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Explaining voter turnout patterns: An information theory*

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Abstract. Voting research is rich in empirical regularities yet a parsimonious theory of voter turnout that can match the facts has proven to be elusive. This paper argues that voter turnout patterns can be explained by extending the traditional rational voter model to include limited information. A model is presented in which utility-maximizing consumers receive higher payoffs from voting the more confident they are of their vote choice. The model provides an explanation for the most important cross-sectional voter turnout patterns. In addition, it suggests a novel explanation for the post-1960 decline in U.S. participation.

1. Introduction

Voting research is rich in empirical regularities yet a parsimonious theory of voter turnout has proven to be elusive. Early attempts to explain why people vote were based on the so-called social-psychological studies, which started with the idea that people vote if they develop the appropriate mental inclinations, for example, if they have a sense of citizen duty.[1] This approach foundered when it became apparent that measured political attitudes were unstable, and their relation to participation varied over time (Nie, Verba and Petrocik, 1979; Aldrich and Simon, 1986).

The social-psychological approach was supplanted, to a large extent, by the rational voter approach.[2] Citizens are assumed to be rational, meaning they vote if the benefit exceeds the cost. In the popular formulation of Riker and Ordeshook (1968), if P is the probability of casting a decisive vote, B is the expected benefit of swinging the election, D is the consumption benefit to voting, and C is the cost of voting, then a person votes if

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$$PB + D > C. \quad (1)$$

Equation (1) is a tautology, conceptually constructive but not a useful theory of voter turnout in itself. A useful theory comes from fleshing out the equation. One particularly successful line of research focused on the C term, identifying voting costs arising from the need to register. This research showed that a healthy amount of voter turnout can be explained by factors such as registration laws, poll hours, and poll taxes (Wolfinger and Rosenstone, 1980; Filer, Kenny and Morton, 1991).

However, the rational voter approach has met with less success in explaining correlations that do not appear to be related to voting costs. A list of well-documented correlations would include the following.[3]

1. Campaign spending increases voter turnout.
2. People who are contacted by campaign workers prior to an election are more likely to vote.
3. Public employees and farm owners are more likely to vote; farm laborers are less likely to vote.
4. Married people are more likely to vote.
5. A person's level of education is positively correlated with her probability of voting.
6. People who recently moved are less likely to vote.
7. A person's age is positively correlated with her probability of voting, other things equal.

Various explanations have been proposed for these correlations, but in a piecemeal fashion. There has been little progress incorporating them into a common theoretical structure.

In this paper, I wish to suggest that the traditional rational voter theory can explain all of these regularities, and more, by explicitly embedding information in the model. Downs (1957) devoted four chapters to information, and there have been many allusions in the voting literature to an information approach (for example, Wolfinger and Rosenstone, 1980; Stigler, 1975; Tollison, Crain and Pautler, 1975; Settle and Abrams, 1976), but I believe this paper is the first detailed investigation of the logical and empirical implications of such an approach for voter turnout.

The basic intuition for the information theory comes from two observations. First, most citizens are predisposed to vote. Surveys consistently show that roughly 90 percent of Americans believe they should vote even if their preferred candidate is certain to lose (Brody, 1978). Second, some citizens abstain because they are unable to evaluate the candidates. Many citizens who go to the polls leave part of their ballot blank, typically for obscure local races. One

important reason is that they do not know anything about the candidates or issues in these races. Citizens who do not even go to the polls sometimes explain that they are too uninformed about the candidates to vote. More systematically, Palfrey and Poole (1987) reported a positive correlation between the amount of information a person had and her probability of voting in the 1980 presidential election.

With this as motivation, the paper offers a simple economic model of voter turnout. The theory takes as given that each citizen is predisposed to vote, and then focuses on how information can lead some to follow through on this inclination and others to abstain. In the model, people who end up with too little information to determine which candidate to vote for are more likely to abstain – rather than cast an ignorant vote, they do not vote at all. Such behavior is shown to be rational from the viewpoint of conventional benefit-cost analysis, and it can be given a consumption motivation as well. The main insight of the model is that even if people believe it is their duty to vote, rational citizens abstain if they feel unable to evaluate the choices. Holding constant the basic inclination to vote, then, variations in turnout can be explained by variations in how informed citizens are.

The mechanics of the model can be summarized as follows. In order for a person to assess which candidate she prefers, she needs to know what policies each candidate plans to implement if elected, and what are the likely consequences of the policies. Her information and knowledge about these things are always incomplete. This implies that if she votes for Candidate 1 there is a possibility that she would have preferred to vote for Candidate 2 if she had perfect information. If the probability that she is making the right voting decision is denoted φ, then it is straightforward to show that B in equation (1) is increasing in φ. Roughly speaking, the value of changing the election outcome is higher when the voter is more confident that she is electing the right candidate. As φ rises, then, she is more likely to vote. The value of φ is shown to be increasing in information about candidates and knowledge about how candidates map into outcomes. Given this link between information and the benefit to voting, turnout can be analyzed as a familiar consumer demand problem: what are the prices that determine how much information a person has?

I believe that one reason the information theory is a particularly attractive theory of voter turnout is its ability to explain most of the empirical regularities identified by previous research. To make this clear, the paper discusses at some length how the key correlations can be interpreted as information effects. For example, campaign expenditure and personal contact provide inexpensive information. Public employees and farm owners interact frequently with the government, giving them cheaper access to information. Married people enjoy economies of scale in information acquisition. Education and age bring knowledge that is useful in processing information. Long time residents in a

community have better contextual knowledge to evaluate the local impact of policies. The usual price effects imply that these factors lead people to be better informed and hence more likely to vote. In addition to its ability to organize the facts we know, the information theory yields a number of new potentially refutable implications about voter turnout.

A novel consequence of the treatment of information in this paper is that even if a person believes it is her duty to vote, she may abstain if she is not confident about making the right choice. This suggests a new interpretation of the decline in U.S. voter participation since 1960. Explaining this decline has posed a troublesome challenge to the rational voter approach. The crux of the argument is that beginning in 1960 the electorate's stock of contextual knowledge underwent a rapid depreciation due to political turbulence, in particular, the civil rights movement and Vietnam. Roughly speaking, people became less certain about how the political world works. This made them less confident of their ability to predict the outcome from election of a particular candidate or implementation of a particular policy and consequently less likely to vote. In short, the information theory suggests that uncertainty about who to vote for may have been a key factor in driving down turnout after 1960. Three fragmentary pieces of evidence consistent with this explanation are offered: (i) U.S. turnout was low in 1932, in the midst of another turbulent period, (ii) turnout in Canada, which did not undergo the U.S. traumas, has not declined since 1960, and (iii) surveys indicate a dramatic shift in the population's attitudes towards politics, parties, and governments beginning with the 1964 election.

It may help avoid confusion to note that this paper does not address the question why anyone should vote in the first place given that one vote cannot change the election outcome. This is an interesting question that has been the subject of a great deal of research attention. As noted above, I assume that people have a basic (psychological?) preference to vote and focus on the factors that affect whether citizens translate this preference into action. This is the standard economic approach: consumers are assumed to have a basic desire for chocolate (for example) and the theoretical task is to explain why some end up eating chocolate and others eat something else. Thus, one could say that the paper provides a theory of turnout "at the margin". This research approach is reflected in the title of the paper, which stresses the objective of explaining the *patterns* of turnout, not the very existence of turnout.

