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#### SUPPLEMENTARY MATERIALS

www.sciencemag.org/content/354/6309/213/suppl/DC1  
Materials and Methods

Figs. S1 to S6

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Movie S1

References (16–59)

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## POLITICAL SCIENCE

# How economic, humanitarian, and religious concerns shape European attitudes toward asylum seekers

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What types of asylum seekers are Europeans willing to accept? We conducted a conjoint experiment asking 18,000 eligible voters in 15 European countries to evaluate 180,000 profiles of asylum seekers that randomly varied on nine attributes. Asylum seekers who have higher employability, have more consistent asylum testimonies and severe vulnerabilities, and are Christian rather than Muslim received the greatest public support. These results suggest that public preferences over asylum seekers are shaped by sociotopic evaluations of their potential economic contributions, humanitarian concerns about the deservingness of their claims, and anti-Muslim bias. These preferences are similar across respondents of different ages, education levels, incomes, and political ideologies, as well as across the surveyed countries. This public consensus on what types of asylum seekers to accept has important implications for theory and policy.

Europe currently faces the largest refugee crisis since the Second World War. In 2015, Europe received ~1.3 million new asylum claims (1), and many more people are expected to flee to Europe as conflicts in the Middle East and other regions linger on. The number of migrants trying to reach Europe via the Mediterranean Sea who have been reported missing or dead totaled 3771 in 2015 alone (2), and this number is likely to be higher in 2016 as asylum seekers embark on new and even more dangerous routes to Europe after the implementation of the refugee deal between the European Union and Turkey (3).

As more and more people flee war-torn countries and persecution, refugee-receiving democracies must confront a fundamental challenge: how to

honor international commitments—including treaties like the United Nations 1951 Refugee Convention—to process asylum claims and provide shelter to accepted refugees, while at the same time developing asylum policies that are supported by domestic voters.

There is considerable heterogeneity in the exposure of European countries to the asylum crisis (Fig. 1). Whereas some countries, like Germany and Sweden, process a large number of asylum applications per capita, others, like the United Kingdom and Czech Republic, share a comparatively small responsibility. Yet the migrant crisis has been so severe that it has resulted in political conflict and social tensions widely across Europe, including extreme right-wing parties mobilizing citizens around asylum issues (4), frequent arson attacks on asylum centers (5), and the partial closing of Schengen borders.

As the crisis threatens national solidarity, the social contract, and continental unity, European policy-makers face increasing public pressure to find policy solutions. Although public preferences may not always directly translate into policies, a sizable political science literature has shown that, in democratic countries, particularly salient

and high-profile public policies often respond markedly to public opinion (6–8). In the context of this study, a case in point is the recent “Brexit” referendum in the United Kingdom in which the public voted for the United Kingdom to exit the European Union, a decision that has been attributed to rising anti-immigrant backlash in the United Kingdom (9). And whereas public opinion is a crucial factor, a key problem for both academic scholars and policy-makers alike is a lack of knowledge as to why some native-born citizens oppose and others support the welcoming of particular asylum seekers.

A large literature has examined public attitudes toward immigrants (10), ethnic minorities (11), and Muslims (12, 13) in general, but far fewer studies have looked at attitudes toward asylum seekers (14–21). The latter studies have provided important insights into the correlates of anti-asylum seeker sentiment, but either they are limited to particular countries or they rely on observational data from standard survey questions that ask about asylum seekers in general and do not use experiments to differentiate between different types of asylum seekers (22). Furthermore, they have mostly been conducted before the current asylum crisis. There still exists very little systematic and experimental evidence to inform the heated ongoing political debates over asylum policies with the voice of European voters. In particular, we lack a comprehensive assessment that captures which particular types of asylum seekers the European public is willing to accept given the current crisis.

To provide such an assessment, we designed a conjoint experiment and embedded it in a large-scale online public opinion survey that we fielded in 15 European countries (23). We used entropy balancing (24) to reweight our sample data to match the demographic margins from the populations of each country. Details about the sample, design, and statistical analysis can be found in the supplementary materials (SM) (25). All analyses, except otherwise noted, were prespecified in a preregistered analysis plan made available at the Political Science Registered Studies Dataverse (<http://dx.doi.org/10.7910/DVN/YUNKUL>).

