SNF Report No. 14/00

DIFFUSION OF ENVIRONMENTAL POLICIES; BAYESIAN LEARNING OR HEURISTICS?

by

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SNF Project No. 4375
Spredning av energi- og miljøpolitikk

The project has been funded by Research Council of Norway under the SAMRAM program

FOUNDATION FOR RESEARCH IN ECONOMICS AND BUSINESS ADMINISTRATION
Bergen, March 2000

ISBN 82-491-0041-7
ISSN 0803-4036

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FOREWORD

This is a report in a series dealing with diffusion of energy and environmental policies and effects of international leadership. The project is funded by the SAMRAM program of the Research Council of Norway. Thanks to Arent Greve at the Norwegian School of Economics and Business Administration for helpful comments.

1. INTRODUCTION

We study the diffusion of public policies to curtail CO_2-emissions. More precisely we study how the innovation of a new policy in one country can come to influence policy making in other countries. Using data from a questionnaire we perform an empirical test of the expected utility model of diffusion from the economic literature, and we explore an alternative hypothesis built on heuristics found in cognitive psychology.

The study is motivated by the desire to reduce global CO_2-emissions. The willingness to curtail CO_2-emissions in a country is likely to depend on the perceived costs of policies to reduce national emissions. The more successful new policies are in terms of stimulating low cost abatements, the more ambitious the emission goals can be. Furthermore, if successful and efficient policies spread from innovating nations to other countries, there will be a multiplier effect on the total global emissions. Since the climate problem is a global one, the benefits would feed back to the innovating nation. Hence, larger emission reductions than the national ones would be obtained per unit abatement cost. If the Kyoto agreement is seen as binding in the near future, these mechanisms will only be of importance for the further development of the agreement.

Surveying a rather limited literature on the diffusion of public policies, Moxnes et al. (1996) conclude that public policies tend to diffuse according to the same basic laws as technologies, Rogers (1995). Most studies of policy innovation, which allow for diffusion effects, find diffusion to be one of the important explanatory factors. Typically, diffusion is strongest between countries or states which are located close to each other and which are culturally related, e.g. Karvonen (1981), Walker (1971), Smith and Glick (1995), and Berry (1994). Diffusion tends to be hierarchical, from more to less developed countries or states. No studies of the diffusion of energy and environmental policies were found. Moreover, traditional diffusion studies are limited to policies that have already diffused and produced the necessary data. Hence, such studies are of limited usefulness if one wants to assess the diffusion potential for alternative new policies, at least as long as historical diffusion is not explicitly linked to observable attributes of policies.

The diffusion literature points to uncertainty as the major reason to seek experiential information. This is formalized in economic theory by employing the theory of expected utility combined with Bayes theorem, Stoneman (1981). However, this theory cannot be applied without reservations to predict the extent to which policies will spread, because the theory has not been extensively tested. A major reason to question the theory is findings in cognitive psychology and economics of deviations between observed behaviour and predictions by expected utility theory and Bayes theorem, respectively Tversky and Kahneman (1974) and Kahneman and Tversky (1979).

To investigate the diffusion potential of new policies, and to test theories, we rely on an alternative method to the traditional diffusion analysis. A questionnaire is used to get data. We study the relationship between perceived uncertainty of policies and their expected utility, and we investigate how experiences made in other countries influence the expected utility. Five different energy policies and four different countries are considered. An effort has been made to create a framing in the questionnaire that seems natural when discussing energy policies.

With this approach we focus on the treatment of information and the sole effect of information on the potential for diffusion. The study does not deal with other influences on diffusion, e.g. networks, preferences for being a modern nation/bureaucracy, direct personal experiences, social norms, opinion leaders, and change agents. Hence, we could both under- and overestimate the true potential for diffusion.

First we discuss the relationship between the diffusion literature and the expected utility theory with Bayes theorem. Next the main hypotheses and the design of the study are presented. The results support the expected utility model in that subjects tend to be risk averse. We also find that experiential information lead to higher expected utility, with a stronger effect for neighbouring countries than nations far away. However, a tendency to rely on the representativeness heuristic implies that the potential for diffusion is unduly restricted. This tendency is strong enough to discard a theory of diffusion which relies on Bayes theorem. Thus an information problem is revealed. Implications for the diffusion literature and for policy making are discussed in a concluding section.

2. DIFFUSION, EXPECTED UTILITY AND BAYES THEOREM

We assume that the choice between one uncertain policy and a set of uncertain alternatives can be described by maximization of expected utility over the entire set of alternatives. The degree to which one particular policy is used

$$V = f(EU(X)),\ f' \geq 0 \qquad (1)$$

naturally increases with the expected utility $EU(X)$ of the policy, see Stoneman (1981) for details behind such a result. For our purpose (performing linear regressions) it suffices to say that the relationship is monotone, that it is likely to be smooth, and that it saturates at low and possibly at high expected utilities. Intuitively, the smoothness follows when the uncertainty is considerable, such that all eggs should not be put in one basket, even when expected policy outcomes differ quite a lot between policy alternatives. Thus, even though our main interest is in the degree to which a policy is used (innovated), we concentrate on the expected utility of policies in the following.

The expected utility of a public policy can be written:

$$EU(X|T) = \sum_i U(x_i)P(x_i|T) \qquad (2)$$

where X is the unknown outcome of the policy, $U(x_i)$ is a utility function reflecting risk aversion, $P(x_i|T)$ is the probability of outcome x_i given the available prior (theoretical) information T. For a given expected outcome μ_T, one will find that the wider the distribution of X is, e.g. measured by the standard deviation σ_T, the lower the expected utility will be, given a risk averse (concave) utility function.

If experiential data D about the policy are available from some other country, the expected utility can be written:

$$EU(X|T,D) = \sum_i U(x_i)P(x_i|T,D) = \sum_i U(x_i)\frac{P(D|x_i)P(x_i|T)}{\sum_j P(D|x_j)P(x_j|T)} \qquad (3)$$

The posterior probability $P(x_i|T,D)$ is given by Bayes theorem in the right-hand side of the equation. $P(D|x_i)$ is the probability of obtaining the data D, and can be interpreted as the relative likelihoods of the various states x_i given the observation D.

$P(D|x_i)$ will be more widely spread the less similar or representative the innovating country is of the home country. The width will also depend on the precision by which one can detect the effects of the actual policy within a dynamic and changing national economy. i.e. the reliability of the observed effects.