The next section develops the model. A review of existing theories beyond what is noted above is not provided as many are available already (for example, Aldrich and Simon, 1986; Grofman, 1987). The third section discusses the cross-sectional implications of the model. The fourth section offers an explanation for the decline in U.S. voter participation since 1960 in terms of the information theory. The last section summarizes and gives concluding remarks.

2. The model

The modeling strategy is in the spirit of Stigler and Becker (1977). Stigler and Becker made a compelling case for maintaining an assumption that preferences at a fundamental level are constant across time and identical across people. They argued by example that intuitive economic models with stable preferences can be formulated consistent with phenomena commonly explained by differences in tastes. Their method was to add a carefully chosen household production function to the basic economic preference structure (more is preferred to less). In this way behavior can be explained in terms of price and income effects, the engines of economic analysis. The approach of this paper is exactly to add a small amount of structure to individual preferences, and then use variations in prices to explain differences in behavior. Although the theory depends on augmented preferences, it assumes that all individuals have the same preferences and these preferences are stable over time.

2.1. Certainty and the expected benefit of a decisive vote

Consider an election with two possible outcomes. Call them "Candidate 1 wins" and "Candidate 2 wins." Let V(1) and V(2) be the utilities a person receives if Candidate 1 wins and Candidate 2 wins, respectively. These are taken to include all forms of payoffs, from government services the individual receives to services to others that she likes for altruistic reasons. It is useful to suppose that these payoffs are determined according to $V(t) = MZ(t)$ where Z(t) represents the characteristics of Candidate t (policies, personal abilities, and so on) and M is the structure of the world, that is, the way candidates map into payoffs. One might think of M as "the model" and Z as the inputs.

Define $Z = Z(1) - Z(2)$ and suppose that $M \in \{-1,1\}$ and $Z \in \{-1,1\}$. Then a voter favors Candidate 1 if $MZ = 1$ and Candidate 2 if $MZ = -1$. The problem confronting a citizen is that neither M nor Z can be observed directly. A voter can never be certain whether $MZ = 1$ or $MZ = -1$ so she can never be certain of supporting the right candidate.

This formulation implies that if a person's vote decides the election, her net payoff is 1 if she chooses the right candidate and -1 if she chooses the wrong candidate. Leaving aside for the moment its exact composition, let I represent the information a person has about M and Z. The probability that Candidate 1 is best can be written $\Pr(MZ = 1 \mid I)$. The probability that Candidate 2 is best is $\Pr(MZ = -1 \mid I)$. If she goes to the polls, she casts her vote for Candidate 1 if $\Pr(MZ = 1 \mid I) > 0.5$; otherwise she votes for Candidate 2. Then the probability that the candidate who receives her vote is in fact the right candidate for her is

$$\varphi = \max \{\Pr(MZ=1|I), \Pr(MZ=-1|I)\}. \quad (2)$$

This is called her "certainty" or "confidence" about her vote. Note that φ takes on values between 0.5 and 1. If $\varphi = 1$ then she is absolutely certain that she is supporting the right candidate, while if $\varphi = 0.5$ then she is completely uninformed, in effect, she is just randomizing.[4]

A more structured formulation of equation (1) can be developed by noting that the expected benefit to casting a decisive vote is

$$B = \varphi \times (1) + (1-\varphi) \times (-1) = 2\varphi - 1.$$

Then for a given election, a person's utility if she votes is $P(2\varphi-1) + D - C$ and her utility if she abstains is zero. It follows that the benefit to voting is higher when φ is high, which captures the intuition that uncertain voters are hesitant to vote. To reduce notation, hereafter it is assumed that $D = 0$.

2.2. An aside on consumption voting

This model is a conventional rational voter model in most respects. As such it is subject to the criticism that P in equation (1) is theoretically and empirically equal to zero (Chamberlain and Rothschild, 1981; Palfrey and Rosenthal, 1985; Matsusaka, 1993; Matsusaka and Palda, 1993). If $P = 0$ then the rational voter theory collapses to a seemingly non-refutable statement that people vote if $D > C$.

One of the strengths of the information approach is that although it is developed in this paper as an investment theory by adding structure to the PB term, it can also be formulated as a consumption theory by adding structure to the D term. Its validity, then, does not hinge on the debate over whether or not P is equal to zero. Furthermore, the information approach is not necessarily at odds with recent attempts to move away from investment voting theories toward non-investment theories (for example, Glazer, 1987; Uhlaner, 1989; Morton, 1991; Knack, 1992).

The theory can be cast as a consumption theory by assuming that D is increasing in φ. That is, people "feel better" about voting when they are confident of voting for the right candidate. It is possible to motivate such preferences with the psychological idea of cognitive consistency (the classic reference is Festinger, 1957). In their analysis of the economics of cognitive dissonance, Akerlof and Dickens (1982: 308) noted that "(i)n practice most cognitive dissonance reactions stem from peoples' view of themselves as 'smart, nice people.'" Suppose most people view themselves as "smart, nice people" and that being a "smart, nice person" requires one to vote responsibly. Then when a

person is unable to make an informed choice, it creates a cognitive dissonance, what might be called a negative utility. As a result, the consumption payoff to an informed vote exceeds the payoff to an uninformed vote.[5]

2.3. Information and knowledge

It remains to specify how a citizen forms φ. Let $k \in [0,1]$ be the person's prior probability that $M = 1$. This variable indicates her contextual knowledge. If $k = 0.5$ she has no contextual knowledge while if $k = 1$ or $k = 0$ she knows the model of the world perfectly. Because M is a parameter of individual utility functions, it may be that $M = 1$ for some people and $M = -1$ for others. Only the case where $k \geq 0.5$ is discussed below; in this specification increases in knowledge are measured with an increase in k. The other case is analytically the same, except that an increase in knowledge is represented by a decrease in k.

Let the prior probability that $Z = 1$ be 0.5, that is, suppose a person has no idea initially which candidate is better. Before the election she receives a signal $S \in \{S_H, S_L\}$. Read these as a high (S_H) or a low (S_L) signal. The probability of a high signal is π if $Z = 1$ in truth and $1 - \pi$ if $Z = -1$, where $\pi = \pi(i) > 0.5$. Thus, if $Z = 1$ then she is more likely to receive a high signal and if $Z = -1$ then she is more likely to receive a low signal. The variable i measures how much information she acquires. The more information she acquires, the more reliable is her signal about Z: $\partial\pi/\partial i > 0$. It is convenient to assume that π is concave.

Then the definition of φ in equation (2) can be restated as follows, where $I = \{S, \pi(i), k\}$:

$$\varphi(S,\pi(i),k) = \max \{\Pr(MZ = 1 \mid S,\pi(i),k), \Pr(MZ = -1 \mid S,\pi(i),k)\}.$$

A citizen's certainty depends on her signal, S, her information, i (through π), and her knowledge, k. The following proposition gives a closed-form statement of φ in terms of the information fundamentals. The proofs of all propositions are given in the appendix.