Conjoint experiments ask subjects to evaluate hypothetical profiles with multiple, randomly varied attributes and are widely used in marketing and, increasingly, in other social science fields to measure preferences and the relative importance

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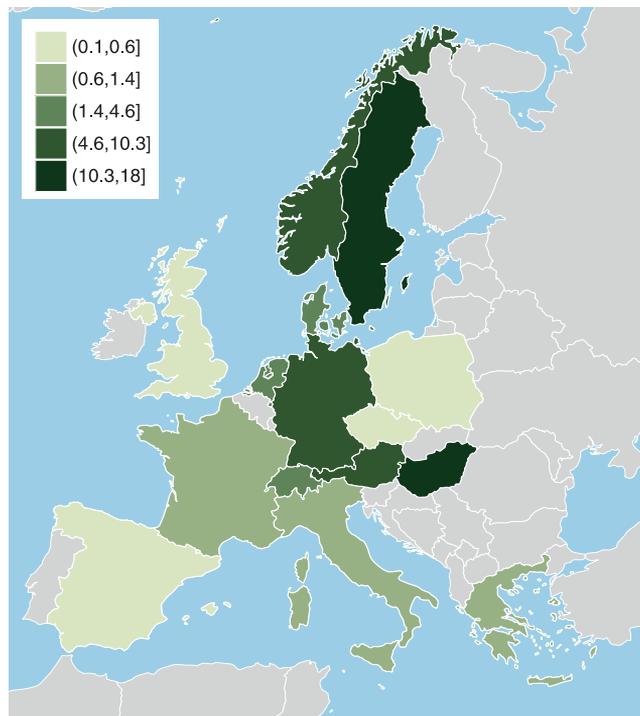
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of structural determinants of multi-dimensional decision-making (26, 27). Specifically, we used a conjoint experiment to ask 18,000 European eligible voters to evaluate 180,000 profiles of asylum seekers that randomly varied on nine attributes that asylum experts and the previous literature have identified as potentially important (table S1 and fig. S1) (28). This design allows us to test which specific attributes generate public support for or opposition to allowing asylum seekers to stay in the host country and how this willingness varies across different groups of eligible voters, countries, and types of asylum seekers.

The effects of the asylum-seeker attributes on the probability of acceptance pooling across all respondents (model 1 in table S9) are plotted in Fig. 2 (29). The results demonstrate that European voters do not treat all asylum seekers equally. Instead, the willingness to accept asylum seekers varies strongly with the specific characteristics of the claimant. In particular, preferences over asylum seekers appear to be structured by three main factors: economic considerations, humanitarian concerns, and anti-Muslim sentiment.

Asylum seekers who previously worked in higher-skill occupations—such as doctors, teachers, and accountants—are about 13 percentage points, 9 percentage points, and 8 percentage points, respectively, more likely to be accepted compared with asylum seekers who have been previously unemployed. We find a similar but smaller premium of about 5 to 6 percentage points, respectively, for asylum seekers who worked in lower-skill occupations, such as farmers or cleaners, compared with those who were unemployed. Respondents also attach high importance to language skills, such that asylum seekers are about 12 percentage points less likely to be accepted when they do not speak the host-country language than when they speak it fluently. Those who have limited host-country language proficiency face a penalty of 6 percentage points. Moreover, asylum seekers who are close to retirement age (62 years) are about 6 percentage points less likely to be accepted than young applicants (21 years). Overall, these results suggest that evaluations of the expected economic contribution or potential economic burden of asylum seekers play an important role in structuring asylum preferences.

Asylum seekers who apply because of fear of political, religious, or ethnic persecution are about 15 percentage points more likely to be accepted compared with those who migrate to seek better economic opportunities. Asylum seekers are also about 11 percentage points less likely to be accepted when they have major inconsistencies in their asylum testimony, compared with when they



**Fig. 1. Asylum applications per 1000 people from the local population, 2015.** There is great heterogeneity in the number of asylum applications per capita in 2015 across the surveyed countries: Austria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Spain, Sweden, Switzerland, and United Kingdom. [Data sources (42, 43)]

have no inconsistencies. Moreover, those who have been the victim of torture are about 11 percentage points more likely to be accepted than are those with no special vulnerabilities. Taken together, these results suggest that public preferences are also highly sensitive to humanitarian concerns about the deservingness and legitimacy of the asylum request, as well as the severity of the claimants' vulnerabilities. Moreover, the public is opposed to admitting asylum seekers whose principal motivation is to seek better economic opportunities and who therefore might be regarded as economic migrants who do not meet the legal definition of refugee status according to the 1951 Refugee Convention.

