Welcome to the Machine: A Model of Legislator Personality and Communications Technology Adoption

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Abstract
Political scientists have long considered ideology, partisanship, and constituency in determining how members of the United States Congress make decisions. Meanwhile, psychologists have held that personality traits play central roles in decision making. Here, we bridge these literatures by offering a framework for modeling how personality influences legislative behavior. Drawing from experimental economics and neuropsychology, we identify core cognitive constraints for the “Big Five” personality model, parameterizing them in ways useful for crafting formal models of legislative behavior. We then show one example of the applicability of this framework by creating a formal decision-theoretic model of constituency communication. We show that when there exists uncertainty over the true state of the world, personality traits have more influence on individual decisions.

Keywords
personality, experimental psychology, psychology, social sciences, computer modeling, computer science, political communication, media & society, mass communication, communication, legislative processes, legal studies, political science, party politics

Introduction
You can have every e-mail I’ve ever sent. I’ve never sent one.

—Senator Lindsey Graham (R–SC) on Meet the Press

During an appearance on NBC’s Meet the Press about the scandal surrounding Hillary Clinton’s use of a private email server, Senator Lindsey Graham (R–SC) dropped a bombshell on the political world and revealed he does not use email. While the response to his disclosure was swift, and much of the mainstream media responded with disdain and chagrin (e.g., Politico referred to Senator Graham as a founding member of the “Luddite Caucus”; French, 2015)—other Senators came out of the woodwork and defended his decision. His colleague and fellow Republican, Senator Richard Shelby (R–AL), claimed that “[t]he best thing is person-to-person like I’m talking to you. To my staff, talk to them on the phone but also notes. Hand notes. I write a lot. I’ve been here a while; I’m a little older than y’all” (French, 2015).

However, Senator Shelby’s support notwithstanding, the story soon broadened to cover Senators’ use of communications technology more generally. Senator John McCain (R–AZ) revealed that, while he does not use email frequently, he uses Twitter to communicate with his constituents. Senator Cory Booker (D–NJ), one of the youngest Senators, concurred and mentioned he also uses Instagram and Facebook, noting that “with one push of a button I can communicate with hundreds of thousands of my constituents through social media platforms” (French, 2015). Octogenarian Senator Chuck Grassley (R–IA) is also active on social media, tweeting about anything and everything from constituent service to congratulating local sports teams and even chronicles of his daily exploits. For example, on November 3, 2014, Senator Grassley tweeted “Windsor Heights Dairy Queen is good place for u kno what” to his followers.

This variation in social media use across legislators of all ages suggests the decision of how best to reach out to constituents is not simply explained by generational differences. Legislators’ choices of how best to do so and what issues to
emphasize are summarized by what Fenno (1978) calls home style. Here, we analyze home styles, focusing on when and why some legislators adopt new methods of reaching out to constituents, and why others never do so.

One possible way to explain the heterogeneity in behavior of members of Congress (and, more broadly, elites in general)—even among those with similar policy preferences and backgrounds—might be to focus on heterogeneity in their personalities. There exists a long history of scholarship emphasizing the role of members’ personalities and other individual characteristics (e.g., Barber, 1965; Caldeira & Patterson, 1987; Dietrich, Lasley, Mondak, Remmel, & Turner, 2012), and personality has been proffered as one explanation for why certain members become “show horses” and other members become “work horses” (e.g., Matthews, 1960; Payne, 1980).

Relatedly, personality psychologists have accumulated copious amounts of information about how stable and persistent individual differences capture myriad human behaviors, and they have developed and proposed several trait taxonomies in attempts to hierarchically organize them. Importantly, they have coordinated upon a five-factor structure for personality traits that have become broadly accepted as characterizing the most important dimensions of individual difference (Eysenck, 1992; John, Naumann, & Soto, 2008). Although they may not represent the “true” structure of personality, these traits—Extraversion, Agreeableness, Openness [to Experience], Conscientiousness, and Neuroticism (sometimes reverse-coded as Emotional Stability)—capture many important individual differences (Costa & McCrae, 1992); this taxonomy also has the strength of research connecting it with lower level traits, other taxonomies, and other phenomena including leadership ability, academic and job performance, and health outcomes (Judge, Erez, Bono, & Thoresen, 2002; McCrae & John, 1992; Ozer & Benet-Martinez, 2006). Importantly, this approach offers the promise of identifying enough fundamental individual differences to provide systematic characterizations of individuals’ persistent unique qualities, while reducing them to few enough in number to be tractably translated into the language of formal modeling, making them accessible to scholars of Congress (and institutions more broadly).

Political scientists and economists have incorporated many individual differences into theoretical models that appear related to the Big Five, while stopping short of developing a general purpose theoretical framework for modeling personality. Discounting is an essential element of the Rubinstein bargaining model (1982), and differences in time preferences between individuals influence the outcome of negotiations. In addition, there have been many attempts to consider the effects of loss aversion, gain sensitivity, reference points, and risk preferences (Berejikian, 2002; Butler, 2007; Levy, 1997). In addition, there has been formal examination of the role social preferences play in politics; for example, consider the impact of heterogeneous lying aversion on strategic communication (Minozzi & Woon, 2013). All of these attempts to consider more nuanced individual differences in politics could potentially be brought together with a behavioral modeling framework for the Big Five personality traits.

In a recent book, Ramey, Klingler, and Hollibaugh (2017) did just this, developing a framework for incorporating personality into models of elite behavior. Here, we leverage their framework and develop a decision-theoretic model of the decision to adopt a new form of communication technology and allow personality to play important roles. Before doing so, however, we review the literature and show how, within their framework, each of the Big Five traits can be connected to nonideological preferences and beliefs identified by experimental economists and variations in brain structure identified by neuropsychologists, demonstrating that formal parameters empirically supported by personality measures may plausibly influence decisions made by legislators. Following this, we discuss the model, analyze its results, and discuss potential avenues for future research.

The Big Five and Modeling Individual Differences

Although a full-fledged recapitulation of Ramey et al.’s (2017) is beyond the scope of this article, a brief overview will help us to better ground our decision-theoretic model in the next section. Importantly, Ramey et al.’s (2017) goal was to demonstrate the relevance of personality in examining decision making in Congress specifically, and institutions more generally; in doing so, they drew from the experimental economics and neuropsychology literatures to obtain parameters correlated with the Big Five that are important to political decision making and can be translated into terms scholars can incorporate into models of institutions. However, doing so required the characterization of the traits as single—mathematically modelable—concepts. This enterprise has a long history in both economics and psychology:

> Personality traits impose constraints on agent choice behavior. More fundamentally, conventional economic preference parameters can be interpreted as consequences of these constraints. For example, high rates of measured time preference may be produced by the inability of agents to delay gratification, interpreted as a constraint, or by the inability of agents to imagine the future. (Borghans, Duckworth, Heckman, & Weel, 2008, p. 977)

In addition, neuropsychology has made significant strides in characterizing differences in neurochemistry, brain region volume, and resting state brain activity associated with the Big Five (Adelstein et al., 2011; DeYoung et al., 2010; Wacker, Chavanon, & Stemmler, 2006). Accordingly, Ramey et al. (2017) identified core cognitive constraints captured through the Big Five factors by focusing on the biological differences
in brain functioning that neuropsychology has associated with each trait, characterized each trait in terms of a constraint, and expressed those constraints in terms of modeling parameters. These constraints influence behavior in systematic and modelable ways, but are dependent on the contexts of the models themselves. Drawing on a simple framework of legislative utility, Ramey et al. (2017) identify useful approximations of each core cognitive constraint’s influence, with the resulting framework directing the incorporation of each trait’s core cognitive constraint into formal models of institutions. In the present case, we leverage this framework to develop a model of constituency communication; this is an ideal tactic to examine, because of the roles played by multiple personality traits and the relative ease of modeling.

