Technology Optimism or Pessimism about Genomic Science:

Social Scientists versus the American Public

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ABSTRACT

Members of the general public, as well as experts in various disciplines, express levels of technology optimism or pessimism about scientific endeavors with which they are more or less familiar. Levels of tolerance for risk may vary according to cognitive or affective characteristics of the individual, the social context, the content of the enterprise being evaluated, or some other dimension; the theory is seriously underdeveloped. In this paper, we explore levels of technology optimism and pessimism through the lens of responses to various arenas within the rapidly developing field of genomic science. The novelty of genomics in the public realm -- along with its unusual combination of profoundly personal implications, stupefyingly complex technology, and broad but as-yet-unknown societal implications, make it an excellent subject for the study of policy formulation, political consolidation, and individual responses to the frontiers of knowledge.

Using a variety of methods and types of evidence -- in-depth elite interviews, content analysis of prominent articles, and a new public opinion survey – we find that social scientists who are deeply knowledgeable about genomics tend to be technology pessimists, while genetics researchers and the American public at large, especially the well-educated or scientifically literate, tend to be technology optimists. More knowledge is associated with increased optimism and support for scientific research among the citizenry but not among some of the scholarly elite; we consider the causes and consequences of that split.

> Scientists are optimists – why else would we devote so much effort to devising intricate experiments to tease out new knowledge? We also continue to innovate, to solve problems, perceived and real. Our world is rife with potential tragedies: rapidly dwindling resources, new diseases that spread with frightening speed, the effects of global warming. The role of science in protecting our lives and our planet is crucial and dramatic. . . . We are learning quickly.
>
> --(Arnold 2012): 10

> [F]orensic DNA repositories are gathered by the state without consent and are maintained for the purpose of implicating people in crimes. They signal the potential use of genetic technologies to reinforce the racial order not only by incorporating a biological definition of race but also by imposing genetic regulation on the basis of race. . . . As the ideology that race is important to genetics . . . is spreading, we are also witnessing the escalation of a particularly brutal form of state control over large numbers of people on the basis of race.
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> --(Roberts 2011): 264-5

A variety of disciplines -- psychology, economics, organizational behavior, political science, and others – all engage with a dichotomy that we label technology optimism or pessimism.[1] Frances Arnold's effort to solve "our world's . . . potential tragedies" through science represents one pole; Dorothy Roberts' claim that forensic DNA biobanks are a "particularly brutal form of state control" represents the other. The basic distinction goes by a variety of names: risk seeking versus risk aversion, preference for type 1 or type 2 errors, and others. At its core is the question of whether an individual, group, or polity should, at the margin, be more engaged with protecting vulnerable individuals or the society against possible or probable disasters, or more focused on promoting possible or probable gains. Ideally, of course, one will

[1] The phrase is in widespread use, but we first learned it in the context of genomics from (Hjorleifsson et al. 2008).

do both -- but where a choice must be made, actors differ dramatically in where they place priority.[2]

As the phrase "technology optimism" suggests, science policy is one arena in which the appropriate level of risk is a prominent concern. The scientific optimist "is centered on advancement concerns. . . . [He or she is driven] by motivations for attaining growth and supports eager strategies of seeking possible gains even at the risk of committing errors or accepting some loss". A technology pessimist, in contrast, "is centered on security concerns. . . [and] supports vigilant strategies of protecting against possible losses even at the risk of missing opportunities of potential gains" [both quotes from (Hazlett et al. 2011): 77)]. An optimist may support construction of nuclear power plants on the grounds that they can provide a clean, cheap source of energy to replace coal and oil; a pessimist focuses on the nuclear catastrophe that can be unleashed by natural disasters or human sabotage or error. An optimist envisions great medical benefits emerging from research on embryonic stem cells; a pessimist sees a threat to the sanctity of life.

Theories about why individuals, organizations, or policies have different tolerances for risk are many, varied, noncumulative, and inconclusive. They range from personality characteristics to cognitive biases [(Slovic 1987); (Tetlock 2005); (Taylor and Brown 1988)] , a history of group oppression or privilege (Urban and Hoban 1997), the play of market forces or

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[2] One can describe not only individuals but also institutions and policies as implicitly technologically optimistic or pessimistic. A technologically optimistic institution or policy will promote research and development, provide funding, minimize regulation, and create incentives for innovative practices. It will focus, in short, on achievement. A technologically pessimistic institution or policy will encourage oversight, set high barriers to approving controversial new products, move cautiously in reconfiguring governmental agencies, and seek rules to limit misuse of genetic information. It will focus, in short, on protection.

Whether technology optimism/pessimism is more usefully understood as a characteristic of human actors or of policies and institutions is a key question for the larger research project of which this paper is a part.

electoral calculations, or modernity itself [(Ghatak 2011); (Beck 1992)]. In this paper we analyze only individuals' levels of technology optimism or pessimism (setting aside group or societal levels), and focus several threads of explanation for those levels – level of education, scientific literacy or subject-matter expertise, religion and religiosity, and partisan or ideological affiliations. The objects of optimism or pessimism that we examine are four aspects of genomic science and, for the sake of comparison, global warming. We justify focusing on such a drastically narrowed slice of the large topic of risk seeking and risk aversion by the fact that it enables engagement with an important paradox: social scientists and legal scholars who are deeply knowledgeable about genomics tend to be technology pessimists, while genetics researchers and the American public at large, especially the well-educated or genetically knowledgeable, tend to be technology optimists. Knowledge, in short, is associated with two opposite judgments of the risks entailed by genomic science.

We also show that this paradox does not hold in the case of climate change; social scientists are almost uniformly technology optimists in that arena. [3] We then use the comparison to analyze whether patterns of technology optimism and pessimism reveal something about genomic science, social scientists and legal scholars, the mass public, or the theory of risk seeking and risk avoidance. To foreshadow our conclusion so far: the paradox emerges from an unusual, perhaps unique, confluence of scholars' political ideology and genomics' distinct characteristics. The more general point is that the implications with regard

[3] Since the research on climate change is not yet complete, this sentence is aspirational rather than descriptive for this version of the paper. We also plan to add other scientific arenas (we are currently focused on human spaceflight) to the set of comparison with genomics.

to political preferences of different levels of knowledge or different values about a given scientific endeavor are indeterminate and in need of careful theorizing and analysis.

The argument develops as follows: We begin with a brief case study to show what is at stake, scientifically and politically, in competition between advancement concerns and security concerns in genomics. We then briefly review standard findings, and recent challenges to them, on the links between education or scientific literacy and support for scientific endeavors. From that review we derive several hypotheses about how elite opinion differs from public opinion, and how scientific literacy, education, and values play a role in distinguishing optimists from pessimists. We then describe three new datasets: a content analysis of 216 prominent articles by social scientists, legal scholars, and genetic researchers; interviews with 45 experts in the same fields; and a new survey of Americans' views about genomic science.[4] Together, these sources of evidence enable us to compare genomics experts' levels of technology optimism or pessimism with the levels of optimism or pessimism held by citizens with varying amounts of knowledge, education, and other values or characteristics. We conclude by exploring possible reasons for the paradoxes revealed through the data analysis.

What Is at Stake? The *Aedes Aegypti* Mosquito

"Researchers estimate that mosquitoes have been responsible for half the deaths in human history" [(Specter 2012): 40. All quotations in this section are from this article.] The *Aedes* mosquito transmits the deadly diseases of yellow fever and the "terrible. . . break-bone fever," dengue. Dengue has no vaccine or cure; it can be controlled only by killing the insects that carry

[4] The next iteration of this paper will add evidence generated from a new module on genetics and genomics in the 2010 GSS, and will complete the content analysis (see below).

it through (ever-increasing use of) insecticides. A British company has developed a technology for genetically modifying male mosquitoes so that they can mate but their offspring die before reaching maturity; the goal is to eradicate the species.

