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The "Trust Gap" Hypothesis: Predicting Support for Biotechnology Across National Cultures as a Function of Trust in Actors

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Using results from the 1999 Eurobarometer survey and a parallel telephone survey done in the United States in 2000, this study explored the relationship between levels of knowledge, educational levels, and degrees of encouragement for biotechnology development across a number of medical and agricultural applications. This cross-cultural exploration found only weak relationships among these variables, calling into question the common assumption that higher science literacy produces greater acceptance (whether or not mediated by lower perceived risk). The relationship between encouragement and trust in specific social institutions was also weak. However, regression analysis based on "trust gap" variables (defined as numerical differences between trust in specific pairs of actors) did predict national levels of encouragement for several applications, suggesting an opinion formation climate in which audiences are actively choosing among competing claims. Differences between European and U.S. reactions to biotechnology appear to be a result of different trust and especially "trust gap" patterns, rather than differences in knowledge or education.

KEY WORDS: Trust gap;biotechnology;public opinion;cultural differences;science literacy

1. INTRODUCTION

The conventional wisdom suggesting that good science education (and, by extension, good science communication) will necessarily result in attitudes favorable toward new technology has not generally held up for the United States. For biotechnology, for example, other factors, such as perceptions of accountability[(1)] and trust in institutional actors,[(2)] seem to be better predictors of support. These data challenge the ideology of the United Sates as a pluralistic society that can be held together, despite diverse values, by the common ground of science. Rather, the social character of science as an activity with political, economic, and ethical dimensions, which are intertwined with the nature and power of scientific institutions and technology-oriented industry and also with the nature, actions, and objectives of various advocacy groups, becomes apparent as we debate issues related to genetically modified foods, to the prospect of human cloning, and most recently to regulation of research using stem cells taken from once-living embryos.

Coping with the development of policy in these areas is a profound challenge for postindustrial societies such as the United Science, which despite a strong democratic—even populist—tradition has few mechanisms for public participation in science-related policy making. The fear is that a public that is miseducated or poorly informed about the science behind such developments will make bad choices that may restrict further scientific and medical progress. The

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reality is that education about the science—the value of which we certainly do not dispute—may nevertheless be largely irrelevant to attitude formation. As is true for other types of risks, factors such as values[(3)] and other nonprobabilistic characteristics of the risk[(4)] may be more important to people's judgments. Differences of opinion on policy issues exist within as well as outside of the scientific community,[(5)] suggesting that science education does not necessarily produce policy consensus.

Much has been made of the differences between the United States and Europe in terms of public responses to biotechnology, especially genetically modified organisms or "GMOs," including GMO foods. These differences are easily overstated, as nearly one-third of the U.S. public is pessimistic about the likely impact of genetic engineering on the quality of life.[(5)] But they do exist. As participants in a major international research project[4] compiling data from the 1999 Eurobarometer attitude survey (1,000 in-person respondents in each participating country[5] except for Luxemburg, which contributed 500), a parallel telephone survey in the United States conducted in the year 2000 with just over 1,000 respondents, and media content and policy outcome data from the 20 participating countries, we wanted to explore whether differences in levels of education or knowledge across countries could help explain these differences in attitudes, or whether trust in relevant institutions and actors (such as industry, scientists, government, farmers, environmental groups, and so on) was more important.

The assumption underlying the larger study of which this analysis is a part is that encouragement is a function not only of risk associated with a development but also with, at a minimum, both utility and morality.[(7)] In fact these four variables—utility, morality, risk, and encouragement—are so closely intertwined in both the United States and Europe that we found we could not justify distinguishing between them in terms of which might be the cause and which the effect. Our analysis is an attempt to model variations in knowledge, trust, and other candidate independent variables using the single most general of these dimensions as the dependent variable: whether or not and to what degree respondents felt particular applications of biotechnology that had been presented to them "should be encouraged."

Our task was made more complicated by our concern with variables we believe researchers are easily tempted to confound. Studies that do not disaggregate scientific knowledge and education from a generally positive attitude toward science could very well indicate a relationship between knowledge and support that does not really exist. People who generally support scientific developments probably also seek out knowledge about them, rather than the acquisition of knowledge necessarily enhancing the support. These are also likely to be people who have generally positive attitudes toward scientific institutions to begin with, as well as (on average) more ready access to formal education. Finally, scientific institutions are certainly not the only ones involved with the development of biotechnology, and it would be naive to suppose that members of the so-called lay public are not aware of this.

The details of our results, presented in this article, are complex and depend on what kind of application of biotechnology is being considered. However, generally speaking, we found trust in institutions to be more important than knowledge of science in predicting levels of support or encouragement for biotechnology. Further, the best predictors were often differences in trust afforded to particular types of institutions, what we term "trust gaps," rather than absolute levels of trust, which we interpret largely as a culture-specific variable. For example, for food biotechnology it is clear that it is the *difference* between how much a nation's population trusts industry and how much they trust environmental groups that is the key predictor of encouragement, rather than either factor alone or even both factors considered together.

Our results are highly consistent with Beck's[(8)] interpretation of postindustrial societies as "risk societies" dominated by or even organized around concerns about risks and their management, not in the sense of concern with weighing costs and benefits in some kind of formula but in the sense of concern over which individuals within society will primarily bear risks such as environmental and health deficits and which social actors, in turn, serve which groups' interests. Individuals negotiating life in a risk

[4] Coordinated by Professor George Gaskell and Martin Bauer at the London School of Economics and funded in Europe by the European Commission. U.S. survey funding was provided by Texas A&M University and conducted by the TAMU Public Policy Research Institute. For details of the comparative study, see Gaskell and Bauer (2001).[(6)]

[5] The non-European Union countries of Switzerland and Norway also conducted parallel studies using essentially the Eurobarometer protocol. Where we show country-by-country results, Northern Ireland is shown separately from the United Kingdom and East and West Germany are distinguished; thus results are shown for a total of 19 European countries.

society may be less concerned with making choices about which risks they are willing to tolerate than they are with grasping which political interests lie behind the promotion of particular choices, and to us this position seems reasonable.[6] However, our concern in this study actually extends beyond risks in considering the relationship between knowledge or science literacy, trust in institutional actors, and the broader notion of "encouragement" of particular developments.

Risk perception (or what one of us[(10)] prefers to describe as risk "interpretation") is clearly a complex process, and competing explanations abound. The conventional wisdom within the scientific community, when expert and lay opinions of risk diverge, has generally been that laypeople typically misunderstand or misinterpret probabilistic data. We might term this the "science literacy hypothesis." Science literacy as a concept has itself become the subject of controversy.[(11)] Other scholars[(12)] have noted that the presumption societies are made up of rational actors is ubiquitous; public responses to risky technologies appear to challenge this presumption, especially where individuals seem to be evaluating risks on "nonscientific" grounds. However, numerous, now classic, studies by Slovic *et al.*[(13)] have unambiguously established that on an individual level risk perception is a function of factors other than the (perceived) probability of harm.