We also find that religion matters: Muslim asylum seekers are about 11 percentage points less likely to be accepted than otherwise similar Christian asylum seekers. This penalty is sizable and larger than the penalty applied to unemployed asylum seekers versus teachers. Moreover, the fact that Christian asylum seekers are only slightly preferred over agnostic asylum seekers suggests that the penalty mostly reflects a strong anti-Muslim bias, rather than a pro-Christian bias. As we show later, this penalty is not uniform across respondents but rather doubles in size for respondents who place themselves on the right of the political spectrum compared with those on the left. These results suggest that anti-Muslim sentiment is a third important factor that structures asylum preferences.

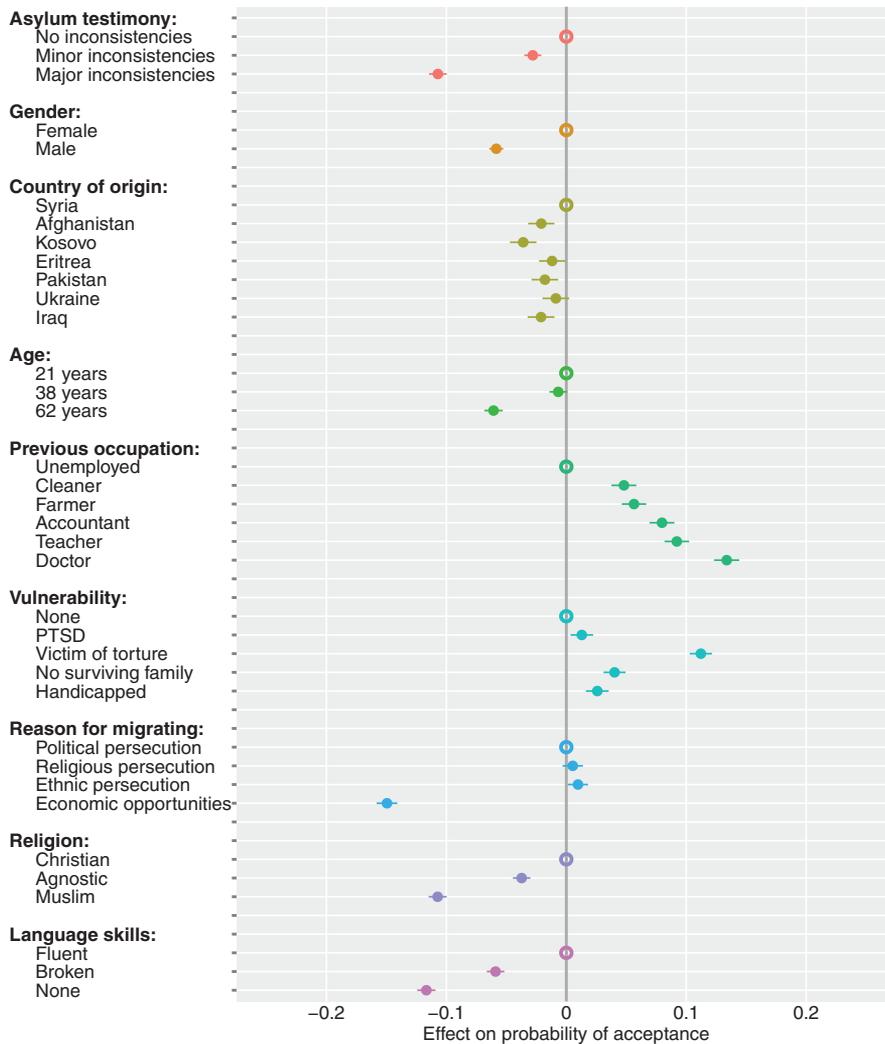
Last, once the other attributes are controlled for, the country of origin of an asylum seeker plays

only a minor role in generating support. Asylum seekers from Kosovo are least likely to be accepted, those from Syria and the Ukraine are most likely to be accepted, and those from Afghanistan, Iraq, Pakistan, and Eritrea fall in between. However, the differences are small in substantive terms; the maximum difference is only 4 percentage points between the most and least popular origin.

