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Beware of feedback effects among trust, risk and public opinion: quantitative estimates of rational versus emotional influences on attitudes toward genetic modification

Abstract

Support for genetic modification in agriculture mainly stems from approval of food and agricultural goals. It is facilitated by trust in the judgment of scientific authorities and undermined by anxiety about the risks involved. But there are symptoms of danger: Any public opinion data that show significant correlations between perceptions of fact (risk, trust etc.) and background characteristics (age, sex, religion, politics) or goals (environmental, medical, economic) typically reflect emotional feedback effects as well as rational scientific ones. Estimates from regression are then biased and more complex models required. Our structural equation analyses of five large, representative national surveys of Australia (*N* = 8730) provide precise estimates of the magnitude of these effects, including reciprocal effects reflecting emotional influences. The author also finds that: (1) acceptance of the scientific worldview modestly increases support both directly and also indirectly through its influence on trust; (2) family socio-economic background increases knowledge of genetic engineering but is otherwise inconsequential; and (3) religious belief greatly hinders acceptance of the scientific worldview and slightly increases anxiety about risks.

Keywords: trust, risk, genetic modification, genetic engineering, scientific worldview, religious belief, public opinion, reciprocal effects, SEM, Australia, survey research, rational choice, emotional feedback, irrational effects.
JEL Classification: Q160, O330, Z130, H430.

Introduction

Is it good or bad to make new scientific discoveries and implement new technologies? Or does the answer depend upon the context? The moral acceptability of new technologies has stimulated lively, sometimes rancorous, debate in Western societies at least since ancient Greece: The moral status of those who, like Daedalus and Faust, push the limits of invention has always been problematic. For example, the emergence of the techniques known as genetic modification (GM) or genetic engineering raises many questions, among them the question of whether it is a good thing for people to delve so deeply into the nature of life. Genetic modification is a particularly informative biotechnology in which to assess public opinion on scientific issues, because it is both relatively new and clearly important. Hence, most people know about it, and many are concerned about it, but public policies are only gradually becoming institutionalized.

Research on public opinion in this area is expanding rapidly (Pin and Gutteling, 2009). Reliable assessment of public opinion requires carefully designed, rigorous sample surveys, as has long been known (Sudman and Bradburn, 1974; Pidgeon et al., 2005). Voluntary comments (including the EU's internet based system: Ferretti and Lener, 2008) may placate demands for public participation, but the information they provide does *not* accurately represent public opinion.

This paper provides rigorous structural equation estimates of the Australian public views based on systematically developed multiple-item scales with data from five large, representative national surveys with 8730 cases. The models distinguish scientific, religious, and emotional/psychological influences on attitudes related to genetic modification, estimate their magnitudes, and estimate reciprocal effects among them.

The outcome is a cautionary tale: Feedback effects are large and ignoring them seriously misleading.

Section 1 describes Australian opinion on a variety of genetically engineered products. The second section outlines a model of the determinants of public opinion on these issues. Section 3 estimates the model and the final concludes. An on-line Appendix describes how the variables are measured and gives details on data and methods.

1. Theory and background

How do people develop attitudes and opinions about emerging technologies? Four styles of moral reasoning play important roles in opinion formation in modern Western societies (Bellah, 1974; Potter, 1972; Tipton, 1982), although their relative importance differs among topics.

1. The deductive mode turns to general principles as the wellspring of morally correct action in particular situations. For example, if the general principle is that taking a life is wrong, deductive moral reasoning will find that the death penalty, euthanasia, and other particular instances are all wrong. Ethics institutions in developed nations commonly reason in this way (Sato and Akabayashi, 2005). Prior research has not explored

the role of the scientific worldview – specifically endorsement of the theory of evolution and modern astronomy – in shaping moral judgments about genetic modification. But this is an important avenue to explore because it may illuminate persistent divergence of opinion on some topics between scientific elites versus ordinary voters and politicians.

2. The authoritative mode adopts the attitudes and opinions of some legitimated moral authority, e.g. the Pope, the established church, and potentially other expertise-based elites such as scientists. The authoritative mode also encompasses the legitimated cultural momentum of tradition and institutions.
3. The expressive mode judges actions as right or wrong according to one's immediate emotive reaction when first confronting a new possibility – colloquially, the "ugh" factor. Psychologists describe moral reasoning in the expressive mode as using "affective heuristics" (e.g. Slovic, 1999; and Slovic et al., 2002). These reactions, of course, may be socially and psychologically determined. Importantly, explicitly analyzing the role of the expressive/affective mode allows us to assess the importance of cognitive consistency. The other modes of moral reasoning all assume a process with perceptions as intermediate influences and moral judgment as an outcome. But the expressive mode allows influence both ways: we cannot simply assume that perceptions influence moral judgments because intuitive moral judgments may also influence perceptions. Wishful thinking may lead supporters of GM to conclude that the risks are small and to imagine scientists to be trustworthy when they say (as they mostly do) that GM is safe. By contrast, intuitive opposition to GM may lead others to project their gloomy predispositions by seeing risks as large and scientists as untrustworthy.
4. Finally, the consequential mode involves assessing the rights and wrongs of actions by their results: Actions are judged as means to ends rather than as ends in themselves. This is, of course, Weber's instrumental rationality (Weber, 1947) and is embodied in cost-benefit ana-lyses, in self-interest calculations, and other approaches that emphasize the goals or values served by the technology rather than its intrinsic moral value. Although consequentialist reasoning plays only a small role in shaping moral judgments about many moral issues, I will suggest that it plays a large role in shaping views about technology (especially biotechnology and medicine, with their clear implications for human well-being) and, by generalization, about political institutions, procedural justice, and other intrinsically neutral mechanisms that have morally important outcomes (e.g. Evans and Kelley, 2011, 2014; Zerbe, 2007). People evaluate the goals the new technology might serve[1] and the risks it might pose. If the goals seem to them good and the dangers small, they approve it. Alternatively, if they do not greatly value the goals, or if they see huge risks, they disapprove of the technology.

With sufficiently intense value commitments to the goals, it may be that we need to allow reciprocal causation within the consequentialist mode as well as in the expressive mode. We need to evaluate empirically the possibility that people's choice of goals also shape their perceptions of the world. It may not be just that people rationally evaluate what is and is not feasible and choose the path that maximizes their utility (as assumed in much prior research using this theoretical model, especially by economists). In addition their choice of goals may in turn shape their perceptions of what is and is not feasible: they want something and therefore imagine it feasible and safe to get it. In short: feedback, reciprocal causation.

This paper evaluates many of these possibilities quantitatively, based on structural equation analysis of on five large, representative national sample surveys ($N = 8730$) in Australia.

The setting. In evaluating genetic modification, the citizenry in Europe and the United States seem to be taking different paths (Frewer et al., 2013). Public opinion on GM differs greatly among countries, as shown by the large and closely comparable Eurobarometer surveys (Lemkow, 1993, pp. 10-14; Schibeci et al., 1994, p. 20-21; Gaskell et al., 1999)[2]. Support for genetic engineering is higher in the USA than in Europe (reinforced by differences in regulatory philosophy: Zerbe, 2007), and is declining in Europe, while the direction of change in the US and other English-speaking countries is unclear (Gaskell et al., 1999, 2000, 2003; Shanahan, Scheufele and Lee, 2001; Priest, 2000).