**Openness [to Experience]**

Openness is associated with desires to explore and imagine new situations and ideas, as well as an appreciation for aesthetic beauty, intellectual pursuits, tastes for novel experiences, and tendencies for creativity and imagination (Borgatta, 1964; Tupes & Christal, 1992). This trait has found applications within political science, with a positive association between Openness and ideological liberalism (Alford & Hibbing, 2007; Barbaranelli, Caprara, Vecchione, & Fraley, 2007); similarly, more Open individuals are less likely to hold racial prejudice, authoritarian beliefs, homophobic attitudes, or stigmatize people with AIDS (Cullen, Wright, & Alessandri, 2002; Duriez & Soenens, 2006; Flynn, 2005; McCrae et al., 2007; Stenner, 2005).

In addition, it is associated with several related cognitive functions, such as reduced latent inhibition—that is, blocking irrelevant stimuli from consciousness (Peterson & Carson, 2000)—as well as resting state functional connectivity (RSFC) activity with areas of the prefrontal cortex (PFC) associated with working memory (DeYoung, Shamosh, Green, Braver, & Gray, 2009; Sutin, Beason-Held, Resnick, & Costa, 2009). More Open individuals have increased RSFC in parts of the brain associated with imagination, as well as pattern recognition and apophenia, the detection of patterns in meaningless data (Adelstein et al., 2011). Increased dopaminergic activity in Open individuals in the PFC reduces latent inhibition and maintains working memory, and further increases motivation for intellectual exploration (DeYoung et al., 2011). Increased intellectual exploration along with greater perception and working memory all serve to combine in powerful ways to both drive and equip Open individuals for cognitive exploration. Therefore, Openness’s core cognitive constraint is a compulsion to gather and process information.

**Conscientiousness**

Conscientious individuals have been described as being hardworking, responsible, and prudent (VandenBos, 2007), and tend to be more driven, goal-oriented, upright, better organized, and have more willpower (Ozer & Benet-Martinez, 2006). Given its association with duty, order, and discipline, Conscientiousness has had clear hypothesized relationships with temperamental and ideological conservatism (Mondak, Hibbing, Canache, Seligson, & Anderson, 2010), and investigation has found evidence in favor of an association with ideological conservatism (Stenner, 2005). One might also think the link with duty might drive Conscientious individuals to be more civically engaged, though findings here are mixed (Bekkers, 2005; Gerber, Huber, Doherty, & Dowling, 2011).

Physiologically, Conscientiousness is correlated with the volume of the middle frontal gyrus in the left lateral PFC, a portion of the brain “involved in maintaining working memory and the execution of planned action” (DeYoung et al., 2010, p. 826) and linked with abilities to plan and follow complex rules (Miller & Cohen, 2001). Examination of RSFC revealed an association between Conscientiousness and parts of the brain associated with planning for the future (Adelstein et al., 2011). Overall, Conscientiousness has strong links with parts of the brain associated with self-control, planning, and execution of planned action. This evidence suggests the core cognitive constraint of Conscientiousness is an increased capacity to realize planned future outcomes.

**Extraversion**

Extraversion is associated with activity of many kinds, as Extraverts are more sociable, talkative, assertive, and energetic; the trait is also associated with positive outlooks on life. That it has been easy to find connections between political activity and Extraversion is thus unsurprising; for example, Extraverts are more likely to become active contributors to voluntary associations (Bekkers, 2005). In addition, politicalpsychologists have found evidence that voters evaluate leaders at least partially on the basis of their Extraversion, as they show preferences for more sociable individuals (Caprara, Schwartz, Capanna, Vecchione, & Barbaranelli, 2006). Although some studies suggest Extraversion is associated with conservatism, the results are not robust (Barbaranelli et al., 2007; Riemann, Grubich, Hempel, Mergl, & Richter, 1993).

Psychologically, one major theory argues. Extraverts have more dopamine terminals than introverts, and a prevailing theory suggests these terminals support coding stimuli in terms of reward, which drives behavior to approach stimuli as sources of potential reward (Depue & Collins, 1999; Fischer, Wik, and Fredrikson, 1997). In addition, Extraversion has been associated with the size of the medial orbitofrontal cortex, which codes the reward value of stimuli, sensitivity to reward, and the extinction of fear responses (Adelstein et al., 2011; DeYoung et al., 2010); relatedly, Extraverts have lower thresholds of reward needed to take given actions, broader abilities to find rewards for stimuli, and easier
conditioning to associated stimuli with reward (Depue & Fu, 2013). Therefore, through dopaminergic activity and the orbitofrontal cortex, Extraversion’s core cognitive constraint is sensitivity to and fixation on prospective reward.

**Agreeableness**

Agreeableness is described as being linked with altruism (DeYoung et al., 2010) and tendencies to trust others, cooperate, and act unselfishly (John, Robins, & Pervin, 2008; VandenBos, 2007). Generally, it is associated with pro-social attitudes and other-minded thinking, suggesting many applications in political behavior; to wit, Agreeableness is associated with a stronger psychological sense of community, which can serve as a basis for political trust and economic liberalism (Gerber et al., 2011; Lounsbury, Loveland, & Gibson, 2003). Agreeableness can be conceptually connected to tolerance, which is supported by findings that it is negatively associated with racial prejudice, negative attitudes about diversity, and stigmatizing people with AIDS (Duriez & Soenens, 2006; McCrae et al., 2007; Strauss, Connerley, & Ammermann, 2003). In line with Agreeable individuals’ inclinations to be concerned about others, the trait is associated with distaste for political discourse and political competitiveness (Hibbing & Theiss-Morse, 2002). Voters also seem to value Agreeableness in their elected officials (Caprara et al., 2006).

Agreeableness has been found to be positively associated with the volume of the posterior cingulate cortex, an area of the brain involved in the process of understanding other individuals’ beliefs (DeYoung et al., 2010; Saxe & Powell, 2006). In addition, the ability to understand others’ beliefs is part of the theory of mind capability thought to be essential in the ability to act altruistically (de Waal, 2008). The larger posterior cingulate cortex has been associated with empathy, and Agreeable individuals have higher measured resting state activity in the posterior cingulate cortex as well (Adelstein et al., 2011). As Agreeable individuals have increased capacities to interpret the beliefs and motivations of others and experience empathy, Agreeableness’ core cognitive constraint appears to be a capacity for altruism.

**Neuroticism/Emotional Stability**

Neuroticism is associated with high levels of anxiety, depression, impulsiveness, and vulnerability to stress; related traits include external locus of control, high irritability, and a sense of vulnerability to external conditions (John, Robins, & Pervin, 2008). Neurotics tend to have low self-esteem and are unstable, withdrawn, easily angered, and difficult to motivate. However, unlike other Big Five traits, there are fewer clear connections between Neuroticism and various political phenomena. One possible connection is an association between Neuroticism and ideological severity, as individuals who are less well adjusted (as Neurotics tend to be) should be more easily drawn into fanatical positions (Soldz & Vaillant, 1999). However, other research has found strong and consistent relationships between Neuroticism and ideological liberalism (Gerber et al., 2011; Gerber, Huber, Doherty, Dowling, & Ha, 2010, Mondak, 2010). In addition, Neurotics may have less stable political attitudes and more uncertainty about the attitudes they do have (Mondak et al., 2010). Psychologists have argued Neurotics experience variability and “mental noise” in their cognitive operations, and this may cause additional uncertainty and instability in their responses (Robinson & Tamir, 2005).