Do the effects of the attributes vary across different types of asylum seekers? For instance, based on psychological research on decision-making under conditions of uncertainty (30), we might expect that respondents rely more on their biases when evaluating profiles where the legitimacy of the claim is ambiguous. This suggests an interaction such that the anti-Muslim bias would be strongest when the applicant's asylum testimony has minor inconsistencies, rather than no inconsistencies or major inconsistencies. However, we find no substantively meaningful first-order interactions among any of the conjoint attributes; the lack of interaction suggests that the economic, humanitarian, and religious concerns are powerful determinants of attitudes toward asylum seekers across all types of profiles (figs. S22 to S48 and tables S32 to S61) (37).

How do asylum preferences vary across different types of voters? In order to test for interactions between respondent characteristics and the effects of the asylum-seeker attributes, we stratify the main analysis by voters' political ideology, age, education, and income (Fig. 3). Overall, we find that the effects of the attributes are broadly similar across the different subgroups; this suggests that there is a general consensus—among left- and right-wing, young and old, less and more highly educated, and richer and poorer voters—on which asylum seekers are preferred (table S10). Additional analyses using more fine-grained subgroups yield similarly homogenous results (figs. S5 to S10 and tables S15 to S20).

This effect homogeneity across subgroups also suggests that the concerns about employability are caused by sociotropic economic evaluations, meaning that respondents are concerned about the economic impact on the host country as a whole. This is in contrast to egocentric economic concerns, which pertain to the impact on the respondents' personal economic situation. If evaluations were shaped by egocentric concerns, we would have expected that preferences vary considerably given that different types of asylum seekers will differently affect a respondent's personal economic situation. For example, highly educated respondents should be more concerned about job competition from highly skilled asylum seekers, and less-educated respondents should be more concerned about competition from low-skilled asylum seekers. Similarly, given progressive tax systems, richer respondents should be



**Fig. 2. Effects of asylum-seeker attributes on the probability that respondents accept the asylum seeker.** Dots with horizontal lines indicate point estimates with cluster-robust 95% confidence intervals (CI) from linear (weighted) least squares regression. The unfilled dots on the zero line denote the reference category for each asylum-seeker attribute. Table S9 (model 1) displays the underlying regression results.

more concerned about the welfare burden imposed by unemployed asylum seekers than poorer respondents.

There is, however, a notable exception to this effect homogeneity: The top left two panels of Fig. 3 show that respondents on the left exhibit stronger humanitarian concerns and weaker anti-Muslim bias than voters on the right. First, the premium for asylum seekers with special vulnerabilities (e.g., victims of torture) and penalty for asylum seekers who migrated in search of economic opportunities are both larger among voters on the left than among those on the right. For instance, among voters on the right, economically motivated asylum seekers are about 13 percentage points less likely to be accepted than those who migrated for fear of political persecution. In contrast, this effect is 19 percentage points for voters on the left (the difference in effects between the left and the right is significant at  $P < 0.0001$ ). This suggests that, although humanitarian concerns are shared among the left

and the right, those concerns play a somewhat stronger role in structuring attitudes toward asylum seekers for the left. Second, although the anti-Muslim bias exists among both left- and right-wing voters, the bias is about twice as large in the latter group (14 versus 7 percentage points, a difference that is significant at  $P < 0.0001$ ). A more fine-grained analysis (figs. S3 and S4 and tables S13 and S14) shows that the anti-Muslim bias increases roughly monotonically moving from the left to the right of the ideological spectrum (32). Further analysis also shows that anti-Muslim sentiment is virtually constant across respondents with different levels of empathy (fig. S11 and table S21). This suggests that the responses are unlikely to be driven by social desirability bias, given the correlation between empathy and social desirability scales found in psychology research (33, 34).