Australia falls in between these two extremes. In many areas of public policy, Australia is similar to Britain, the USA and other English-speaking countries, but in others it is closer to Scandinavia and other Northern European nations (Evans and Kelley 2004). Moreover, it is a small, open economy with

[1] Who receives potential benefits is also relevant to the public, generally with less support for benefits going to big business and more for benefits going to favored groups (e.g. farmers, poor people) and favored causes (e.g. the environment, Norton and Wood, 1998).

[2] Australian surveys up to the mid-1990s are concisely reviewed and unpersuasively traduced in Davison, Barns and Schibeci (1997).

important agricultural exports exposed to heavy world-wide competition, so genetically modified organisms (GMOs) in agriculture are very salient. To explore Australian opinion, we included a module on attitudes towards genetic engineering in five surveys between 1994 and 2002 as part of the International Social Science Survey/Australia (IsssA), Australia's leading academic survey.[1] The module began by asking people to rate a series of goals for Australian scientists, to get a general assessment of the desirability of different goals. We then introduced the concept of genetic engineering, and asked respondents to rate the desirability of a set of specific potential uses of genetic engineering[2]. We then asked people about their understanding of genetic engineering.

Measurement details and basic results have been reported elsewhere (Kelley, 1995, 2003) and are briefly recapitulated in the on-line Appendix which is freely available at www.international-survey.org. This paper presents new results on variables not described previously, new models, new structural equation estimates involving them, and new conclusions flowing from the analysis.

2. Data and methods

2.1. Data. This report is based on five rounds of the International Social Science Survey/Australia (IsssA), conducted from 1994 through 2002 which are described in detail in: Kelley and Evans (1999), Evans and Kelley (2004), pp. 317-326. The IsssA surveys are from simple random samples of Australian citizens drawn by the Electoral Commission from the compulsory electoral roll. They are conducted by mail using a modification of Dillman's (1993) Total Response Method. Completion rates run around 60 to 65%, which compares favorably with recent experience in Australia, the USA, and many other industrial nations. Previous analyses suggest they are representative of the population (Bean, 1991; Evans and Kelley, 2002, 2004; Sikora, 1997). There are 8730 cases in the surveys analyzed here.

2.2. Methods. Effects are estimated by structural equation (SEM or LISREL) methods (Bollen, 1989; Joreskog and Sorbom, 1993), as implemented in the AMOS program (which is now part of SPSS). As well as allowing the estimation of reciprocal effects, these methods correct for attenuation due to random measurement error (which is important: Bollen, 1989; Fan, 2003; Kelley, 1973). For single items we use the reliabilities shown in the last row of on-line Appendix Table A; reliabilities for multiple item scales are estimated in the (full information, maximum likelihood) model. Alternative estimates are by ordinary least squares regression. Since the IsssA data are simple random samples, no adjustment for sample clustering is required.

We omit effects too small to make much practical difference, specifically those under .10 (standardized) in magnitude. They might well be artifacts of the usual minor uncertainties of measurement and model specification. Given the large sample size, smaller effects are often statistically significant, even if unimportant. Sensitivity analysis shows that the conclusions are robust – we estimated alternative structural equation models with all possible influences included, however small, and also a third model estimated by OLS with no correction for attenuation. While it is well known in the measurement literature that OLS estimates are biased, often seriously, in the present case the differences are small[3].

Details are in the on-line Appendix (www.international-survey.org).

2.3. The structure of opinion on genetically modified products. *2.3.1. Measurement.* Because genetic engineering was new and unfamiliar when this series of surveys started in 1994, we adopted a multiple indicator strategy of asking about a large number of particular, concrete instances (Frewer, Howard and Shepherd, 1997). We gave a lengthy introduction, as a reminder to people already familiar with genetic engineering and an explanation for those previously unacquainted with it.

The eight particular instances were already well into development in Australia and other countries (Australian Science and Technology Council, 1993; Gaskell et al., 1999): treatments for cancer and high blood pressure, pesticides for cotton and other crops, viruses to control insect pests, leaner pork, healthier cooking oil, and fresher tomatoes. Wording is in the on-line appendix (at www.international-survey.org).

People had clear opinions on these questions: only 2% declined to answer, on the average. That is lower than average for the questionnaire and well below the levels of missing data usual for obscure topics[4]. The low level of missing data and the high inter-item correlations (shown in the on-line Appendix) suggest that real public opinion on the topic exists; evidence from other nations and using other methods concurs (e.g. Connorand Siegrist, 2013).

[1] Changes over time are small but complex (as in the USA: Shanahan, Scheufele and Lee, 2001) and I deal with them in a separate publication (2003), drawing especially on the panel component of the surveys.

[2] We also asked about the desirability of labelling genetically engineered products; about how much people worry about some potential risks of genetic engineering; whether they expect that they themselves would use genetically engineered products; and asked for a global evaluation of whether the benefits of genetic engineering are likely to outweigh the risks. These issues are the focus of separate publications.

[3] Fan 2003 is a clear exposition. For the present analysis, the only important difference is that OLS greatly underestimates the importance of support for medical research in legitimating genetic engineering.

[4] For example, in another survey we asked people to rate the Chinese leader of the day and 25% declined to answer the question.

2.3.2. Attitude structure. The public might well not have coherent attitudes about genetic engineering, if only because it is so new, especially when this series of surveys began in 1994. However, people often do form opinions on the basis of very limited knowledge – for example, about the economics of globalization – so novelty does not imply incoherence. To assess this issue empirically, the preferred procedure is to ask a substantial number of separate questions and then investigate the links (or lack of them) among the answers (e.g. Judd and Milburn, 1980). For example, to discover what voters think about government regulation of the economy, best practice is to ask many specific questions about regulation in particular industries (railways, steel, farms, universities, hospitals etc.) and then investigate the structure of responses (Sikora, 2000). This is the strategy we followed. If people have no clear views, their answers to different questions will be uncorrelated (and measurement reliability will be zero). But if they have well-defined views correlations positive, typically in the range of .20 to .60, and factor analysis will find a single factor.

The results clearly show that the Australian public has well-formed attitudes about genetic engineering: people who favor one GM product tend strongly to favor all of them, and conversely those who are leery of one tend to be dubious about all (correlations shown in the on-line Appendix). The correlations average a substantial .51 and the factor analysis shows a strong general factor. For comparison, correlations average .31 among items measuring attitudes toward government regulation, .42 among price control items, .61 among trade union questions, and .60 among abortion attitudes, so attitudes to GM are well within the normal range for Australian political and economic attitudes (Evans and Kelley, 2002, 2004; Sikora, 2000).