More Neurotic individuals have been found to have larger mid-cingulate gyri, a region of the brain associated with the detection of error and pain (DeYoung et al., 2010); larger mid-cingulate gyri may be associated with higher sensitivities to possibilities of error and negative outcomes (Eisenberger and Lieberman, 2004). A broader theory of Extraversion and Neuroticism has argued that Neuroticism is a biochemically induced counterpoint to Extraversion, and as Extraversion is associated with a fixation on reward, Neuroticism is associated with a fixation on negative outcomes (DeYoung & Gray, 2009; Gray & McNaughton, 2003). In the lab, Neurotics are prone to behavioral inhibition through passive avoidance and freezing, presumably due to their fixation on threat and negative outcomes (DeYoung & Gray, 2009). If Neurotics are preoccupied with error and threat, absent some shock, the best way to avoid negative outcomes and stress would be to withdraw and maintain the status quo. Whether it is through sensitivity to error, stress avoidance, or a tendency to negative self-evaluation and rumination, Neuroticism’s core cognitive constraint is a sensitivity to and fixation on prospective negative outcomes.

**A Framework for Political Choice**

Having briefly described how the Big Five traits translate into core cognitive constraints, we outline Ramey et al.’s (2017) framework for incorporating personality into models of institutions. Given the present focus on the United States Congress, a general model of legislative utility is first considered; it considers utility in terms of that derived from policy, from holding office (including both reelection and influence within Congress), and leisure. Importantly, this model has been used to motivate much Congressional research over the past half-century, and it has been modified in various ways over time (Calvert, 1985; Fenno, 1973; Mayhew, 1974). Every action legislators may take has policy, and office implications, and after weighing the different sources of utility, legislators compare the expected utilities of possible actions to determine the optimal course of action. Note that this model can be extended by incorporating the core cognitive constraints that characterize each trait, and this is outlined in the following paragraphs.

The utility gained from winning future office incorporates any policy utility that may be obtained by holding it (Mayhew,
1974). Conscientiousness’ core cognitive constraint is a capacity to realize planned future outcomes, and less Conscientious individuals should derive lower levels of utility from future policy gains they can neither imagine nor obtain through planned actions. This arises as a smaller discount factor for future utilities, be they from office, policy, or other sources. This modeling decision is supported by attempts to link personality with measures of time preference. Experimentally, higher scores on Conscientiousness are associated with lower discounting of future payoffs; indeed, “conscientiousness is particularly implicated in the ability to make sacrifices now for rewards later” (Daly, Harmon, & Delaney, 2009, p. 3). Therefore, the model is expanded to include motivation to hold office, enact policy, leisure, and time preferences.

A second necessary component is utility gained from the well-being of others. Agreeableness is strongly associated with the capacity for empathy and development of theory of mind that enables individuals to understand the incentives of others and act altruistically (Adelstein et al., 2011; de Waal, 2008). As Agreeableness is a top-level trait, we must consider the impact of every action on the well-being of others. This has support in models of legislative utility that put weight on selfish statemanship, as well as the idea of the “welfare of the nation” apart from policy and office goals (Cavanagh, 1982; Uslaner, 1996). More Agreeable individuals with higher capacities for empathy and understanding others are capable of deriving more utility from others. Therefore, the consideration of utility is expanded to include motivation to hold office, enact policy, leisure, and act according to the norms of selfless statesmanship, all subject to discounting.

The core cognitive constraint of Openness—a compulsion to gather and process information—has both direct and indirect effects on behavior. Foremost, any action that provides information, experience, or learning will likely provide additional utility to more Open members. A second implication is more useful for modeling the utility of political elites, as situations with multiple possible outcomes require individuals to devote cognitive resources to the imagination (and retention) of alternative scenarios—such as policy outcomes—and Open individuals pay fewer costs for the collection and retention of this information. Thus, Openness is associated with higher utilities for convex combinations of outcomes, and reduced risk aversion by implication (Borghans et al., 2008; Pratt, 1964). Therefore, after considering Openness, utilities can be modeled as being affected by four motivations (policy, office, leisure, and statesmanship) which may be transformed by time or risk preferences.

Extraversion has connections with sensitivity to reward and fixation on positive incentives (Derryberry & Reed, 1994; DeYoung, 2014), resulting in a direct parameterization as higher weights on potential rewards when calculating expected utilities. This implies that Extraverts will persistently overestimate the successes they expect in contests, offering a more useful alternative application of the parameter as a subjective resource in contest success functions (Pearce-McCall & Newman, 1986). Therefore, after accounting for Extraversion, utilities are derived from policy, office, leisure, and statesmanship motivations, which may be altered by biased expectations of success and preferences over risk and time.

The sensitivity to negative outcomes underlying Neuroticism implies a parameterization of the trait as greater weights on potential losses, which is supported by Neuroticism’s association with sensitivity to error (DeYoung et al., 2010). Greater weights on potential losses implies a preference for a “safe” status quo to avoid making errors; this is supported by the finding that Neurotic individuals experience indecision when forced to decide between conflicting goals (DeYoung & Gray, 2009; Gray & McNaughton, 2003). This “freezing” effect can be modeled with an inhibition parameter in the utility function for legislative actions that represent decisions not to decide, such as voting present, or not taking action, such as missing votes or not introducing legislation. Therefore, after accounting for Neuroticism, utilities are derived from policy, office, leisure, and statesmanship motivations, which may be altered by biased expectations of success and failure and preferences over risk and time.

All core cognitive constraints described in Ramey et al.’s (2017) framework, as well as the associated parameters, are summarized in Table 1. This framework allows for the incorporation of the Big Five traits into models of elite decision making. In the next section, we incorporate four out of the five traits, Openness, Conscientiousness, Extraversion, and Neuroticism, into a decision-theoretic model of technological adoption when the quality of the technology is uncertain, with communications technology as the motivating case.

A Model of Constituency Communication

Twitter debuted in 2006 and allowed users to send “tweets,” short messages limited to 140 characters. By 2014, the number of active Twitter users in the United States was estimated to be around 45 million (Ribiero, 2014). In its early days, few American politicians viewed Twitter as a valuable means for connecting with their constituents. Because of the rarity of major elected officials on Twitter, people took notice when, in April of 2007, then-Senator Barack Obama registered a public Twitter account and issued his first tweet.

While then-Senator Obama became quite popular and would go on to lead a successful presidential campaign, few of his fellow legislators felt that his Twitter presence was so indispensable to his success that they ended up following suit—at least until after he became President. Using data from Chi and Yang (2010), Figure 1 shows the percentage of members of the House with active Twitter accounts during Twitter’s early days—2007 to 2010. While the percentage
with accounts grew over this period, it was not until 2009—after Senator Obama became President Obama—when it rose precipitously, though we can see that as late as mid-2010, only about 40% of Representatives were on Twitter.

Why did some legislators adopt Twitter while others did not? And among those who did, what explains when they adopted it? More generally, why do legislators vary at the rates and speeds at which they adopt new technologies for constituency communication? As mentioned, even the now-ubiquitous technology of email is not yet fully adopted. Extant research on technology adoption and usage among American politicians has examined how both demographics and partisanship affect the decision of politicians to adopt and use such technologies (Gulati & Williams, 2015; Vaccari & Nielsen, 2013). While these factors undoubtedly matter, it seems obvious that even more fundamental factors associated with both the politicians and the technology itself—for example, risk, patience, prospective rewards, and/or negative outcomes—matter as well, perhaps even more so.