Proposition 1. $\varphi(S,\pi,k) = k\pi + (1-k)(1-\pi)$.

Because the priors on Z are even, φ does not depend on the actual signal received. That is, a high signal gives a person the same degree of confidence in her vote for Candidate 1 as a low signal gives in her vote for Candidate 2. Hereafter, the S term is suppressed from the φ function.

Note that $\partial\varphi/\partial i \equiv \varphi_i = (2k-1)\pi' > 0$. If i increases then the accuracy of the signal increases, and the probability of casting of a bad vote declines. Also

note that $\varphi_k = 2\pi - 1 > 0$. More knowledge makes a person more confident she understands the model of the world, M, which makes her more confident of her voting decision. Finally, note that $\varphi_{ik} = 2\pi' > 0$. If a person's knowledge increases, she makes better use of a given amount of information.

In simple terms, the model posits that a person's confidence depends on her general knowledge, k, which gives insight into the true value of M, and raw information, i, which helps to understand Z by delivering a clearer signal. This breakdown of information echoes Downs (1957: 208): "The knowledge (a person) requires is contextual knowledge as well as information."

In practice it is not always clear where to draw a line between k and i. One might think of i as media coverage of campaigns and k as accumulated learning about history, civics, politics, and economics. The main formal distinction is that i represents endogenously determined information and k is exogenous information.

Recall that a person votes if $P(2\varphi-1) > C$. If C is a random variable then the probability of voting is increasing in φ. This implies that the people who are most certain of their choice are the most likely to vote. So, for example, a voter at the polls who notices a race in which she has never heard of any of the candidates ($i=0$; $\pi \approx 0.5$) has a very noisy estimate of Z, a low value of φ, and is unlikely to vote. In fact, survey research indicates that people who have a difficulty distinguishing candidates on the issues are unlikely to vote (Zipp, 1985; Sigelman et al., 1985). To take a different example, suppose a person knows that judicial Candidate 1 is a strict constructionist while Candidate 2 believes judges should interpret the constitution liberally. But suppose she knows nothing about the role of courts in the American political system ($k=0.5$). Then although she has plenty of raw information (suppose she knows Z with certainty), her understanding of what the information means is weak (her estimate of M is noisy). Her confidence in her ability to cast the right vote is low ($\varphi \approx 0.5$), and she is likely to abstain. In short, raw information is worthless without a means to interpret it, and contextual knowledge is useless in evaluating candidates without current data as inputs.

2.4. Individual maximization

In order to investigate the effect of prices on the purchase of information, there must be a second good in the model to purchase. Call this good x. Then a person can use her income, $y > 0$, to purchase information, i, or the consumption good, x. The budget constraint is $y = qi + x$, where the price of x is normalized to 1. The price of i in terms of x is q, and income is denoted in units of good x.

In addition to deciding how much i and x to purchase, a person must decide whether or not to vote. For analytical simplicity I assume she chooses i and

x before C is known. One way to think about this is that a person accumulates information in the course of a campaign and then on the day of the election observes the weather, how healthy she feels, and so on, and decides to vote or abstain. This view of voting fits with what appears to be a high degree of unpredictability in the turnout decision (Matsusaka and Palda, 1992b).

A person receives utility from the election and from consumption of x. Let utility from x be a concave function u(x).

When she decides how much information to acquire, she is concerned with her expected election payoff, where her actual signal and voting cost are unknown. Her utility from the election is the weighted average of her payoff if she votes, $P(2\varphi-1) - C$, and her payoff if she abstains, zero. The weights are equal to the probability of voting and the probability of abstaining. The election payoff depends on how much information she acquires as well as whether or not she votes. Denote the expected election utility $e(\pi(i),k)$. It does not depend on S or C because it is an expectation over the distributions of these variables. Let C be distributed uniformly over [0,1]. Then the function e takes a particularly convenient form:

Proposition 2. $e(\pi(i),k) = 0.5P^2(2\varphi-1)^2$.

Proposition 2 indicates that a person's expected utility from an election is increasing in φ. There are two forces driving this. First, as φ increases a person's utility contingent on voting goes up. Second, as φ increases a person becomes more likely to vote.

In all, the cons mer's problem is

$$\max_{i,x} u(x) + e(\pi(i),k) \qquad \text{subject to } y = qi + x.$$

3. Cross-sectional implications: Matching the facts

The maximization problem is a straightforward calculus problem. From the first order conditions for x and i and the budget constraint, the equilibrium is

$$qu'(y-qi) = 2P^2\pi'(2\varphi-1)\varphi_\pi. \tag{3}$$

This is the familiar condition that the marginal utility of a dollar spent on x equals the marginal utility of a dollar spent on i. In this study the quantities of x and i are not particularly of interest; it is the equilibrium probability of voting that is of concern. Indicate the solution to equation (3) as i* and define $\Pr(\text{person votes}) = \alpha^* = P(2\varphi(\pi(i^*),k)-1)$. Comparative statics on equation

(3) show how i* varies with q, k, and y, and thus how the equilibrium probability of voting, α^*, responds to changes in these parameters.

The rest of this section explores the comparative statics. After each derivation, an attempt is made to show how the proposition can account for the important correlations. There are alternative explanations for several correlations; when possible, I cite evidence or suggest tests that can distinguish between them. A number of new implications are also developed.

3.1. The price of information

The first result is that a decline in the price of raw information leads to an increase in turnout.

Proposition 3. $\partial\alpha^*/\partial q < 0$.

The reasoning behind this result is fairly transparent. Note that $e(\pi(i),k)$ is increasing in i. Information increases a person's confidence in her decision and hence her payoff to voting. As the price of i falls relative to the price of x, the substitution effect induces the consumer to purchase more information. With more information, she is more certain of her voting decision, her benefit from voting increases, and she is more likely to vote.

The first stylized fact consistent with this proposition is the positive relation between voter turnout and the level of campaign spending by candidates and parties. This relation holds even after controlling for the closeness of a race. The correlation has been found at the aggregate level – electoral districts with high spending have high turnout rates – and at the survey level – the more spending in a person's district, the more likely she is to vote; and it has been demonstrated to hold in the United States, Canada, and Britain.

A significant fraction of campaign expenditure is used to advertise. Advertising effectively reduces the price of information. It may even result in some information being costly to avoid ($q<0$). Television commercials fit into this category. According to the model, when the price of information is low, the fraction of people who vote is high. An interesting corollary to this implication is that turnout declines if campaign spending limits are implemented.

One objection to this interpretation might be to question whether campaign advertising really provides any information to voters. Campaign advertising is often criticized for being biased or for trying to appeal to the electorate's "baser" instincts. However, biased information is not useless information, although the voter has to clean it mentally, and even a commercial that appeals to racism provides information to both racists and their opponents about which candidate to support. Wattenberg (1984) found that voters were more

willing to identify the issue positions of congressional candidates (candidates were more "salient") in districts with high levels of media advertising.