A second key line of evidence is the test-retest reliability (e.g. Wilkinson and American Psychological Association Task Force on Statistical Inference, 1999). If people lack well-defined views, their answers at different times will be uncorrelated, but the more clear and stable the attitude, the higher the correlation among the answers. Test-retest reliabilities for the GM questions average $r = .44$, over a 3-year period for just over 3000 panel cases. This is somewhat lower than most social and religious attitude items in our surveys, typically $r = .55$ to $r = .65$, but much the same as for many public policy issues in the US over 4 years in the National Election Studies (Krosnick, 1991: Tables 1 and 3)[1].

2.3.3. Levels of support. Public support for GM differs among products. It is overwhelming for medical uses, high for agricultural non-food uses, and least for GM foods[2], similar result emerge in Europe, the USA, and other nations (Gaskell and Allum, 2003; Millward-Brown, 2003; Priest, 2000; Shanahan, Scheufele, and Lee, 2001). See the on-line Appendix for details.

2.4. Knowledge and support for genetic engineering. The public's limited knowledge of genetic engineering worries many researchers, who wonder whether ill-informed citizens can have well-formed views about genetic engineering. But a large majority of Australians, 73%, say they have "heard much about genetic engineering" and almost as many claim to have "a basic understanding" of it. So, in fact, there is at least a modest level of comprehension. Moreover, voters routinely make decisions about policies about which they lack sophistication, including abstruse issues of economic and environmental policy.

Importantly, even those who know little about genetic engineering have reasonably coherent attitudes about it (see Table 2 in the on-line Appendix). Correlations among their answers are well within the normal range (averaging $r = .44$), although lower than correlations for more knowledgeable respondents (averaging $r = .53$). The reliability of the scale used in subsequent analyses is quite satisfactory for less knowledgeable respondents, as it is for the more knowledgeable.

Knowledge of GM does not lead to greater support. If anything, the more knowledgeable are slightly *less* supportive (Table 2 in the on-line Appendix).

2.5. Changes over time. Support for GM products has declined slowly over our eight-year period. In this Australia resembles Europe, not the USA (Gaskell et al., 1999, 2000, 2002; Singer et al., 2008). This decline is small but statistically significant ($t = -10.69$, $p < .001$), controlling by regression for everything else in our model. Concretely, the decline comes to about 7 points (out of 100) per decade. Even at its lowest point, at the end of our period, the vast majority remain in favor, averaging 71 points out of 100. But if the decline were to continue at this rate (a very arguable assumption), then GM products would lose majority support in Australia sometime around 2030.

2.6. Sources of support and opposition: theoretical orientation. Why do some people support genetically modified products and others oppose them? I build on previous models (Besley and Shanahan, 2005; Ho, Brossard et al., 2008; Peters, Lang et al., 2007) especially those emphasizing on

[1] Test-retest correlations measure the joint effect of measurement reliability and over-time stability, thus they understate measurement reliability unless there is complete stability over time. Given the rapid and controversial changes in genetics, there is likely to be more genuine change over time than in most other social and political domains; thus test-retest correlations will understate measurement reliability. That the scale's alpha reliability is considerably higher than its test-retest correlation also suggests instability over time.

[2] Similar results have been found in other Australian surveys (Norton and Wood, 1998; Millward-Brown, 2002, 2003).

benefits and costs (e.g. Owen and Louviere, 2005). But I extend prior theory to include novel elements: the scientific worldview, psychological elements, and the possibility of reciprocal causation (see Figure 1).

The conventional view set out in Figure 1 Panel A – widely held in science, economics and by policy analysts – is that people have well-defined goals and preferences, possibly reflecting in part their background and religion. Facts about the world are objective and universal, and can be discovered by science and analysis. People choose their actions in light of their goals and their understanding of the facts about the world, choosing in a way that they hope maximizes their chance of getting what they want (full arrows in the diagram). This is rational and scientific.

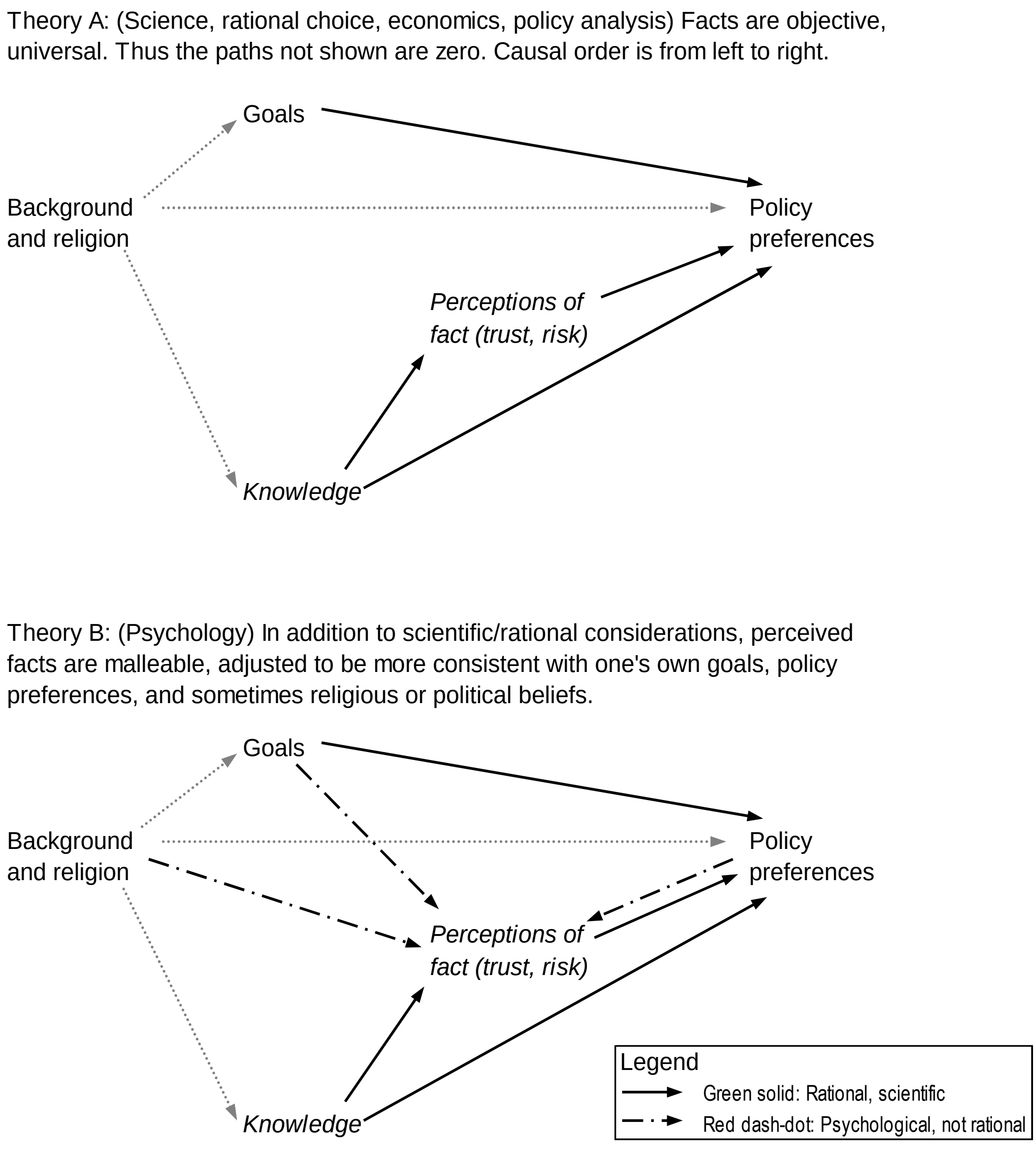


Fig. 1. Theoretical orientation

But there are also irrational, emotional and psychological possibilities in addition to rational, scientific ones (Figure 1, Panel B). Perceived facts may be malleable, adjustable to be more consistent with one's own goals, policy preferences, religious and political beliefs (dash-dot arrows in the diagram). Religion may shape how people perceive the facts about the world; people may see the world as more compatible with their goals and policy preferences than objectively it is. All these are possibilities.