To answer these questions, we model the decisions of legislators with respect to communications technology adoption, therein incorporating the Big Five model described above. Like investing in a start-up company, adopting a new technology requires time and energy. Moreover, as the technology is new, adoption may bring gains or losses. On the upside, if the medium proves to be adopted by the public at large, the legislator will be rewarded for being “ahead of the curve.” These rewards could be electoral—for example, young and tech-savvy voters might jump on his or her electoral bandwagon—or they could come in the form of prestige from their foresight. For example, in the 2008 Presidential campaign, then-Senator Obama assembled a team of technological “wizards” to develop sophisticated models of voter turnout. While the class of traditional consultants scoffed at this decision initially, Obama’s success vindicated the risks and countless politicians tried desperately to copy his approach.10

Of course, there are potential losses as well. If the new medium proves to be a dud, the legislator might suffer a loss

| Trait         | Cognitive constraint                        | Parameter                      |
|---------------|---------------------------------------------|--------------------------------|
| Openness      | Compulsion to gather and process information| Risk preferences               |
| Conscientiousness | Capacity to realize planned future outcomes| Time preferences               |
| Extraversion  | Sensitivity to and fixation on prospective reward | Weighted relative gains       |
| Agreeableness | Capacity for altruism                       | Utility from well-being of others|
| Neuroticism   | Sensitivity to and fixation on prospective negative outcomes | Weighted relative losses       |

Table 1. Big Five Traits as Core Cognitive Constraints and Parameters.

Figure 1. Twitter adoption by house members (2007-2010).
in prestige. Furthermore, the time and effort invested will be seen as wasted. In addition, it is possible that constituents who prefer more traditional forms of political communication may retaliate against the incumbent electorateally. Thus, the question of who adopts is really about the relative emphasis on the prospective rewards and negative outcomes for doing so.

To formalize this, we introduce a simple model based on the logic described by Ramey et al. (2017). Assume a set of legislators \( i = 1, 2, \ldots, N \) who must decide whether to adopt a technology at various times, \( t = 1, 2, \ldots, \infty \). We assume legislator \( i \)'s decision to adopt at time \( t \) is a function of the signals he or she has received to date and his or her priors for whether it is worthwhile to invest effort in the new technology. The (unknown) true value of the technology is given by \( \nu \in \mathbb{R} \), and legislator \( i \)'s uninformative prior for the value of the technology is given by \( \nu_0 \sim \mathcal{N}(0, \sigma_v^2) \). We define the signals at each time point \( t \) as a combination of the true value plus error, that is, \( s_t = \nu + \epsilon_t \), where \( \epsilon_t \sim \mathcal{N}(0, \sigma_{\epsilon}^2) \). In the Bayesian context, it is useful to redefine variances in terms of precisions (or inverse variances). As such, let \( \tau_v = 1/\sigma_v^2 \) and \( \tau_{\epsilon} = 1/\sigma_{\epsilon}^2 \). Having received \( n_t \) signals by time \( t \) (where each “signal” can be considered to be an observation of the results of another legislators’ adoption), \( i \)'s updated belief of the variance of \( \nu \) is a weighted average of the \( n_t \) signals with the prior belief about \( \nu \), that is,

\[
\text{Var}(\nu | n_t) = \frac{1}{n_t \tau_v + \tau_v}.
\]  

(1)

The updated belief for the mean is, similarly, a precision-weighted average of the prior and the observed signals to date (hereafter simply referred to as the “mean”):

\[
E[\nu | n_t] = \frac{n_t \tilde{s}_t \tau_v}{n_t \tau_v + \tau_v}.
\]  

(2)

Note that as \( n_t \to \infty \), \( \tau_v \to \infty \), or \( \tau_v \to 0 \), the expected value converges to the mean of observed signals to date, \( \tilde{s}_t \). This makes sense, as an increase in the number of signals, an increase in the precision of knowledge of the error term, or a decrease in the precision of the prior leads the legislator to rely more on the available data.

We assume \( i \)'s utility, given these updated beliefs, is a combination of several factors. First, we assume legislators get value from the technology itself and model this as their current expected belief about \( \nu \). Second, we assume legislators also care about the noisiness of the signals received and model this by the current belief about the variance of \( \nu \). Third, we assume legislators accrue some reward, \( r > 0 \), to adoption if the technology is good \( (\nu > 0) \) and incur some negative outcome, \( \lambda > 0 \), if the technology is bad \( (\nu < 0) \).

By assumption, the rewards are greater than the negative outcomes, \( r > \lambda \). We can think of these parameters as increased prestige or potentially attracting new voters if the new technology is valuable and loss in prestige or lost time from investment if the new technology turns out to be a dud. Therefore, denoting the decision of \( i \) to adopt in period \( t \) by \( a_{it} \in \{0, 1\} \), the expected utility of adopting today is (see Appendix A for full derivation)

\[
\begin{align*}
\text{Eu}_i(a_{it} = 1) &= -\frac{n_t \tilde{s}_t \tau_v - \rho}{n_t \tau_v + \tau_v} - \beta \lambda + \\
&\left(\frac{n_t \tilde{s}_t \tau_v}{n_t \tau_v + \tau_v}\right)(\alpha r + \beta \lambda),
\end{align*}
\]  

(3)

where \( \rho \), \( \alpha \), and \( \beta \) are nonnegative and \( \Phi(\cdot) \) is the normal cumulative distribution function (CDF). We can think of \( \rho \) as a measure of \( i \)'s degree of risk aversion, inversely related to \( i \)'s Openness. Thus, as \( \rho \to 0 \), the legislator only cares about the mean signal whereas as \( \rho \to \infty \), the legislator maximizes the weight placed on the noisiness of the signals received. That is, more Open legislators are less affected by uncertainty. The \( \alpha \) and \( \beta \) terms are, respectively, measures of the legislator’s sensitivities to reward and negative outcomes, or Extraversion and Neuroticism. These capture the extent to which legislators care about the benefits and costs of adoption. More Extraverted legislators place greater weights on the benefits, and more Neurotic legislators place greater weights on the costs. Finally, we normalize the expected utility of not adopting to 0.

As noted, when \( n_t \to \infty \)—which implies \( N \to \infty \) as described above—the expected value converges to the mean of signals to date and the variance goes to 0. The probabilities of the new technology being “good” converge to either 0 or 1, depending on the sign of the expected value. Thus, the limiting value of the expected utility for adoption is

\[
\begin{align*}
\lim_{n_t \to \infty} \text{Eu}_i(a_{it} = 1 | \tilde{s}_t > 0) &= \tilde{s}_t + \alpha r. \\
\lim_{n_t \to \infty} \text{Eu}_i(a_{it} = 1 | \tilde{s}_t < 0) &= \tilde{s}_t - \beta \lambda.
\end{align*}
\]  

(4)

The upper limit is always positive and the lower is always negative. Thus, when the number of signals is sufficiently large, decisions will be based solely on the sign of the mean signal received to date. This is because, in the limit, all legislators will join when the mean signal is positive, and none will join when the signal is negative (see Note 15). Proposition 1 and Corollary 1 are thus derived.
**Proposition 1:** When the number of signals is sufficiently high, adoption will be based solely on the sign of the average signal received to date.

**Corollary 1:** Only when uncertainty is sufficiently high will risk aversion and sensitivities to reward and/or negative outcomes play a role in the decision to adopt.

These results suggest that in the current Twitter environment, when many legislators have joined and there are millions of members, the number of existing signals is high and the role of personality in determining whether to join now is small. However, in the early days of any new technology, including Twitter, the number of existing signals will be small.