An alternative explanation is that the correlation between campaign expenditure and turnout is spurious. It has been suggested that people are induced to vote by pressure from "elites", and that high levels of expenditure coincide with high levels of elite mobilization (Cox and Munger, 1989). Because one might expect political pressure to be delivered by party workers, the strength of this argument is reduced to some extent by the finding that spending has a positive effect on the probability of voting even after controlling for whether or not a person is contacted by party officials (Matsusaka and Palda, 1992a). A more definite way to untangle these possibilities (which has yet to be done) is to look at the effects of different kinds of campaign expenditure on turnout. The information theory predicts a correlation between *advertising* expenditure and voter turnout, while the elite mobilization theory predicts that *administrative* expenditure is correlated with participation.

A different way to address the role of media is to estimate the effect on turnout of press, radio, and television. Relative to a situation where only print media are available, it is plausible to suppose that q is lower if radio also becomes available, and lower still if television becomes available. Settle and Abrams (1976) studied turnout in U.S. presidential elections from 1868 to 1972 and found that participation increased when radio was introduced and increased again when television was introduced, controlling for a number of other factors. Matsusaka (1992) found the same pattern in a study of voting on California ballot propositions from 1912 to 1989.

A second stylized fact is that people contacted by campaign workers prior to an election, either in person or by phone, are more likely to vote. As with advertising, such campaign activities are likely to reduce the cost of information to the contacted individual, and increase her probability of voting. Another, not incompatible, explanation of this correlation is that people who are contacted come under greater social pressure to vote. However, Matsusaka and Palda (1992a) found that campaign contact had little effect on the turnout of voters who had already decided which candidate to support. If contact stimulates participation with pressure, it should have similar effects on informed and uninformed citizens.

Proposition 3 suggests an explanation for the high turnout rate of public employees and farm owners and managers. These people have in common extensive dealings with the government. Such interaction is likely to provide them with low cost information about candidates and parties, leading to a high propensity to vote. Consistent with this is the fact that farm laborers, who have limited interaction with government, have relatively low part cipation rates. The model does not offer an easy explanation for the high turnout rates of clerical and sales workers.

A fourth empirical regularity is that married people are more likely to vote, other things held constant. The model can explain this by noting that the average price of information for a married person is likely to be lower than for a single person (see also Knack, 1992; Filer and Morton, 1993). If the cost of transmitting information between a husband and wife is less than the price of acquiring information outside the home then there is an information scale economy within a married household. For example, if transmission costs are zero, then the effective average price of information for a married person is $q/2$. Information transmission between couples is likely to be relatively inexpensive because they are in frequent contact, have similar value systems, and tend to trust each other. Individuals in other social groups, for example, churches, unions, and clubs, are likely to enjoy economies of scale in information acquisition as well, for much the same reasons as married people, which is predicted to make them more likely to vote. The information explanation also has the virtue of being consistent with the observation that married people tend to be joint voters and non-voters (Straits, 1990). A social pressure theory can explain why spouses vote jointly, but not why they are more likely to vote overall.

Proposition 3 also provides an explanation for several voting regularities that are not listed in the introduction. One frequently-observed pattern of behavior is that the number of votes cast declines moving down a ballot. Typically, the presidential election receives the most votes followed by gubernatorial and senate elections. At the bottom of the ballot, receiving the fewest votes, are obscure races (for example, school board member, port commissioner, city attorney). Observation suggests that it is less expensive to acquire information about national and statewide races than local races. One reason is that expenditure tends to be greater in the more prominent races. Another reason is that because media serve geographically dispersed areas, they are unlikely to give extensive coverage to races that affect only a subset of their customers. For example, the television networks can be confident that all their viewers are concerned with the presidential election, but only a few are interested in a given county or city election.

Turnout in primary elections is generally lower than in general elections. Exceptions are local elections in one-party areas (for example, in the city of Chicago or in the Old South). It is more expensive for a citizen to acquire information in primary elections: many of the candidates are obscure, campaign spending is low, and media coverage is reduced.

Filer, Kenny and Morton (1993) showed that in presidential elections turnout is higher in candidates' home states in other states. This can be explained by the fact that people in the candidates' home states are more familiar with the local candidate (have more information) than people in other states.

Proposition 3 also provides a testable implication that appears to go against

the conventional wisdom. It predicts that turnout is higher when an incumbent is on the ballot. The reason is that voters have more information about incumbents, other things equal. A proper test of this implication must control for campaign expenditure because an open seat may attract large amounts of campaign spending, which itself drives up turnout.

3.2. Knowledge

Proposition 4. $\partial\alpha^*/\partial k > 0$.

Proposition 4 says that a person is more likely to vote as her knowledge increases. The result is driven by two effects. The direct effect is that as a person acquires a better understanding of the model of the world, M, she becomes more confident of the conclusions she draws from a given amount of information. The indirect effect of knowledge is to increase the value of information, leading the citizen to purchase more. For both reasons, knowledgeable people tend to be more confident in their voting decision and more likely to vote.

A person's education level is likely to be correlated with her k. The model is thus consistent with the stylized fact that educated people are more likely to vote. This explanation stands in contrast to the explanation that education is a proxy for a person's socioeconomic status, which itself drives voting. Others have proposed that education leads to higher turnout by making it easier for a person to maneuver through the bureaucratic requirements of registration. This argument is undermined by the finding that education has a significant positive effect on voting in Canadian elections where registration is costless. An as-yet untested implication of the education-as-knowledge interpretation is that schooling which emphasizes models of the world (college) should increase participation more than education which develops job-specific skills (vocational-technical schools). On similar grounds, people who studied history, economics, political science, and so on, are predicted to vote more often than people who studied mathematics, engineering, literature, dance, art, and so on.

Propositions 3 and 4 provide an explanation why people who recently moved are less likely to vote. In the United States the need to re-register at one's new address – which may require gathering documentation, finding the registration office, and traveling to the site – accounts for this to some extent. However, Squire, Wolfinger and Glass (1987) found that the effect of mobility is not consistently related to ease of registration. And there is a mobility effect in Canada as well, where election officials go door-to-door to register people before each election, requiring no effort on a citizen's part to re-register.

The model suggests that two factors combine to reduce the turnout rate of recent movers. First, to the extent that the impact of policies varies across

geographical regions, a migrant suffers from limited knowledge about the model of the world. In addition, she may find it more expensive to acquire information until she can identify appropriate and reliable local suppliers. In terms of the model, a migrant experiences a fall in k and a rise in q, both of which reduce her probability of voting. An as-yet untested implication is that turnout by migrants falls more for local elections than national elections.

The seventh stylized fact, that voting increases with age, is also explicable in terms of knowledge. It is helpful here and below to develop an additional property of the model when a person receives signals about M. Suppose a person receives a signal $T \in \{T_H, T_L\}$ at regular intervals, say, once a year. This formulation is intended to capture the learning that takes place as a consequence of daily life. Let the probability of a high signal ($T = T_H$) be $\sigma > 0.5$ if $M = 1$ and $1 - \sigma$ if $M = -1$. A high signal confirms her priors. If k is a person's prior on $M = 1$ before receiving a signal, let $\hat{k}(T,k)$ be her probability estimate that $M = 1$ after receiving a signal T. Suppose the true model is $M = 1$ (the choice of true M is arbitrary). The next proposition states that the expected value of $\hat{k}$ is greater than k.