2.7. Symptoms of danger. Any data that show statistically significant correlations between perceptions of fact (risk, trust, and the like) on the one hand and background characteristics (age, sex, religion, politics) or goals (environmental, medical, economic, etc.) on the other hand, are likely to reflect feedback effects (reciprocal causation). Normal estimates from regression (OLS, multi-level models, etc.) are then biased. In particular, they are likely to exaggerate the influence of background and goals, as has long been known (Bollen, 1989). In short, such correlations are usually a sign of danger.

Let us see what the reality is for attitudes toward genetic modification.

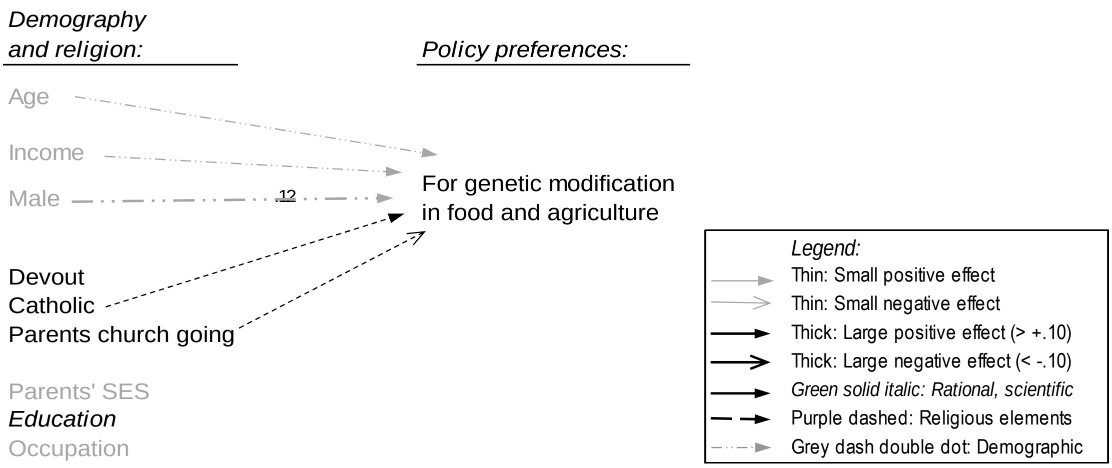
3. Analysis Part 1: Demographic and religious influences

Our model begins with potential causes that are stable individual characteristics, known to affect many attitudes and values: Age, sex, education, occupation, religion, politics and other background variables. Most are widely used in other studies of public opinion on biotechnology issues (Hossain et al., 2003; Hallman, 2000; Plutzer, Maney and O'Connor, 1998). We take them as fixed, causally prior to the other variables we consider here. Details are in the on-line Appendix. This assumption about causal order implies the existence of direct and indirect effects; the logic of such effects is set out clearly in many places (Alwin and Hauser, 1975; Bollen, 1989; Kelley, 1973).

For simplicity, we do *not* analyze the causal links among these variables (the subject of large literatures in the Blau-Duncan paradigm, the sociology of religion, and social psychology, among others). Rather we treat them all as background factors potentially shaping goals and knowledge relevant to genetic modification.

Effects are estimated by structural equation (SEM) methods (Bollen, 1989; Joreskog and Sorbom, 1993). Details are in the on-line Appendix (www.internatinal-survey.org).

3.1. Results: Demographic and religious effects. The main demographic and religious influences shaping the Australian public's views of genetic engineering are shown in Figure 2. Conservatively, the model disregards small effects. It shows the total effects of demographic and background variables, regardless of whether they come about directly (rare) or indirectly through shaping people's goals and perceptions of fact (usual).



Notes: Only statistically significant effects (at $p < .01$) with standardized effects greater than .05 are shown.

Fig. 2. Total effects of demographic and religious variables on policy preferences about genetic modification in food and agriculture

Demographic differences in age and gender have little impact on support for genetic engineering, as in other Australian studies (Owen and Louviere, 2005) but unlike in Switzerland (Siegrist, 2000) and the US (Hossain et al., 2003). The only noticeable effect is that men are a little more likely than women to support genetic engineering. The total effect is .12 in standardized terms (Figure 2); the direct effect other things being equal is only .06 (shown in Figure 3 below) or more concretely, 2 points out of 100. This comes about because men more often adopt a scientific worldview and, for that reason, a little more likely to support genetic engineering. However, this is offset by their tendency to know more about genetic engineering, and therefore be fractionally *less* supportive of it.

Other things being equal, old and young hardly differ: there is only a very small direct effect. Age does have some small indirect effects (shown later in Figure 3). Older people are more sympathetic to agricultural goals, and so for that reason more supportive of genetic engineering. However, they are also less likely to accept the scientific worldview, and for that reason less supportive of genetic engineering. Taken together, these two offsetting effects leave older people just a fraction more supportive of genetic engineering: other things being equal, a 60 year old is likely to be 2 points out of 100 *more* supportive than a 20 year old.

Neither education nor occupation have any substantial effect on attitudes to genetic engineering (Figure 2). Other things being equal, well-educated people have no different views on genetic engineering than the poorly educated: there is no direct effect at all. Similar results have been found in other nations (Priest, 2000; Rundgren, 2011).

Education does, however, have important indirect effects (Figure 3 below). The well-educated are far more knowledgeable about genetic engineering, and for that reason just a little less supportive. But the well-educated are also more likely to accept the scientific worldview, and for that reason are a little *more* supportive of genetic engineering. These two indirect effects almost exactly cancel each other out.

High status people are no different than people in low status occupations, either directly or indirectly: they have the same views on genetic engineering, the same goals for scientists, the same knowledge of genetic engineering, and are equally likely to hold the scientific worldview. Apparent differences between them are due to pre-existing educational differences.

3.2. Analysis Part 2: Goals and knowledge. *3.2.1. Measurement.* Many theories of decision-making hold that people judge the "means" by the "ends" (consequentialist reasoning): They are less concerned with understanding mechanisms and risks involved in new technologies than with judging whether the technologies help attain valued goals (Gaskell et al., 2004; Hossain et al., 2003). One prominent goal is health and medicine ("New medicines to cure serious diseases like cancer").