We can examine how the perceived benefits vary as the number of signals increases. Figure 2 presents the results of a simulation with six parameter profiles: (a) The legislator is Open and minimally Extraverted and Neurotic ($\rho = 1$, $\alpha = 1$, and $\beta = 1$); (b) the legislator is minimally Open, Extraverted, and Neurotic ($\rho = 10$, $\alpha = 1$, and $\beta = 1$); (c) the legislator is Open and Extraverted, and minimally Neurotic ($\rho = 1$, $\alpha = 10$, and $\beta = 1$); (d) the legislator is Open and Neurotic, and minimally Extraverted ($\rho = 1$, $\alpha = 1$, and $\beta = 10$); (e) the legislator is Open, Extraverted, and Neurotic ($\rho = 1$, $\alpha = 10$, and $\beta = 10$); and (f) the legislator is Extraverted and Neurotic, but minimally Open ($\rho = 10$, $\alpha = 10$, and $\beta = 10$).

We first focus on the outermost panels. Although difficult to see due to the large degree of overlap (which is by design), all three Neurotic profiles overlap when the latent value of the technology is low (leftmost panel; $v = -10$), and all three Extraverted profiles overlap when the value is high (rightmost panel; $v = 10$). In addition, those who are not highly Neurotic all generally overlap in the leftmost plot, and the same can be said for those who are not highly Extraverted in the rightmost plot. This suggests that in the presence of potentially high negative outcomes, the most important trait is Neuroticism; highly Neurotic members act similarly, as do those who are not. The same is true for Extraversion in the presence of high levels of reward. Moreover, when the expected negative outcomes are high, the (small) expected reward does not matter. Similar results hold for expected negative outcomes in the presence of high expected rewards. We also note the role of Openness in the early stages; even in the absence of information, Open individuals will immediately adopt even when the technology is low-valued, and minimally Open individuals will not immediately adopt high-valued technology. Finally, we note the sensitivity to individual signals is low, and within-profile variance in expected benefits is low once a sufficient number of signals has been observed.

![Figure 2. Simulated instantaneous benefits of adoption.](image-url)
Things look different when the value of the technology is ambiguous (middle panel; \( v = 0 \)), with the most immediate difference being the much higher degree of within-profile variance, largely due to the much higher degree of uncertainty about the technology’s value. As such, the variance in the individual signals becomes much more important. In addition, for legislators who are very Open and minimally Extraverted and Neurotic, their perceived benefits of adoption do not change much once a sufficiently high number of signals have been observed. Neither overweighting expected rewards nor expected negative outcomes, their perceptions of the expected benefits of adoption move very closely to the true values. Moreover, they will be willing to adopt relatively early on, even in the absence of data. However, they do not expect large rewards from doing so. It should also be noted that after a sufficiently high number of observed signals (\( n_t > 100 \)) their behavioral patterns do not meaningfully differ from those who are minimally Open and similarly Extraverted and Neurotic. However, when data are scarce, those who are less Open are more reluctant to adopt. This suggests Openness only really matters when uncertainty is present; in its absence, the effects of Openness are minimal.

We can also look at the effects of Extraversion and Neuroticism. Those who are more Extraverted, as they overweight the potential rewards from the new technology, see higher perceived benefits across the board. Those who are more Neurotic, as they focus more on the potential negative outcomes, generally see lower perceived benefits; the one exception to this dynamic is in the early stages when less Open individuals (those with high \( \rho \)) are so discouraged by the lack of information about the utility of the technology that they actually see fewer benefits than even those who are highly Neurotic. In addition, interesting patterns emerge when we look at those who are both quite Neurotic and Extraverted. For these individuals, the Neurotic tendencies seem to dominate when the perceived latent value of the technology is negative (when those who are minimally Extraverted and Neurotic perceive negative utility from adoption), whereas the Extraverted tendencies dominate otherwise. We also see the same Openness dynamic in these cases; in the very beginning, those who are both Extraverted and Neurotic but not Open see less benefit from the technology than those who are similarly Extraverted and Neurotic but more Open. This provides additional information about the effects of Openness.

However, while these results are intriguing, their applicability is somewhat limited, as the adoption decision incorporates expectations about what the future might hold. Indeed, we are arguably more interested in whether a legislator will adopt today or delay until later when the informational environment will be more useful. That said, this depends on whether waiting will improve the estimate of the value of the technology via additional signals. Suppose that with probability \( \pi \in [0,1] \), another legislator adopts today and with probability \( 1 - \pi \), no one else takes the plunge. In the first case, the (first) legislator will acquire one additional signal.

In the event the legislator observes a new signal tomorrow, we need to compute what his or her expected utility would be given the information available today. Thus, we recompute the expectations over future signals conditional on the available information available at present, obtaining

\[
E \left[ E \left[ v \mid n_t + 1 \right] \mid n_t \right] = E \left[ v \mid n_t \right],
\]

\[
E \left[ \text{Var} \left( v \mid n_t + 1 \right) \mid n_t \right] = \frac{1}{(n_t + 1) \tau_v + \tau_v}.
\]

The expectation of the value tomorrow is simply today’s estimate. For the variance, as it is independent of the signal and only depends on \( n_t \), it is updated accordingly.

Thus, legislator \( i \)'s expected utility for adoption tomorrow (given their information today) is

\[
\text{Eu}_i \left( a_{i,t+1} = 1 \right) = E \left[ v \mid n_t \right] - \beta_v - \rho \cdot \text{Var} \left( v \mid n_t \right) + \Phi_i \cdot (\alpha \cdot r + \beta_v) + \pi \left( \rho + (\alpha \cdot r + \beta_v) \cdot (\Phi_{i,t+1} - \Phi_i) \right).
\]

where \( \Phi_i = \Phi(E[v \mid n_t] / \sqrt{\text{Var}(v \mid n_t)}) \) and \( \Phi_{i,t+1} = \Phi(E[v \mid n_t + 1] / \sqrt{\text{Var}(v \mid n_t + 1) \mid n_t}) \). Therefore, as \( \text{Var}(v \mid n_t) = 1/n_t \tau_v + \tau_v \) and \( E[\text{Var}(v \mid n_t + 1) \mid n_t] = 1/(n_t + 1) \tau_v + \tau_v \), it follows that \( \Phi_{i,t+1} > \Phi_i \) if and only if \( E[v \mid n_t + 1] > 0 \), and \( \Phi_i > \Phi_{i,t+1} \) if and only if \( E[v \mid n_t] < 0 \) if \( E[v \mid n_t] = 0 \), then \( \Phi_{i,t+1} = \Phi_i \).

We assume legislators discount the future at a rate \( \delta \in (0,1) \), which captures his or her underlying Conscientiousness; more Conscientious legislators are more willing to forgo gains in the present for (potentially) larger gains in the future. If a legislator adopts today, he or she receives the expected utility of adoption both today and tomorrow, appropriately discounted; adopting tomorrow leads to 0 utility today plus the \( \delta \cdot \text{discounted expected utility} \) for tomorrow. Thus, a legislator will adopt today over tomorrow if the net benefit is positive, that is,

\[
B_t = (1 + \delta) \text{Eu}_i \left( a_{i,t} = 1 \right) - \delta \text{Eu}_i \left( a_{i,t+1} = 1 \right) \geq 0,
\]

where \( B_t \) is the net benefit of contemporaneous adoption. This expression has several interesting properties. First, we examine the effect of the discount factor, \( \delta \). Differentiating \( B_t \) with respect to \( \delta \),
\[ \frac{\partial B_n}{\partial \delta} = \pi \left[ \rho \left( \mathbb{E} \left[ \text{Var} \left( \frac{n_i + 1}{n_i} \right) \right] \right) - \mathbb{E} \left[ \text{Var} \left( \frac{n_i}{n_i} \right) \right] \right] + \left( \Phi_f - \Phi_{f+1} \right) \cdot (\alpha \tau + \beta \lambda), \tag{10} \]

The difference in the variances is always negative, as the variance tomorrow will always be less than today. The term involving the differences in probabilities that the value of the technology is positive or negative will vary in sign according to the signals observed to date. If the signals to date are negative, the term will be negative, thus making the entire derivative negative. This is sensible, as the legislator’s signals to date are not good and the he or she knows that waiting will lead to less variance. However, as mentioned when the signals to date are positive, \( \Phi_f - \Phi_{f+1} \) will be positive. Thus, the partial derivative with respect to \( \delta \) might still be negative if uncertainty about the true value of the technology is sufficiently high (given the values of \( \rho \), \( \alpha \), and \( \beta \)). Thus, Proposition 2 and Corollary 2 are derived.