The head of Brazil's National Program for Control of Dengue is cautiously optimistic about the experimental release of genetically modified *Aedes* in some Brazilian communities: " 'I am not saying this alone will solve the problem of that there are no risks. There are always risks- that's why we start with small studies in geographically isolated neighborhoods. But people are dying here and this mosquito is resistant to many insecticides. We really do need something better than what we have' " (p. 39). Community residents are less cautious. "In Juazeiro, where few families remain unaffected by dengue, the Moscamed team and its mosquitoes are treated with reverence" (p. 39). But others view the experiment differently. The executive director of the British environmental group GeneWatch describes the genetically modified *Aedes* as "Dr. Frankenstein's monster, plain and simple. To open a box and let these man-made creatures fly free is a risk with dangers we haven't even begun to contemplate" (p. 39).

Dengue broke out in Key West, Florida, in 2009 after seventy-three years of absence. The number of cases has remained small, but as the director of the Florida Keys Mosquito Control District points out, " 'A couple of hundred cases here could be devastating to the tourist economy' " (p. 43). Should the genetically modified *Aedes* be released in Key West? The Mosquito Control director ruminated, " 'If this actually worked we would win in every possible way. Other approaches are more costly and more environmentally challenging. The data looked solid, and certainly we need to think differently about mosquito control than we have in the past' " (p. 43).   But opponents mobilized before a hearing, describing it as a meeting to discuss " 'releasing and testing genetically modified (man-made) mosquitoes on you, your family, and the environment'"(p. 44). All public comments at the hearing were hostile, with accusations that the government has already secretly released dangerous new life forms. A researcher at the British environmental group EcoNexus spelled out the Floridians' concern more systematically:

> Genetic modification leads to both intended and unintended effects. . . [particularly] if the mosquitoes are eliminated altogether. . . . What will fill the gap or occupy the niche should the target mosquitoes have been eliminated[?] Will other pests increase in number? Will targeted diseases be able to switch vectors? Will these vectors be easier or more difficult to control? (p. 44).

Scientists say that these questions have been addressed, and "if the results [of the research] were put to the vote of biologists, the overwhelming response would be: the potential benefits far outweigh the risks" (p. 44). It is not biologists, however, who vote on such questions; in fact, it is unclear who "votes" in the United States federal government. Are genetically modified mosquitoes animals (under the jurisdiction of the Department of Agriculture) or drugs (under the FDA)? More profoundly, should citizens, or even their legislators, be able to vote on trial releases of the modified *Aedes?*   Who can and should weigh the risks of these " 'robo-Franken mosquitoes' " (p. 46) against the risks of insecticide or dengue fever? The Brazilian official is a committed democrat: " 'There is only one way to get people on your side: talk to them. This is a new technology. It is scary. But it also carries tremendous possibilities. People are not stupid. You just have to tell them all of that. Lay it out so they can decide' " (p. 46). Perhaps his faith is warranted -- but the politics of making decisions about genomics innovations – from the tiny *Aedes* mosquito to who knows where – are at least as difficult as the science itself.

Does Scientific Literacy Explain Public Support for Science? Maybe

Public hearings in an aroused community are an important form of politics, as the Florida Keys Mosquito Control director discovered, if he did not already know. But contentious events bear no clear relationship to overall public opinion on a given issue. To develop hypotheses about citizens' levels of tolerance for risk in genomics, we turn to existing research on public attitudes toward science. The literature can be roughly organized into three distinct, partially competing, strains of argument, two of which are relevant for our comparison between experts and ordinary citizens. In order of their appearance in scholarly debate, the arguments cluster into the scientific literacy model, the low information rationality model, and the value-predisposition model; we focus on the first and third. Along the way, we discuss how the two relevant models can also predict expert opinion.

Scientific Literacy: Starting in the 1970s (Shen 1975), scholars studying opinion toward developments in science and technology have focused on measures of the public's knowledge about scientific facts and the nature of scientific inquiry [for a small sample, see (Bodmer 1985; Brossard and Lewenstein 2009); (Nisbet and Goidel 2007)]. Although Shen proposed that appropriate literacy might vary in different contexts (e.g. what one needs to know as a consumer of science may differ from what one needs to know for understanding scientific culture), most work addresses the type of scientific literacy needed for effective citizenship (Durant 1994); (Kolsto [accent] 2001)]. Operationalizations vary, but Jon Miller has established the widely-accepted premise that an acceptable level of public or civic scientific literacy is the sophistication needed to understand science articles in major newspapers (Miller 1983; 1998; 2004).

Surveys generally implement the concept of scientific literacy through a battery of questions about processes (e.g., the scientific method or probability theory) and specific areas of knowledge (e.g., definitions of DNA or a black hole). Collectively, the surveys show several things. First, Americans know little about scientific processes, although knowledge is increasing. "In 1988 just 10 percent of U.S. adults had sufficient understanding of basic scientific ideas to be able to read the Tuesday *Science* section of the *New York Times*. . . . By 2008, 28 percent of adults scored high enough to understand scientific ideas at that level" [(Swanbrow 2011), citing (Miller 2010)].

Second, the picture is uneven with regard to specific scientific topics. By 2008, at least 80 percent of Americans knew that light travels faster than sound, that "all plants and animals have DNA," and that "the center of Earth is very hot." But only half knew that "electrons are smaller than atoms," only a quarter could define a molecule, and only a fifth could define a stem cell. The proportion of Americans who accepted the concept of continental drift, who agreed that astrology is not scientific, who accepted the theory of human evolution, and who concurred that the universe started with a "huge explosion" declined between 1988 and 2008 (Miller 2010: 246).

Third, high levels of scientific literacy are associated with high levels of support for scientific endeavors. As Miller puts it, civic scientific literacy

> is the key link between science and technology policy and democratic government. As modern science has become more expensive and more controversial, it has inevitably

> moved into the public arena. Science and technology are essential to a wide array of public policy objectives in environmental and biomedical areas but are also essential tools for sustaining American competitiveness in the emerging global economy . . . . Scientific literacy is . . . a prerequisite for preserving a society that values science and is able to sustain its democratic values and traditions (Miller 2010: 253).

Thus the scientific literacy model implies:

> *H1, Scientific Literacy in the Public: the more that members of the general public know about genetics or genomics, the more they express technology optimism (or are risk-seeking, or prefer type 1 errors), about the field or particular instantiations of it.*

Relaxing the meaning of "scientific literacy" from knowledge about a particular subject to knowledge about science or the scientific method in general enables us to broaden the claim about the positive association between knowledge and support. Hence:

> *H2, Education in the Public: the higher the level of education, the more people express technology optimism (or are risk-seeking, or prefer type 1 errors), about the field or particular instantiations of it. Education here encompasses years of schooling, schooling credentials, and access to the internet.*

Nothing in the scholarly literature implies a break in the link between scientific knowledge and support for scientific endeavors. Since scientific and technological experts have substantially more scientific literacy than members of the public, under the scientific literacy model they should be significantly more likely to endorse and even champion genomics research. In addition, they have a unique self-interest in promoting their own research and research in their field of expertise. Thus:

> *H3, Scientific Literacy among Experts: experts in the field of genetics or genomics are even stronger technology optimists (or are more risk-seeking, or are even more likely to prefer type 1 errors), than even the most knowledgeable members of the general public.*

We do not offer a hypothesis about experts' education analogous to *H2, Education in the Public,* since almost by definition, genomics experts have advanced professional or academic degrees. So there is no variation on this variable.