Culture has also been implicated as one determinant, following Douglas and Wildavsky's well-known work in this area.[(14)] Widely recognized gender differences in perceptions of risk might best be conceptualized as differences in subculture or worldview among men and women that persist in contemporary Western societies.[(3)] Not all scholars accept explanation in terms of culture, however. Despite data obtained that relate risk perceptions in some degree to both cultural biases and political attitudes, Sjöberg argues that explanation in terms of worldviews or cultural theory is simply wrong.[(15)] While it is not plausible, to a social scientist, that culture has no bearing on risk perception, it is clear that the relationship between culture (in the sense of worldview), social structure, and risk perception (or risk interpretation) is not yet very well understood.

Nevertheless, social theory directs us to consider these relationships more carefully. Like Beck, Giddens[(16)] has called our attention to the central role of risk as an organizing principle in contemporary societies in which scientific expertise *may not* be taken at face value as a means to resolve questions of risk. This general line of thinking has led to a number of studies about trust, distrust, and risk that suggest new explanations. For example, one group of researchers has proposed that social trust in risk managers is important, especially when personal knowledge of the risk is low.[(17)] Trust can also be used to predict levels of acceptance for gene technology among Swiss citizens.[(18)] As Earle and Cvetkovich note, social distrust might best be thought of as "a strategy for the reduction of cognitive complexity" in the face of complicated risks that are difficult to evaluate.[(19)] Willingness to eat beef in Wales in the wake of the "mad cow" controversy in Great Britain can be related to the idea of "knowing where it came from," reflecting local relationships of trust between consumers and farmers, butchers, and so on.[(20)]

Although psychometric and worldview studies of risk would appear to challenge a conceptualization of risk responses as rational choices, in fact what they do is challenge our notion about what kinds of choices rational actors are making. This, in turn, calls our attention to patterns of trust and distrust as they exist in particular social settings. The results of the present study, although concerned primarily with societal level contrasts rather than local or individual decisions, suggest that we need not give up the notion of a rational actor when confronted with evidence that an individual's technical knowledge has only a relatively weak influence on his or her evaluation of a risky technology. Our results are consistent with a portrait of a rational actor making rational choices among which institutions to trust—not which risks are to be feared or even how much particular groups or institutions are to be trusted, but which ones are to be trusted more. This portrait is substituted for a vision of an isolated individual actor figuring out (through the distorting lens of both personal and cultural values and perceptions) what to make of probability calculations.

While we set out to explore a data set rather than to test a predetermined hypothesis, we believe we are able to account for variations among nations in their acceptance of biotechnology in terms of a particular type of worldview variation—specifically, variation in the nature of patterns of social (institutional) trust and distrust characteristic of the societies included in our study. This accounting is concerned with how individuals embedded within a particular culture and social structure might make decisions based on their understanding of the actions of others organized into

[6] Awareness of institutional issues and actors has been proposed as an alternative or complementary definition of "science literacy"; Bauer *et al.* (2000).[(9)]

Table I. Encouragement by Application

	Europe[a]			U.S.			
	Disagree	Don't Know	Agree	Disagree	Don't Know	Agree	Chi-Square Value
Food	46.3%	20.1%	33.7%	33.3%	9.0%	57.7%	249.05
Crops	35.2	21.9	42.9	22.5	8.7	68.9	265.07
Cloning	41.9	22.4	35.8	42.0	8.8	49.2	127.18
Medicine	18.3	22.4	59.3	12.5	9.5	77.9	144.75
Tests	15.2	20.1	64.7	10.2	6.7	83.1	155.38

[a]European results are from all European Union countries plus Norway, weighted equally (except for Luxembourg, weighted at 60%). U.S. results weighted to compensate for observed bias in educational level of sample. Percentage of respondents who agree, disagree, or are neutral about whether five applications should be encouraged. Chi-square values calculated on weighted results with N for Europe = 15,600 and N for United States = 1,002; $p < 0.001$ in each case.

institutions that are also embedded in that same culture and social structure. For our accounting to explain the available data, it had to take into account both levels of trust and the magnitude of "trust gaps," by which we mean simply differences in levels of trust attached to competing institutional actors.

Our operationalization of the term "trust" is somewhat problematic. The international research group with which we are affiliated chose to use the wording "doing a good job for society" as their primary measure of trust. (In the European data, a second metric was provided by a question about truth telling, but this question was not included in the U.S. survey and could not therefore be used for this cross-Atlantic comparison.) The original team's goal was to ask about trust indirectly; the measure used was therefore not dependent on respondents' interpretations of the abstract concept of trust, which could be expected to vary among individuals and across cultures, but on a more concrete representation, "doing a good job" in terms of altruistic effects ("for society"). This metric undoubtedly taps into at least one important dimension of social trust, entailing both competence and motivation. We make no claim that this phrasing exhausts the concept, however, and would encourage others to explore alternative formulations.

2. SCIENCE LITERACY, SCIENCE EDUCATION, AND BIOTECHNOLOGY ENCOURAGEMENT

The data we used for this study asked respondents in both the United States and Europe about five different applications of biotechnology: food biotechnology, genetically engineered crops, cloning of animals,[7] using bacteria to produce medicines, and genetic testing of people for hereditary disease. (In the remainder of this article, we will refer to these applications more briefly as food biotechnology, crop engineering, cloning, medicine production, and genetic testing, respectively.) The key "encouragement" question asked respondents whether they agreed, tended to agree, tended to disagree, or disagreed that each application "all in all" should be encouraged. As Table I shows, the U.S. population was more positive about all five applications than the European population, taken as a whole.[8]

The Eurobarometer and U.S. surveys also asked respondents two other series of questions that were crucial to our analysis: a series of 10 true-or-false genetics items that had been developed through previous efforts of the European team and a series of questions on whether or not they believe that various institutions and actors were "doing a good job for society" with respect to biotechnology development. These institutions and actors were the media, industry, ethics committees, consumer organizations, environmental groups, government, shops, farmers, churches, and doctors. These results are summarized in Table II.

We had speculated that the economic, cultural, and political climates of the different countries might support different patterns of institutional trust. For example, would agrarian countries have more trust in farmers but perhaps less in industry? Would some

[7] This was described as being for the purpose of producing medicines, as in the widely publicized "Dolly" sheep cloning experiment.

[8] For detailed analysis of support on a country-by-country basis, see Gaskell *et al.* (2000).