**Proposition 2:** Even if the mean signal received to date has been positive, the technology will only be adopted if uncertainty is sufficiently low, with the acceptable level of uncertainty decreasing in the discount factor.

**Corollary 2:** The technology will not be adopted if the mean signal received to date has been negative.

For the risk-aversion factor, \( \rho \), the comparative statics are easier to see. When \( \rho \) is close to 0, the legislator is risk-seeking and Open, and the net benefit of adoption is always nonnegative so long as the precision-weighted mean of the signals to date is nonnegative. For large \( \rho \), the legislator is so risk averse that the available signals today are dwarfed by potential gains tomorrow. This is seen clearly by differentiating the net benefit of adoption by \( \rho \):

\[ \frac{\partial B_n}{\partial \rho} = -\mathbb{E} \left[ \text{Var} \left( \frac{n_i + 1}{n_i} \right) \right] + \pi \left( 1 + \frac{\delta \pi}{n_i} + \frac{\delta \pi}{n_i + 1} \right). \tag{11} \]

Regardless of the value of \( \delta \), the effect of increased \( \rho \) is always negative. To see why, note that the variances are decreasing in \( n_i \). This means the first term is always larger in magnitude than the term that is multiplied by \( \delta \). Moreover, this means that sufficiently risk-averse legislators will expect to never adopt the technology in the future. Absent some difference in the distribution of signals received to date and future signals (or priors that are sufficiently divergent from the true quality), they will never adopt the technology in finite time. Proposition 3 is therefore derived.

**Proposition 3:** Given a finite number of signals, sufficiently risk-averse legislators will never adopt the technology, regardless of the quality of signals received to date.

Adjusting the sensitivity to reward and negative outcomes also has important and intuitive effects on the net benefits. Differentiating with respect to \( \alpha \) and \( \beta \),

\[ \frac{\partial B_n}{\partial \alpha} = \rho \left[ \Phi_f + \delta \pi \left( \Phi_f - \Phi_{f+1} \right) \right], \tag{12} \]

\[ \frac{\partial B_n}{\partial \beta} = \lambda \left\{ -1 + \Phi_f + \delta \pi \left( \Phi_f - \Phi_{f+1} \right) \right\}. \tag{13} \]

Note that \((1 + \delta \pi)\Phi_f - \delta \pi \Phi_{f+1} \in (0,1)\). Therefore, increases in \( \alpha \) increase the expected net benefit and increases in \( \beta \) reduce it.\(^{18}\) Therefore, changes in these personality traits often result in divergence over how the net benefit of adoption is perceived, a dynamic previously suggested in Figure 2.

Last, what happens when we adjust the prior precision, \( \tau_s \)? When this parameter is close to 0, the legislator is uncertain about the value of adoption. The net benefit of adoption is thus

\[ \lim_{\tau_s \to 0} B_n = \tilde{s}_i - \beta \lambda - \rho \left( \frac{1 + \delta \pi}{n_i} + \frac{\delta \pi}{n_i + 1} \right) \left( 1 + \frac{\delta \pi}{n_i} + \frac{\delta \pi}{n_i + 1} \right) \cdot \left( \Phi_f + \beta \lambda \cdot \Phi \left( \tilde{s}_i \sqrt{n_i \tau_s} \right) - \Phi \left( \tilde{s}_i \sqrt{(n_i + 1) \tau_s} \right) \right). \tag{14} \]

Here, much hinges on \( \delta \), which is illustrated by differentiating \( \lim_{\tau_s \to 0} B_n \) with respect to \( \delta \).

\[ \frac{\partial \left( \lim_{\tau_s \to 0} B_n \right)}{\partial \delta} = -\rho \left( \frac{\pi (1 + n_i)}{n_i^2 + n_i} \right) + \pi (\alpha \tau + \beta \lambda). \tag{15} \]

Note that \(-\rho/\tau_s (\pi(1+2n_i)/n_i^2+n_i)\) is always negative. In addition, \( \pi(\alpha \tau + \beta \lambda) \) is always positive, as are \( \Phi(\tilde{s}_i \sqrt{n_i \tau_s}) \) and \( \Phi(\tilde{s}_i \sqrt{(n_i + 1) \tau_s}) \). However, the difference \( \Phi(\tilde{s}_i \sqrt{n_i \tau_s}) - \Phi(\tilde{s}_i \sqrt{(n_i + 1) \tau_s}) \) will be negative if and only if \( \tilde{s}_i > 0 \). Thus, if the mean signal to date has been positive, increases in Conscientiousness will reduce the benefits from adoption today as opposed to tomorrow, as legislators will be more cognizant of future losses in the presence of almost complete uncertainty. However, this does not tell the whole story, as this will be true even if the mean signal to date has been negative, so long as it is not sufficiently negative. Indeed, so long as
holds, increases in Conscientiousness reduce the relative benefits from adoption today. This will always be true if \( \hat{s}_t > 0 \), as the left side is guaranteed to be negative, and the right positive. However, as the right-hand side is always positive, there will exist some \( \hat{s}_t < 0 \), where this inequality will hold so long as \( \hat{s}_t > \hat{s}_t \). Only when \( \hat{s}_t < \hat{s}_t \) holds (which will be dependent on the other parameters) will increases in Conscientious increase the net benefits of adoption today as opposed to adoption tomorrow. That is, the decision will largely hinge on the mean signal to date. If it has not been sufficiently low, then increases in Conscientiousness will reduce the benefits from adoption today as opposed to tomorrow, as legislators will be more cognizant of future losses in the presence of almost complete uncertainty. In this case, they will be willing to wait until they will be more certain of the benefits. However, if the mean signal to date has been sufficiently low, then increases in Conscientiousness will increase the net benefits (though not necessarily the absolute benefits), as more Conscientious members will place more weight on the draw from the the narrower distribution with the same low mean in the next period. However, it should be reiterated that decreases in the quality of the technology will always decrease the expected instantaneous utility from adoption.

The interactions between Conscientiousness and the other parameters should also be noted. As the right-hand side is always positive, increases in \( \rho \) as well as decreases in \( \alpha \) and \( \beta \), will increase the likelihood that increases in \( \delta \) reduce the benefits from adoption today as opposed to adoption tomorrow. The results for \( \rho \) are because the greater aversion to risk will drive legislators to wait for more information at higher rates. Conversely, the results for \( \alpha \) and \( \beta \) are simply because decreases in either place more relative weight on the negative utility from uncertainty. Proposition 4 is therefore derived.

**Proposition 4:** When the legislator has weak priors on the technology’s value, higher discount factors increase the likelihood that increases in risk-aversion and decreases in the sensitivities to reward and negative outcomes will reduce the net benefits from adoption today as opposed to adoption tomorrow.