Proposition 5. $\Pr(T = T_H | M = 1)\hat{k}(T_H,k) + \Pr(T = T_L | M = 1)\hat{k}(T_L,k) > k.$

Proposition 5 implies that if $M = 1$ is the true model of the world, then a person's k rises over time. That is, beliefs converge over time to the truth. If initially $k < 0.5$ then a person's φ will fall as k approaches 0.5. Eventually, however, it will be the case that $k > 0.5$ and from that point on each successive signal will, on average, increase her φ.

According to the model, then, age exerts a positive effect on the probability of voting because older people have more knowledge (a higher k) and are more confident of their voting decision. Empirically, the effect of age diminishes over time. In the model, as successive signals arrive (as a person ages), k converges to 1, and the effect of subsequent signals (years) diminishes.

Proposition 5 suggests other as-yet untested implications of the model; they are not consequences of the model as developed but it is easy to see how they would follow from extensions. Suppose the model were to be generalized so that a person's priors about Z were different from 0.5. Assuming her priors reflected the true Z on average, then she would be more likely to vote. We expect people to use political parties to some degree when setting their priors. One implication is that turnout is lower in non-partisan elections and primaries than in other elections because party cues are unavailable.

3.3. Income

The following proposition completes the cross-sectional implications.

Proposition 6. $\partial\alpha^*/\partial y > 0$.

This proposition indicates that higher incomes do lead to higher participation, but only through an income effect. To the extent that high income is associated with a high cost of time, the effect of Proposition 6 is ameliorated. Thus the model is consistent with a weak positive relation between income and voting. Downs (1957: 273) made a similar argument. Filer, Kenny and Morton (1993) found a negative relation between income and turnout for low levels of income, but most studies have reported a positive relation across various ranges of income, although the relation is often statistically insignificant.

4. An application to declining U.S. voter participation

4.1. The basic issue

The issue addressed in this section is the well-known and much-maligned decline in voter turnout in U.S. presidential elections. As can be seen in Figure 1, turnout fell monotonically (except for 1984) from a postwar high of 62.8 percent in 1960 to a low of 50.3 percent in 1988.[6]

The fall in participation is especially puzzling because demographic and legal changes since 1950 would seem to favor *increased* turnout, based on the cross-sectional evidence.[7] The population's level of education has dramatically increased: in 1960 about 20 percent of the population attended college while by 1988 about 40 percent had some college education. Business cycle effects aside, real income per capita has also risen. The cohort of women who grew up around 1920 when female suffrage was in dispute has a low turnout rate – as time goes by the effect of this older cohort diminishes. Legal impediments to voting like the poll tax and literacy requirements that had the effect of disenfranchising the poor and especially blacks in the South were systematically dismantled in the 1960s and 1970s. The major events were the Twenty-Fourth Amendment in 1964 which barred the poll tax, the Voting Rights Act of 1965 which effectively removed literacy requirements, and the Voting Rights Act Amendments of 1970 which reduced residency requirements to no more than 30 days.

Before suggesting an explanation for the turnout decline in terms of the information theory, a few words on alternatives are in order. First, it can be seen in Figure 1 that the largest decline in turnout occurred in the 1972 election –

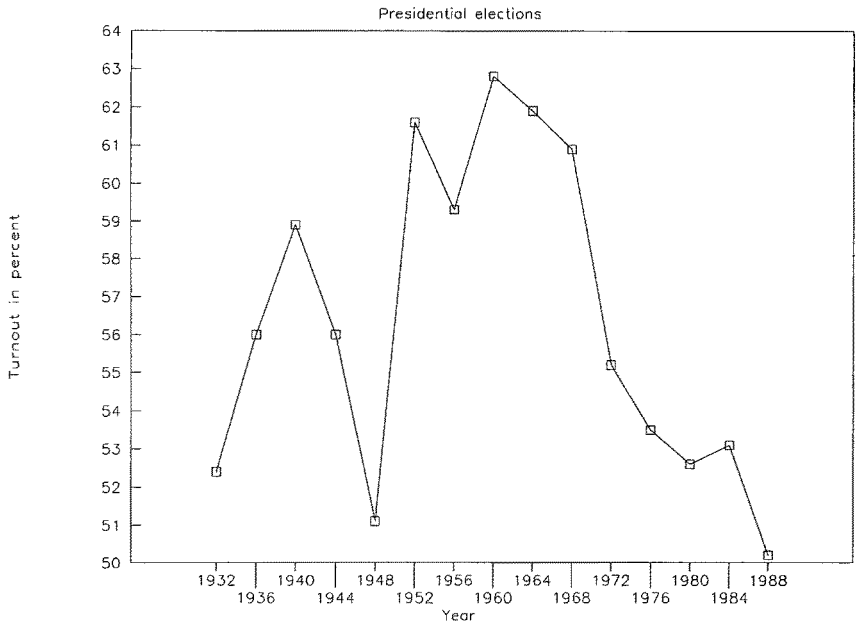

Figure 1. U.S. voter turnout, 1932–1988.

it fell 5.7 percent from 1968 – which was the first presidential election in which 18–20 year olds were allowed to vote. The participation rate of young voters is notoriously low, which contributed to the decline. However, Wolfinger and Rosenstone (1980) showed that the low turnout of 18–20 year olds can account for at most one-fourth of the 1972 decline.

Second, it is difficult to explain the decline in voter participation in terms of the distance between candidates or the closeness of the elections. According to some versions of the rational voter model, turnout should be high when candidates are far apart on the issues and when elections are close. The Goldwater-Johnson election in 1964 and the McGovern-Nixon election in 1972 were races where the candidates presented the electorate with a clear choice. Turnout in 1964 was just below the postwar peak of 1960, consistent with the prediction, but turnout in 1972, as mentioned above, was very low. It is of no help in these cases to appeal to the closeness of the elections because both were expected and turned out to be one-sided contests. Looking only at closeness, the Kennedy-Nixon election in 1960, the Carter-Ford election in 1976, and the Carter-Reagan election in 1980 were all expected to be close races. But although turnout in 1960 was the postwar high, consistent with the theory, it was extremely low in 1976 and 1980.

A third alternative explanation is that voters became discouraged, disillusioned, or cynical during the 1960–1976 period. There has been a decline since

1968 in measures of "political efficacy," which gives this explanation some plausibility. Roughly speaking, efficacy measures are constructed from the answers survey respondents give to questions about how responsive they think political and government organizations are to the people's interests. Still, trends in these variables cannot statistically account for more than a small part of the decline (Cassell and Luskin, 1988). Moreover, implicit in this argument is the notion that there is a link between cynicism and voting, which appears to contradict the cross-sectional evidence (Knack, 1992).

Although there have been numerous attempts to explain the decline in terms of conventional theories and variables, none have been entirely successful. This led Cassel and Luskin (1988: 1327) to conclude, "(m)ost of the post-1960 decline in turnout is still unexplained, and we shall have to do some hard thinking, then cast a wider net, to explain substantially more."