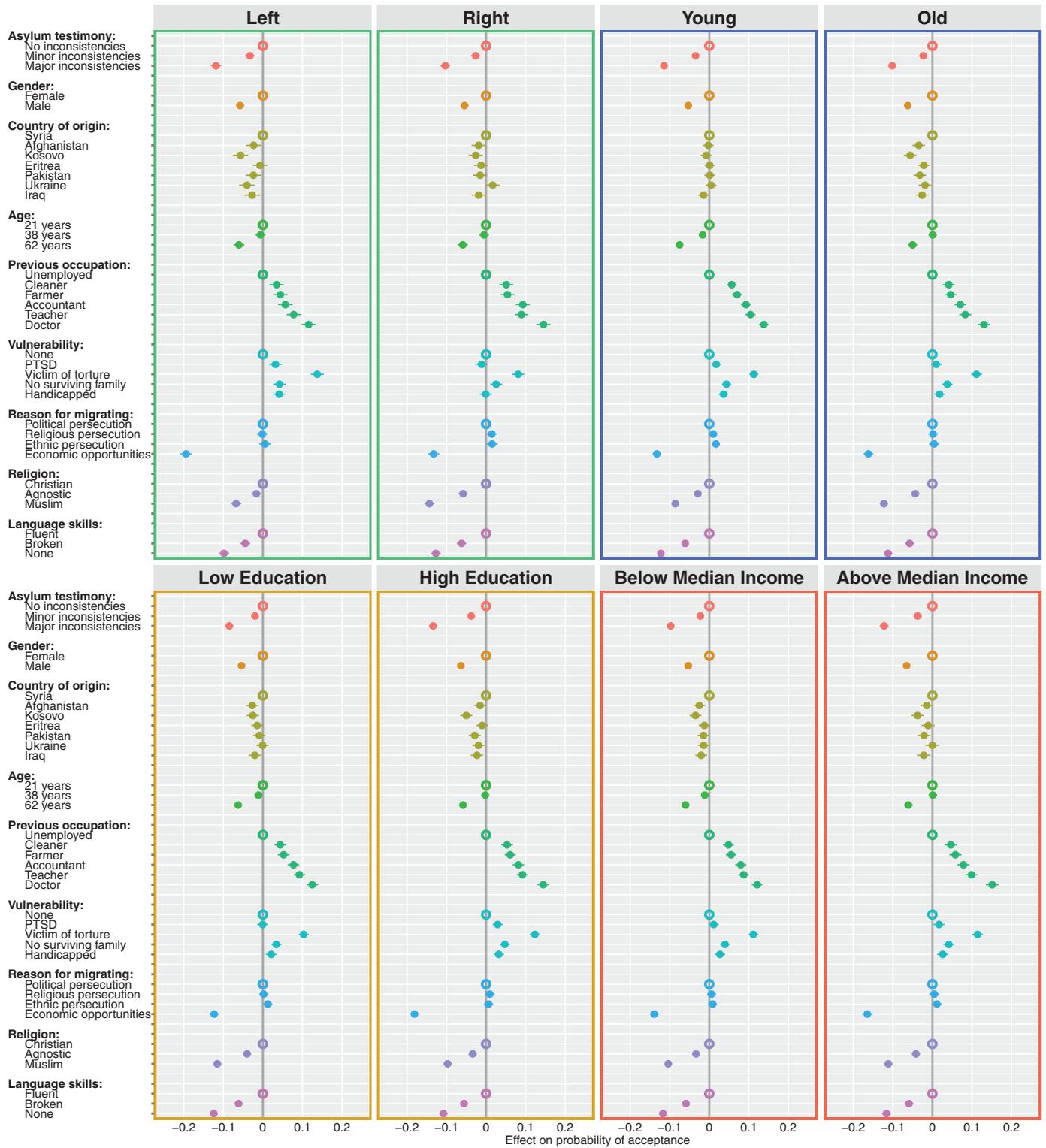
The 15 surveyed countries exhibit major differences with regard to several potentially relevant factors for shaping domestic asylum preferences,

such as the number of immigrants, the number of asylum applications per capita (compare Fig. 1), the existence of a European Union external border, the generosity of their welfare states, their economic strength and levels of unemployment, and other general political and economic characteristics that have an impact on the number of asylum seekers they can integrate. Despite these differences, the asylum preferences follow a similar pattern across the 15 surveyed countries (fig. S2). The partial exceptions include that the magnitude of the anti-Muslim bias varies somewhat, and the penalty against asylum seekers who migrate for economic reasons is somewhat smaller in poorer countries (e.g., Czech Republic, Greece, Hungary, and Poland) compared with richer countries (e.g., Austria, Denmark, Germany, Netherlands, Norway, Sweden, and Switzerland).