Challenges to Scientific Literacy: Two strong critiques challenge the claim of a positive relationship between scientific literacy and support for science. For one thing, at the aggregate level, low scientific literacy is not paralleled by a lack of interest in or enthusiasm for science and technology. As even Miller points out, "[f]or the last 15 years, approximately 70 percent of US adults have reported that they are very interested in new medical discoveries" and most Americans are "enthusiastic" about science (Miller 2004: XX). Forty-three percent of the more than 34,600 GSS respondents accumulated since 1973 express "a great deal" of confidence in "the scientific community" – roughly twice the proportion with a reasonable level of scientific literacy -- while only 7 percent report "hardly any confidence at all." Even more, 48 percent of the 37,000 queried since 1973, express great confidence in medicine. These are the two strongest endorsements among the thirteen institutions that have been the subjects of the GSS's repeated confidence questions.[5]

In addition, attitudes toward scientific topics vary considerably among people with similar levels of scientific literacy, according to a meta-analysis of two hundred articles (Allum et al. 2008). Studies have even found a negative association between scientific literacy and support for specific areas of science, such as manipulation of human embryos (Evans and Durant 1995). The evidence on the scientific literacy model is thus mixed.

[5] Analysis by authors. The next highest is the Army, at 40 percent across 36,400 respondents since 1973. At the other end of the continuum, 12 percent endorse organized labor, and 14 percent endorse both television and Congress.

Confidence in medicine has declined, from an average of 53% saying "great deal" across the six surveys of the 1970s to 39% saying the same across the six surveys of the 2000s. Confidence in science declined only 2.5 percentage points from the average of 45% in the 1970s.

Low-Information Rationality: In response to these lacunae in the original model, some have pursued the theory that policy views about science are more closely linked to attitudes and beliefs than to knowledge. One line of research begins from the premise that the public is "miserly" about acquiring information; people form policy preferences largely on the basis of cues from friends, family, group members, and co-workers, or from favored elites and the media [(Fiske and Taylor 1991); (Brossard and Nisbet 2007); (Scheufele and Lewenstein 2005)]. Thus if the public (or a segment) receives consistent, trusted messages endorsing (disputing) the efficacy or importance of science and technology, opinion will tend toward (dis)approval for scientific endeavors. If the messages are mixed, the public's views will look, and perhaps be, shallowly rooted or essentially random (Zaller 1992). This model resembles political scientists' standard argument that most voters, for better or for worse, use simple and easily accessible heuristics (donkey or elephant, "a New Deal") or cues from an accessible elite in making political or policy choices [(Popkin 1993); (Kuklinski and Quirk 2000); (Lau and Redlawsk 2001)].[6]

The theory of low-information rationality is important for explicating public opinion about science. By definition, however, it is irrelevant to the study of attitudes about genomics among genomics experts. Thus, given our focus on comparing experts to the mass public, we do not consider it further in this paper.

Value Predisposition Models: The most recent round of scholarship seeking to explain levels of support for science and technology merged aspects of the first two models, and added new variables. The value predisposition model (Nisbet 2005; Ho et al. 2010) focuses research on the

[6] Knowledge is not absent in the model of low information rationality. Deference to scientific authority and science knowledge, both associated with education, have direct as well as indirect impacts on the public's views of agricultural biotechnology (Brossard and Nisbet 2007). But scientific literacy, or education more generally, tends to play a relatively small role in this model compared with heuristic devices.

claim that the public might use both values and knowledge in developing views about science and technology. Religiosity is an important predictor of beliefs about whether nanotechnology is "morally acceptable"(Brossard et al. 2009); religiosity and political conservatism both moderate the otherwise positive effects of knowledge in beliefs toward stem cell research [(Ho et al. 2008); see also (Hayes and Tariq 2000); (Sturgis and Allum 2004)]. Ideological conservatives are more skeptical of science and technology research, development, and funding than are liberals [(Gauchat 2012); (Binder 2002)]. Some even argue that conservative elites seek to distort or inhibit scientific research -- that there is a "Republican war on science" (Mooney 2005).

As Mooney's book title implies, whether and how values and beliefs are associated with enthusiasm for science can be asked of experts as well as of the mass public. After all, some evidence suggests that experts are not able to set aside their ideological biases even (especially?) in arenas where their knowledge and experience are extensive [(Tetlock 2005); (Halberstam 1972)]. Furthermore, members of certain disciplines such as the law and the social sciences tend to be more attuned to normative inquiries – including possible policy or distributive concerns emerging from significant social or cultural change -- than are bench scientists or the general public. There is little non-tendentious research on this topic [for an exception, see (Gross 2013); nevertheless, we offer two parallel hypotheses, one about ordinary citizens and one, with subheads, about experts:

> *H4, Value Predispositions in the Public: deeply held values -- especially on religion, religiosity, and ideology -- are associated with, and arguably shape, levels of optimism or pessimism about genomics or particular aspects of it. Depending on the content of the values and the scientific endeavors at stake, these values reinforce or contradict the optimism generally associated with scientific literacy and education.*

H5, Value Predispositions among Experts: as in the public, experts' attitudes draw upon values predispositions, especially on religion, religiosity, and ideology.

H5a: Given that they have chosen to devote their professional life and reputation to genetics or genomics, life scientists' values generally reinforce their extraordinary scientific literacy and high levels of education – thus implying very high levels of technology optimism.

H5b: Given their relatively greater focus on normative and policy issues, the values of social scientists and legal scholars who study genomics may contravene the optimism generally associated with scientific literacy and high levels of education – thus implying low levels of technology optimism.

Examining Genomics Experts' Technology Optimism or Pessimism

Two sets of evidence provide the relevant information on experts' levels of tolerance for risk in the field of genomic science.

Article Coding Project: We used the *Journal Citation Report* to identify the ten journals with the highest impact factors in political science, economics, anthropology, law, psychology, cultural studies, history and philosophy of science, ethnic [including racial] studies, and sociology.[7] We then used the *Social Science Citation Index* to identify the twenty articles with the highest citation counts in each of the ten journals of each discipline, using the same key words, dates, and English language criterion. The keywords were DNA, genetic*, or genomic*; the dates were since January 1, 2003. So far, this process has yielded 216 articles across 35 journals in eight social science disciplines plus law.[8]

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[7] In a few cases we set aside a journal that is clearly irrelevant, and added the eleventh highest-impact journal for that discipline.

[8] The number of journals is well below 90 (9 disciplines x 10 journals each) since many journals had no relevant articles. In parallel fashion, the number of articles in the completed coding project will be well below 700 (35 journals x 20 articles each) since the keyword search yielded only a few articles in many journals.

A combination of the authors and three trained undergraduate coders hand-coded each article. (Not only is the coding incomplete, as noted earlier, but also we do not yet have measures of inter-coder reliability.) Since roughly half of the articles remain to be coded, we caution against treating these preliminary results as exhaustive or even as a likely representation of the universe of articles. Nevertheless, they are intriguing.

The key dimension of coding for this paper is:

Valance: Describe the overall tone of the article with regard to advances in genetics or genomics:

a. *Positive*
b. *Negative*
c. *Neutral*
d. *Mixed*
e. *Too hard to tell*

The student coders, who were responsible for most of the coding done so far, did not know the thesis of this paper. We did, however, discuss with them the meaning of technology optimism or pessimism and we jointly evaluated illustrative articles from a variety of disciplines.

Table 1 identifies the number and percent of articles coded so far by discipline. (We exclude from this analysis all anthropology articles that are purely biological rather than social or cultural.) Note that three-fifths of the items coded to this point are from history or philosophy of science.