Rogers (1995), who has surveyed the diffusion literature, claims that utility and uncertainty are central among the attributes found to be important for diffusion of technologies. The five most important attributes are: relative advantage, compatibility, complexity, trialability, and observability (p.206). These factors are related to utility, and/or they reflect uncertainty (or factors of importance for efforts to reduce uncertainty). Uncertainty is seen as the driving force in the exchange of information during the diffusion process (p.138). Rogers also writes that the more complex an innovation is, the greater the uncertainty about its effects (p. 397), that uncertainty leads to resistance towards innovations (p.397), that earlier adopters are more intelligent and rational than later adopters, and that they are “better able to cope with uncertainty and risk” (p.273).

To simplify our discussion of the model, we assume that the experiential outcome x_D coincides with the expected outcome μ_T of the prior distribution. In this case the experiential data are most likely[1] to reduce the standard deviation of the posterior distribution $\sigma_{T,D}$. In turn, a more narrow posterior distribution contributes to a higher expected utility for the policy, given risk aversion. In case the data are completely uninformative, there will be no effect on the posterior distribution and expected utility. Figure 1 illustrates the distributions around an expected outcome μ_T together with an exponential utility function.

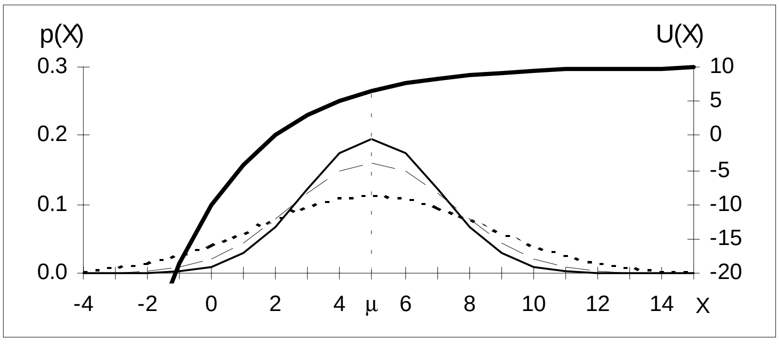

Figure 1: Utility function (thick line), prior distribution (dotted thin line), likelihood based on experiential data (dashed thin line), and posterior distribution (thin solid line).

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1 There is one possible exception. If apriori one expects the outcome in the experiencing nation to be higher than the expected outcome in one’s home country, the posterior expected utility for the home country could drop if the experienced outcome equals the apriori expectation for the home country. For such an effect to become important, much apriori knowledge about the nations would be needed.

Even though utility and uncertainty are central in the diffusion literature, most studies of diffusion do not explicitly use a model of expected utility. Exceptions are Stoneman (1981), Oren and Schwartz (1988) and Tsur et al. (1990). These authors simply assume that the expected utility theory with Bayes theorem is applicable, they do not test it.

However, two potential problems deserve attention. First, the expected utility theory has been extensively tested and challenged, Kahneman and Tversky (1979). People have been found to be risk-averse with respect to gains and risk-acceptant with respect to losses. In our case, it is not obvious how people will treat policies to reduce emissions of CO_2.

Second, in the case of diffusion, the expected utility theory includes Bayes theorem. According to Tversky and Kahneman (1974) and other contributors, people rarely behave according to Bayes' theorem. In experiments, subjects have been asked to come up with estimates of probabilities of simple outcomes, e.g. what is the probability that the colour of a ball is blue rather than yellow. The results typically depend on the framing of the problem. The representativeness heuristic holds that people neglect prior information and base their estimates solely on the representativeness of the data given. The anchoring and adjustment heuristic holds that the estimate is anchored on some prior information and that this estimate is adjusted (typically insufficiently) to account for the representativeness of the data given, see e.g. Edwards (1968, 1982) on conservatism.

The formulae in Equation 3 indicates that the task at hand is more complicated than the typical experiment in the literature testing Bayes theorem. Expected utility not only demands point estimates of the probability of one outcome, it requires an estimate of the entire posterior distribution. Thus, an exact application of Bayes theorem requires correct problem formulation, knowledge of the idea of the theorem, and means to calculate answers. Even though the task is more complex than the traditional experiments, it seems that the problem can be formulated as a combination of the anchoring and adjustment heuristic and the representativeness heuristic. A subject has a prior idea about the expected utility of a policy, which serves as an anchor. When information about the experience with the policy arrives from another country, the anchor will be adjusted according to how representative the other country is as a testing ground for the policy. Hence, the diffusion effect, i.e. the adjustment due to experience, will only reflect the representativeness of the other country. It will not be influenced by the uncertainty of the prior estimate, which it should.

It could be tempting to ignore the above heuristics, presuming that biases will go away with learning. However, many problems involving Bayes theorem, including the diffusion problem, do not provide the feedback about outcomes and the number of repetitions needed for efficient learning, see Camerer (1995). Camerer also refer to studies showing that there is little transfer of knowledge, or problem solving ability, from problems where learning is possible to similar problems with a different framing.

The diffusion literature distinguishes two channels of influence, mass media and interpersonal communications. While mass media are found to contribute to the awareness of new options, interpersonal communication seems most influential with regard to innovation decisions, Valente (1995) and Rogers (1995). The tendency for innovations to travel along networks is also observed for public policy diffusion, see references in the introduction. The theories discussed above do not reflect information costs or the availability of information (networks). This means that we limit ourselves to the study of subjects' treatment of information, i.e. whether they behave according to one or the other theory.

3. MAIN HYPOTHESES

The hypothesis testing is based on data from a questionnaire describing five different energy policies and experiential data for four different countries. The subjects are asked to report their knowledge and understanding of the policies, to indicate how certain they are about the effects of the policies, and to evaluate the policies without and with additional experiential data.

First we want to see if there is a relationship between reported certainty about the outcome of a policy and the reported understanding of the policy (complexity).

Hypothesis 1: There is a positive relationship between a subject's reported understanding of a policy and the reported certainty of the outcome of the policy.

Hypothesis 1 is included because it provides a link between complexity, which is focused in the diffusion literature, and uncertainty, which influences expected utility. Next we investigate the effect of reported certainty on the expected utility of the policies.

Hypothesis 2: Greater certainty about outcomes leads to higher expected utility of policies.

That certainty matters is consistent with the expected utility theory. A positive relationship is consistent with risk aversion.

Then we test if the respondents make rational use of experiential information, i.e. if they behave according to the expected utility theory including Bayes theorem. We presume risk aversion.