This consensus on what types of asylum seekers are preferred also has cross-country implications for the average number of asylum seekers accepted, based on a dichotomized version of a rating variable that distinguishes between accepted and rejected profiles (table S2). The percentage of asylum seekers accepted by country is shown in Fig. 4. In most countries, the fraction of accepted asylum-seeker profiles is close to the average of 45% accepted in the pooled European sample (35). This suggests that, despite the major differences between the countries, there is a considerable consensus in terms of not only the types but also the overall number of asylum seekers that should be admitted. Furthermore, only a small percentage of respondents—9% overall and less than 14% in every country—categorically rejected all 10 of their asylum-seeker profiles (table S8 and fig. S49).

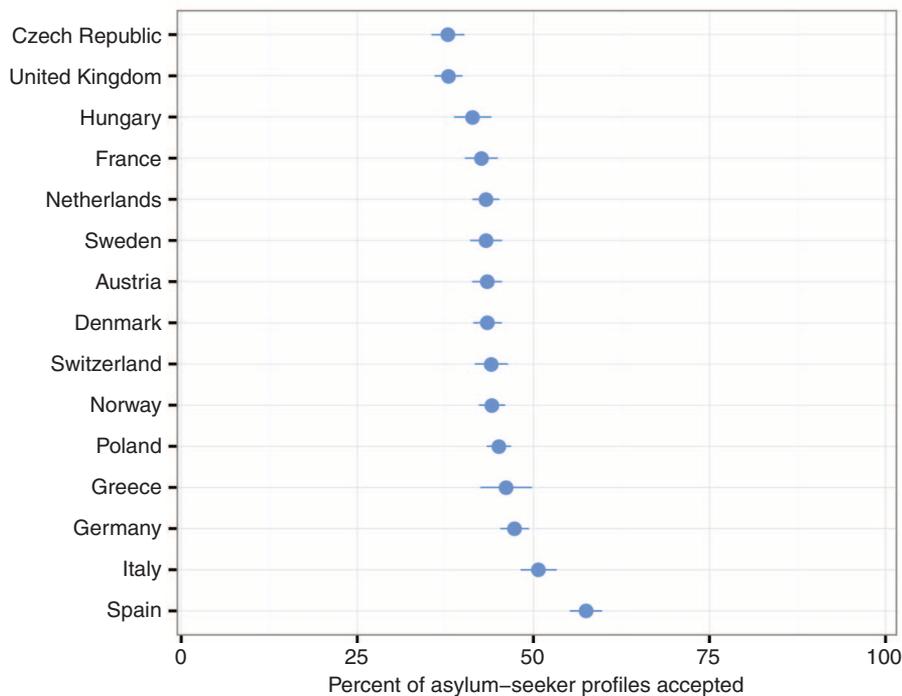
This study examined the impact of different asylum-seeker attributes on generating public support for granting asylum. We conducted a large-scale conjoint experiment and asked 18,000 voters in 15 European countries to evaluate profiles of asylum seekers that randomly varied on multiple attributes. We find that asylum seekers have a higher probability of being accepted when they are more employable and skilled, have special vulnerabilities, have more consistent asylum claims, and are Christian rather than Muslim. Furthermore, these effects are strikingly similar across sociodemographic subgroups and countries. Additional analysis reported in the SM also reveals that all the findings are similar regardless of whether we use a rating or choice outcome (table S2) to evaluate the asylum-seeker profiles (figs. S16 to S21 and tables S9 and S26 to S31). Finally, the results are similar across all five evaluation tasks asked of each respondent and when comparing respondents above and below the median time of survey completion (this test was not prespecified); this suggests that the results are not diluted by survey fatigue (figs. S14 and S15 and tables S24 and S25).

