, Ireland, Croatia, Latvia, Lithuania, Malta, the Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Germany, Hungary, and France.

3 The correlation coefficient between the variables "confirmed new COVID-19 cases per million" and "the number of cumulative deaths per million and country" is 0.232. We can therefore include both these variables in the same regression.

References

Anderson M et al. (2020) Covid-19 exposes weaknesses in European response to outbreaks. BMJ 368:m1075

Bengoechea JA, Bamford CG (2020) SARS-CoV-2, bacterial co-infections, and AMR: the deadly trio in COVID-19? EMBO Mol Med 12(7):e12560

Brooks E, de Ruijter A, & Greer SL (2020) COVID-19 and European Union health policy: from crisis to collective action. In Vanhercke, BSS and B Fronteddu, (ed.) "*Social policy in the European Union: state of play. Facing the pandemic*", Brussels, European Trade Union Institute (ETUI) and European Social Observatory (OSE)

Brooks E, Geyer R (2020) The development of EU health policy and the Covid-19 pandemic: trends and implications. J Eur Integr 42(8):1057–1076

Bump JB, Friberg P, Harper DR (2021) International collaboration and covid-19: what are we doing and where are we going? BMJ 372:n180

Calderón-Parra J, Muiño-Miguez A, Bendala-Estrada AD, Ramos-Martínez A, Muñez-Rubio E, Fernández Carracedo, E., … & SEMI-COVID-19 Network (2021) Inappropriate antibiotic use in the COVID-19 era: Factors associated with inappropriate prescribing and secondary complications. Analysis of the registry SEMI-COVID. PloS One 16(5):e0251340

Caparrós Gass A, Finus M (2020) The corona-pandemic: a game-theoretic perspective on regional and global governance. Environ Resour Econ 76(4):913–927

Clancy CJ, Buehrle DJ, Nguyen MH (2020) PRO: the COVID-19 pandemic will result in increased antimicrobial resistance rates. JAC-Antimicrob Resist 2(3):dlaa049

Congleton RD (2021) Federalism and pandemic policies: variety as the spice of life. *Public Choice*, 1–28

Cooper J, Lewis J, and Pett T (2020) Health Expenditure, UK Health accounts: 2018. *Stat Bull. Available at* file:///C:/Users/xlamel/Downloads/Healthcare%20expenditure,%20UK%20Health%20Accounts%202018.pdf, Accessed 16 Jun 2021

Donà D, Di Chiara C, Sharland M (2020) Multi-drug-resistant infections in the COVID-19 era: a framework for considering the potential impact. J Hosp Infect 106(1):198–199

ECDC (2020) Antimicrobial consumption in the EU/EEA Annual Epidemiological Report for 2019, https://www.ecdc.europa.eu/sites/default/files/documents/Antimicrobial-consumption-in-the-EU-Annual-Epidemiological-Report-2019.pdf, p. 5, Accessed 10 Mar 2021

Ekström AM, Berggren C, Tomson G, Gostin LO, Friberg P, Ottersen OP (2021) The battle for COVID-19 vaccines highlights the need for a new global governance mechanism. Nat Med 27(5):739–740

European Commission (2020) Regulation of the European Parliament and the Council on the establishment of a Programme for the Union's action in the field of health –for the period 2021–2027 and repealing regulation (EU) No 282/2014 ("EU4Health Programme")

Eurostat (2021), Current healthcare expenditure, 2018 SPS20.png, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Current_healthcare_expenditure,_2018_SPS20.png, Accessed 16 Jun 2021

Frid-Nielsen SS, Rubin O, Baekkeskov E (2019) The state of social science research on antimicrobial resistance. Soc Sci Med 242:112596

Greer SL, Jarman H (2021) What is EU public health and why? Explaining the scope and organization of public health in the European Union. J Health Politics Policy Law 46(1):23–47

Hausman JA (1978) Specification tests in econometrics. Econometrica 46:1251–1271

Hirshleifer J (1983) From weakest-link to best-shot: the voluntary provision of public goods. Public Choice 41(3):371–386

Hsu J (2020) How covid-19 is accelerating the threat of antimicrobial resistance. BMJ 369
John Hopkins University & Medicine (2022), Coronavirus Resource Center, https://coronavirus.jhu.edu/, Accessed 7 Oct 2022
Jonas O, Irwin A, Berthe F, Le Gall F Marquez P (2017) Drug-resistant infections: a threat to our economic future (Vol. 2) : final report. HNP/Agriculture Global Antimicrobial Resistance Initiative Washington, D.C. World Bank Group
Knight GM, Glover RE, McQuaid CF, Olaru ID, Gallandat K, Leclerc QJ, Chandler CI (2021) Antimicrobial resistance and COVID-19: intersections and implications. Elife 10:e64139
Kung S et al. (2021) Underestimation of COVID-19 mortality during the pandemic. ERJ Open Res 7(1)
Metsemakers WJ, Zalavras C, Schwarz EM, Chen AF, Trampuz A, Moriarty TF (2021) Antimicrobial resistance, the COVID-19 pandemic, and lessons for the orthopaedic community. JBJS 103(1):4–9
Miranda C et al. (2020) Implications of antibiotics use during the COVID-19 pandemic: present and future. J Antimicrob Chemother 75:3413–3416. 12
O'neill JIM (2014) Antimicrobial resistance: tackling a crisis for the health and wealth of nations. Rev Antimicrob Resist
Our World in Data (2021), The complete Our World in Data COVID-19 dataset, https://ourworldindata.org/coronavirus-data, Accessed 23 Apr 2021
Rawson TM, Ming D, Ahmad R, Moore LS, Holmes AH (2020a) Antimicrobial use, drug-resistant infections and COVID-19. Nat Rev Microbiol 18(8):409–410
Rawson TM, Moore LS, Zhu N, Ranganathan N, Skolimowska K, Gilchrist M, Holmes A (2020b) Bacterial and fungal coinfection in individuals with coronavirus: a rapid review to support COVID-19 antimicrobial prescribing. Clin Infecti Dis 71(9):2459–2468
Richterich P (2020) Severe underestimation of COVID-19 case numbers: effect of epidemic growth rate and test restrictions. medRxiv 2020–04
Sandler T (2015) Collective action: fifty years later. Public Choice 164(3):195–216
WHO (2020), Covid-19 response, A73/CONF./1 Rev.1 https://apps.who.int/gb/ebwha/pdf_files/WHA73/A73_CONF1Rev1-en.pdf, Accessed 8 Sep 2021
Wu SL, Mertens AN, Crider YS, Nguyen A, Pokpongkiat NN, Djajadi S, Benjamin-Chung J (2020) Substantial underestimation of SARS-CoV-2 infection in the United States. Nat Commun 11(1):1–10

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Author contributions

All the authors have contributed to the idea of the study, the design of the survey, and writing of the paper during the whole process.

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Competing interests

The authors declare no competing interests.

Ethical approval

Our survey did not include any questions that, according to Swedish legislation, are considered sensitive and would therefore require ethical approval.

Informed consent

On the first page of the survey, we informed our respondents that participation in the survey was completely voluntary, and that each respondent had the right to cancel at any time, without explanation. We also informed them that their answers and results would be processed so that unauthorized persons could not access them and in accordance with the General Data Protection Regulation (GDPR) rules. Consequently, proceeding with answering the survey after this information had been provided is interpreted as having given consent to participate.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-023-01948-9.

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