4.2. An explanation based on the information theory

The following property of the model motivates an explanation for the turnout decline based on the information theory.

Proposition 7. If $k > 0.5$, then $\hat{k}(T = T_L, k) < k$.

The proposition says that when a person who believes the model of the world is $M = 1$ (a person with $k > 0.5$) receives a signal to the contrary ($T = T_L$), she revises down her prior that $M = 1$. Put differently, she becomes less certain that her model of the world is correct. In effect, her knowledge falls. By Proposition 4, a decline in knowledge reduces φ and hence turnout.

With this in mind, an explanation for the turnout decline can be offered: between 1960 and 1976 U.S. citizens received a succession of signals suggesting that their model of the world was incorrect. This made them less confident of their ability to evaluate the consequences of policies and candidates, and less likely to vote.

The following quote (King, 1978: 2), taken from a book entirely devoted to changes in the American political system since 1960, gives a flavor of the pace of events and degree of change between 1960 and 1976.

> No one who lived through the period between the inauguration of John Kennedy and the inauguration of Jimmy Carter needs to be reminded that this was an enormously turbulent period. It was the period of the New Frontier and the Great Society, of the abortive invasion of the Bay of Pigs and Cuban missile crisis, of riots in the cities and unrest on campuses, of civil rights and women's rights, of the war in Vietnam, of America's rapproche-

> ment with China; a period in which one President was assassinated and another became the first American President ever driven from office. The period began with the American economy the strongest in the world and looking as though it would remain that way indefinitely; as it closed . . . its prospects seemed bleaker than at any time since before the Second World War.

Note that some of the more important events had the character of signals that challenged the prevailing model of the world. The civil rights movement in the early 1960s, with its vivid television images of fire hoses and police dogs being directed at nonviolent marchers, and the inner city riots in the late 1960s led to a dramatic change in the way many Americans perceived race relations in the country. Passage of the Voting Rights Act in 1965, which added many thousands of blacks to the voting rolls, suddenly shifted the political rules of the game throughout the South. The conflict in Vietnam called into question both the efficacy and appropriates of using American armed forces as foreign policy instruments; for some it also created ethical doubts about the country's leadership. The Watergate affair led to additional questions about the integrity of the country's highest officials.

On top of this turbulence, or perhaps because of it, the 1960s witnessed an abrupt pronounced reversal of party positions on racial issues. Prior to 1960, by longstanding tradition stretching back to the Civil War years, the Republican Party tended to favor more liberal racial policies than the Democratic Party. Since the late 1960s, these positions have been reversed. Carmines and Stimson (1989) documented this shift using roll-call votes in the U.S. Congress from 1945 to 1980. They found that Republican senators were substantially more liberal on racial issues in every year between 1945 and 1959. By 1965, the votes of Democratic senators were more liberal, and this pattern persisted every year through 1980, the end of the sample period. In the House, Republican votes were more liberal on racial issues for every year between 1945 and 1965, but by 1968 Democratic votes were more liberal and continued to be so throughout the rest of the sample period. Carmines and Stimson argued forcefully that race played a central role in the evolution of American politics over the last several decades. If this is correct, then it is likely that the transformation of party positions on racial issues contributed to the deterioration of the electorate's model of the world, for political partisanship has long been recognized as one of the most important cues used to make voting decisions.[8]

To summarize, the information theory suggests that between 1960 and 1976 Americans received information that called into question what they had come to believe was the model of the world. The most important of these "signals" originated from racial developments and the conflict in Vietnam. This depreciation of the model of the world was accentuated by a sudden transformation

of party positions on the central issue of race. As a group, Americans' k declined which made them less confident of their ability to evaluate candidates. This reduced their benefits from voting and fewer of them turned out.

Because k cannot be observed, there is no direct evidence whether people radically revised the model of the world they used to make political decisions over the 1960–1976 period. But we do have abundant survey evidence that suggests they did. The received wisdom on the behavior of measured political attitudes was nicely summarized in a survey by Aldrich and Simon (1986: 278–279).

> From the earliest national studies to about 1964, a great number of (attitudinal) variables seemed very stable. Party identification, for example, was in what Converse later called the "steady state" period. Trust in government was high. Efficacy of either the internal or external sort was high. And all three variables were quite stable in the aggregate ... (It was observed), beginning in the mid-1960s, that ... many of the long-term attitudes were showing aggregate change of sometimes alarming proportions ...

A change in the electorate's political attitudes is not the same things as a change in the electorate's model of the world. Nevertheless, it does not seem implausible to associate fluctuations in *attitudes* toward politics with fluctuations in *beliefs* about how politics works.

The decline in party affiliation as a reliable voting guide is also posited to have depreciated k. In addition to evidence of attitudinal flux, there is abundant evidence that the role of political parties in voting decisions has diminished since 1960s. For example, studying the period 1952–1980, Wattenberg (1984) reported that approximately 75 percent of the electorate identified themselves as either Democrats or Republicans (as opposed to Independents or apoliticals) from 1952 to 1964. By 1972, the number had fallen to 64 percent. Based on thermometer questions about the policy positions of the parties, Wattenberg also found a pronounced increase in the fraction of the population with strictly neutral (as opposed to positive or negative) views about both parties – the fraction rose from 16.8 percent in 1960 to 36.5 percent in 1980.

As this brief review of survey evidence suggests, there is some support for the hypothesis that k declined in the aggregate during the 1960s. The following collection of circumstantial evidence is also consistent with an information theory explanation of the turnout decline.

If the information theory is correct, we expect low turnout in other time periods when people received signals that challenged the model of the world. The Great Depression seems like a good example of such a period. First, contemporary accounts indicate that such a massive contraction of the economy was a great surprise to most people. Second, the contraction was followed by an

unprecedented expansion in the role of the federal government which suggests that people concluded their old limited-government model of the world was flawed.[9]

The information theory explanation predicts a low turnout in the Depression. Figure 1 shows that turnout in 1932, the depths of the Depression, was 52.4 percent, lower than any turnout rate in the post-1960 period except 1988. I have not found a reliable series for elections before 1932, although the approximate numbers I have seen suggest participation was even lower in the 1920s which does not appear to fit the explanation. Confounding matters is that fact that women achieved universal suffrage in 1920, which depressed turnout rates because many of them did not believe it was their place to vote or had not accumulated human capital relevant for participating in elections. The low turnout rate in the 1948 election is puzzling.

The "turbulence" that is hypothesized to have generated the confounding signals was specific to the United States. So the information provided by these signals should not have affected the model of the world used by citizens of other countries, like Canada. Moreover, Canadian political parties did not experience the secular changes and dramatic fluctuations that afflicted American parties (Clarke and Stewart, 1987). In other respects, demographically and culturally, Canada is similar to the United States. If the information theory explanation is correct, then we should not see a decline in Canadian voter turnout in the post-1960 period. If, in contrast, demographics in some way or another were driving the fall in U.S. turnout then we should observe falling participation in Canada as well. Figure 2 reports the turnout rates in Canadian national elections from 1898 to 1988, taken from various years of *Canada Yearbook*. Canada follows a parliamentary system, which is why the elections do not occur at regular intervals. As can be seen, there is no evident downward trend in turnout, which is the prediction of the information theory.