Table II. Trust in Societal Actors for 19 European Countries and the United States

Country	Media	Industry	Ethics Committees	Consumer Organizations	Environmental Groups	Government	Shops	Farms	Churches	Doctors	Mean Trust (Average for all 10 Actors)	Knowledge Score (10 Items)	Aggregate Encouragement (Five Applications)
Greece (Gre)	82%	25%	74%	89%	84%	80%	88%	87%	77%	94%	78%	5.00	–0.36
Finland (Fin)	86	52	82	91	64	81	89	77	47	93	76	5.82	1.83
Netherlands (Net)	92	49	83	96	62	89	94	55	42	95	76	6.40	1.74
Austria (Aus)	75	35	61	81	68	65	76	71	50	83	67	4.93	–1.03
Denmark (Den)	70	31	70	84	67	43	65	58	27	79	59	6.26	0.59
E. Germany (EGe)	61	37	50	78	57	46	61	69	42	76	58	5.32	1.82
Switzerland (Swi)	63	44	60	73	68	45	63	62	32	73	58	5.42	0.44
W. Germany (WGe)	65	35	54	77	63	44	63	62	38	69	57	5.03	0.86
Spain (Spa)	64	34	59	68	60	46	53	55	33	75	55	4.81	2.22
Belgium (Bel)	68	37	62	71	51	49	56	45	20	71	53	5.48	0.96
France (Fra)	57	26	57	74	68	41	49	54	22	70	52	5.68	0.39
Portugal (Por)	59	35	48	58	49	51	55	56	47	62	52	3.77	1.22
Luxembourg (Lux)	66	32	54	65	63	41	54	47	23	64	51	5.37	–0.03
Sweden (Swe)	50	23	62	73	57	43	54	44	27	73	51	6.76	0.64
Italy (Ita)	44	20	42	56	45	37	51	48	37	57	44	4.97	1.20
UK (UK)	45	26	42	58	52	33	55	43	21	58	43	5.30	0.40
Ireland (Ire)	51	22	42	52	55	36	43	34	29	52	42	4.76	0.46
Norway (Nor)	57	20	45	64	57	39	22	17	17	57	40	5.39	–0.82
N. Ireland (NIr)	40	18	31	48	46	26	40	30	25	45	35	5.30	0.21
Europe (Eur)	63	32	57	71	60	49	60	53	35	71	55	5.20	0.89
USA (USA)	44	58	47	59	51	40	59	73	37	59	53	6.50	3.42

Note: Trust is expressed as the percentage of all respondents who feel actor is "doing a good job for society" with respect to biotechnology. Knowledge score is mean percentage correct on 10 true-or-false genetics items. Aggregate encouragement is mean response on a scale from –2 (definitely disagree) to +2 (definitely agree), with "don't know" responses counted as zero, for five applications included in both U.S. and European surveys.

countries have more faith in experts such as doctors? However, when we searched for patterns in the trust data for all 20 countries using the SPSS(r)[9] clustering routine we were unable to find meaningful groups that appeared to reflect anything other than generally higher or lower levels of trust. While differences along these lines surely exist, they are probably very complex and may be unique to particular national situations. At any rate, no clear patterns emerged on the basis of our cluster analysis. Rather, residents of some countries seem to express higher general levels of trust than residents of others. This may be a result of actual national differences in tendencies to trust a variety of institutions and actors, cultural differences in willingness to express trust or distrust, or both, or it may reflect the limitations of the particular question wording that had been chosen.

Whatever the explanation, these differences in overall levels of expressed trust among the various countries appeared more prominent than observed patterns in levels of trust for different kinds of institutions or actors within the various countries. Thus Table II lists the 19 European countries in order of "most" to "least" expressed trust averaged over all 10 institutions/actors included. The percentages given are the percentage of all respondents who agreed that the particular actor was "doing a good job." (It is important to remember that this is a very narrow and specific operationalization of the concept of trust; other operationalizations might well produce very different results.) While some contrasts across countries are intriguing, in most cases the patterns of trust do not seem to hold across multiple countries in statistically consistent ways and seem more indicative of the richness of cultural variation reflected in the data than anything else.

Table II also presents average scores on the 10-item test of genetic knowledge used in all 20 countries plus a score for average aggregate encouragement of all five applications together, based on assigning each encouragement score (for each application and each respondent) a value ranging from –2 to +2. (For this purpose "don't know" responses have been recorded as zero.) Generally speaking, knowledge of genetics appears somewhat lower across Europe than in the United States; the details are presented in Table III. By and large, the patterns of correct and incorrect responses are some-

Table III. Knowledge of Biotechnology: Comparison of Europe and United States

	Europe	U.S.
There are bacteria which live from waste water.	84	96
Ordinary tomatoes do not contain genes, while genetically modified tomatoes do.	35	49
The cloning of living things produces genetically identical offspring.	64	71
By eating a genetically modified fruit, a person's genes could become modified.	42	65
It is the father's genes that determines whether a child is a girl.	45	70
Yeast for brewing beer consists of living organisms.	67	78
It is possible to find out in the first few months of pregnancy whether a child will have Down's Syndrome.	79	76
Genetically modified animals are always bigger than ordinary ones.	34	57
More than half of human genes are identical to those of chimpanzees.	49	50
Animal genes cannot be transferred into plants.	27	36
Mean number of correct answers	5.2	6.5

Note: Percentage of people responding correctly out of all respondents. European results are from 15 EU countries weighted according to population size.

what similar, however. Most respondents on both continents correctly agreed that "there are bacteria which live from waste water," for example. And both United States and European respondents tended not to know that animal genes can be transferred into plants.

While we can only speculate about actual causes, some of the differences in patterns of U.S. and European scores may be consistent with educational, as well as cultural, differences between the United States and Europe. Public education curricula in U.S. schools might possibly account for the higher proportion of correct answers on the question about determination of the sex of a child by the father's genes, for example. And some differences in knowledge are also logical candidates as partial explanations of differences in support for certain forms of biotechnology. Europeans are substantially less likely than U.S. nationals to know that all tomatoes contain genes, that eating genetically modified fruit cannot change a person's genes, and that genetically modified animals are not necessarily bigger than "ordinary" animals. However, knowledge *per se* is only one of several such candidates.

As an initial attempt to understand and summarize the relationship between knowledge (10-item

[9] Originally known as Statistical Package for the Social Sciences, this software was used for all of the numerical analysis items we report here.