Hypothesis 3a: There is a positive net effect of experiential information on expected utility, given that the experience coincides with the expected outcome according to prior information.

Hypothesis 3b: The net effect of experiential information on expected utility increases with the representativeness of the country where the experience has been made, given that the experience coincides with the expected outcome according to prior information.

Hypothesis 3c: The net effect of experiential information on expected utility decreases with reported apriori certainty, given that the experience coincides with the expected outcome according to prior information.

All hypotheses follow directly from Equation 3. Note that a rejection of hypothesis 3c implies support to the alternative hypothesis that respondents use the heuristics described in the preceding section. According to this theory, subjects ignore the prior distribution of policy effects when making the adjustments, such that the adjustments depend solely on the representativeness of the experiencing country. Note here that we do not postulate that the posterior utility is independent of the prior distribution, it is only the net effect of experiential information on expected utility that is independent, i.e. the diffusion effect.

A rejection of hypothesis 3c implies that the data do not support the theory of expected utility combined with Bayes theorem. Still the theory could be correct, the effect of prior certainty could be too small to be detected by an inaccurate test. To reject the existing theory, a more demanding test is needed:

Hypothesis 4: The net effect of experiential information on expected utility decreases with reported apriori certainty, and the effect of certainty is considerable.

For this hypothesis, a benchmark needs to be established for what we mean by considerable.

No particular hypotheses are stated when we explore differences between policies and subjects.

4. TESTS OF HYPOTHESES

Hypothesis 1 is tested by a general linear model (GLM):

$$C_{sp} = \gamma_0 + \gamma_K K_{sp} + \gamma_U U_{sp} + \gamma_s s + \gamma_p p + \varepsilon_{Csp} \quad (4)$$

where C_{sp} is the reported certainty of the outcome of policy *p* by subject *s*, K_{sp} is the reported knowledge of the policy, and U_{sp} is the reported understanding. All variables are reported on the same scale from 0 to 10. Subject *s* and policy *p* are treated as categorical variables. Hence, γ_s and γ_p should be seen as parameter vectors for the underlying dummy variables. We include *s* to account for individual differences with respect both to actual valuations and to positioning along the scale from 0 to 10.

Hypothesis 2 is tested similarly:

$$V_{sp}(T) = \alpha_0 + \alpha_C C_{sp} + \alpha_s s + \alpha_p p + \varepsilon_{Vsp} \quad (5)$$

where $V_{sp}(T)$ is a reported measure of the extent to which subject *s* wants to utilize policy *p*, given his or her prior information *T*. If the function *f* in Equation 1 had been linear, $V_{sp}(T)$ would be a perfect substitute for expected utility $EU_{sp}(X|T)$ in this linear test. Since the function *f* is monotone and is likely to be smooth, we treat $V_{sp}(T)$ as a substitute for expected utility. This measure of expected utility is on the scale from 0 to 10. A positive sign of α_C is consistent with risk aversion (*C* increases with certainty).

Since the existence of risk aversion is important for the interpretation of later tests, we search for details in three dimensions. First, we test for differences between individuals. This is done by including the interaction between C_{sp} and subject *s* in equation 5.

Second, the number of policies is small (five) and may not represent a random sample. If for instance the policies with the highest expected outcomes also are the ones with the most certain effects, a positive relationship between *C* and $V(T)$ could follow even without risk aversion. We cannot test for such a relationship directly since we lack information about expected outcomes. However, we will observe if differences between average values of *C* over policies are small compared to the total variation in *C* over individuals and policies (from 0 to 10). If this is the case, a systematic relationship between expected outcomes and certainty, is not likely to matter very much. To test the importance we will reestimate Equation 5 for the two policies which are most similar in terms of average values of *C*.

Third, we want to test for a possible tendency towards risk acceptance for policies with low expected outcomes. According to prospect theory Kahneman and Tversky (1979), people tend to become risk seekers when they face choices between expected losses. Hence, in case of large uncertainty, it could be that some subjects do not risk leaving out policies with low expected outcomes. Having no direct information about expected outcomes, it is not easy to test this possibility formally. However, the potential for such an effect should be indicated by the spread of average values of $V_{sp}(T)$ over policies. If no policy comes out with a much lower average than the others, there should at least on average over subjects, be little reason to expect risk acceptance. Another test is to include an interaction term between C_{sp} and *p* in Equation 5. This test will reveal if the degree of risk aversion varies over policies.

A GLM similar to the one in Equation 5 is used to test Hypotheses 3a, 3b, and 3c regarding net effects of experiential information.

$$E_{sp} = \beta_0 + \beta_C C_{sp} + \beta_L L + \beta_s s + \beta_p p + \varepsilon_{Esp} \qquad (6)$$

The net effect on expected utility of experiential data from other nations is given by $E_{sp} = V_{sp}(T) - V_{sp}(T,D)$, where $V_{sp}(T,D)$ is the extent to which subjects want to use the policies after experiential data *D* have been received. As in the case with prior information, we take this measure to be an indicator of expected utility. Nation (land) *L* is treated as a quantitative variable moving in steps of 3.33. For the nation closest geographically and culturally *L*=0, for the most distant nation *L*=10.

It is in the case of high apriori uncertainty (low *C* and wide apriori distribution) that experiential data are the most useful. Expected utility combined with Bayes theorem implies that β_C is negative.

For hypothesis 4 we need to establish an upper limit (benchmark) for β_C. We use Equations 2 and 3 to find $E = EU(X|T) - EU(X|T,D)$ as a function of the apriori certainty *C* (related to the standard deviation of the prior distribution $P(x|T)$):

$$E = \sum_i U(x_i)P(x_i|T) - \sum_i U(x_i)\frac{P(D|x_i)P(x_i|T)}{\sum_j P(D|x_j)P(x_j|T)} \qquad (7)$$

This relationship is then used to generate data which are used to estimate a benchmark (coefficient) $\beta_{C,b}$ in a linear regression between *E* and the apriori certainty *C* (independent variable).