It should be emphasized that the information theory explanation for the turnout decline is fundamentally different than the cynicism explanation. According to the cynicism explanation, the electorate became psychologically detached from the political process, and skeptical about the basic value of voting. The information theory, on the other hand, suggests that most people continued wanting to vote, but abstentions increased because many did not feel capable of making a wise decision in the voting booth. The information theory appears to be more consistent with evidence that measure of citizen duty remained high and constant over the period of the decline (Brody, 1978). For example, the fraction of Americans who believed a person should vote even if her preferred candidate was certain to lose held at about 90 percent. The fraction of people who said it mattered to them (personally) whether or not they voted even though there were so many other voters in national elections also held at about 90 percent.[10]

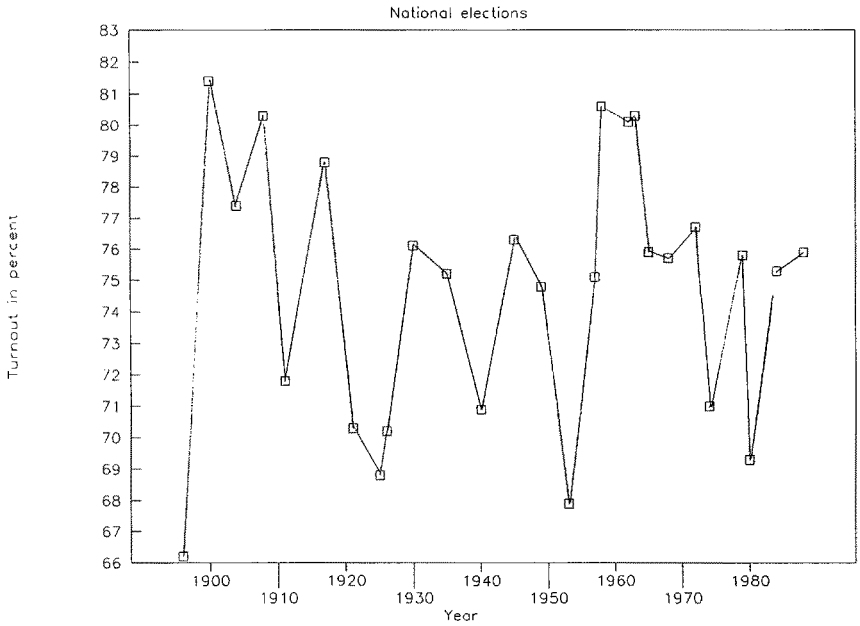

Figure 2. Canadian voter turnout, 1896–1988.

The information theory predicts that the decline in turnout should stop when the turbulence ends and then begin to climb upward again as people settle on a new model of the world. This is also different from the cynicism explanation. In fact, turnout in the 1976, 1980 and 1984 elections was roughly the same, with 1984 even showing a slight increase from 1980. The extremely low 50.2 percent turnout in 1988 does not fit the pattern. Preliminary estimates for the 1992 election indicate a continued upward trend.

The information theory also suggests some implications for which there is partial or no evidence at present. The signals were primarily national in character so there should be less of a turnout decline in state and local elections. A fall in k lowers the demand for i so there should be a reduced consumption of political information. Shaffer (1981) reported a decline in the number of people reading about election campaigns in the newspaper, from 46.4 percent in 1960 to 26.6 percent in 1976, but this may only reflect a shift into television. Knack (1992) reported a secular decline in the number of people who read a daily newspaper or watch an evening news program. Contradictory signals are likely to have the greatest effect on people with k's close to 0.5 – people who "know a lot" are less inclined to change their views in the face of new evidence. Thus, the turnout decline should be observed primarily among the uneducated and young. Reiter (1979) gave direct evidence in support of this, and Filer, Kenny, and Morton (1991) showed that the difference in turnout between the educated and uneducated has grown over time.

5. Conclusion

This paper embeds an information theory in the standard rational voter model. The key link is that a person's expected benefit from casting a decisive vote is increasing in her certainty that she is supporting the best candidate. As a result, the person is more likely to vote as she becomes more sure about which way to vote. Confidence in a voting decision is increased by raw information about candidates and knowledge about the model of the world. Thus, as the price of information falls and knowledge rises, a person's probability of voting goes up. The model is parsimonious, fits the important facts, and gives a number of untested implications. It extends the rational voter theory into an area where it has previously met with limited success, and also supports the contention of Stigler and Becker (1977) that problems sometimes thought to lie outside the domain of economics can profitably be addressed with stable preference models and the usual price and income effects.

The treatment of information in this model yields clean refutable results, but at the cost of generality. In practice, more information can make people *less* likely to vote if it contradicts their priors about P, B, D or C. The parsimonious approach seems natural for this paper, but exploration of a richer information structure may yield additional insights.

One of the more important contributions of the model, I believe, is that it provides a simple theory to organize the main stylized facts of voting. The model is developed with the seven stylized facts in mind. Because they have been widely observed, these facts would seem to make a benchmark for the minimal set of implications a proposed theory should deliver. Other voting theories have failed to exploit the bulk of what is known about turnout. The information theory is not the only theory that can explain any given fact, but it is the only theory that can explain them all. Whether this explanatory power is commendable or overreaching remains to be seen. Recent research by Husted, Kenny and Morton (1991) contained some encouraging results. They found that individuals with high levels of education, age, and income, union members, and longtime residents in an area could more accurately evaluate their Senator's record, which supports the idea that information is the key link between these variables and voter participation.

As another way of suggesting the utility of an information theory, the model is used to shed some light on the puzzle of declining voter turnout in the United States. One property of the model is that if voters receive evidence that disconfirms their understanding of the world, they become less confident of their voting decision and less likely to vote. A possible explanation for the turnout decline, then, is that voters received contradictory signals during the 1960s, especially as a result of contentious racial developments and the conflict in Vietnam. This explanation appears to be consistent with a diverse array of

evidence, but the evidence at this point can only be considered suggestive. Additional research would seem to be in order.

Notes

1. The classic works include Campbell et al. (1960) and Verba and Nie (1972).
2. The classic reference is Downs (1957).
3. See Ashenfelter and Kelley (1975), Wolfinger and Rosenstone (1980), Matsusaka and Palda (1992a), and the references therein. The latter study shows that these correlations also hold in Canada where registration is essentially costless. Hence, they cannot be explained in terms of registration costs.
4. Note that φ indicates how accurate a voter *believes* her opinion is, not how accurate it is in an objective sense (although the latter probably effects the former).
5. These preferences may be "internalized social norms" that have arisen for efficiency reasons (see Margolis, 1982; Coleman, 1990).
6. Turnout percentages are Census Bureau estimates of total votes as a fraction of voting age population.
7. This paragraph is based on Brody (1978).
8. When parties reverse positions on a single issue, some voters may end upwith divided loyalties, supporting the Democrats on some issues and the Republicans on others. The early social-psychological literature suggested that in such situations people were "cross-pressured," leading to a psychological conflict that made them less likely to vote (Lazarsfeld, Berelson and Gaudet, 1944; Berelson, Lazarsfeld and McPhee, 1954). See Wolfinger and Rosenstone (1980) for evidence against the cross-pressure hypothesis.
9. The Great Depression had an analogous effect on the economics profession, leading many economists to abandon their old (classical) model of the economy in favor of the new Keynesian model.
10. To be specific, people were asked whether they agreed or disagreed with the following statements: (1) It isn't so important to vote when you know your party doesn't have a chance. (2) So many other people vote in the national elections that it doesn't matter much to me whether I vote or not. For a careful discussion and a list of sources, see Brody (1978).