Another prominent goal is **food quality and agricultural productivity** ("Tastier, fresher food; Cheaper food; Healthier, more nutritious foods; Crops that would create a new export market for Australian farmers"). Australia, like the USA and Argentina, has a thriving export industry subject to intense world-wide competition. Farmers are only a few percent of the population, but the general public is very sympathetic to their interests (e.g. Evans and Kelley, 2013) and willing to support policies to benefit them, even at some personal cost. Agricultural subsidies are widely supported in the US and Europe on similar altruistic grounds, even though they result in higher prices for most supporters.

Yet another important goal is **protection of the environment** ("How do you feel about... Protecting the environment?").

Knowledge of genetic engineering ("Before reading about it in this questionnaire, have you heard much about genetic engineering? Would you say you have a basic understanding of genetic engineering?) is included because many theories of decision-making hold that people only form attitudes after they have acquired relevant information. Many regulators working in science-based regulatory regimes (like the US and Australia), and more practicing scientists, would expect that greater knowledge makes for sympathy toward genetic engineering. But others would posit the opposite effect, and there are more complex possibilities as well (Jallinoja and Aro, 2000).

Central to the **scientific world view** is acceptance of Darwin's theory of evolution – which implies that mankind is not unique but just one of millions of species shaped by natural forces – and acceptance of various aspects of modern astronomy that suggest our world is neither unique nor everlasting, but just one of many similar worlds elsewhere in the universe (Evans and Kelley, 2004). Adherence to the scientific worldview will, we argue, shape attitudes towards genetic engineering. People who reject the scientific worldview might be inclined to see genetic engineering as tampering with divine creation, and hence immoral and possibly dangerous.

3.2.2. Effects. Knowledge of genetic engineering. Interestingly, knowledge of genetic engineering has only a small impact on attitudes toward it: those who are more knowledgeable are fractionally *less* likely to approve, all other things equal. The effect is just -.06 in standardized terms (so small it is not even shown in Figure 3). Concretely, someone who is greatly interested in genetic engineering and feel themselves very knowledgeable about it would average 5 points out of 100 *less* supportive than someone with absolutely no interest and absolutely no knowledge. It may be that both effects posited by (opposing) information-base decision theorists are real: increases in knowledge lead some people to be more supportive of genetic engineering, but lead other people to be less supportive, and the two effects almost cancel each other out (Jallinoja and Aro, 2000). Other studies have also found few effects of knowledge, although sometimes tending to increase support for genetic engineering (e.g. Dawson and Schibeci, 2003; Hossain, 2003; Priest, 2000). Knowledge and opinion expressed by the press, judging from US research, do not appear to be influential either (Eyck, 2005).

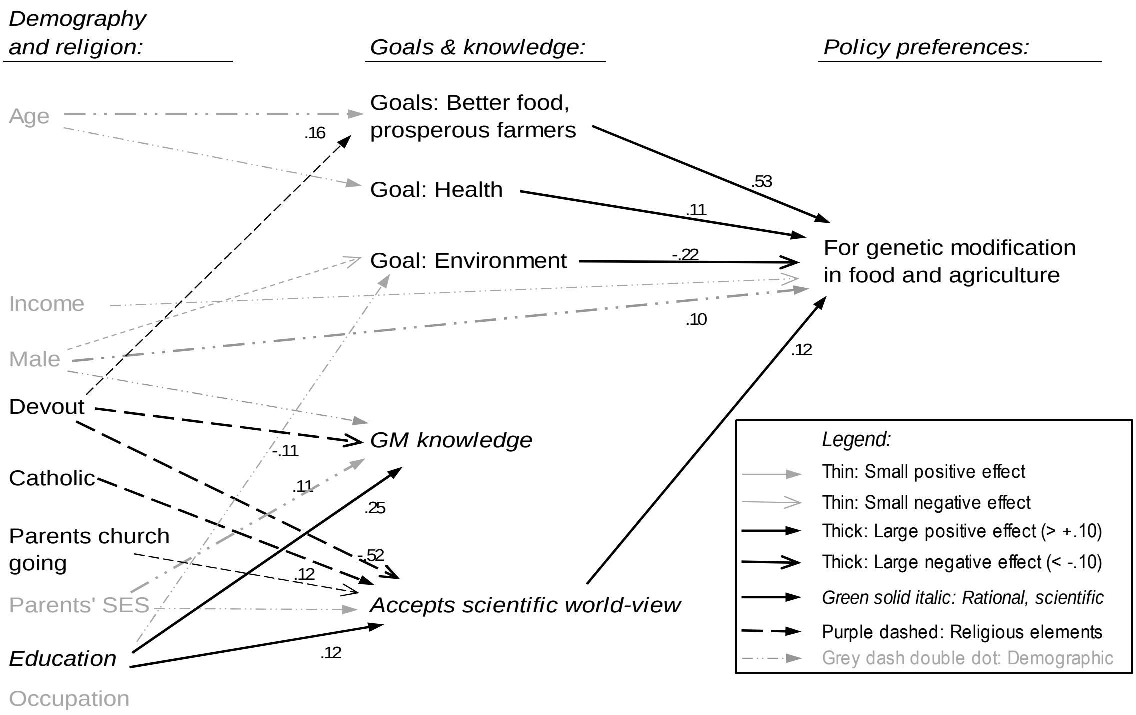


Fig. 3. Effects of goals and knowledge on policy preferences for genetic modification in food and agriculture

3.2.3. Scientific worldview. Acceptance of a scientific worldview in which mankind is not unique but just one of millions of species evolved over the millennia by natural selection, living in a world like countless others in an unimaginably vast and changing universe, leads people to take a more relaxed attitude to changing species by genetic engineering. If our world is not the culmination of a divine plan, or the unique exemplar of life in an arid universe, changing it to suit our interests seems reasonable. The impact is not large, but neither it is small, a standardized effect of .12. In concrete terms, the difference between someone who whole-heartedly accepts evolution and modern astronomy and one of the (surprisingly large) number of people who unequivocally reject them is, other things being equal, a difference of 11 points out of 100 in support for genetic engineering. So far as I know, this important effect has not previously been documented in the literature.

Religious belief itself has no direct connection to approval of genetic engineering, despite much speculation to the contrary and its demonstrated importance in other areas of biotechnology (Evans and Kelley, 2011). But most people with strong Christian beliefs reject the scientific worldview, which thereby indirectly reduces their support for genetic modification. In concrete terms, the difference between a devout Christian and an uncompromising atheist is 3 points out of 100, other things being equal. The absence of a direct effect of religious belief, net of acceptance/rejection of the scientific worldview, has also been found for attitudes about conventional organ transplants (Evans and Kelley, 2014).

Surprisingly, Catholics are slightly *more* likely to accept the scientific worldview than are equally devout members of other denominations. As a consequence, they just fractionally are more likely to support genetic engineering, by half a point out of 100, other things being equal.