Conversely, when \( \tau_r \) is very large (and, hence, the legislator has very strong priors about \( \nu \)), the expected net benefits from adopting today over tomorrow reduce to a simple weighted trade-off between the instantaneous reward and the instantaneous negative outcome:

\[
\lim_{\tau_r \to \infty} B_{\nu} = \frac{\alpha \nu - \beta \lambda}{2}.
\]

This makes sense; we assumed the legislator’s prior for the true value of \( \nu \) had mean 0, so as \( \tau_r \to \infty \), the prior trumps the data.\(^{19}\) Waiting indefinitely will be preferable when one’s sensitivity to negative outcomes multiplied by the expected negative outcome is less than one’s sensitivity to reward multiplied by the expected reward. When this is not true, the technology will be immediately adopted. Put more simply, when legislators have strong priors, the technology will be adopted when legislators are sufficiently Extraverted and it will not be adopted when they are sufficiently Neurotic. Proposition 5 is therefore derived.

**Proposition 5:** When the legislator has strong priors on the value of the technology, the net benefits of adoption today relative to adoption tomorrow depend solely on the expected rewards and negative outcomes as well as the sensitivities thereto.

Overall, the results line up with the proposed framework. Recall that Extraversion and Neuroticism are related to sensitivity to rewards and negative outcomes, respectively. Specifically, Extraverts are more sensitive to rewards than introverts and Neurotic legislators are more sensitive to negative outcomes than those who are more Emotionally Stable. In our model, the parameters \( \alpha \) and \( \beta \) are respectively defined as sensitivity to rewards and negative outcomes. Linking the comparative statics with the Big Five, we should expect Extraverted (Neurotic) legislators to be more willing to undertake the risks associated with adopting the technology sooner (later).

Going further, it seems natural to think that, as information is revealed, the risks associated with adopting the new platform will dissipate. Recall that \( \rho \) is multiplied by the (negated) variance term. As the variance goes to 0 as \( n_t \) increases to infinity, we should expect adoption to speed up with an accumulation of favorable signals about the technology’s worth.\(^{20}\) However, those with lower \( \rho \)s (e.g., those who are more Open) will be more willing to adopt the technology under greater uncertainty. Finally, we show that \( \delta \)—which captures the personality trait of Conscientiousness—enhances/mitigates the roles played by the other traits.

**Discussion and Next Steps**

Our findings highlight an opportunity to enrich models of elite behavior with parameterizations of cognitive constraints informed by personality. Psychology is accumulating evidence that the traits discussed here are particularly important, and we can apply the clarity of formal modeling to develop theories about how cognitive constraints affect
behavior. We see no reason why this framework is only applicable to legislators, and we believe it can be applied to create models of the presidency, bureaucracy, and judiciary, and even international relations.

The model described herein could even be extended to a number of legislative decisions that involve uncertain investments with learning, including the decision to make endorsements or cosponsor. These decisions could affect the utilities of others, offering an opportunity to incorporate Agreeableness and ensure that each of the Big Five traits are considered. For example, the decision to endorse candidates might also include a term capturing the degree to which potential endorsers weigh united partisan fronts versus their own preferences; this would be another way to incorporate Agreeableness into the model. In addition, given the ability to estimate personality traits of elites from speech (Hall, Hollibaugh, Klingler, & Ramey, 2017; Ramey, Klingler, & Hollibaugh, 2016; Ramey et al., 2017), these models can even be brought to bear on data. While we should expect contextual variables such as age, length of tenure, district population density, Internet adoption, and Twitter adoption to be associated with the use of Twitter by members of Congress, we should also still expect the underlying preferences captured by measures of the Big Five to have a significant relationship.

Overall, focusing on elites’ personalities offers new insights into why politicians vary in how they pursue their goals. We believe personality trait measures capture underlying cognitive constraints associated with officeholders’ decisions to choose certain political tactics in a manner conducive to formal modeling. Our findings suggest voters have reason to pay attention to representatives’ personalities, and suggest additional work to connect personality with specific legislative actions are needed. This will significantly enrich our understanding of how citizens, elected officials, and policy interact.

Appendix A
Derivation of Some Equations

Derivation of Equation 3:

\[ Eu_{i}(a_{i,t+1} = 1) = E[u_{i} | n_{t+1} = 1] - \rho \text{Var}(v | n_{t}) + \text{Pr}(v > 0 | n_{t}) \alpha r - \text{Pr}(v < 0 | n_{t}) \beta \lambda \]
\[ = E[u_{i} | n_{t} ] - \rho \text{Var}(v | n_{t}) + \text{Pr}(v > 0 | n_{t}) \alpha r - \left(1 - \text{Pr}(v > 0 | n_{t})\right) \beta \lambda \]
\[ = E[u_{i} | n_{t} ] - \rho \text{Var}(v | n_{t}) - \beta \lambda + \text{Pr}(v > 0 | n_{t}) \left(\alpha r + \beta \lambda\right) \]
\[ = E[u_{i} | n_{t} ] - \rho \text{Var}(v | n_{t}) - \beta \lambda + \frac{E[u_{i} | n_{t} ]}{\sqrt{\text{Var}(v | n_{t})}} (\alpha r + \beta \lambda) \]
\[ = \frac{n_{t} \bar{s}_{t} \tau_{t} - \rho}{n_{t} \tau_{t} + \tau_{v}} - \beta \lambda + \Phi \left(\frac{n_{t} \bar{s}_{t} \tau_{t}}{\sqrt{n_{t} \tau_{t} + \tau_{v}}}\right) (\alpha r + \beta \lambda). \]

Derivation of Equation 8:

\[ Eu_{i}(a_{i,t+1} = 1) = \pi E[u_{i} | (a_{i,t} = 1 | n_{t} = 1) | n_{t} = 1] + (1 - \pi) E[u_{i} | (a_{i,t} = 1)] \]
\[ = \pi \left( E[u_{i} | n_{t} ] - \rho \text{Var}(v | n_{t} + 1) | n_{t} ] - \beta \lambda + \Phi_{t+1}(\alpha r + \beta \lambda) \right) + (1 - \pi) \left( E[u_{i} | n_{t} ] - \rho \text{Var}(v | n_{t} ) - \beta \lambda + \Phi_{t}(\alpha r + \beta \lambda) \right) \]
\[ = E[u_{i} | n_{t} ] - \beta \lambda + \pi \left( -\rho E[u_{i} | n_{t} + 1] | n_{t} ] + \Phi_{t+1}(\alpha r + \beta \lambda) \right) + (1 - \pi) \left( -\rho E[u_{i} | n_{t} ] + \Phi_{t}(\alpha r + \beta \lambda) \right) \]
\[ = E[u_{i} | n_{t} ] - \beta \lambda - \rho E[u_{i} | n_{t} ] + \Phi_{t} \cdot (\alpha r + \beta \lambda) \]
\[ + \pi \left( \rho \left( E[u_{i} | n_{t} ] - E[u_{i} | n_{t} + 1] | n_{t} ] \right) + (\alpha r + \beta \lambda) \cdot (\Phi_{t+1} - \Phi_{t}) \right). \]
Derivation of Equation 9:

\[(1 + \delta) Eu\left(a_{i, s} = 1\right) - \delta Eu\left(a_{i, s+1} = 1\right) \geq 0\]

\[Eu\left(a_{i, s} = 1\right) - \frac{\delta}{1 + \delta} Eu\left(a_{i, s+1} = 1\right) \geq 0\]

\[(1 + \delta \pi) \left\{ E\left[v \mid n_t\right] - \rho \text{Var}\left(v \mid n_t\right) - \beta \lambda + \Phi_r \cdot (\alpha r + \beta \lambda) \right\}