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Appendix

This Appendix contains proofs of Propositions 1–7.

Proof of Proposition 1

By Bayes' Rule, $\Pr(MZ=1|S,\pi,k) =$

$$\Pr(M=1|S,\pi,k)\Pr(Z=1|S,\pi,k) + \Pr(M=-1|S,\pi,k)\Pr(Z=-1|S,\pi,k) =$$

$$k\frac{.5\Pr(S|Z=1)}{.5\Pr(S|Z=1) + .5\Pr(S|Z=-1)} + (1-k)\left(\frac{.5\Pr(S|Z=1)}{.5\Pr(S|Z=-1) + .5\Pr(S|Z=1)}\right).$$

Call this equation (A). The section in the text discussing signals contingent on Z gives the values for $\Pr(S|Z)$. For a high signal ($S = S_H$), substituting the signal probabilities into equation (A) gives

$$\Pr(MZ=1|S=S_H,\pi,k) = k\pi + (1-k)(1-\pi) \geq 0.5$$

where the inequality follows from $k \geq 0.5$ and $\pi \geq 0.5$. For a low signal ($S = S_L$), equation (A) reduces to

$$\Pr(MZ = 1 | S = S_L, \pi, k) = k(1-\pi) + (1-k)\pi \leq 0.5.$$

A person votes for Candidate 1 if she receives a high signal and for Candidate 2 if she receives a low signal. Hence, $\varphi(S = S_H, \pi, k) = k\pi + (1-k)(1-\pi)$, and

$$\begin{aligned}\varphi(S = S_L, \pi, k) &= \Pr(MZ = -1 | S = S_L, \pi, k) \\ &= 1 - \Pr(MZ = 1 | S = S_L, \pi, k) \\ &= 1 - (k(1-\pi) + (1-k)\pi) \\ &= k\pi + (1-k)(1-\pi).\end{aligned}$$

Thus φ is invariant to S, and $\varphi(S, \pi, k) = k\pi + (1-k)(1-\pi)$. QED

Proof of Proposition 2

The investment benefit to voting is $P(2\varphi-1)$ and the cost is C. Then a person who votes has an election utility of $P(2\varphi-1) - C$. An abstainer has an election utility of zero. Because C is distributed uniformly over the interval [0,1], the probability of voting is $P(2\varphi-1)$, and the expected cost contingent on voting is $0.5P(2\varphi-1)$. Then the expected election utility is

$$e(\pi, k) = P(2\varphi-1)(P(2\varphi-1) - 0.5P(2\varphi-1)) = 0.5P^2(2\varphi-1)^2.$$ QED

Proof of Proposition 3

The proof takes advantage of the fact that it is easy to change the maximization problem into a univariate problem by substituting out x. Let

$$W(i,k,q,y) = u(y-qi) + 0.5P^2(\varphi(\pi(i),k)-1)^2.$$

Then i^* is defined by $W_i(i^*,k,q,y) = 0$. The usual comparative statics imply $\partial i^*/\partial q = -W_{iq}/W_{ii}$. Note that $W_{ii} < 0$ by the second order condition and $W_{iq} = -u' + qi^*u'' < 0$ so $\partial i^*/\partial q < 0$. From the definition of α^* and Proposition 1,

$$\frac{\partial \alpha^*}{\partial q} = 2P(2k-1)\pi' \frac{\partial i^*}{\partial q} < 0.$$

Thus, as q falls a person is more likely to vote. QED

Proof of Proposition 4

Using the same notation as in the proof of Proposition 3, note that $\partial i^*/\partial k = -W_{ik}/W_{ii}$. Differentiation of W_i gives

$$W_{ik} = \pi'(\varphi_k\varphi_\pi + \varphi\varphi_{\pi k}).$$

From Proposition 1 it is evident that all the terms are positive: $W_{ik} > 0$. Now from the definition of α^*,

$$\frac{\partial \alpha^*}{\partial k} = 2P(2\pi-1) + 2P(2k-1)\pi'\frac{\partial i^*}{\partial k}.$$

The first term in parentheses is positive because $\pi > 0.5$. This reflects the direct effect of knowledge on φ. In the second term, $2k - 1 > 0$ because $k > 0.5$. Because $\partial i^*/\partial k > 0$ the second term is positive as well. This reflects the indirect effect of knowledge in increasing the value of information and hence the quantity acquired. Adding the effects together, $\partial \alpha^*/\partial k > 0$. QED

Proof of Proposition 5

This proposition is a basic result in Bayesian updating. By Bayes' Rule,

$$\hat{k}(T,k) = \frac{kPr(T|M=1)}{kPr(T|M=1) + (1-k)\,Pr(T|M=-1)}.$$

Note that the signal process defined in the text implies that $Pr(T=T_H|M=1) = \sigma$ and $Pr(T=T_L|M=1) = 1-\sigma$. Then

$$\begin{aligned} &Pr(T=T_H|M=1)\hat{k}(T=T_H,k) + Pr(T=T_L|M=1)\hat{k}(T=T_L,k) \\ &= \sigma\hat{k}(T=T_H,k) + (1-\sigma)\hat{k}(T=TN,k) \\ &= \sigma\left(\frac{k\sigma}{k\sigma+(1-k)(1-\sigma)}\right) + (1-\sigma)\left(\frac{k(1-\sigma)}{k(1-\sigma)+(1-k)\sigma}\right). \\ &= k\left(\frac{\sigma^2}{k\sigma+(1-k)(1-\sigma)} + \frac{(1-\sigma)^2}{k(1-\sigma)+(1-k)\sigma}\right). \end{aligned}$$

Algebraic manipulation of the term in parentheses indicates that it is greater than or equal to 1 for all values of $k \in [0,1]$ and all $\sigma \in (0.5,1]$. This establishes the proposition. QED

Proof of Proposition 6

Using the same notation as in the proof of Proposition 3, note that $d\alpha^*/dy = W_{iy}/W_{ii} = qu''/W_{ii} > 0$. QED

Proof of Proposition 7

By definition (see the proof of Proposition 5),

$$\hat{k}(T=T_L,k) = \frac{k(1-\sigma)}{k(1-\sigma) + (1-k)\sigma} = k\left(\frac{1-\sigma}{k(1-\sigma) + (1-k)\sigma}\right).$$

Algebraic manipulation shows the term in parentheses is less than 1. Thus $\hat{k}(T=T_L,k) < k$. QED