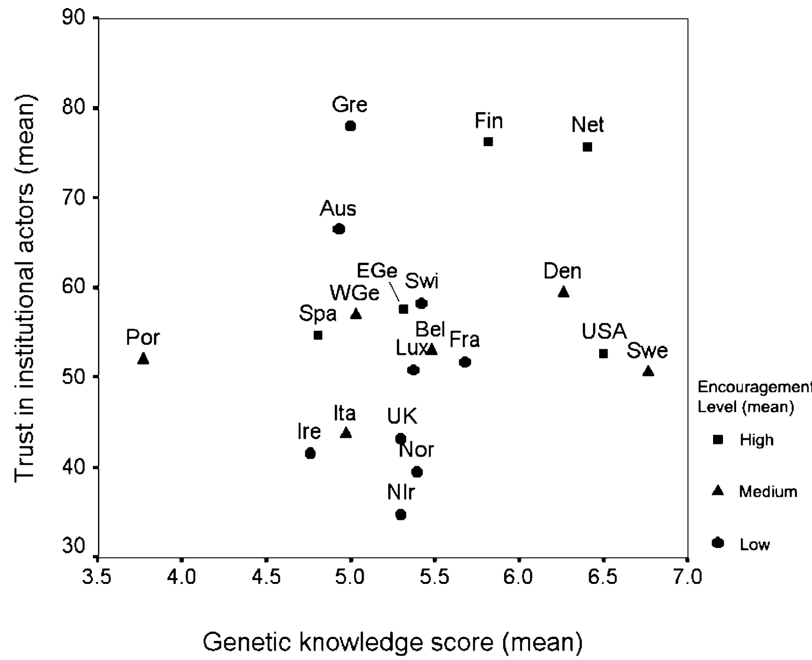


Fig. 1. Mean institutional trust and knowledge scores for each of 20 countries. High, medium, or low encouragement levels (averaged over five applications of biotechnology; see text) are also indicated (key). No simple relationship is apparent between either knowledge or trust and encouragement. Country abbreviations are as follows: Aus = Austria; Bel = Belgium; Den = Denmark; EGe = East Germany (former); Fin = Finland; Fra = France; Gre = Greece; Ita = Italy; Ire = Ireland (Republic); Lux = Luxembourg; Net = Netherlands; NIr = Northern Ireland; Nor = Norway; Por = Portugal; Spa = Spain; Swe = Sweden; Swi = Switzerland; UK = United Kingdom; USA = United States; WGe = West Germany (former).

test score), trust (10-percentage average), and encouragement (five-application total[10]) on a country-by-country basis, we calculated Pearson correlation coefficients for these values, using each country as a case (that is, $N = 20$). The total correlation of knowledge and encouragement as measured by these variables was only 0.260, meaning that less than 7% of the variance in encouragement could be directly explained (in the statistical sense) by variations in knowledge; this is not to suggest that the role of knowledge is unimportant, but only that it is insufficient as a "stand alone" explanation of encouragement. The total correlation of trust and encouragement was even lower, at 0.139. Finally, the correlation between trust and knowledge was 0.191. Despite the conventional wisdom suggesting that knowledge of genetics would predict encouragement of biotechnology and our speculation that trust would also predict encouragement but was also likely intercorrelated with knowledge, none of these relationships was strongly supported by the data.[11]

Fig. 1 shows the relationship between trust and knowledge for each of the 20 countries and distinguishes among countries that are high, medium, and low in average encouragement, showing little in the way of obvious relationships among these three factors. Low-encouragement countries (circles) are all near average in knowledge but range widely as to trust. Medium-encouragement countries (triangles), with the exception of Italy, are all near average in trust but range widely in knowledge. There is a suggestion of a possible positive relationship between trust and knowledge for the remaining, high-encouragement countries (squares), but the United States does not fit this pattern. We did not find a logical interpretation for this configuration and indeed it may represent no more than random scattering. We found no simple and clear relationship among these three variables that holds across all countries and respondents when all five applications are considered together.

Next, we looked at correlations between knowledge of biotechnology and membership in various demographic groups (by gender, age, and education) in the United States and Europe. The individual, rather than the country, is the unit of analysis for this purpose. Table IV shows the mean knowledge scores for these various groups and both the Pearson correlation

10 Again, this is the mean, averaged over five applications, on five-point scales coded from −2 to +2. Five countries with composite scores over 1.5 were classified as "high encouragement"; seven with scores below 0.5 were classified as "low encouragement."

11 While averaging trust across multiple institutions and encouragement across multiple applications is an obvious oversimplification, we felt it was necessary to rule out the possibility that some cultures that are simply (overall) more trusting (less inclined to doubt the trustworthiness of *any* actor) would also be more generally encouraging or optimistic about biotech applications across the board. It seemed important to include our evidence that this is not the case alongside our evidence that knowledge also fails as a simple explanation of observed levels of encouragement.

Table IV. Knowledge of Biotechnology Across Social Segments: Comparison of Europe and United States

	Mean Knowledge Scores[a]					
	Europe[b]			U.S.		
	Mean	Corr.[d]	Part. Corr.	Mean	Corr.	Part. Corr.
Total	5.2	—	—	6.5	—	—
Women	5.1	−0.08**	−0.07**	6.4	−0.05	0.01
Men	5.4			6.6		
Over 64	4.2	−0.19**	−0.05**	5.7	−0.17**	−0.19**
45–64	5.2			6.4		
26–44	5.6			6.8		
15–25	5.6			6.8		
High education[c]	6.2	0.31**	0.26**	7.1	0.29**	0.30**
Medium education	5.3			6.5		
Low education	4.4			5.7		

[a]Knowledge score: 0 to 10 points based on the percentage of correct responses to 10 items, with low scoring 0–4, medium scoring 5–6, and high scoring 7–10.
[b]European results are from 15 EU countries weighted according to population size.
[c]Low education: up to 15 years (in United States, through high school); medium: 16–19 years (in United States, some posthigh school education); high: 20 + years or still studying (in United States, college graduate or higher).
[d]Controlling for the other two sociodemographic factors.
$^{**}p \leq 0.01$.

coefficients between each demographic variable and knowledge for each area (United States and Europe) and the partial correlation coefficients for each demographic group and area controlling for the other two demographic categories for that area. (Note that even very small correlations, especially for Europe, achieve statistical significance because of the large sample size used.)

For both Europe and the United States, gender apparently makes little difference to level of knowledge, although it makes some difference in Europe even when education and age are controlled. Age, on the other hand, makes very little difference to knowledge in Europe when gender and education are controlled for, but continues to contribute to knowledge in the United States even when controls are applied. In other words, in the United States, but not in Europe, older people know less about genetics than younger people do. Finally, and perhaps rather reassuringly, level of education makes a clear and consistent difference, independent of both gender and age, in both Europe and the United States. Even so, the partial correlation between knowledge and education is only 0.30 in the United States and 0.26 in Europe, suggesting the crucial role mass media and other forms of public discourse could play in conveying new information about emerging scientific developments.

Finally, we looked more closely at knowledge and education in relation to one another and as predictors of biotechnology encouragement (Table V; see table for explanation of encouragement index used in this case). Most of the relationships indicated are extremely weak, whether all respondents are considered together or whether respondents with different education or knowledge levels are considered separately. Across all knowledge levels, there is little or no correlation between encouragement and education in either the United States or Europe. There is some relationship indicated between knowledge and encouragement, especially in the United States; this relationship is strongest for highly educated people. Even here, however, the partial correlation is only 0.27.