3.2.4. Goals. Much the most important factor is that people who value goals that genetic engineering serves are much more supportive of it (Figure 3). People who warmly endorse **agricultural and food goals** – fresher, cheaper, healthier food, increased earnings and new export markets for farmers – are very favorable towards genetic engineering, other things being equal. This is by far the largest influence we have discovered, with a standardized effect of fully .53. Concretely, someone who was absolutely "delighted" with all these benefits would on average be 38 points out of 100 more supportive of genetic engineering than someone who thought all these goals "terrible". Of course, few people actually think these goals are "terrible". But even if we confine the comparison to those who are merely indifferent to them[1], the difference is fully 19 points. The great importance of goals has been found in other research using quite different methods (Owen and Louviere, 2005).

People who greatly value **health goals** for science – specifically, new medicines to cure serious diseases like cancer – are also more favorable towards gene-

[1] That is those who give them neutral scores half way between "delighted" and "terrible".

tic engineering. This is the second largest effect that we have found, with a standardized effect of .18. Concretely, someone who was absolutely "delighted" with the prospect of new medicines would on average be 17 points out of 100 more supportive of genetic engineering than someone who was indifferent to them[1].

Of course, medical progress is highly popular in Australia, 95 points out of 100, as it is in Europe and the USA[2]. Support for improvements in food quality and for financial benefits to farmers is also widespread in Australia – over 80 points out of 100. The widespread support for agricultural subsidies in Europe and the USA suggests such views are widespread there as well; certainly, genetically engineered improvements in agricultural production are widely supported in many nations (Gaskell et al., 1999; Hoban and Kendall, 1992; Lemkow, 1993; Optima, 1994; U.S. Congress, 1987).

3.2.5. In all. The strong support for agricultural and medical progress is probably the reason that most Australians support genetic engineering rather than being indifferent to it[3]:

- Imagine, hypothetically, a world where nothing has changed except that Australians are indifferent to agricultural and medical goals, rating them a neutral 50 points out of 100. In such a world, our model implies that the level of support for genetic engineering would be just 48 points out of 100, just on the negative side of "mixed feelings". Thus a majority of Australians would be indifferent to genetic engineering, or opposed to it, in this hypothetical world.
- In a world where nothing has changed except that support for the scientific worldview completely disappeared, public support for genetic engineering would remain high, 69 points out of 100.
- Nor does knowledge of genetic engineering make much difference to the big picture. In a hypothetical world where nothing has changed except that the public knows nothing at all of the science underlying genetic engineering, support would still be high, 79 points. And alternatively, if everyone thought themselves fully informed about the science, support would be only a little lower according to our model, 74 points.

Thus the most important source of Australian opinion about genetic engineering is not to be found in the scientific worldview, although the scientifically inclined are more supportive; nor it is to be found in knowledge of the science, although that matters too; nor it is to be found in religion, demography or class. Rather it is to be found in the goals to be pursued: medical progress, better food and prosperity for farmers.

This is substantial support for goal-oriented "consequentialist" model of moral reasoning (green solid italic arrows in Figure 3), a model of moral reasoning widely held by scientists, economists, and policy analysts. It is also something we suspect is generally important in evaluating technology and other intrinsically neutral processes with morally important outcomes.

3.3. Analysis Part 3: Perceptions of fact, rational choice, and emotions. *3.3.1. Measurement.* Cost-benefit calculations try to balance potential gains with the potential risks ("That medical genetic engineering could accidentally create a new disease? That genetically engineered plants might get out of hand and spread on their own? That genetically engineered food plants might be a long run danger to human health?") Such risks form the focus of much regulatory consideration (Falck-Zepeda and Zambrano, 2011), but are difficult to measure reliably (Pidgeon, Kasperson and Slovic, 2003).

Trust ("In deciding if it is safe enough for you and your family, who would you believe...The Commonwealth government committee set up to regulate genetic engineering? A committee of university scientists? A committee of medical doctors. CSIRO – the Commonwealth Scientific and Industrial Research Organization?") is also likely to be important, both directly (Brewer and Ley, 2013) and indirectly through its major influence on perceptions of risk (Poortinga and Pidgeon, 2004)[4]. Trust is a key mechanism through which authoritative moral reasoning works: Those who hold scientists trustworthy are likely to endorse the policies they perceive the scientists as endorsing, in this case agricultural genetic modification.

3.3.2. Estimates. **Trust** in scientist's veracity about GM is important influence on acceptance of GM policy, about three-quarters as important as accepting food and agricultural goals (Figure 4). So it is a big story, if this result is to be believed.

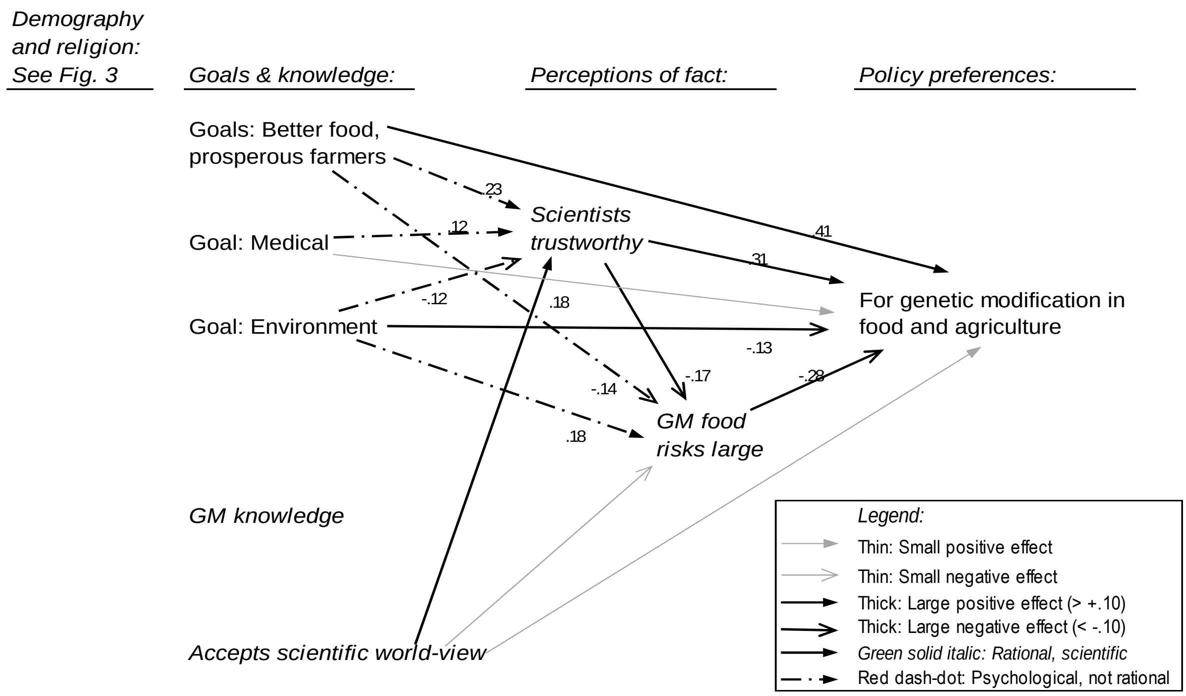
Risk raises complex and important issues. Fear of risks from GM agriculture is an equally important influence on acceptance of GM policy, again about three-quarters as important as accepting the food and agricultural goals.