Table 1: Articles coded so far, by social science discipline

	Sociology	*Political science*	*Economics*	*Anthropology*	*Racial or ethnic studies*	*History or philosophy of science*
% *Number*	7% (16)	10% (21)	6% (12)	11% (23)	5% (11)	62% (133)

Note: Row percentages (with numbers in each cell reported in parentheses)

To provide more context on these articles, Table 2 lists the journals in our sample with the largest number of articles identified through the keyword search; most are interdisciplinary, lying especially at the nexus of genetics (or biology more generally) and ethics or public opinion. Note that table 2 considerably underestimates the proportion of genomics-related articles published in these interdisciplinary journals, since we capped the number collected at 20.

Table 2: Journals in our sample with the most articles

Journal Name	Number of articles in data set
Social Studies of Science	20
Public Understanding of Science	20
Isis	20
Human Nature	20
Biology and Philosophy	20
American Journal of Bioethics	20
Medicine Health Care and Philosophy	19
American Journal of Sociology	13
Stanford Law Review	8

Turning from preliminaries to the core evidence, Table 3 shows the coding so far of the articles' valance. As row 1 shows, overall almost half are coded as neutral, expressing neither technology pessimism nor optimism. More surprisingly, so far we have found an equal proportion of articles showing positive and negative attitudes toward some aspect of genomic science.

Table 3: Valence of articles in various social science disciplines

	Positive	*Negative*	*Neutral*	*Mixed*	*Impossible to determine*
% *Number*	16% (25)	16% (25)	46% (74)	21% (34)	2% (3)
Sociology	19 (3)	0 (0)	56 (9)	25 (4)	0 (0)
Political science	41 (7)	6 (1)	24 (4)	24 (4)	6 (1)
Economics	100% (10)	0 (0)	0 (0)	0 (0)	0 (0)
Anthropology	4 (1)	0 (0)	91 (21)	4 (1)	0 (0)
Racial and ethnic studies	18 (2)	45 (5)	18 (2)	0 (0)	0 (0)
History or philosophy of science	2 (2)	14 (14)	29 (38)	19 (25)	2 (2)

Note: Row percentages (with numbers in each cell reported in parentheses)

Despite its incompleteness, the more detailed results of the coding project are already suggestive. Experts' tolerance for risk fluctuates by research area. Researchers in racial and ethnic studies, and in history or philosophy of science, tend to be technology pessimists (or at least not technology optimists), while political scientists and economists are disproportionately technology optimists – perhaps because they have more in common with the STEM fields than do the experts in the other disciplines on our list. *H3, Scientific Literacy among Experts*, is not supported, or is even reversed in a few disciplines, so far.

Elite Interviews: During the past two years, we have conducted forty-five interviews with genetics and genomics researchers, medical personnel, government officials both elective and appointive, legal scholars, social scientists from various disciplines, and representatives of advocacy groups. (We plan to do roughly fifty more.) The interviews were open-ended and loosely structured, generally starting with a brief introduction to this project and the simple query, "So, tell me the three most important things we need to know about the relationship between genomics and politics or policy." Given the knowledge, passion, and generosity of our interview subjects, that tended to be enough of a cue to keep them talking for an hour or so. Their views are sufficiently varied, and the topic sufficiently broad, that we have not yet seen much overlap among interview subjects' responses.

These interviews have done a great deal to shape our analysis, but the transcripts have not yet been systematically coded. In lieu of a rigorous analysis, we offer at this point some illustrative pairs of observations. On genetic ancestry testing:

- People have the right to gain access to own genetic information. The government should [only] control companies to ensure that tests are accurate and based on real science, to ensure that companies explain results and give consumer access to genetic counselors (interview #29);

- Both scientists and consumers should approach genetic ancestry testing with caution because (i) the tests can have a profound impact on individuals and communities, (ii) the assumptions and limitations of these tests make them less informative than many realize, and (iii) commercialization has led to misleading practices that reinforce misconceptions. . . . Test-takers may . . . may suffer emotional distress if test results are unexpected or undesired. Test-takers may also change how they report their race or ethnicity on governmental forms. . . . This could make it more difficult to track the social experiences and effects of race and racism" (Bolnick et al. 2007): 399.

On direct-to-consumer (DTC) genetic medical information:

- "Should the FDA regulate [DTC genetic tests as medical devices]? We testified, and there are no data that people who do DTC testing suffer any harms. There are a lot of things where people do suffer harm-- this shouldn't be at the top of the list for regulation. People aren't getting much benefit [from DTC tests], and waste money -- but it's not like gambling, people do derive personal intangible benefits. . . .

  I'm pretty agnostic. I'm a scientist -- look at the data. The APOE data show that people did not become depressed [after receiving information about an increased risk of

Alzheimer's disease].[9] We are psychological animals that know how to protect ourselves. People already have a lot of information regarding family, and make attributions that may be highly inaccurate. So one could argue that genetic information could *relieve* people. . . .

The real challenge for science to is to ensure that the public has a sharp and keen understanding [of the role of genetics in behavior or disease.] *They do*, the public gets it regarding the complexity of gene/environment [interaction] (Interview #35).

- [Genomic sequencing] is an unbelievably cool scientific tool. . . . [But the idea that] "knowing your own genome is empowering" is just silly, [comes from] a political motivation to get money, is wildly oversold, will come back to bite us later. The return of [all] results runs headlong into the way that the health care system is governed. Some tests do harm; returning everything will increase costs [as people demand new tests]. How can we do this responsibly in a context where medical professionals *should* exercise stewardship? . . . [A focus on DTC testing] distracts attention from what makes a big difference [in health outcomes] – eat right, exercise, regardless of genetics (Interview #40).

On biobanks for use in the criminal justice system:

- "The DNA database is neither as large or as current as it could be. . . . The increased ability to solve cold cases is a compelling argument to expand Idaho's database. . . .DNA evidence is the gold standard of forensic science. It has the ability to free the innocent, and to blindly identify the perpetrator from a database of human profiles. However, DNA evidence can also be misused, misunderstood, or under-utilized" (Visser and Hampikian 2012): ((Visser and Hampikian 2012): 47, 49, 62-63)

- "Are there distinctive harms or benefits within your area of expertise?" Answer: "invasion of privacy; collection of genetic evidence by (legal) compulsion or by stealth/lack of informed consent; lack of oversight of labs; exploitation of genetic material without express legal authorization" (legal scholar, Qualtrics survey)

This small sample of contradictory observations barely scratches the surface of debates about the impact of genomics; to this list one could add the issues of prenatal genetic testing, race-based medicine, familial searching from forensic databases, genetically modified food, gene patenting, the reporting of incidental findings, privacy, epigenetics, genetic discrimination by

[9] The reference here is to (Green 2009).

employers and insurance companies, personalized medicine, the balance between a focus on genetic and environmental causes of phenotypes, and probably a dozen others.

Examining the American Public's Technology Optimism or Pessimism

We can identify and examine the paradox of genomics, in which high levels of knowledge are associated with both technology optimism and technology pessimism, only by comparing experts' views with those of the mass public. We turn now to the latter.

Through Knowledge Networks, we fielded a survey in May 2011 of 4,291 United States adults. The Genomics Knowledge, Attitudes, and Policies survey (GKAP) was stratified by race or ethnicity; table 4 shows the number of respondents in each racial or ethnic category. [10] Latinos could take the survey in Spanish (n = 578) or in English (n = 518). The survey included over 100 questions about genetics and genomics, and we received Knowledge Network's demographic information on these respondents as well as self-reports on use of technology, religiosity, many aspects of personal and family health status, and several forms of political activism. The survey included knowledge items, views of the relative importance of inheritance and environment in determining various traits, levels of support for various uses of genetics or genomics, views on government regulation and funding, links between genetics and morality or religion, trust in various actors, the role of genomics in racial differences, and other questions. (The questionnaire is available from the authors upon request.)

[10] A respondent could identify with a racial group or as multiracial while also being Hispanic (that is, "Hispanic" is an ethnicity rather than a race in GKAP). However, because many self-identified Hispanics opted not to provide a racial identification, we divided the sample into mutually exclusive categories and treat Hispanics as a "race" from here on.