An exploratory analysis of these relationships on an application-by-application basis, using countries rather than individuals as the unit of analysis, helped clarify why only weak relationships had been apparent in the combined data. Relevant patterns are very different for different applications of biotechnology. The correlation between mean knowledge score and encouragement for biotechnology in medicine production is an impressive 0.58 ($p \leq 0.01$); for genetic testing it is 0.38 (*ns*). But for food biotechnology and animal cloning, it is only 0.05 in each case, and for crop engineering it is only 0.10. The correlation between mean trust (percentage data) and encouragement for genetic testing is 0.47 ($p \leq 0.05$), but for animal cloning it is −0.12, for food biotechnology it is

Table V. Knowledge and Education as Predictors of Biotech Encouragement

	Mean Encouragement Scores[a]													
	Europe[b] 1999							U.S. 2000						
	Total	Low Knowledge[c]	Med Knowledge	High Knowledge	Difference (Lo-Hi)	Simple Corr. (Encouragement by Knowledge)	Partial[d] Corr. (Encouragement by Knowledge)	Total	Low Knowledge	Med Knowledge	High Knowledge	Difference (Lo-Hi)	Simple Corr. (Encouragement × Knowledge)	Partial Corr. (Encouragement × Knowledge)
Total	1.8	0.5	2.0	3.0	+2.5	+0.18**	+0.13**	3.6	1.7	2.7	4.9	3.2	+0.23**	+0.22**
High education	2.6	1.1	2.7	3.1	+2.0	+0.13**	+0.11**	4.7	2.3	3.1	5.7	3.4	+0.25**	+0.27**
Medium education	1.7	0.7	1.8	3.0	+2.3	+0.17**	+0.14**	3.1	1.8	2.2	4.1	2.3	+0.17**	+0.14**
Low education	1.1	0.1	1.7	2.6	+2.5	+0.18**	+0.13**	2.9	1.4	2.8	4.2	2.8	+0.19**	+0.18**
Difference (low to high)	+1.5	+1.0	+1.0	+0.5	–	–	–	+1.8	+0.9	+0.3	+1.5	–	–	–
Simple correlation (encour. × education)	+0.10**	+0.07**	+0.06**	+0.03**	–	–	–	+0.14**	+0.07	+0.02	+0.13**	–		
Partial correlation (encour. × education)	+0.01**	+0.01**	+0.02**	+0.00**	–	–	–	+0.13**	+0.06	+0.03	+0.02	–		

[a]Encouragement Score: For Europe, scored as –14 to +14 based on seven applications of biotechnology, each application rated as strongly agree (+2), agree (+1), don't know (0), disagree (−1), strongly disagree (−2) with respect to encouragement. U.S. data is scored from −12 to +12 based on five identical applications plus one similar one.

[b]Overall results (first column) are for European Union countries only, weighted by population size.

[c]Knowledge Score: 0 to 10 points based on the percentage of correct responses to 10 items, with low scoring 0–4, medium scoring 5–6, and high scoring 7–10.

[d]Partial correlations controlled for age, gender, education/knowledge, and trust in biotechnology.

** $p \leq 0.01$.

−0.04, for crop engineering it is 0.11, and for medicine production it is 0.16. It seems logical that using bacteria to produce medicines could seem positive only to those with higher familiarity with the science involved, and might seem less attractive to others. It seems logical that genetic testing of humans for disease factors might seem positive only to those with a high general level of trust, and might seem threatening to others. But more general explanations remained elusive.

We then experimented with looking at the differences between trust levels for certain kinds of institutions and actors, rather than looking only at the absolute level (percentage) of trust within each country for certain actors. If neither knowledge, education, nor trust were strong predictors of encouragement, perhaps the explanation lay in relative trust in some sense. After considerable additional exploratory analysis, we created seven new variables based on what we considered logical trust pairs representing interests that seemed likely to be posed against one another in public discourse. These seven "trust gap" variables were as follows: the differences between trust in industry and trust in environmental groups, between trust in industry and trust in consumer organizations, between trust in farmers and trust in environmental groups, between trust in farmers and trust in consumer organizations, between trust in shops and trust in consumer organizations, between trust in government and trust in media, and between trust in doctors and trust in ethics committees.[12]

Our initial explorations of the relationship between these "trust gap" variables, the single-actor trust variables, knowledge, and application-specific encouragement across all 20 countries (with unit of analysis as the country rather than individual) did show that the "trust gap" idea seemed to explain variance not otherwise explained. We then developed step-wise regression models for each of the five applications included in both the U.S. and European studies, using all of these variables (knowledge, single-actor trust, and "trust gaps" as independent variables predicting encouragement). We believe that our results—which are somewhat different for each of the five applications and less ambiguous for some of them than for others—suggest that the "trust gap" is a potentially very useful explanation of observed public response phenomena, one with substantial theoretical power. Our statistical results and initial comments are presented below. Their initial theoretical interpretation we will address further in the discussion section.

3. REGRESSION MODELS FOR FIVE APPLICATIONS USING "TRUST GAP" VARIABLES

Using the SPSS stepwise regression routine, we entered independent variables consisting of seven "trust gap" variables, 10 individual trust items (percentage for each country), and average knowledge score (10-point scale) for each country. The dependent variable in each case was encouragement for a specific application common to both the European and U.S. studies, measured on a five-point scale as described above. The seven "trust gap" variables were defined as simply the absolute differences in the percentages "trusting" each member of the seven identified pairs of institutions/actors for the particular country (with trust defined as saying the actor is "doing a good job for society" with respect to biotechnology).

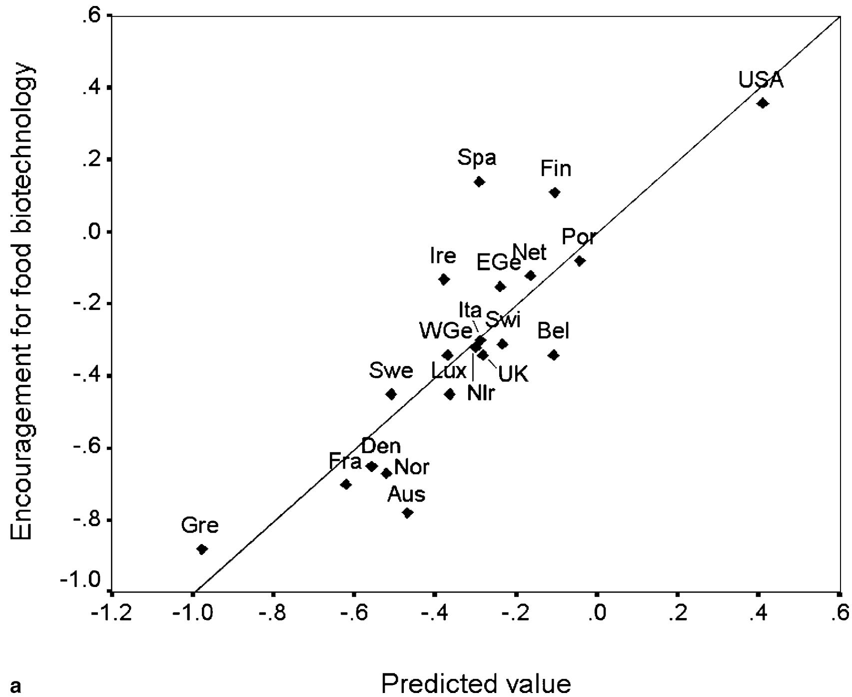
The stepwise regression routine begins by including the best predictor variables into the model first; then additional variables are added if (and only if) they improve the accuracy of the prediction. Sometimes the addition of a new variable that meets this criterion results in the elimination of another variable if it no longer has independent predictive value. SPSS and other statistical packages offer the researcher many choices as to procedure; it is possible to "force" certain variables into the equation first, for example—typically, on theoretical grounds—rather than starting with those that are the best predictors of the dependent variable. In our analysis all 18 independent variables were treated identically, as our study is exploratory rather than a formal test of a theoretically derived hypothesis.[13]

Below, the results for each of the five applications and some initial speculations as to their interpretation are discussed. The factors that best predict encouragement for each application differ, with correlations between predicted and actual values ranging from 0.755 to 0.913 for all applications except cloning, where

[12] While it was theoretically possible to create many more such variables based on the 10 available single-actor trust variables, after additional exploratory analysis we felt such results would be too difficult to interpret and thus counterproductive. We chose instead to concentrate on those "trust gap" variables that made the most intuitive sense. We cannot claim that these are the only or necessarily the most important ones, however.