Although the experimental design of our study (i.e., the randomization of attributes) ensures its internal validity, as with all survey studies, there are potential external validity issues. However, four factors help to alleviate concerns about the



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**Fig. 3. Effects of asylum-seeker attributes on the probability of accepting the asylum seeker across subgroups of respondents.** The effects of the various asylum-seeker attributes are similar across different sociodemographic subgroups, stratified by ideology (top left, green), age (top right, blue), education (bottom left, orange), and income (bottom right, red). Dots with horizontal lines indicate point estimates with cluster-robust 95% CI from linear (weighted) least squares regression. The unfilled dots on the zero line denote the reference category for each asylum-seeker attribute. The test for education and income was not specified in the preanalysis plan. The underlying regression results are displayed in table S10, and how the subset variables were coded is described in table S3.



**Fig. 4. Percentage of accepted asylum-seeker profiles by country.** The percentage of accepted asylum-seeker profiles is similar across countries. Corresponding 95% CI are also shown.

external validity of our study. First, the one external validation test that we are aware of has shown that the paired conjoint design we used can achieve high external validity in reducing social desirability bias and replicating real-world voting behavior (36). Second, the number of profiles that each respondent accepted in their conjoint tasks, based on their ratings of the profiles, is highly correlated with respondents' general attitudes toward asylum seekers as measured by an additional question in our survey that asked respondents whether they want to decrease or increase the number of people granted asylum in their country (37). This suggests that respondents' judgments of individual cases are closely linked to their support for broader asylum policies. Third, given the homogeneity of the results across the countries and subgroups of respondents, it is unlikely that our results would have been substantially different had our sample contained different distributions on age, gender, education, or income—and in fact, the results are similar if we do not use reweighting for the analysis (table S9). Fourth, as already noted, the vast majority of respondents in all surveyed countries neither categorically rejected nor categorically accepted all of their asylum-seeker profiles. These results suggest that our findings on how voters condition their support on the basis of specific asylum-seeker attributes has broadly meaningful implications for European public attitudes toward asylum seekers rather than being applicable only on the margins.

These findings have important implications for our theoretical understanding of public opinion on asylum seekers and migrants more generally. Mirroring the findings from research on

the drivers of general anti-immigrant sentiment, we find strong evidence that sociotropic economic evaluations are shaping attitudes toward asylum seekers. In addition, we also find that humanitarian concerns with regard to asylum seekers' deservingness and vulnerability play a major role. Given that the sizable literature on immigration attitudes has largely ignored humanitarian concerns as a central explanatory factor (38), our results suggest that humanitarian concerns might be particularly important for structuring attitudes toward asylum seekers. Moreover, the finding of general agreement across different subsets of the population on which asylum seekers should be admitted echoes a similar consensus identified in previous research on American attitudes toward immigrants more broadly (39). However, to the extent that the respondents on the left exhibit a weaker anti-Muslim bias and place stronger emphasis on humanitarian considerations, our analysis also discovers new heterogeneity in attitudes toward migrants across the left-right ideological spectrum.

Our study also has important implications for policy. We find mixed evidence on the extent to which public preferences reflect the requirements of international law. It is important to note that all 15 countries included in the study are signatories to the 1951 Refugee Convention. This United Nations treaty commits its parties to granting asylum to persons with legitimate claims, which include asylum seekers who face political, religious, or ethnic persecution in their home countries. In light of these obligations, the results of our study can be interpreted in two ways. On the one hand, the results suggest that European policy-makers

are confronted with a disjuncture between public opinion and international legal norms (40, 41). The fact that our respondents exhibit anti-Muslim bias and a preference for higher employability, even when evaluating legally legitimate asylum seekers who face persecution, is at odds with the legal requirements that asylum not be given on the basis of religion or professional skills. On the other hand, the results reveal that humanitarian concerns have a pronounced effect, such that asylum seekers who face persecution, have consistent asylum testimonies, and have special vulnerabilities are substantially more likely to be accepted. Most important, these preferences are widely shared across countries and apply across all types of asylum seekers, regardless of their religion and employability. This suggests that the public has partially internalized the central pillars of international refugee law.