We analyzed the data using standard regression techniques. We repeated the analyses several times, each time with a different optimism/pessimism answer regressed on a variety of variables designed to test the hypotheses.[11] Because the response categories are ordered (from pessimistic to optimistic), we employ ordered logistic regression, with respondents weighted so that the final analyses were representative of the U.S. national population. In all instances, we drop respondents who did not answer the question.[12] We present the results visually; in all of these instances, the plots represent coefficients, with 95% and 90% confidence intervals around the point estimates. Unless otherwise noted, whites comprise the baseline category to which racial and ethnic minorities are compared. High school graduates comprise the baseline category for the education variable.

Descriptive results: We begin with some descriptive results in table 4 for variables of particular theoretical importance or interest; we refer to these data through the course of the discussion.

Table 4: Race, education, and knowledge about genetics in GKAP, 2011 (N= 4291)

8th grade	*Some high school*	*High school degree*	*Some college*	*Associate degree*	*Bachelor's degree*	*Master's degree*	*PhD or professional degree*
179	333	1090	965	359	813	398	154

White	*Black*	*Hispanic*	*Asian*	*Multiracial*	*Hawaiian or Pacific Islander*
1143	1031	1096	337	635	49

[11] Collapsing across categories results in similar inferences.

[12] For all GKAP responses, DK/NA represented no more than approximately 3% of the sample; we are therefore not concerned that these individuals are systematically biasing our results.

0 genetics questions correct[13]	*1 genetics question correct*	*2 genetics questions correct*	*3 genetics questions correct*
1071	1473	1125	622

GKAP asked parallel questions on four genomics arenas: research on inherited diseases especially likely to affect people of one race or ethnicity, development of genetic tests to determine an individual's likelihood of getting an inherited disease, the use of DNA samples collected from patients or the general public for scientific research, and the use of DNA samples collected from people convicted of a serious crime for law enforcement purposes. For purposes of comparison, we also asked parallel questions about efforts to slow or prevent global warming, sometimes termed climate change. For each arena, we asked respondents if research or activity would lead to "more good than harm," "equal amounts of harm than good," or "more harm than good" for society.[14] We also asked, separately for each arena, whether respondents trust scientists, government officials, and private companies to act for the public good (with slight variations in question wording, explained below). Here we report mainly on the harm/good items; regression analyses for the trust items are available from the authors.

Note initially that three-fifths of the 1416 respondents in a 2010 GSS module on genetics and genomics agree that genetic testing will do more good than harm for society, compared with a quarter saying the opposite. Figure 1 shows a similar response among all

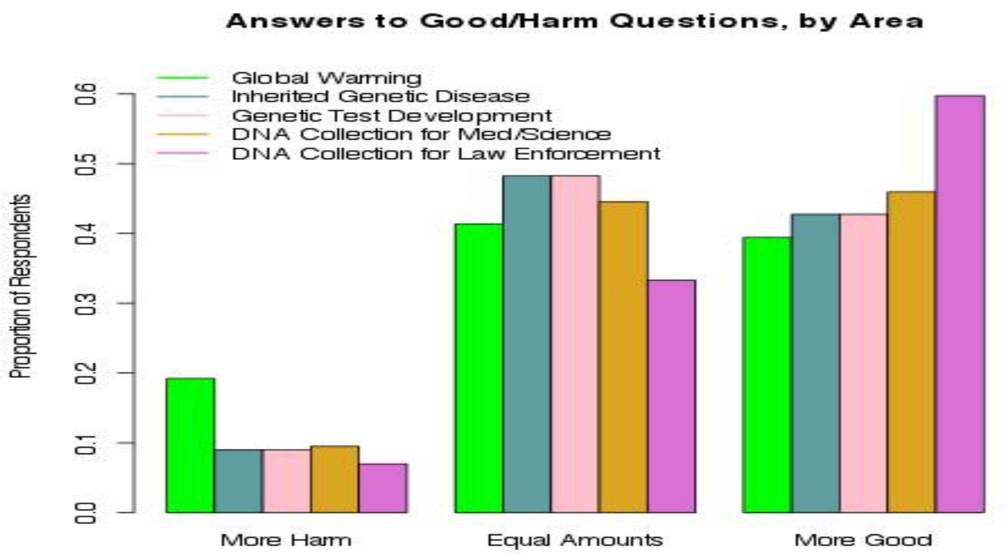
[13] The three items testing scientific literacy with regard to genomics were:

- Location of DNA in the body (*in every cell in the human body*, only in specific organs and cells in the human body, don't know enough to say) – 72 percent correct
- Share of white person's genes identical to those of a black person (*more than half*, about half, less than half, don't know enough to say) – 44 percent correct
- Share of human being's genes identical to those of a mouse (*more than half*, about half, less than half, don't know enough to say) – 17 percent correct

[14] Variants of this question have been used in surveys around the world, and in arenas ranging from space flight to regulation, Congress, and Facebook.

GKAP respondents, now with the finer-grained questions about particular arenas within genomics, along with climate change.[15]

Figure 1: Technology Optimism across Scientific Arenas, GKAP 2011



[15] Figure 1 and some of the explanatory sentences come from (Hochschild et al. 2012).

The distributions are skewed to the right; the American public is more likely to say that research into these arenas will result in a net good for society than to say the reverse. Few perceive net harm to society. However, this pattern has two partial exceptions: research on global warming (green bars) shows a relatively high level of pessimism, while the arena of use of DNA samples for law enforcement purposes (in purple) shows a spike in technology optimists. In both cases, social scientists and legal scholars typically express the opposite view.

Despite their tendency toward technology optimism, GKAP respondents express mixed views about the elites who generate or oversee genomic and other sciences, as table 5 shows:

Table 5: Trust in Elite Actors, GKAP 2011

	Trust XXX to act in the public good "a lot" + "some"		
	Scientists	*Government officials*	*Private companies*
Efforts to slow global warming	59%	40%	33%
Research on group diseases	70	50	45
Tests for inherited disease	72*	49	44
Research biobanks	70	50	45
Legal biobanks	--	70**	76***

Note: DK/NA are excluded from the denominator; for all items, fewer than 5 % of respondents did not answer.

* "doctors" rather than "scientists"
** "police officers" rather than "government officials"
*** "judges and juries" rather than "private companies"

In four of the five arenas, Americans trust scientists the most (roughly seven in ten), government officials next (roughly half), and the private sector least (roughly two fifths). Legal biobanks are the exception, with very high levels of trust in both police officers, and in judges and juries. But – a point important in explaining the paradox of genomics knowledge -- levels of trust have as much to do with the substantive arena under discussion as with the actor being considered. Americans overall are least likely to trust all three sets of elites with regard to global warming and most likely to trust elites creating and using forensic biobanks.

Regression Analyses: Starting at roughly the same point that Miller, Gauchat, and others ended -- Americans generally favor the scientific enterprise but make intelligible distinctions within it -- we turn now to the hypotheses about variations within the public's technology optimism or pessimism. We remind the reader that our empirical focus for the general public lies in the relationships between tolerance for risk and scientific literacy (or education more generally), and between tolerance for risk and values (or ideology), so that we can address our central analytic concern, differences in technology optimism between the general public and genomics experts in various disciplines.

Figures 2 through 6 show the results from ordered logit regressions where the outcome variables are perceptions of the ratio between harm and good for society in pursuit of each of the four genomics arenas, and global warming. In all analyses a positive direction indicates more optimism; the respondent agrees that research on the technology in question is more likely to do " more good than harm" for society as opposed to "more harm than good" to society. The point estimates represent coefficient estimates with the horizontal lines representing 90 and 95% confidence intervals.