[13] Probability of F required for a variable to enter into the equation was set at 0.30; probability of F required for an entered variable to be removed on a subsequent iteration was set at 0.50.

Fig. 2a–2e. Values predicted from regression model and actual values for encouragement for each of five applications across all 19 participating European countries and the United States. Independent variables in model vary by application as explained in text and could include knowledge, trust, and "trust gap" variables. See Fig. 1 for country abbreviations.



a

$R = 0.562$. But in only one case, the genetic testing application, did knowledge remain in the final regression model produced under the stepwise procedure.

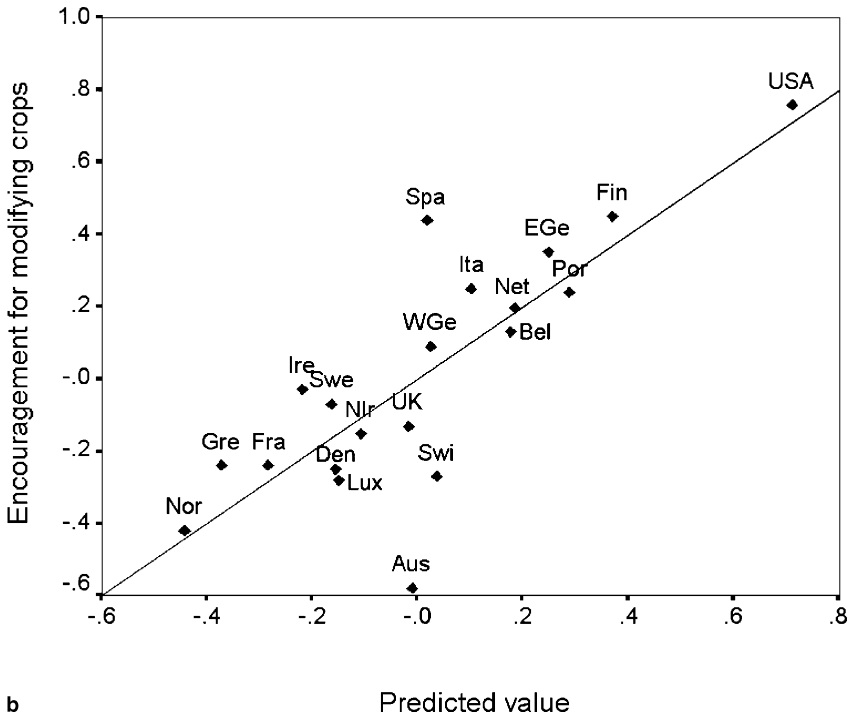
Food biotechnology (Fig. 2a): Much of the public discussion of differences between the United States and Europe in terms of reactions to biotechnology has revolved around differences in responses to food biotechnology specifically. The regression model built for predicting food biotechnology encouragement used only two independent variables, the industry-environmental group "trust gap" ($P = 0.004$, beta $= 0.661$) and the industry-consumer organization "trust gap" ($P = 0.253$, beta $= 0.234$). As the figure illustrates, both the highest-encouragement country (the United States) and the lowest (Greece) lie almost exactly on the regression line for this model, which achieved a correlation of 0.855 between the predicted and actual values (adjusted R^2 of 0.699, $F = 23.071$, $P = 0.000$).

The model helps make sense out of the often-cited differences between the United States and many European countries in terms of acceptance of food biotechnology. The fact that in the United States there appears to be substantially more trust in industry and less trust in environmental and consumer organizations is clearly tied to the greater acceptance of food biotechnology. This same type of relationship appears to hold across much of Europe; only Spain, where the model would predict somewhat lower acceptance, is an apparent outlier in this model.

Crop engineering (Fig. 2b): The model for crop biotechnology is rather similar to that for food, but in this case the important independent variables are the industry-environmental group "gap" ($P = 0.004$, beta $= 0.563$) and the farmer-environmental group "gap" ($P = 0.048$, beta $= 0.356$). The correlation between the predicted and actual values in this case is 0.807 (adjusted R^2 0.611, $F = 15.920$, $P = 0.000$). This time Austria seems to be the most apparent outlier; the model would have predicted higher acceptance. Again, the United States behaves about as the model predicts, as do most other European countries.

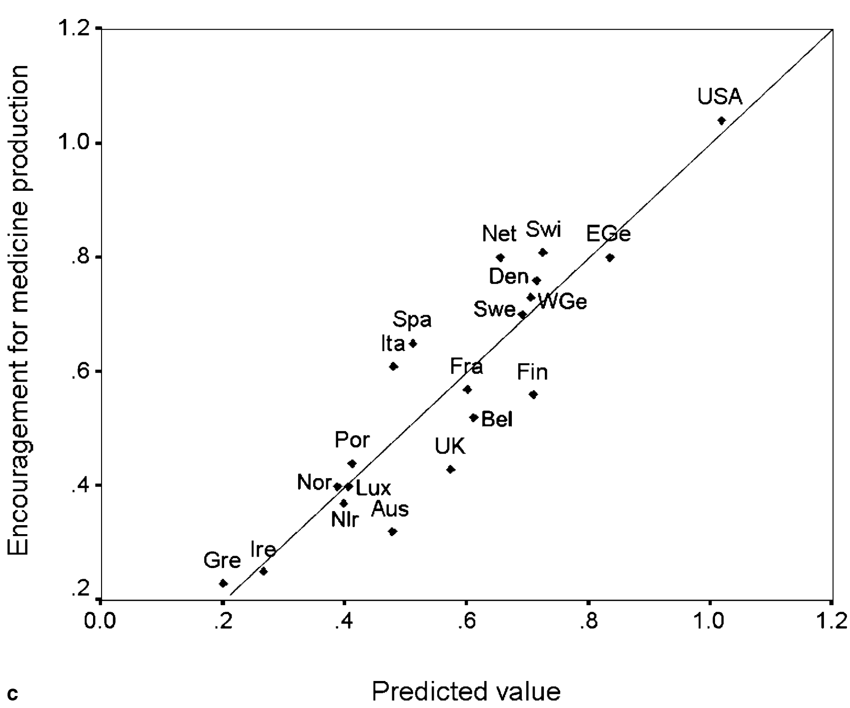
Of course, food and crop applications overlap. In part, these results may reflect higher salience of the term (and associated concept of) "industry" suggested by the choice of the word "food," versus "farming" and "environment" in the context of "crops." The similarity of the two models in other respects is not particularly surprising but nevertheless illustrates the relationship between particular "trust gaps" and particular, highly specific applications.