This procedure requires assumptions and data. We assume that prior distributions of outcomes $P(x|T)$ as well as likelihoods $P(D|x)$ are normally distributed. The expected values are the same for both distributions. A separate questionnaire is used to establish a relationship between the measure *C* of certainty, and the standard deviation that is needed to describe the normal distribution. Another questionnaire is used to produce an estimate of the standard deviation of the likelihood. Next we assume the following exponential utility function:

$$U(x) = 10(1 - e^{-\psi(x-x_0)}) \qquad (8)$$

This utility function does not tend towards minus infinity for an outcome of x=0. Negative outcomes are allowed, as they should for a policy with limited implications for national welfare. The exponential function has a constant absolute risk aversion[2] ψ. The parameter x_0 defines the outcome for which utility equals zero. The parameter ψ will be set to obtain an appropriate degree of risk aversion. From the test in Equation 5 we have a measure of risk aversion in terms of the parameter α_C. Using only the prior distribution (Equation 2) to find a relationship between $EU(X|T)$ and *C*, we can estimate a similar parameter $\alpha_{C,b}$ from this relationship. By the use of iterations, we find a value of ψ which makes $\alpha_{C,b} = \alpha_C$. Note that we have not specified the function *f* in Equation 1. To roughly mimic such a function, the range for the utility function is chosen such that expected utility cannot exceed 10 in value. A max-function ensures that the extent of use does not go below zero. With these assumptions, expected utility represents the desired use of policies.

2 Pratt-Arrow absolute risk aversion defined as $r(x) = -u''(x) / u'(x)$.

5. DATA AND ADDITIONAL TESTS

As mentioned above, a questionnaire was used to get data. The following five energy policies were described as follows (translated from Norwegian):

p=1. Equal CO_2-taxes for all emissions, paid as excise taxes on coal, oil, and gasoline. The only exception is the process industry which has to reach certain emission goals to be entirely or partly exempted from paying CO_2-taxes. Enhanced governmental incomes are used fully to reduce labour and income taxes, i.e. a movement towards green taxes.

p=2. Standards for household equipment, automobiles, industrial processes, buildings etc. with respect to emissions of CO_2. Equipment which are not brought within the limits are outlawed.

p=3. Subsidizing efforts to reduce CO_2-emissions in all sectors (loans, investment subsidies, exemption from VAT etc.)

p=4. Information campaigns to make decision makers in all sectors better suited to make appropriate choices with respect to energy efficiency (e.g. product labelling).

p=5. Automobile taxes which increase with the model's gasoline consumption per 10 kilometres. Automobiles with a consumption of e.g. 0.3 l/10 km are subsidized by 10 percent, automobiles with a consumption of 1.0 l/10 km gets a tax of 90 percent etc. The average tax rate is set such that the total governmental incomes from automobile taxes are not changed. Analysis shows that the policy will reduce yearly CO_2-emissions from private automobiles by 25 percent compared to what they would otherwise have been. This estimate is uncertain with a lower limit of 4 percent and an upper limit of 46 percent[3].

For each of the five policies, 5 questions were asked. The sequencing of the questions and their wording were intended to resemble (within limits) a normal conversation about each of the policies, first introducing prior thoughts about the policies and next introducing experiential information. Hopefully, this choice has prevented undesired framing effects. In each question, integers in the range from zero to 10 were expected.

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3 The additional and constructed information about expected effects and of uncertainty, was given for this policy to see if this lead to more uniform answers. It did not.

1. How well do you know the policy from before? 0=not at all, 10=to a great extent:

2. How well do you understand how the policy works? 0=poorly, 10=very well:

3. How certain are you about the effects of the policy? 0=very uncertain, 10=very certain:

4. Norway is committed to limit its CO_2-emissions, such that some policies have to be implemented. If you were to choose, to what extent would you apply policy *p* [*p*=letter for policy] (within the niches it naturally applies)? 0=not at all, 10= to its full potential:

5. If you got to know that the policy has been used in country *L* [*L*=name of country] for three years, and that they have experienced exactly the effects you expect from your knowledge of the policy, would you answered question 4 differently? Make a new estimate of to what extent you would apply policy *p* [*p*=letter for policy]:

In light of our needs, the answers to question 3 should have been in terms of a coefficient of variation. However, a pre-test revealed that subjects (with higher education than the students answering the main questionnaire) are not sufficiently familiar with this measure of uncertainty. To serve our needs, 16 individuals were asked to provide a translation of certainty *C* on a scale from 0 to 10, to coefficients of variation $C_{c.v.}$, given a focus on public energy policies. They received the necessary guidance to perform the task. The translation took place for four given coefficients of variation (0.1, 0.2, 0.5, and 0.8). 8 respondents got the coefficients in reversed order to reveal starting biases. The results can be summarized by a linear relationship: $C_{c.v.} = 0.93 - 0.10C + 0.07d_{0.8}$, where $d_{0.8}$ denotes a dummy for the case when a c.v. of 0.8 is presented first. All coefficients were highly significant with t-ratios of respectively 42, -29, and 4.0. R^2=0.93 and the standard error of the residuals were 0.07.

That the group of 16 is representative of those answering the main questionnaire is roughly indicated by average answers to policy 5, where a confidential interval was given in the text. If the given range is interpreted as plus and minus two standard deviations, the given coefficient of variation is 0.42. Using the above formula to translate the average reported value of *C* (5.22) for this policy, yields a value of $C_{c.v.}$ equal to 0.44 ($d_{0.8}$=0.5). Thus, given that the subjects make use of the given information on uncertainty, the test indicates a close correspondence.

The answers to questions 4 and 5 are in terms of utilization and not in terms of expected utility. As mentioned earlier, the reasons for this is that our original interest lies in the use or innovation of policies. Besides, the task would have been perceived as more abstract had the subjects been asked to quantify utility rather than utilization.

To get a more orthogonal design, the nations were rotated over the policies. The four countries were Denmark (*L*=0), France (*L*=3.33), Hungary (*L*=6.67), and Malaysia (*L*=10). The first quart of the respondents got this sequence with Denmark repeated for the fifth policy, the next quart got a shifted version with France first and repeated for the fifth policy, and so on. For the two policies *p*=1 and *p*=5 which receive experiential data from the same country, we expect E_{s1} and E_{s5} to be fairly close to each other, at least if evaluations and degree of certainty are similar. The difference $E_{s1} - E_{s5}$ will be used as a rough test of consistency in responses.

Seen from Norway, Denmark is close both with respect to geographical distance and culture, France and Hungary have the same geographical distance, while France is likely to be viewed as culturally closer to Norway than Hungary. Finally, Malaysia is likely to be perceived as being far away both geographically and culturally. The differences among the selected nations should be sufficient to test hypothesis 3b.