We operationalize levels of knowledge as the number of questions relating to DNA that respondents answered correctly; the total possible was 3 (see note 13). We included Knowledge as a categorical variable, so as to capture the possibility that the effect of scientific literacy could be non-linear (e.g., that the change in optimism increases more dramatically when getting one question right rather than zero, as compared with getting three questions right rather than two). We also include control variables that consistently appear in the research literature on attitudes toward policy issues (such as Citizen, South, Income, Age, and so on).

Figure 2: Technology optimism with regard to research on inherited diseases especially likely to affect people of one race or ethnicity, GKAP 2011

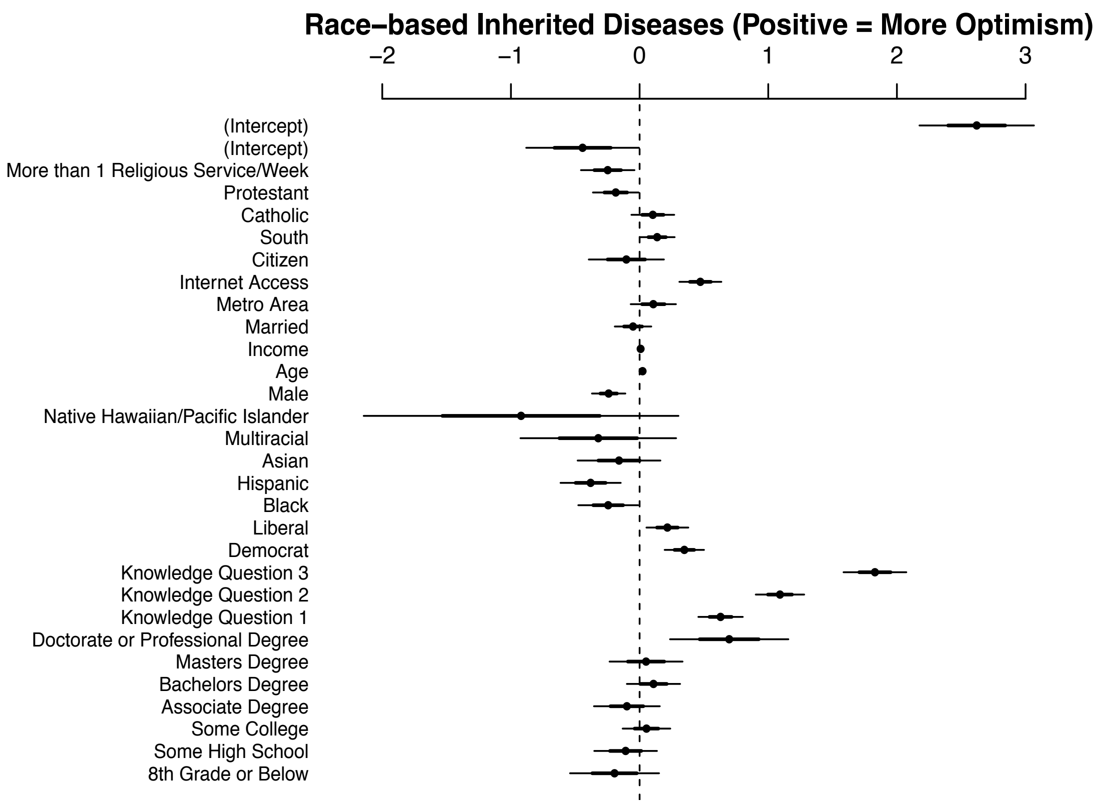


Figure 3: Technology optimism with regard to development of genetic tests to determine an individual's likelihood of getting an inherited disease, GKAP 2011

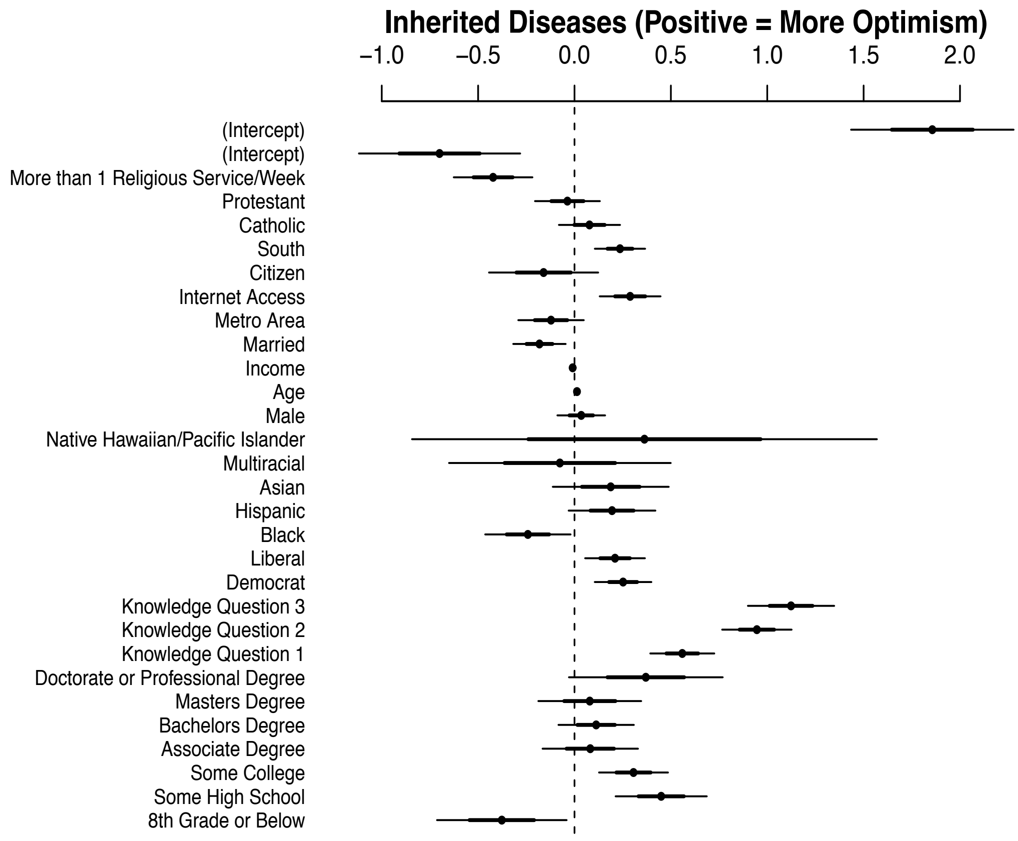


Figure 4: Technology optimism with regard to the use of DNA samples collected from patients or the general public for scientific research, GKAP 2011