- \delta \pi \left\{ E\left[v \mid n_t\right] - \rho E\left[\text{Var}\left(v \mid n_t + 1\right) \mid n_t\right] - \beta \lambda + \Phi_{r+1} \cdot (\alpha r + \beta \lambda) \right\} \geq 0.\]

Derivation of Equation 14:

\[\lim_{\tau_v \to 0} B_v = (1 + \delta \pi) \left\{ \tilde{s}_t - \frac{\rho}{n_t \tau_c} - \beta \lambda + \Phi\left(\tilde{s}_t \sqrt{n_t \tau_c}\right) \cdot (\alpha r + \beta \lambda) \right\}

- \delta \pi \left\{ \tilde{s}_t - \frac{\rho}{(n_t + 1) \tau_c} - \beta \lambda + \Phi\left(\tilde{s}_t \sqrt{(n_t + 1) \tau_c}\right) \cdot (\alpha r + \beta \lambda) \right\}

= \tilde{s}_t - \beta \lambda - \frac{\rho}{\tau_c} \left( \frac{1 + \delta \pi}{n_t} + \frac{\delta \pi}{n_t + 1} \right)

+ (\alpha r + \beta \lambda) \left\{ (1 + \delta \pi) \Phi\left(\tilde{s}_t \sqrt{n_t \tau_c}\right) - \delta \pi \Phi\left(\tilde{s}_t \sqrt{(n_t + 1) \tau_c}\right) \right\}.\]

Appendix B

Additional Simulations

Figure B1. Simulated instantaneous benefits of adoption: The number of signals in period \(t\) is \(\tilde{n}_t\), where \(\tilde{n}_t \sim \text{Poisson}(1)\).
Figure B2. Simulated instantaneous benefits of adoption: The number of signals in period $t$ is $n_t$, where $n_t \sim \text{Poisson}(5)$.

Figure B3. Simulated instantaneous benefits of adoption: The number of signals in period $t$ is $n_t$, where $n_t \sim \text{Poisson}(10)$. 
Authors’ Note
Author order was decided by a round-robin matching pennies tournament. All contributed equally to the article.

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Notes
1. As said to Chuck Todd on March 8, 2015 (https://www.nbcnews.com/meet-the-press/lindsey-graham-ive-never-sent-email-n319571).
2. https://twitter.com/ChuckGrassley/status/529356795924725760
3. Other work (Gallagher & Allen, 2014; Hall, 2018) examines the importance of personality traits in institutions but relies on traits themselves as opposed to representing modelable parameters.
4. Before proceeding, however, it should be noted that the process of incorporating personality traits into formal models of political institutions requires that each trait be translated into one or more modelable parameters, which itself requires several simplifying assumptions about the nature of each trait to state them in modelable terms. Importantly, the chosen parameters are not the traits themselves; instead, these parameters are approximations of the traits in terms of the variables used in models of institutions.
5. Also see Klingler, Hollibaugh, and Ramey (2018).
6. In some situations, a source of utility linked to information consumption may be useful.
7. This assumes no exogenous negative outcomes from indecision, which would drive Neurotic individuals to act to avoid negative outcomes. As long as such a negative outcome may be avoided, more Neurotic individuals would prefer to be indecisive and avoid any negative outcome rather than take action and face a potential negative outcome from an exaggerated probability of being wrong.
8. This inhibition parameter’s influence on the utility of indecision and inaction is diminished and may even be negative if there is a negative outcome for inactivity.
9. The limit has since been increased to 280 characters.
10. However, Hillary Clinton’s failure to win the 2016 Presidential election likely cautioned future campaigners against an over-reliance on data, at least without fully understanding the data-generating processes in play.
11. We assume once a legislator has adopted the technology, he or she cannot unadopt it in the future.
12. While it might seem that a binary variable might be inappropriate for a model attempting to ascertain the effects of several unobservable factors, this framework allows for a wide variety of results to emerge while maintaining reasonable levels of mathematical tractability.
13. The claim about \( n_t \to \infty \) is contingent on \( N \to \infty \).
14. There have been several notable instances of members of Congress facing setbacks—or even being forced to resign—because of either a misunderstanding of how Twitter works and its broad subscriber base, or an imperfect ability to utilize the technology. Perhaps the best-known example of this is former Congressman Anthony Weiner (D–NY), who resigned after it came to light he was using Twitter to send explicit photos of himself to young women; his explanation indicated he intended to send private messages as opposed to publicly posting them.
15. As the variance decreases to zero, \( \rho \) also drops out.
16. The other parameters include \( \sigma_x = 2, \sigma_y = 2, r = 1, \) and \( \lambda = 1 \); the simulation was run until 500 signals were observed. In addition, Appendix B provides additional simulations where multiple signals may be observed at one time—that is, the observed number of signals in time \( t \) is denoted \( n_t \) and distributed \( \text{Poisson}(\Lambda) \), where \( \Lambda \in \{1,5,10\} \) and 500 draws from the Poisson distribution were completed. Results are substantively identical.
17. The restriction of either zero or one additional signals is admittedly a bit artificial, but is more mathematically tractable. Allowing for more than one additional signal would not affect the mean, and would only serve to decrease the variance. The substantive results would be unchanged.
18. Importantly, \( 1 + \delta t \Phi_t - \delta t \Phi_{t+1} \geq 1 \) can never happen, as this inequality is equivalent to \( \Phi_t + \delta t (\Phi_t - \Phi_{t+1}) > 1 \). As \( \Phi_t \) is the normal cumulative distribution function (CDF) applied to a finite number, this quantity is strictly less than one. Therefore, for this condition to hold, \( \delta t (\Phi_t - \Phi_{t+1}) \) must be positive. However, \( \Phi_t > \Phi_{t+1} \) if and only if \( E[v|n_t] < 0 \). But if this is the case, then \( \Phi_t \in (\Phi_{t+1},1/2) \). As the difference between \( \Phi_t \) and \( \Phi_{t+1} \) is strictly less than \( 1/2 \), and \( \Phi_{t+1} \) is also strictly less than \( 1/2 \), it follows that \( \Phi_t + \delta t (\Phi_t - \Phi_{t+1}) < 1 \), even if \( \delta = 1 \) and \( \pi = 1 \). In addition, \( 1 + \delta t \Phi_t - \delta t \Phi_{t+1} \leq 0 \) can also never happen. Note that this inequality is equivalent to \( \Phi_{t+1} - \Phi_t > \delta t/\delta \). However, \( \Phi_t \) is a probability, so it must be positive, and \( \Phi_{t+1} > \Phi_t \) if and only if \( E[v|n_t] > 0 \). But if this is the case, then \( \Phi_t \in (1/2,\Phi_{t+1}) \). Therefore, \( \Phi_{t+1} - \Phi_t \in (0,1/2) \). Even if \( \delta = 1 \) and \( \pi = 1 \), it can never be true that \( \Phi_{t+1} - \Phi_t \geq \delta \).
19. This is a natural result of \( E[v|n_t], E[v|n_t + 1], \text{Var}(v|n_t) \), and \( \text{Var}(v|n_t + 1) \) all approaching zero as \( \tau \) approaches infinity, and \( \Phi_t \) and \( \Phi_{t+1} \) each approaching \( 1/2 \).
20. Chi and Yang (2010) approximate this idea for Twitter by controlling for the average of the number of followers divided
by the number of tweets for legislators who adopted prior to legislator $i$ as a proxy for this evolving uncertainty. When the number of Twitter users among Congress was low, prospective users would have to rely on few signals when making their adoption decision.

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