To get a rough estimate of the perceived relevance of foreign experience, 16 individuals were asked to give an estimate of the coefficient of variation of the likelihood $P(D|x_i)$. They were presented with the case of a transfer of an energy policy to reduce CO_2-emissions from Denmark to Norway. "Given an experienced effect of 100 units in Denmark, and that the same effect of 100 units is expected in Norway, indicate (using the same unit) the c.v. for the outcome in case Norway implements the same policy." The results were as follows: the average c.v. was 0.31 with a standard deviation of 0.05. The reported coefficients of variation varied from of 0.1 to 0.75.

For the main questionnaire the respondents were first year students at the Norwegian School of Economics and Business Administration in Bergen. The average age of first year students is 22 years. The students were recruited in class and encouraged by participation in a lottery of lottery tickets. 135 received the questionnaire and 80 returned useful answers (four additional replies were discarded because they were not filled in properly). Hence the response rate was nearly 60 percent.

The group of students is not fully representative of neither Norwegian voters nor decision makers. Notably, they are on average younger and most likely more intelligent than the average voter. However, besides providing a quick and cheap response, they are likely to reflect general tendencies concerning the questions we address. Two additional questions were asked to investigate the sensitivity of the results to attributes that vary across the entire population.

6. What group of parties did you vote for in the last election?
(Conservatives (H&FrP), Center parties, Labour parties (Ap&SV), or none of these groups)

These groups are represented as a categorical variable, using the respective code numbers 4, 1, 2, and 3.

7. When it comes to the effort to reduce emissions of CO_2 in the world, do you mean that the effort is: Much too small, too small, appropriate, too large, much too large.

The answers are represented as a numerical variable ranging from 0 to 10 in steps of 2.5, where 10 is "much too small". Since the answers do not vary with the five policies, the answers cannot be used in Equations 4 and 5. Therefore we test for effects using average responses over the five policies[4]:

$$\overline{V}_s = \rho_0 + \rho_C \overline{C}_s + \rho_G G_s + \rho_A A_s + \varepsilon_{Vs} \qquad (9)$$

Here bars denote averages over policies p for degree of use V and certainty C. G_s is the categorical variable for party group, and A_s is the attitude towards current abatement efforts. A similar equation is used to study average net effects E of experiential information:

$$\overline{E}_s = \delta_0 + \delta_C \overline{C}_s + \delta_G G_s + \delta_A A_s + \varepsilon_{Es} \qquad (10)$$

As a final investigation of the representativeness of the students, we ask them the following question:

8. What attributes did you put most weight on when evaluating the policies in earlier questions? Mark up to three squares [attributes], if you weigh that the policy: is uncertain (complicated), is popular, is just, is profitable (low cost), entail adjustment costs for those who are hurt, fits own attitudes, fits Norwegian conditions, is something else.

4 Tests on separate policies show that the test on averages provides a good summary of individual results.

The answers will be compared to answers to a similar question posed to civil servants working with public (economic and environmental) policies.

With five policies for each of the 80 respondents, there is a total of 400 potential data points. From 11 to 14 points are missing in the different tests. An attempt to leave out cases that could represent outliers[5] did not produce qualitatively different results. Hence we report results for the entire data set.

Two problems might arise when data from a questionnaire are used to test our hypotheses. First, respondents are asked about their desired utilization of policies, we do not observe actual choices. In market research this typically poses a problem since intentions do not show a perfect match with actual choices, e.g. Fishbein and Ajzen (1975). There are different reasons for this mismatch, among them practical problems and distorted decision processes. In our case this is less of a problem since we focus on the treatment of information. Second, the halo effect might be at work. If the respondents lack detailed understanding about individual energy policies, underlying general impressions and attitudes toward energy policies (or public policies at large) may come to influence individual evaluations. If all policies turn out to be evaluated identically, all reflecting a common underlying general impression, we will not be able to distinguish policies in our results. However, importantly, we will still be able to test our main hypotheses.

5 Eliminate subject s if $\left|E_{s1} - E_{s5}\right| \geq 3$ (seven respondents), eliminate subject s if $\left|E_{sp}\right| \geq 5$ for at least one policy p (seven respondents), and eliminate subject s if the scale is simplified to include only the values 0, 5, and 10 (two respondents).

6. RESULTS

First the hypotheses are tested. Next the representativeness of the respondents is investigated.

6.2. Tests of hypotheses

Table 1 summarizes the data in terms of average responses and standard deviations. Knowledge *K* is typically low, understanding *U* is high, while certainty *C* is in-between. Average responses plus and minus two standard deviations typically cover the entire range from 0 to 10.

Table 1: Average responses (standard deviations).

	p=1	*p*=2	*p*=3	*p*=4	*p*=5
K	2.72	2.39	2.43	3.24	3.05
	(2.6)	(2.2)	(2.6)	(3.1)	(3.0)
U	5.43	5.35	5.30	5.94	6.69
	(2.7)	(2.5)	(2.6)	(2.7)	(2.2)
C	4.20	4.48	4.76	4.75	5.22
	(2.0)	(2.5)	(2.4)	(2.8)	(2.4)
$V_p(T)$	5.62	5.14	5.13	5.28	5.59
	(2.5)	(2.5)	(2.7)	(3.0)	(2.8)
$V_p(T,D)$	6.10	6.04	5.63	5.89	6.09
	(2.9)	(2.5)	(2.9)	(2.8)	(2.9)
E	0.51	0.88	0.51	0.61	0.41
	(0.20)	(0.17)	(0.17)	(0.15)	(0.19)

Note: Estimates for *E* are based on cases where both $V_p(T)$ and $V_p(T,D)$ are reported.

A general linear model (GLM) is used to test Hypothesis 1 by Equation 4. Table 2 shows that the relationship between reported understanding U_{sp} and reported certainty C_{sp} is highly significant. The magnitude of the coefficient indicates that understanding is important for certainty. Reported knowledge of the policy K_{sp} is not as important. This indicates that our respondents know relatively little about quantitative and practical aspects of the policies, for which prior knowledge beyond what is given in the text is needed. The results do not vary over policies.

Table 2: Test of Hypothesis 1, using Equation 4.

Testing of factors		Selected parameter estimates		
Factor	p-value	Variable	Estimate	p-value
s	0.000	Constant	0.88	0.35
p	0.245	*p*=1	-0.33	0.26
K	0.040	*p* =2	0.038	0.90
U	0.000	*p* =3	0.32	0.28
		p =4	-0.086	0.77
		p =5	0	
		p =5	0	
		K	0.11	0.040
		U	0.49	0.000

Note: *N*=389, R^2=0.57, p-value model=0.000.