Production of medicines (Fig. 2c): Results of the model for this application produced the highest correlation between predicted and actual encouragement ($R = 0.913$, adjusted R^2 0.774, $P = 0.000$,

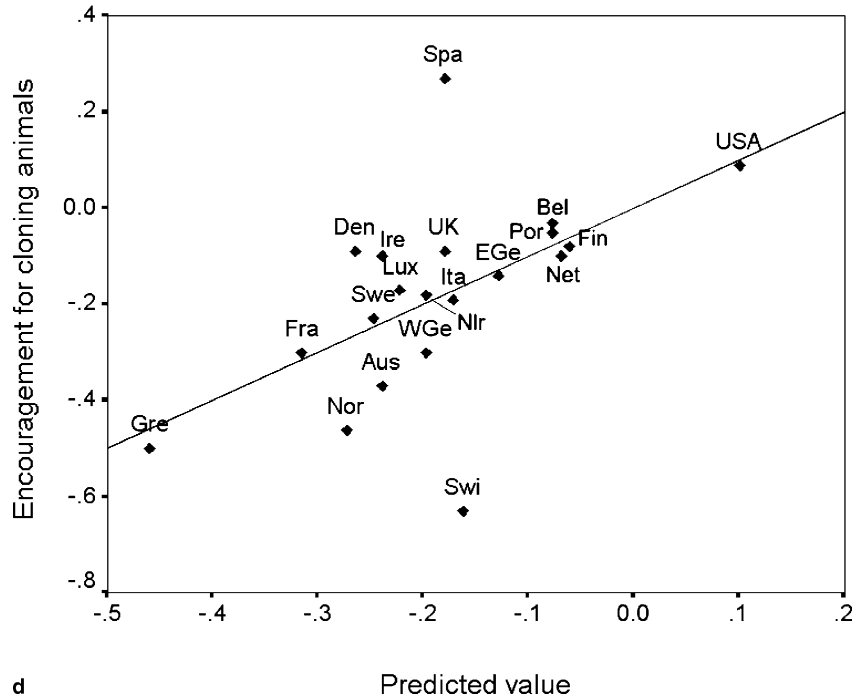


b

beta = 1.494). This model was also more complex than any of the others. The most important predictors in this case were not "trust gap" variables but absolute levels of trust in industry ($P = 0.000$) and government ($P = 0.000$, beta $= -1.564$), followed by three "trust gaps": industry-consumer organizations ($P = 0.000$, beta $= -1.332$), government-media ($P = 0.019$, beta $= 0.435$), and industry-environmental groups



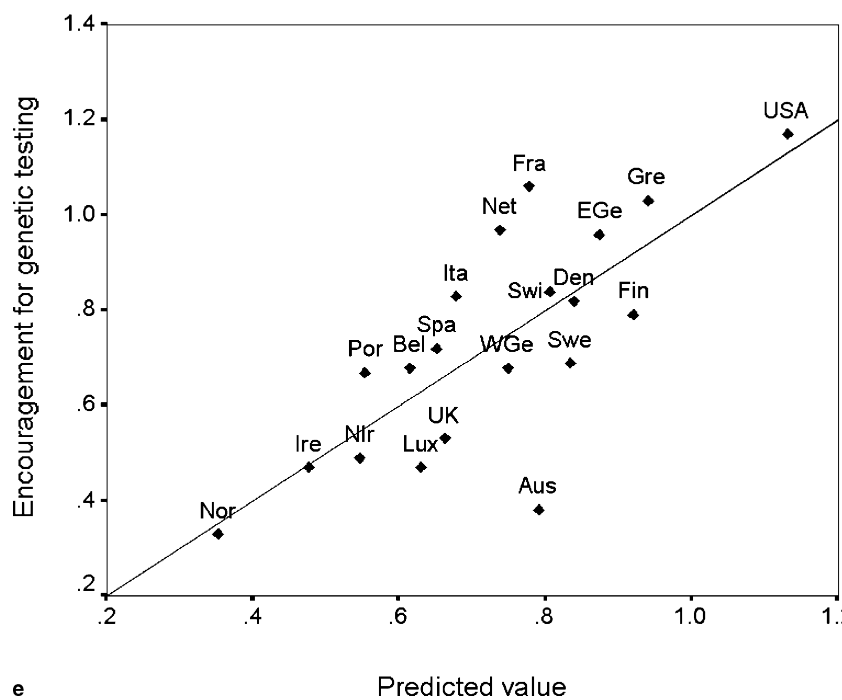
c



d

(P = 0.101, beta = 0.450). No countries stand out as outlier exceptions. The pattern is quite dissimilar from those found for food biotechnology and crop engineering.

Generally, the predictors here make intuitive sense. If medicine production using genetically engineered bacteria is an idea that has not been as widely debated or criticized, as we expect, then it seems



e

reasonable that support for this application would be more directly predictable on the basis of trust in industry and government. "Gaps" with respect to trust in potential critics of these institutions would be important, but to a lesser extent, if critics have not been especially active on this issue. This application has probably not emerged as a public controversy calling for consumer-citizens to "take sides." Encouragement therefore depends more on attitudes toward developers/promoters (industry) and regulators (government) than on "trust gap" factors. However, we do not have a well-developed explanation for the negative beta coefficient developed in this model for trust in government.

Cloning animals (Fig. 2d): The correlation between predicted and actual encouragement values for this application is by far the lowest of any of the five at 0.562 ($F = 8.321$, $P = 0.010$, adjusted R^2 0.278). Further, only *one* of the independent variables, the industry-environmental group "trust gap" ($P = 0.010$, beta = 0.562), is included in the model. And there are in this case two unambiguous outliers, Spain and Switzerland, suggesting cultural variables not well captured by any of our trust or "trust gap" variables could also be important (for example, cultural attitudes toward domesticated animals).

Cloning has been highly controversial and highly publicized; it should not be a great surprise that its pattern is unlike that of the other biotechnology applications tested. Nevertheless, we think it is worth noting that both the United States and most European nations do actually fall close to the regression line predicted by the model, and that the single predictor variable (industry-environment "gap") is the same as one in the models for other applications of agricultural biotechnology tested (food and crops).

Genetic testing (Fig. 2e): In this case, the predictor variables in the final model, which predicts values with a 0.755 correlation with the actual encouragement levels ($F = 7.081$, $P = 0.003$, adjusted R^2 0.490), do not include any "gap" variables at all. Further, this is the only model that includes genetic knowledge scores as a predictor; the three independent variables in the model are trust in farmers ($P = 0.001$, beta = 0.748), knowledge ($P = 0.041$, beta = 0.366), and trust in media ($P = 0.041$, beta = −0.243). As before, the United States is nearly on the line—albeit at one end of it. Austria and possibly Finland appear to be statistical outliers.