The results also inform the ongoing debate over how to resolve the current refugee crisis. In particular, they illuminate both challenges and opportunities for policy-makers who are struggling to meet their legal responsibilities to protect refugees while simultaneously respecting the public will on this salient and divisive issue. The public's strong anti-Muslim bias and preference for highly skilled asylum seekers who can speak the language of the host country points to a mounting challenge for solving the current crisis and successfully integrating asylum seekers, given that most asylum seekers currently originate from Muslim-majority countries and may lack the desired professional and language skills. Yet at the same time, the fact that the European public shares common humanitarian and sociotropic concerns suggests a clear narrative to increase support for accepting refugees. If the goal is to alleviate the social tensions of the current refugee crisis and generate more public acceptance of asylum seekers, European policy-makers have an opportunity to highlight refugees' deservingness and vulnerability, as well as their economic contributions to their host societies.

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Science Registered Studies Dataverse; <http://dx.doi.org/10.7910/DVN/YUNKUL>.

#### SUPPLEMENTARY MATERIALS

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## MICROBIAL PHYSIOLOGY

# Methane production from coal by a single methanogen

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Coal-bed methane is one of the largest unconventional natural gas resources. Although microbial activity may greatly contribute to coal-bed methane formation, it is unclear whether the complex aromatic organic compounds present in coal can be used for methanogenesis. We show that deep subsurface-derived *Methermicrococcus* methanogens can produce methane from more than 30 types of methoxylated aromatic compounds (MACs) as well as from coals containing MACs. In contrast to known methanogenesis pathways involving one- and two-carbon compounds, this “methoxytrophic” mode of methanogenesis couples O-demethylation, CO<sub>2</sub> reduction, and possibly acetyl-coenzyme A metabolism. Because MACs derived from lignin may occur widely in subsurface sediments, methoxytrophic methanogenesis would play an important role in the formation of natural gas not limited to coal-bed methane and in the global carbon cycle.

Coal-bed methane (CBM), a form of natural gas distributed in coal seams or adjacent sandstones, is a relatively untapped energy source with a large potential: The global reserves in 2014 were estimated at 50 trillion m<sup>3</sup>, equivalent to 11% of conventional natural gas resources (1). Large-scale CBM production has been implemented in the United States, Canada, Australia, and other countries worldwide. The contribution of biogenic methane to CBM is quite large (2, 3); geochemical studies have estimated that 40% of CBM produced in the United States is of microbial origin (4). Live microbial communities are present in coal seams and are associated with methanogenesis from coal in subsurface environments (5–10). Geomicrobiological studies have shown that enhanced CBM production in coal seams might be achieved by the stimulation of methanogenic activity (11). Although extensive efforts have been made to de-

velop this technology, very little is known about what components of coal can be used for methanogenesis and which microorganisms possess the metabolic capabilities to do so.

Coal is an extremely complex and heterogeneous material whose structure consists of single and condensed aromatic rings (12, 13). Aromatic compounds in coal are derived from lignin monolignols and are often substituted with hydroxyl, methoxy, and carboxyl groups (14, 15). Methoxy groups are especially abundant and common in immature coal (14, 16). Because methanogenesis from coal tends to occur in immature coal rather than in mature coal (4, 17), coal-bed microorganisms may produce methane from methoxy groups. Methanogenic microorganisms in CBM fields are commonly dominated by methylotrophic methanogens belonging to the archaeal order Methanosarcinales (5, 18, 19). The methylotrophic methanogens are capable of using methyl compounds such as methanol, methylamines, and/or dimethylsulfide (20), but it is unclear whether they can directly use methoxylated aromatic compounds (MACs) as substrates.

To investigate the possibility of MACs as substrates for methylotrophic methanogens, we tested the methane production ability of one archaeal isolate (*Methermicrococcus shengliensis* strain AmaM)

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## How economic, humanitarian, and religious concerns shape European attitudes toward asylum seekers

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### A consensus in Europe about asylum seekers

Violent conflicts between groups often generate large numbers of noncombatant refugees. Bansak *et al.* surveyed western European attitudes toward such asylum seekers. They found that voters favor applicants who will contribute to the recipient country's economy, who have suffered severe physical or mental distress rather than economic hardship, and who are Christian rather than Muslim. These preferences are similar across countries and independent of the voters' personal characteristics.

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