Next we test hypothesis 2. Table 3 shows that it is supported by the data. The effect of certainty *C* on the valuation of the policies is highly significant. The estimated coefficient for *C*, α_C equals 0.75, i.e. for a one unit increase in *C*, *V* increases by 0.75. Both policy *p* and subject *s* have significant effects. Pairwise comparisons show that policy 1 has a significantly higher average value of *V* than all the other policies. A few subjects (around 5 percent) deviate significantly from the rest.

Table 3: Test of Hypothesis 2, using Equation 5.

Testing of factors		Selected parameter estimates		
Factor	p-value	Variable	Estimate	p-value
s	0.000	Constant	1.13	0.21
p	0.042	*p*=1	0.73	0.02
C	0.000	*p* =2	0.14	0.63
		p =3	-0.15	0.63
		p =4	0.07	0.81
		p =5	0	
		C	0.75	0.000

Note: *N*=389, R^2=0.62, p-value model 0.000.

The details of the above result are explored in three more tests. First we test for differences between subjects with respect to the effect of certainty *C*. The above test is repeated with the interaction of *C* and subject *s* in Equation 5. No significant effect of *C*s* is found (p-value of 0.44). I.e. risk aversion is not found to vary significantly between subjects.

Second, could the particular choice of policies have influence the results? We see from Table 1 that average values of *C* do not differ much (from 4.20 to 5.22) compared to the total variation in *C* (0 to 10). Policies 3 and 4 are almost identical with respect to average values of *C* (4.76 and 4.75). Repeating the estimation of Equation 5 with only these two policies yields an estimate of α_C of 0.76 (p-value of 0.000), i.e. almost identical to the estimate based on all five policies.

Third, could it be that subjects are risk acceptant for policies with low expected outcomes? From Table 1 we note that neither average values of $V(T)$ nor average values of C differ much over policies, respectively from 5.13 to 5.62 and from 4.20 to 5.22. Therefore it seems unlikely that on average, expected outcomes of the policies should differ much. Hence, none of the policies is a likely candidate to benefit from risk acceptance. Repeating the estimation of Equation 5 with the interaction of C and policy p, we find that α_C for policy 1 is lower than α_C for policy 5 (difference is 0.39, p-value of 0.009). The other differences are smaller and not significant. Policies 1 and 5 have nearly the same average values $V(T)$ while subjects on average are more certain about the outcome of policy 5 than of policy 1. Hence, on average, the expected outcome of policy 5 is likely to be lower than the expected outcome of policy 1. In case of risk acceptance for the policy with the lowest expected outcome (policy 5), one should expect α_C to be negative for this policy. Since, policy 5 turns out to have a positive and larger α_C than policy 1, we conclude that risk acceptance is unlikely.

From the above we conclude that the subjects behave as if they maximize expected utility under risk aversion. This finding will be assumed when we go on to test the net effect of experiential data, i.e. diffusion. Table 4 shows that Hypothesis 3a is supported by the data. The grand mean for the effect of experiential information is 0.60 (significantly greater than 0.48).

Table 4: Test of Hypothesis 3, using Equation 5.

Testing of factors		Selected parameter estimates		
Factor	p-value	Variable	Estimate	p-value
Intercept	0.000	Grand Mean	0.60	0.000
s	0.000	*p*=1	0.31	0.11
p	0.09	*p* =2	0.53	0.007
L	0.001	*p* =3	0.40	0.04
C	0.21	*p* =4	0.35	0.07
		p =5	0	
		L	-0.054	0.001
		C	-0.042	0.21

Note: N=386, R^2=0.38, p-value model 0.000. Grand mean evaluated at C=4.76 and N=4.91.

Hypothesis 3b is also supported in that the effect of country, L, is significant. As the distance from the home country increases, the net effect of experiential information decreases. The reduction when replacing Denmark by Malaysia is 0.54, i.e. a large portion of the grand mean.

Hypothesis 3c is not supported, the effect of certainty is not significantly different from zero. Thus, the data are consistent with the alternative hypothesis. To test for individual exceptions to this finding, an interaction term between subject s and certainty C is included in Equation 6. Four subjects turn out to have negative coefficients and one has a positive one (5 percent level).

To see if the data is strong enough to reject hypothesis 4, we need to establish a benchmark for what is meant by a considerable effect of *C*. We assume that both the prior and the likelihood of the data are normally distributed around an expected value of $\mu_T = \mu_D$ =5. Using the utility function in Equation 8 with x_0=2, we calculate expected utilities for different coefficients of variation for the prior. Ideally, we should have used an estimated function, as in Equation 1, to calculate the degree to which policies are used. To simplify, we assume that expected utility represents the desired rate of use as long as the expected utility is greater than zero. For expected utilities below zero, a max-function ensures that utilization does not go below zero. The following coefficients of variation are used: 0.10, 0.35, 0.60, 0.85, and 1.10. According to the estimated relationship between *C* and coefficients of variation in the preceding section, these values correspond to the following values of *C*: 8.7, 6.3, 3.9, 1.5, and 0.7 (the latter estimate is adjusted upwards to get a more likely number than the negative one produced by the estimated linear relationship). Based on these values of *C* and the calculated expected utilities, a regression is performed to find $\alpha_{C,b}$. By iteration we find the measure of risk aversion ψ=0.34 such that $\alpha_{C,b} = \alpha_C$ =0.75.

Using this estimate for ψ in the utility function, we can calculate net improvements in expected utility *E* due to experiential data. To do this we need an estimate of the perceived coefficient of variation for the likelihood of the data. Our supplementary questionnaire gave an average of 0.31. A rather conservative estimate is produced by adding four standard deviations to this average and choose a c.v. of 0.50. Figure 2 shows the calculated net effect on expected utility of experiential information as a function of prior certainty *C*. Regressing over the five data points yields a slope $\beta_{C,b}$=-0.60.

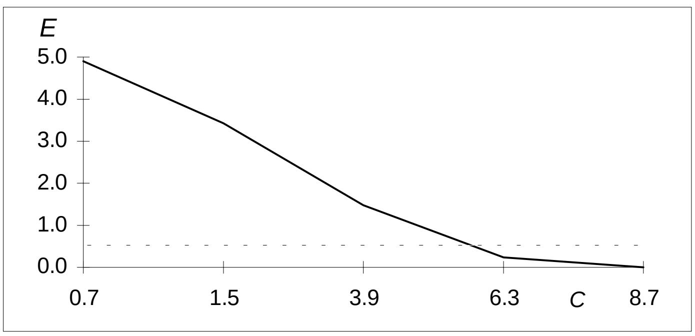

Figure 2: Calculated net effect of experiential information on desired use as a function of prior certainty (solid line) versus estimated effect (dashed line).