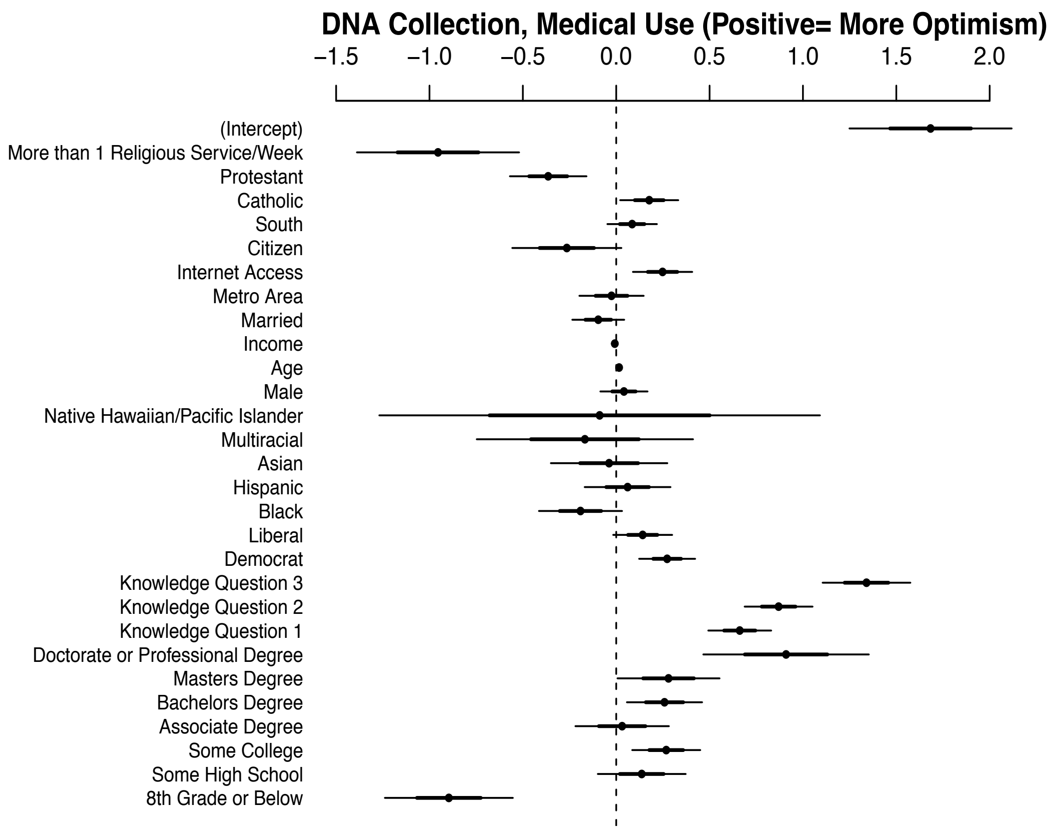


Figure 5: Technology optimism with regard to the use of DNA samples collected from people convicted of a serious crime for law enforcement purposes, GKAP 2011

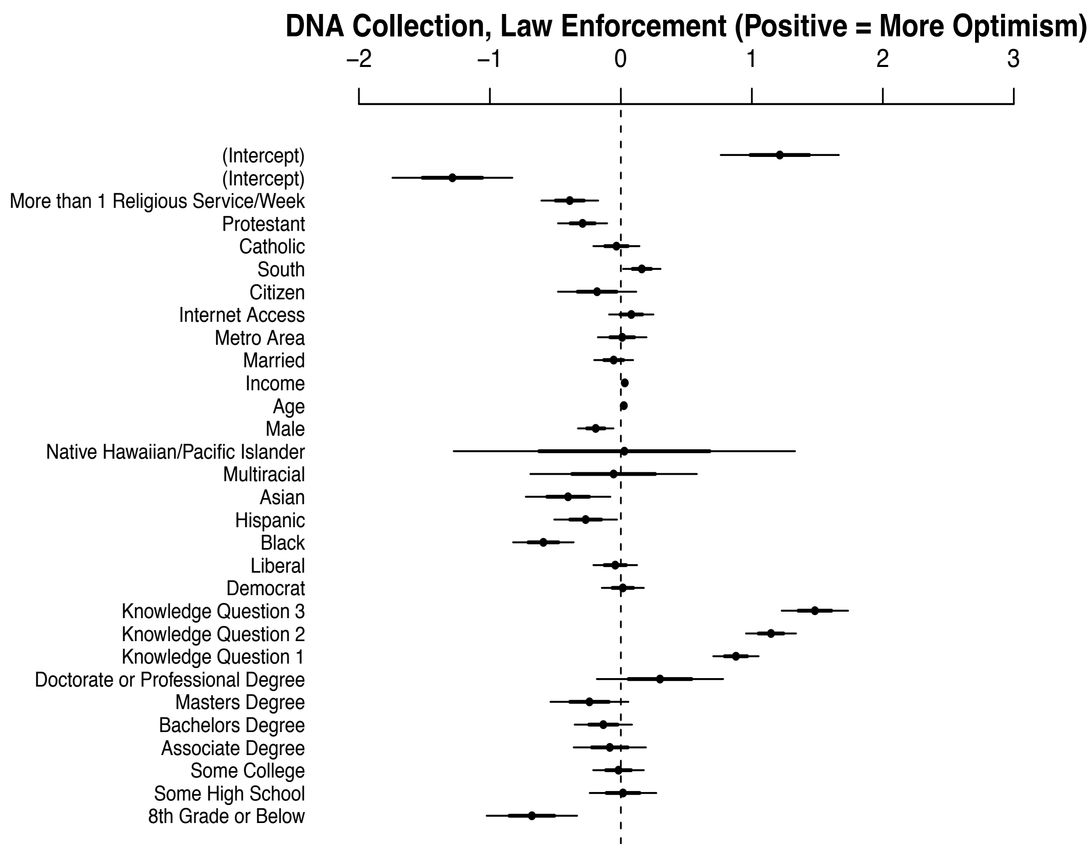
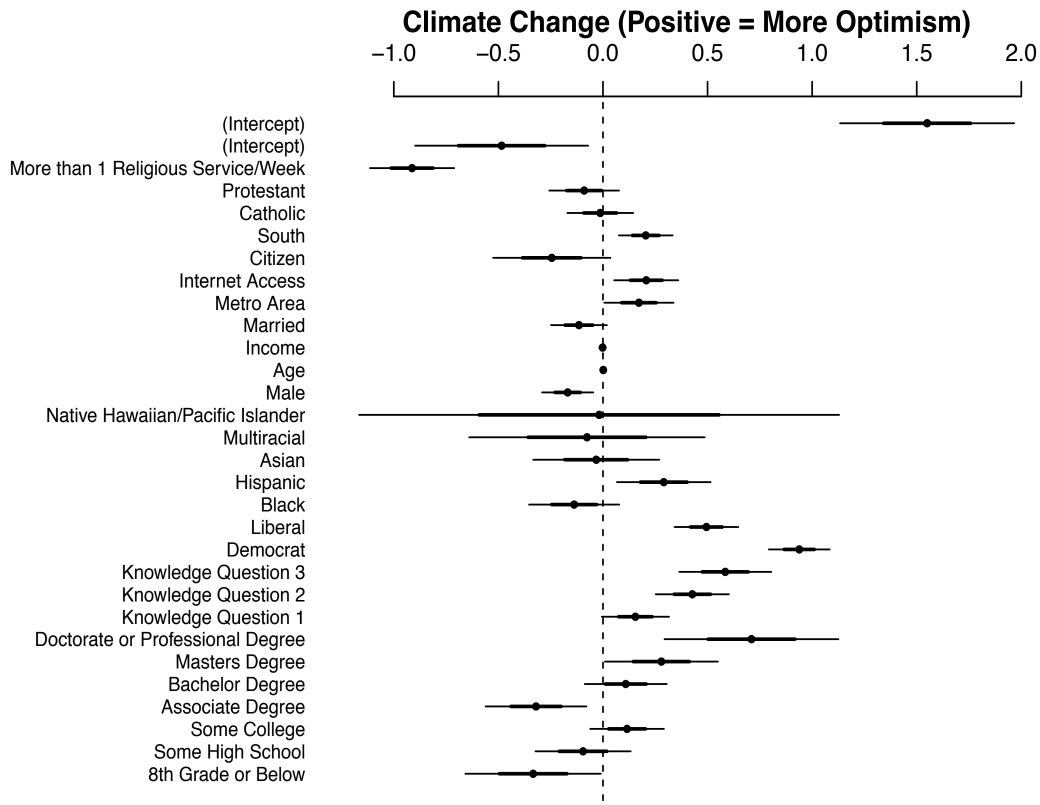


Figure 6: Technology optimism with regard to efforts to slow or prevent global warming, sometimes termed climate change, GKAP 2011



The figures reveal strong and consistent support for *H1, Scientific Literacy in the Public.* Across all five policy arenas, increased knowledge about genetics is associated with increased optimism, with substantively and statistically significant differences between a person who answers all three knowledge questions correctly and a person who answers none correctly. We see some (though not as conclusive) evidence for *H2, Education in the Public*. In all five policy arenas, respondents with doctorates or other professional degrees have higher levels of optimism than those with a high school degree. With regard to climate change and medical biobanks, the association between optimism and level of education is linear. Similarly, in four of the five analyses (the exception is forensic biobanks), respondents with access to the internet were more likely to see more good than harm to society in these scientific endeavors.