[1] In concrete terms, support for medical goals is almost as important as support for agricultural goals, but in standardized terms it is just half as important. The smaller standardized effect is because there is less variation in support for medical goals, which are almost universally endorsed, than in support for agricultural goals, about which a significant minority have reservations.

[2] This popularity is probably the key cause of the enormous biomedical research budgets in the developed world.

[3] These calculations are based on the preferred model, specifically the metric structural equation results in the last two columns of Table 3. It assumes that everything remains as before, except for the changes explicitly mentioned.

[4] Perceptions of risk and trust are little correlated with evaluation of goals or other variables in the present model and their effects are additive. Thus including them, although it increases the variance explained, leaves other effects virtually unchanged.



Notes: Simple recursive model without reciprocal causation. For simplicity, effects of demographic and religious variables, which are few and small, are not shown.

Fig. 4. Effects of perception of fact (concerning how trustworthy scientists are about GM and how risky GM food is) on policy preferences for genetically modified food and agriculture

Trust and fear are *not* closely correlated – nor should they be, as both are perceptions of fact, at least on the face of things, and so should be uncorrelated.

Since they are facts, they might reasonably be more accepted by educated folk, or by those knowledgeable about GM, or by those who already accept the scientific worldview. But not much in fact: there is only a little link from the scientific worldview.

Emotional/psychological (as opposed to logical/rational) influences also exist (links in dash-dot). Since the trustworthiness of scientists and the risks of genetic modification are facts, they should *not* be influenced by wishful thinking – just because you favor better food and more prosperity for farmers is no *logical or rational* reason to think scientists are truthful when they say genetic engineering is safe (alignment would be comfortable, but agreeing with your predispositions does not make, nor break, a scientific truth). Similarly, wanting better food and richer farmers is no logical/rational reason for assessing the risks of genetic modification to be small.

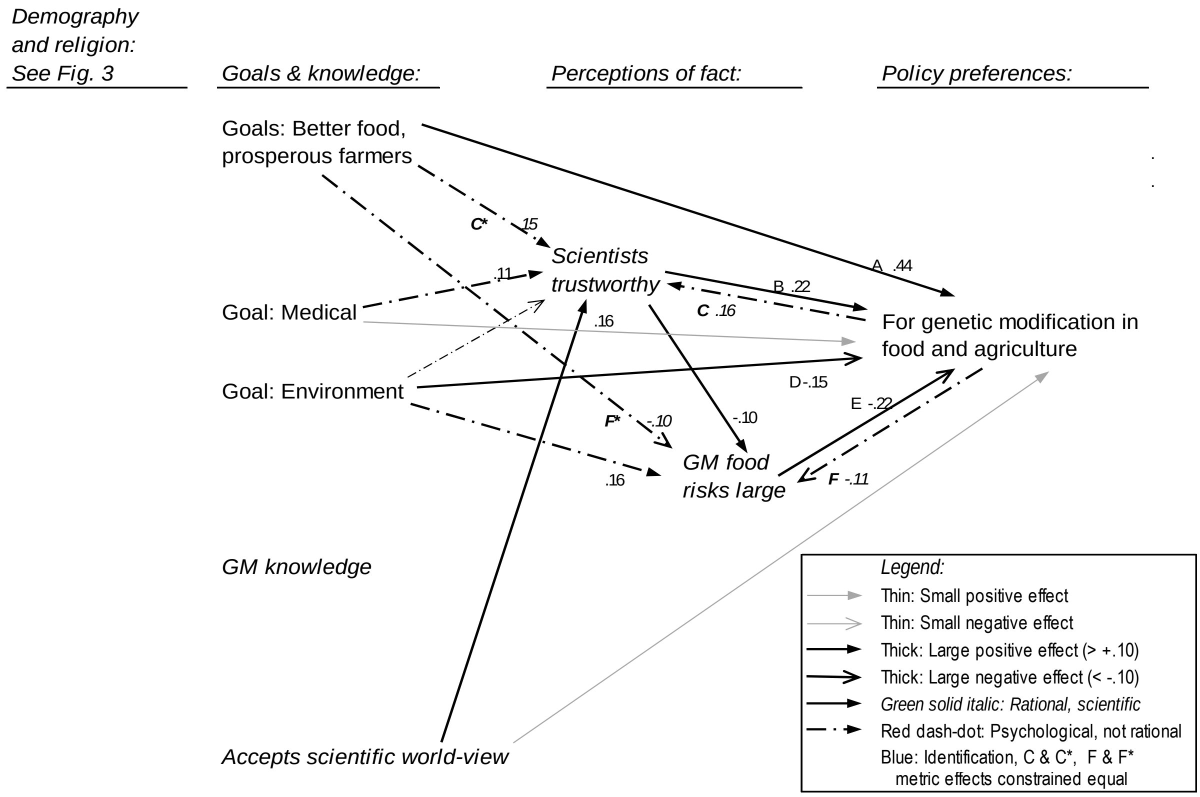
Similarly, accepting *environmental goals* is no good scientific/logical/rational reason for finding scientists untruthful about GM, or for finding that GM is risky. All that fits your prejudices, but disagreeing with your prejudices is no logical/rational evidence of lying.

Nonetheless all this *does* happen, and to a substantial degree (red dash-dot arrows in Figure 4): people seem to let their preferences and desires shape their perception of facts. They see the world as consistent with their hopes (for food and farmers) and with their fears (for the environment). Those who hope for better food and richer farmers see the world through rosy glasses, while those who fear for the environment see gloom and doom.

Thus, there are substantial elements of emotion, of wishful thinking, of irrational hopes and fears involved in assessing how much scientists are to be trusted to say the truth, and in assessing risks of genetic engineering (links in red dash-dot). This is the psychological force of cognitive balance/alignment, not rationality.

3.4. Analysis Part 4: Reciprocal effects. Since there seem to be substantial elements of wishful thinking, of irrational hopes and fears shaping people's view of the world, there is a further possibility: that peoples' views about genetic modification shape their perceptions of fact – that wishful thinking leads supporters of GM to imagine scientists to be trustworthy when they say (as they mostly do) that GM is safe, and to think that the risks of GM are few. Conversely, that opponents of GM therefore make the world fit their gloomy predispositions by seeing scientists as untrustworthy and risks as large.

If this is so, then there is an emotional/psychological (as opposed to logical/rational) connection from policy preferences shaping perceptions of trust in scientists (red dash-dot path C in Figure 5), as well as the logical/rational effect the other way, where trust in scientists assurances of safety leads to support for genetically modified food and crops (green solid italic path B). In short, reciprocal effects.