Before we go on, we repeat the above procedure for different values of $\mu_T = \mu_D$ and x_0 to test the sensitivity to these rather arbitrary choices. First we note that logically, $\mu_T = \mu_D$ must be somewhat greater than x_0. If that is not the case, our calculation predicts zero utilization, for any level of certainty. This would not be consistent with our data which show that for levels of certainty C greater than 2, there is only one single case where the rate of use is zero. Hence we perform sensitivity tests where there is a minimum distance between $\mu_T = \mu_D$ and x_0. The following combinations of $\mu_T = \mu_D$ and x_0 are tested: 10/4, 10/0, 5/2, 5/-2. For all cases ψ is adjusted to make $\alpha_{C,b} = \alpha_C$ =0.75. All the resulting estimates of $\beta_{C,b}$ fall in the range from -0.77 to -0.57. Furthermore, if we raise the estimate of the coefficient of variation for the likelihood from 0.5 to the high extreme in the sample, i.e. 0.75, the estimate of $\beta_{C,b}$ changes from -0.60 to -0.46. Hence we conclude that our estimate of the benchmark $\beta_{C,b}$ is not very sensitive to our assumption.

Then we are ready to test hypothesis 4. A 95 percent confidence interval for the estimate of β_C in Table 4 ranges from -0.11 to 0.02. The above benchmark $\beta_{C,b}$ is clearly outside of this interval. Hence we discard hypothesis 4; the subjects do not make a proper use of Bayes theorem in this case.

There are significant differences between policies 5 and 2 and between policies 5 and 3 with respect to the net effect of experiential data. The diffusion potential for policy 5 is the lower one. The differences are not considerable and do not seem to be of practical value.

6.2. Representativeness of respondents

Then we turn to the tests of the representativeness of our subjects, the students. Table 5 compares the sample to national averages with respect to political group and attitude towards the climate problem. With respect to political groups, conservatives are slightly over-represented in the sample, while center parties are correspondingly underrepresented. In both cases the groups of "others" are neglected, 7.8 percent in the sample and 3.7 percent in the election.

Table 5: Comparisons of sample and national averages with respect to political sympathies and attitude towards the climate problem, percent.

Group	Political group Sample	Election 1999	Attitude	Attitude Sample	National 1996
1. Center (KrF, Sp, V)	18.3	24.2	Much too small/ very concerned	20.8	25
2. Labor (Ap,Sv)	39.4	39.0	Too small/some-what concerned	59.7	35
3. Conserva-tive (H, FrP)	42.2	36.8	Appropriate/a little concerned	18.2	33
			Much too and too large/not concerned	1.3	8

Source for national attitude 1996: “Norsk Monitor”, Markeds- og Mediainstituttet (MMI), Oslo.

Table 5 also compares attitudes. Here definitions differ somewhat. While we asked about the appropriateness of global abatement efforts in question 7, MMI asked about degree of concern about the climate problem. There is good correspondence for the “much too small effort” and “very concerned” groups. The remaining groups do not indicate alarming differences.

In case there are differences with respect to political group and attitude, do they matter? Regarding prior evaluations, we estimate Equation 9 on aggregate data. Table 6 shows the results. As found for disaggregate data, the effect of certainty *C* is large and highly significant. There is a significant effect of attitude *A*. The more insufficient current abatement efforts are perceived to be, the higher the desired use of energy policies. The difference between political groups *G* is not significant (the difference between group 1 and 4 is significant at the 9 percent level). However, we note that the ranking of the sample parameters for the groups coincides with prior impressions of the ranking.

Table 6: Effects of attitude and political group on the prior evaluation, average data over policies.

Testing of factors		Parameter estimates		
Factor	p-value	Variable	Estimate	p-value
G	0.30	Constant	0.70	0.28
A	0.002	*G* =1 (Center)	0.66	0.09
C	0.000	*G* =2 (Labor)	0.45	0.14
		G =3 (Other)	0.13	0.80
		G =4 (Conserv.)	0	
		A	0.23	0.002
		C	0.57	0.000

Note: *N*=77, R^2=0.54, p-value model 0.000.

Then we use Equation 10 to test the effects of political group and attitude on the net effect of experiential data on desired utilization of policies. Table 7 shows that it is only the grand mean that is significantly different from zero. There is no effect of the degree of prior certainty *C*, attitude *A* does not matter, and there is no difference between political groups *G*. Hence, we conclude that the diffusion effect is not sensitive to the attitude towards the climate problem, nor is it sensitive to political group. Measured along these two dimensions, our findings could be generalized.

Table 7: Effects of attitude and political group on the net effect of experiential data (diffusion), average data over policies.

Testing of factors		Parameter estimates		
Factor	p-value	Variable	Estimate	p-value
G	0.85	Grand Mean	0.58	0.000
A	0.45	*G* =1 (Center)	0.15	0.61
C	0.71	*G* =2 (Labor)	0.12	0.60
		G =3 (Other)	-0.17	0.65
		G =4 (Conserv.)	0	
		A	-0.04	0.45
		C	-0.02	0.71

Note: N=77, R^2=0.018, p-value model 0.94.

Finally, we compare reported weights on different policy attributes to similar weights found in a survey we have made among civil servants working with energy- and environmental policy making[6]. Since the two investigations did not present identical sets of attributes to the respondents, we compare only for the common attributes. For each of the studies, the common attributes are assumed to make up 100 percent of the answers, hence Table 8 present relative weights within the subsets.

Table 8: Attributes that are reported to be weighted when evaluating policies, percent.

	Sample of students	Sample of civil servants
Fairness	44	36
Cost effectiveness	22	36
Uncertainty	20	9
Adjustment costs	11	15
Popularity	3	3

Note: Maximum number of nominations per subject is 3. The total number of nominations among civil servants is 59 and among students it is 190.

From the table it seems that reported attributes for our sample of students are not very different from those reported by civil servants. The ranking of attributes only differ for uncertainty and adjustment costs. To the extent that such self-reports are indicators for how decisions are made, the result is reassuring for the generality of our findings.