While the ability of this model to predict encouragement is reasonably high, in most cases we have no ready explanation for why these particular trust variables would be involved. What does it mean that more trust in farmers, but *less* trust in media, are associated with support for genetic testing? We have to suspect that trust in farmers and perhaps also trust in media are themselves correlates of relevant cultural or political variables we have not captured in our study at all (as for cloning, but not necessarily the same ones). In this as in the other models, we cannot claim to have developed complete explanations for levels of public support for biotechnology, but we do feel justified in claiming that our data confirm the existence of patterned relationships involving "trust gaps" alongside other variables.

As was true for medicine production, the other purely medical application, "gaps" are not important here. This is consistent with the observation that food biotechnology has become more openly controversial in public discourse (making the "gaps" more salient, if not actually producing them), in comparison with medical applications. Since active DNA manipulation is not involved—despite ethical issues in such areas as privacy, insurability, and selective abortion—some cultural objections may not arise.

4. DISCUSSION: THE "TRUST GAP" AS A NEW MODEL OF PUBLIC OPINION FORMATION

Despite extensive analysis of survey data and other forms of social research in both Europe and the United States extending over some years, cultural differences in support for particular forms of biotechnology across cultures have continued to represent an enormous puzzle. They have seemed arbitrary, unpredictable, and—to some extent—"irrational" in the sense of not being based on science. While we have only a partial solution in terms of the "trust gap" hypothesis, we feel it represents substantial progress in an area where sound, integrative theory has largely been lacking. Our results have implications both for understanding public reactions to biotechnology specifically and for understanding public opinion formation in complex postindustrial societies.

Differences among nations—in particular, differences between the United States and European nations—in responses to biotechnology have become politically volatile. From the perspective of many in the U.S. scientific community, European reactions have been difficult to fathom except as a function of misinformation and fear. However, given that knowledge gaps do not serve very adequately to explain public responses on either side of the Atlantic, U.S.

acceptance is just as much in need of explanation as is European rejection. We have chosen the term "trust gap" to characterize the differences we have observed and at the same time to serve as a reminder that factors other than knowledge gaps seem to be at work. Differences in political culture are implicated, in our results, as important explanations of observed differences in public response; these differences are reflected in differential responses to actors and institutions that may or may not be perceived as relatively legitimate, trustworthy, credible, and/or reflective of salient social values held by the individuals who are making judgments about biotechnologies. For example, people in the United States may trust industry to look out for their important interests more than they trust environmental groups to do so. In Europe, this is apparently less often the case.

Researchers trained in the psychology of risk often see *cultural* differences in terms of *individual* (or perhaps distributional) differences in attitudes and behaviors. (For an example, see the discussion of culture in Finucane.[21]) Culture can be variously defined, but by most all definitions commonly used in sociology and cultural anthropology culture is something that is shared within a group, not something easily reduced to the characteristics of individuals. Our study has certainly made use of aggregate data about individuals, but in the end we have used the nation (itself a conglomerate, admittedly, of cultures) rather than the individual as the unit of analysis. We have tried to link individual actors and the sociocultural matrix in which they act; we conceptualize our trust and "trust gap" variables as representing genuinely social (that is, trans-individual) phenomena, not just choices made by individuals in isolation, that are reflective of differences in the climate of opinion, not just individual opinions. Explaining such national differences is of more than academic interest, since different nations have distinctly different stakes in the biotechnology debate.[22]

While trust in particular institutions and actors and "gaps" among them are important to different degrees and in different ways in each individual application we considered, they are in some way important for *all* applications we examined, both food-related and medical. It appears as though knowledge, while important in some cases, is as a whole much less important than trust in predicting encouragement. That this rule should hold true across such a broad variety of both national cultures and specific biotechnology applications is an important finding, and no less so because the details of which institutions are the most important are not always the same or because "trust gaps" are more important for some applications than for others.

Consumer/citizens certainly appear to be making sophisticated distinctions among different applications of biotechnology and do not simply substitute knowledge of science for relevant social knowledge. In other words, scientific knowledge does not always translate into support, and scientific ignorance does not necessarily undermine it. Rather, consumer responses appear to be the result of considered judgments about which social actors are most to be relied on. These judgments may be more salient for developments that have become the subjects of public sphere controversy in which alternative voices compete for credibility with audiences. In any case, they are inseparable from the sociocultural matrix in which they take place.

This study is based on analysis of data originally gathered for other purposes and can provide no more than tentative interpretations. We acknowledge, for example, that as the variables we analyzed were based on questions about which actors are "doing a good job" for society in the area of biotechnology, rather than about trustworthiness itself, there is a certain amount of conceptual overlap between our independent and dependent variables. Nevertheless, the fact that the pattern of relationship between institutional trust and encouragement is different for each application suggests some level of public awareness of the distinctive social actors relevant to each, implying a more cognitively engaged public than might otherwise have been assumed. Our results also suggest a public divided over who to believe rather than by degrees of mastery of scientific facts, a vision consistent with the idea of a "risk society."

In terms of public opinion theory, studies of source credibility have had a long history since their emergence in the World War II era. But this literature has primarily been concerned with associating a single actor or spokesperson with an isolated opinion response. Our analysis suggests a much more nuanced picture in which the relationships between levels of trust vested in various institutions and actors (not just trust in the spokesperson associated with a particular isolated message) are implicated in opinion formation. Our results are consistent with an understanding of audiences not as passive and often ignorant recipients of information but as thinking individuals actively engaged in weighing the "truths" proposed by competing voices, using a complex calculus that our measurements and models were too crude to do more than suggest. We certainly hope that other researchers, using alternative definitions of trust and perhaps a broader selection of "trust gap" pairs, will be able to test and refine this approach.

These results have implications for the maintenance of democracy in postindustrial societies. How can policy be democratically derived in situations in which the average person, even the well-educated citizen, cannot be expected to keep abreast of the relevant scientific facts? Our study suggests individuals in contemporary society engage in a reasoned process of distinguishing among trustworthy and less trustworthy actors as part of their strategy for "taming the information tide."(23) While it would be possible to interpret this pessimistically by imagining today's media-saturated societies as composed largely of people who are easily manipulated into trusting particular institutions and messages, a more optimistic interpretation sees rational and constructive strategies being employed by active audiences making reasoned choices among competing points of view.

Much of the literature on risk perception seems to us to have entailed the tacit assumption that lay individuals confronted with a risk respond primarily by engaging in a cognitive process of weighing costs and benefits. Without appropriate technical training and full access to relevant scientific information, these individuals may (of course) make faulty judgments. This process has been seen as subjective and flawed, even by those inclined to acknowledge the value-laden character of definitions and weights associated with those costs and benefits. In other words, the process of risk assessment (especially in lay hands) is seen as being distorted by the introduction of social factors such as values, resulting in inaccurate and even volatile evaluations of riskiness. Our study as reported here implies a different vision. We also see individuals as making complex (and potentially flawed) judgments under conditions of uncertainty and imperfect knowledge, but the subject of those judgments is not primarily costs and benefits. Rather, social judgments about other social actors who may or may not share one's social values or be trusted to respect one's interests are paramount. While it undoubtedly remains very possible that errors in judgment will occur under these circumstances, we believe our analysis suggests a very different sort of calculus is taking place than that generally assumed.

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