Note: Model with reciprocal causation (paths C and F). For simplicity, effects of demographic and religious variables, which are few and small, are not shown here (they are in Table 3).

Fig. 5. Effects of perceptions of fact (concerning how trustworthy scientists are about GM and how risky GM food is) on policy preferences for genetically modified food and agriculture

Moreover, the same logic implies that there is an emotional/psychological (as opposed to logical/ rational) connection from policy preferences which shapes perceptions of risk (red dash-dot path F in Figure 5), as well as the logical/rational effect the other way (green solid italic path E). So more reciprocal effects.

Estimating reciprocal effects persuasively is famously problematic since the logic must be defended only theoretically – there is rarely any empirical evidence that would rule out other assumptions (Bollen, 1989). Here I argue that we do, theoretically, have some reasonable leverage. (1) We know that accepting the goals of better food and prosperous farmers leads people to trust scientists' (generally favorable) pronouncements about GM, and assume that this is on psychological as opposed to logical/rational grounds (red dash-dot path *C** in Figure 4). So it seems likely that the corresponding psychological effect leading those who favor GM also to trust scientists should be about the same size (red dash-dot path *C*). So we assume that $C = C^*$ (i.e. that the metric effects are the same size). That is sufficient to identify the reciprocal path (green solid italic path B). (2) Analogously, we know that people who accept goals of better food and prosperous farmers are less fearful of the risks GM food brings, presumably on psychological as opposed to logical/rational grounds (red dash-dot path *F** in Figure 5). It thus seems likely that the psychological tendency for those who accept the policy of genetic modification will also tend on psychological grounds equally to be less fearful of the risks (red dash-dot path *F*). So we assume that $F = F^*$. This is sufficient to identify the reciprocal effect (green solid italic path *E*).

All this is problematic but, we suggest, not wholly implausible. Certainly it is more plausible than the assumption (maintained in Figure 4) that there are substantial psychological effects from goals to trust, but not from policy preferences to trust, and that there are psychological effects from goals to fear, but not from policy preferences to fear. We suspect that the estimates in Figure 5 with reciprocal causation, while admittedly problematic, are closer to the truth than the estimates of Figure 4, a conventional recursive model without any reciprocal effects.

These results, if accepted, have important implications. First, they imply that a conventional estimate of trust's effect on acceptance of GM policies (green solid italic path B) *overstates* trust's importance substantially, by around 30% (compare its effects in Figures 4 and 5).

Second and analogously, a conventional estimate of fear's effect on policy preferences (green solid italic path E) overstates its effects as well, by about 20% (again compare Figures 4 and 5). In both cases the observed correlation reflects substantial emotional/psychological adjustments as well as conventional rational/logical influences.

Third, after allowance is made for reciprocal effects, the effect of acceptance of food and agricultural goals on acceptance of the GM policy – the means to fulfill the goals (green solid italic path A) – is even *more* dominant. Its magnitude, fully .44 in standardized terms, is huge in absolute terms and in comparison with other influences: more than twice as large as trust's effect (path A versus path B) and more than twice as large as risk's effects (path A versus path F).

Fourth, much of the debate about trust in scientists and about the risks of GM is not based on logical/rational considerations (green solid italic paths in Figure 5) but reflects psychological processes of people adjusting their perceptions of fact to suit their goals and policy predispositions (red dash-dot paths). In short, emotion and psychology rather than science.

Conclusion

The Australian public, like the American, is broadly supportive of a wide range of genetic engineering projects. The average Australian rates the average genetic engineering project as a "good idea". In general, views about genetic engineering in Australia are broadly similar to those in the USA, Canada and some of the more favorable European Union nations.

Importantly, the level of support depends crucially on the goals served. Of the genetic engineering products we asked about in the survey, the most popular are a treatment for blood cancer, a drug that lowers blood pressure, and cotton that resists insect pests. More than 90% of Australians favor these. Then comes healthier cooking oil, genetically modified viruses to protect farm crops by attacking insect pests, viruses to control imported animal pests, and lean pork. Support is lowest for the genetically engineered tomato but even here a clear majority is in favor.

People who favor genetic engineering tend to be those who favor the goals, especially agricultural benefits, and those who have a scientific worldview. Conversely, against genetic modification – the minority – tend to be those who are less keen on agricultural goals than most Australians, less keen on new medicines, and who reject Darwin's theory of evolution and modern astronomy.

These Australian results have implications for public opinion in other Western nations:

- Like people everywhere, Australians are very strongly in favor of scientific research in medicine. For that reason, they tend to support genetic engineering in medical domains, and that is likely to be true for people in other Western nations as well. Genetically engineered medicines are therefore likely to come increasingly into favor in the future.
- Australians are also very strongly in favor of many agricultural goals, particularly crops that would create an export market and ones that provide healthier food, but also ones that would increase farmers' incomes, provide cheaper food, or provide tastier food. These are again views that are likely to be mirrored in other countries, particularly food-exporting ones like the USA, although probably less so in the European Union with its huge food surplus. This will lead to steady pressure for the introduction of genetically modified farm products.
- A majority of Australians accept what we have called the 'scientific worldview' – Darwin's theory of evolution and modern astronomy (the 'big bang' and the like), although many others, especially devout Christians, reject it. Acceptance of the scientific worldview is an important source of support for genetic engineering. This source of support is likely to salient in irreligious nations (including Scandinavia and much of Northern Europe) but lead to opposition in more religious ones. But it will also create a potentially troublesome gap between opinion among the scientific elite – which overwhelmingly accepts evolution and scientific astronomy – and more religious politicians and the general public.

How these attitudes will evolve in future years is unclear. The scientific worldview might become more widespread (which would increase support for genetic engineering) or fade (which would lead to decreased support for genetic engineering), but it has been stable over recent decades, so major changes seem unlikely.

The most important sources of support for genetic engineering are support for its instrumental goals: medical progress, healthy food and prosperous farmers. Support for medical research is very high and, with a prosperous but ageing population, likely to remain so. Diet is notoriously subject to fad, and so hard to predict. Farm prosperity is a surprisingly highly valued goal in Australia – as in some European nations and the USA – and that holds even among urban populations who pay heavily for their sympathy through farm subsides and higher food pries. But it is perhaps the most likely source of change. The huge subsidies given to the developed world's farmers and the high prices due to those and to other farm protection measures may eventually erode public sympathy for farmers. If so, there is likely to be an unexpected consequence: a sharp decline in public support for genetic engineering.

Symptoms of danger in the structure of public opinion. Many analyses of public opinion about genetic engineering emphasize the importance of trust and evaluations of risk. So do many analyses of other public policy issues. Simplistic analyses usually suggest that both are important. But our results strongly suggest their apparent importance is exaggerated: much of the debate about trust in scientists and about the risks of GM is not based on logical or rational considerations. Instead it also reflects emotional and psychological processes of people adjusting their perceptions of fact to suit their goals and policy predispositions (the dangerous red arrows in our theory diagrams). In short, emotion rather than science. That is a risk best avoided.

Supplementary materials on-line at: www.international-survey.org.

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