6 Respondents were recruited from the Norwegian departments of the environment and of finance.

7. CONCLUSIONS

A questionnaire to students was used to study the basic information treatment underlying diffusion of energy policies between nations. The questions were framed to mimic a natural reasoning about the desired use of such policies. First the respondents evaluated five policies in light of prior information, next the policies were evaluated in light of experiential data from other countries. The difference between the evaluations represents the diffusion effect, i.e. the effect of experiential data.

Consistent with the empirical diffusion literature we find that reported certainty of policy effects is related to reported understanding (complexity) of the policy. We find prior evaluations to be consistent with the expected utility theory. Subjects behave as if they are risk averse. We also find that experiential information has a statistically significant effect on posterior evaluations, i.e. we find a diffusion effect consistent with findings in the empirical diffusion literature. Moreover, the diffusion effect is found to decline with geographical and/or cultural distance between the experiencing nation and the home country, again consistent with the diffusion literature.

Our findings are not consistent with economic theory of diffusion, which assumes information updating by the use of Bayes theorem. According to this theory, the diffusion effect should be highly dependent on the uncertainty of prior information. The more uncertain, the larger effect of experiential information of a given quality. Our observation of the effect of prior uncertainty is significantly lower than a calculated benchmark for this effect. In fact, we find the effect of prior uncertainty not to be significantly different from zero. This favours an alternative hypothesis based on heuristics from cognitive psychology. We postulate that subjects anchor on their prior estimate of expected utility or desired use of a policy. Next they adjust this estimate according to how representative the experiencing country is of the home country. This seems a likely approach to simplify the highly complex problem of finding posterior expected utilities when information is updated according to Bayes theorem. In fact, the case of diffusion represents a more complex situation than those having been studied extensively in cognitive psychology and in economics. Subjects not only have to deal with probabilities of single outcomes, they have to deal with entire distributions. Hence, the need for simplification seems even stronger than in earlier experiments, and therefore the result seems even more likely.

Can the results be generalized to other groups than students and to the actual problem of choosing energy policies in democracies? Data show that the students are representative of the population at large with respect to attitude towards the climate problem and with respect to the distribution on political groups. Furthermore, our test of students indicate that attitude and political party cannot be used to predict diffusion effects. Reported weights on policy attributes are quite similar to what has been reported by civil servants working with climate policies. However, these tests do not rule out the need for further research on the generality of our findings. Will the diffusion effect vary with subject position and prior knowledge, with education, with financial incentives, with possibilities for learning, and with different framings?

Our findings have implications for the theory of diffusion. An important point in diffusion theory has been to explain the difference between (exponential) media-diffusion and the sigmoid growth pattern typically observed in the diffusion literature. Stoneman (1981) and Oren and Schwartz (1988) deduce sigmoid growth for the case when information is updated according to Bayes theorem. Hence, our findings are not needed for this prediction. However, the considerable under-valuation of experiential information in the case of low prior certainty about effects, is likely to have a significant effect on the speed of diffusion and possibly also on the exact shape of the diffusion pattern. In the case of considerable uncertainty, experiential data from more than one neighbouring country would be needed to get the equivalent effect of that predicted by Bayes theorem. It is an interesting theme for further research to detail the implications for the diffusion pattern. Similarly, there might be interesting implications for economic theory, which often relies on effective learning between market actors.

The diffusion effects we find for energy policies, add to earlier empirical findings of policy diffusion. The tendency for policies to spread, implies that experimentation with new policies could be seen as a global public good. Just as national governments support R&D in individual firms, all nations or groups of nations should support experimentation with promising policies in individual countries. If a new policy to curtail CO_2-emissions proves to be cost effective, it is likely to spread to other countries. In turn, lower costs could lead to higher goals and lower global CO_2-emissions in the long run. If so, the benefits would feed back to the innovating nation, which would see larger effects of its initial policy effort than the strict national emission reductions.

We have focused on treatment of information and have left out network effects. In reality, diffusion depends on media channels and networks. Just as experimentation with new policies could be seen as a global public good, the provisions of information about policy experiences is also a public good. Public information about the appropriateness (representativeness) of other nations as a testing ground for home country policies, is also needed. Finally, and probably most difficult, information is needed to prevent that uncertain actors rely too heavily on the representativeness heuristic when adjusting prior estimates of expected utility in light of experiential data.

REFERENCES

Berry, F.S. (1994). "Innovation in Public Management: The Adoption of Strategic Planning." *Public Administration Review* **54**(4):322-330.

Camerer, C. (1995). "Individual Decision Making." in *The Handbook of Experimental Economics*, edited by John H. Kagel and Alvin E. Roth. Princeton: Princeton University Press.

Edwards, W. (1968, 1982). "Conservatism in human information processing." Pp. 359-369 in *Judgment under uncertainty: Heuristics and biases*, edited by P. Slovic and A. Tversky D. Kahneman: Cambridge Univ. Press.

Fishbein, M., and Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Kahneman, D., and Tversky, A. (1979). "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* **47**(2, March 1979):263-291.

Karvonen, L. (1981). "Med vårt västra grannland som förebild. En undersökning av policy diffusion från Sverige till Finland." . Åbo: Åbo Akademi.

Moxnes, E., Greve, A., Heijden, E.v.d., and Singh, B. (1996). "Spredning av miljø- og energipolitikk over landegrenser." SNF-rapport 73/96 . Bergen: SNF.

Oren, S.S., and Schwartz, R.G. (1988). "Diffusion of New Products in Risk-Sensitive Markets." *Journal of Forecasting* **7**(4):273-287.

Rogers, E.M. (1995). *Diffusion of innovations*. New York: The Free Press.

Smith, J.D., and Glick, H.R. (1995). "The right to die: a cross-national analysis of agenda setting and innovation." *Environment and Planning C: Government and Policy* **13**:479-501.

Stoneman, P. (1981). "Intra-firm Diffusion, Bayesian Learning and Profitability." *Economic Journal* **91**:375-388.

Tsur, Y., Sternberg, M., and Hochman, E. (1990). "Dynamic Modelling of Innovation Process Adoption with Risk Aversion and Learning." *Oxford Economic Papers* **42**(2):336-355.

Tversky, A., and Kahneman, D. (1974). "Judgment under Uncertainty: Heuristics and Biases." *Science* **185**(Sept.):1124-1131.

Valente, T.W. (1995). *Network models of the diffusion of innovations*. Cresskill, New Jersey: Hampton Press, Inc.

Walker, J. (1971). "Innovation in State Policies." Pp. 358-381 in *Politics in the American States: A Comparative Analysis*, edited by Herbert Jacob and Kenneth N. Vines. Boston: Little Brown.