We also see evidence for *H4, Value Predispositions in the Public*, that ideology or religion is associated with technology optimism. Respondents who identify as either liberal or Democratic are more likely than moderates and conservatives, or than Independents and Republicans respectively, to support tests for inherited diseases, research into genetic diseases that may be racially inflected, DNA collection for medical or scientific use, and efforts to mitigate climate change. Liberals or Democrats do not, however, differ from non-liberals and non-Democrats in support for forensic biobanks. Those who report attending religious services at least weekly are significantly *less* likely to see more good than harm for society in all five policy arenas. Protestants evince consistently, though slightly, less technology optimism than the non-religious; that finding needs more careful examination (e.g. in further subdivisions within the category of Protestants).

Although this point is not central to the focus of the current paper, we note important variations by race and ethnicity of GKAP respondents. African Americans are more technologically pessimistic than whites on all five scientific endeavors. Hispanics are more pessimistic than whites on two of the five, and more optimistic on two others. Asians are less optimistic than whites with regard only to legal biobanks. This set of patterns also warrants further investigation – in particular, by examining patterns in the parallel analyses about trust in scientists, government officials, and private companies to act in the public interest on these five arenas.[16]

Looking across the five parallel analyses suggests a needed modification to the hypotheses on scientific literacy, education, and value predispositions in the general public. The nature of the scientific endeavor is substantively important in determining levels of and correlates with technology optimism or pessimism. Forensic biobanks especially stand out among the four genomics arenas for their evocation of distinct pattern of responses, both in top-line responses and in the many regression analyses. That suggests that the underlying political valance of an issue -- whether it is new in the public arena, or already politicized -- affects the extent to which and the direction in which individual characteristics and values are meaningfully predictive.

Conclusion

> The frame shifting [from technology pessimism to technology optimism] goes deep, it is not superficial. [It is a shift] from, "Is this technology harmful?" to "How can we make it helpful?" You ask very different questions (Interview #35).
>
> The long tail [of genomics] is eugenics (Interview #33).
>
> "NIH tends to see itself as liberal – answer any questions, pursue knowledge" (interview #35)

The novelty of genomic science in the public arena -- along with its unusual combination of profoundly personal implications, stupefyingly complex technology, and broad but as-yet-unknown societal implications, make it an excellent subject for the study of policy formulation,

[16] We also have about 4000 open-ended responses to two queries on whether and why respondents would be willing to contribute their own DNA to a medical biobank, and (separately) to a forensic biobank. Those responses have been coded but not yet analyzed.

political consolidation, and public and experts' engagement with difficult policy questions. Few members of the public have given significant thought to genomics. But if GKAP is a good indication, they are capable of coherent, intelligible, substantively meaningful responses to the field in general and distinct arenas within it. Still, public attitudes and preferences are just beginning to congeal and could well change or remain highly labile; we plan to study the issue as attitudes develop (or fail to develop) over time. In contrast, among experts who have been analyzing genomic science for a decade or more, attitudes and policy views have consolidated. If our preliminary analyses hold up under further research and scrutiny, what is developing is a divergence between expert opinion in some disciplines and the American public with regard to the relative harms and benefits of genomics.

Summarizing results of the evidence deployed in this paper – the 2011 GKAP, 45 expert interviews, and content analysis of over 200 prominent articles – is fairly easy. In the general population, the more one knows about genomics or the higher one's level of education, the more one favors its development and use both in general and in particular arenas. People on the political left and secular respondents support this new science more than do people on the right and the religiously active. In contrast, social scientists and legal scholars who are experts in genomics -- despite their education, deep knowledge, and political leanings -- tend to focus on risks and dangers, especially in particular arenas. The public are technology optimists and the most knowledgeable are the most optimistic of all; the experts who are not themselves geneticists are technology pessimists.

Why the Difference between Public and Experts? One possible explanation, of course, is that the American public, even those with high levels of schooling attainment and some genetics knowledge, simply do not know enough of the dangers of genomic science to be appropriately risk averse. In this view, genomics is the genie of the lantern; its promises are alluring but the likelihood of genuine benefit from yielding to temptation is slim. Geneticists may be fully honorable and brilliant scientists, but they are blind to the dangers of letting loose "Franken-mosquitoes," broadly defined, on the American public.

A second possibility speaks to *H5, Value Predispositions among Experts*. Perhaps social scientists' stock in trade is to view with alarm. Social scientists and legal scholars (including us) have written hundreds of papers since the 2008 presidential election to prove that the United States is not a post-racial society, but only a few arguing that the United States is no longer a racial hierarchy. Social scientists (including us) have written dozens if not hundreds of papers on the difficulties of immigrant incorporation, the dangers of growing economic inequality in western societies, or the risks of environmental degradation. Relatively few write about immigrant assimilation, economic opportunity, or declines in water or air pollution. Correctly or not, professional norms of sociologists, scholars of race and ethnicity, legal scholars, and researchers in the field of science and technology studies promote attention to problems more than to gratifications, to failures more than to successes.

A third possibility also speaks to *H5, Value Predispositions among Experts*, but with a rather different connotation. Perhaps the substance of genomic science intersects with social scientists' and legal scholars' moral convictions differently than is the case with other scientific arenas. In general, Democrats and liberals are more pro-science than are Republicans or conservatives. Support for mitigation of global warming or for the teaching of evolutionary theory, to pick only two examples, are strongly and increasingly polarized. But genomic science may evoke for many liberals the old and dishonorable association between genetics and racism in the United States. Everyone in this arena knows the history of nineteenth century racial science, in which scull sizes and forearm length were used to “prove” whites’ mental or physical superiority. Experts are equally cognizant of the history of twentieth century eugenics, in which ethnic ancestry was used to promote northern Europeans’ dominance in all domains. The memory of the Tuskegee syphilis experiment, among other medical shames, remains vivid [(Jones 1992); (Washington 2006); (Reverby 2009)]. Racial bias in the criminal justice system is widely assumed and frequently demonstrated. Most generally, for roughly half a century most social scientists have concurred that race is socially and not biologically constructed, that the etiology of most diseases is environmental and not biological, that the search for genetic causes of social ills is largely fruitless as well as dangerous, that new technologies often make the criminal justice system more overweening. Genomic science, in this view, can threaten whatever gains the United States has made toward racial equality, intergroup trust, and constructive policy interventions. How the split between experts and the public, especially among people with the same value predispositions and equally high levels of education, plays out remains to be seen.

Genomics is not the only scientific endeavor in which the left is more technologically pessimistic than the right; the use of nuclear power for energy, surveillance techniques, and perhaps human spaceflight are other examples. So we end with yet another question to which political scientists should attend: how does the interaction between scientific literacy and value predispositions lead social scientists and legal scholars, or Democrats and liberals, to consistently endorse some scientific endeavors and not others – and which ones? That question implies further development of the theories of scientific literacy and its successors, a new approach to theories of risk seeking or risk aversion, a new dimension from which to study politicization and partisan polarization, a new sociology of the academy, and a new set of policy considerations. “Be admonished: of making many books [and articles] there is no end; and much study is a weariness of the flesh.”

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