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1. Introduction

When administrative agencies regulate, how do they go about quantifying the costs and benefits of their regulations? They are legally required to conduct cost-benefit analyses of major regulations by executive orders issued by President Reagan and affirmed (or expanded upon) by every president since (Bronsteen, Buccafusco & Masur 2013). Yet most agencies struggle mightily at quantifying and monetizing the costs and benefits of their regulations (Masur & Posner 2016). This is partly because the dynamic effects of regulations can be uncertain, particularly so in future years. But the problem is exacerbated substantially by the fact that many of the benefits produced by regulation are difficult to assess in monetary terms, even though the benefits are almost surely sizeable.

Many regulations protect human life and health, which are goods that people effectively buy and sell in markets. Pricing those benefits is complex, but at least it can be done on the basis of what people will actually pay for them, using transactions in real dollars (Bronsteen, Buccafusco & Masur 2013). At the same time, a large number of regulations also provide benefits that are not traded in markets and cannot be so easily priced. For instance, many regulations protect the environment and wildlife from harm associated with various sources of pollution. Other regulations are meant to reduce social ills, such as discrimination or prison rape that similarly are not bought and sold. Without being able to observe how much individuals are willing to pay to obtain such benefits, agencies cannot attach reliable prices to them. Agencies typically try to price these types of benefits using contingent valuation studies, which are essentially surveys that ask people how much they would be willing to pay without any real money actually changing hands. Unsurprisingly, contingent valuation surveys have proven to be inaccurate and unreliable (Hausman 2012). What is more, in some cases nonmarket benefits plausibly comprise a substantial portion of the overall benefits of the regulation. That suggests that agencies are either under-regulating or over-regulating owing to their inability to monetize nonmarket benefits accurately.

Despite the obvious limitations of contingent valuation studies, no alternative has yet to gain traction. Agencies have been using contingent valuation studies for decades in the belief that no better options present themselves.

That is no longer the case. Agencies should use quadratic voting (QV) to price nonmarket goods that are otherwise difficult to value accurately. Quadratic voting, developed by Glen Weyl (2012), is a decision procedure in which voters use actual dollars to buy votes for or against a ballot proposition or candidate (Lalley & Weyl 2016). Each dollar does not translate into one vote, however. The cost of buying votes is proportional to the square of the number of votes purchased. Both the marginal cost of buying an additional vote and the marginal benefit of doing so—the probability of casting the pivotal vote—increase linearly with the number of votes cast. When marginal costs and marginal benefits are equal, individuals are likely to buy votes in proportion to their actual preferences. This leads to socially efficient outcomes. Quadratic

voting thus sets marginal benefits equal to marginal costs, which leads to efficient outcomes. Voters are able to express more intense preferences than a one-person, one-vote system would allow, but wealthier voters cannot hijack the election by buying vast numbers of votes. A quadratic vote allows individuals to trade public goods—here, the benefits of the regulation—against private goods—what they might otherwise have purchased with the dollars they spent voting. QV thus mimics a marketplace and should lead to more accurate results than contingent valuation surveys. In subsequent work, Posner and Weyl (2013, 2014, 2015) have suggested that quadratic voting might be applied to broad swaths of law and policy.

Quadratic voting is particularly suited to the administrative state because agencies already have the legal authority to use quadratic votes as inputs to the regulatory process. A large number of organic agency statutes not only permit but require agencies to conduct research aimed at understanding and estimating the costs and benefits of their regulations. Quadratic voting falls well within these statutory grants. In fact, it is quite likely that agencies could write regulations that would automatically be triggered by the results of quadratic voting. A regulation could be written to take effect only if a quadratic vote resulted in a particular outcome, or it might be written to vary in stringency depending upon the result of a quadratic vote. This would effectively make quadratic votes legally binding, even without legislative intervention. Given the advantages of quadratic voting, and the fact that agencies could adopt QV without waiting for Congress, there is little reason for them not to act.

2. QV as a substitute for contingent valuations

Consider a hypothetical environmental regulation that would force coal-fired power plants to substantially reduce their level of hazardous emissions—including mercury, sulfur dioxide, and particulate matter—at a cost of $10 billion. At the same time, the regulation would prevent 1000 fatal cases of cancer and 5000 cases of emphysema, and create a vast array of other benefits to the environment and wildlife. The regulation would prevent the death of ten million migratory birds that would otherwise be harmed when rainfall introduced airborne pollutants into the water supply. As for the costs of the regulation, some would be passed along to consumers in the form of higher electricity prices; some firms would see their profits reduced; and some workers at those firms would be laid off.

How should the EPA, or the government in general, go about deciding whether to promulgate this regulation? The difficulty is that the regulation involves nonmarket benefits that are difficult to price. Agencies do a credible job of estimating the value of preventing cases of terminal cancer (and saving lives more generally) because there is in some sense a market for those goods: individuals demand higher wages when they take more dangerous or more unpleasant jobs (Sunstein 2002). But they are not well equipped to monetize the value of non-market goods such as protecting the environment or saving wildlife because these goods are not traded on markets. Individuals do not buy and sell protected wetlands or wildlife. In lieu of being able to observe actual market behavior, agencies instead use "contingent valuation" studies, sometimes called "stated preference" studies. These are essentially surveys, in which respondents are asked how much they would pay to protect some natural resource or save the lives of some wildlife.

Yet contingent valuation surveys are susceptible to enormous error and viewed as highly unreliable by most scientists and regulators (Hausman 2012). The fundamental problem is that study participants are not making real choices, contributing their own money or confronting opportunity costs, so they have no incentive to provide accurate measures of their own preferences. Instead, each respondent has an incentive to try to skew the overall results toward their own preferences. Someone who believes that she values a benefit more than other people has an incentive to report a valuation even much higher than her own, in an attempt to bias the result toward her own valuation by compensating for others' lower values. For instance, suppose that an individual values the preservation of endangered wetlands at $1000 but believes that the average person values wetlands protection only at $10. That individual might report a value of $100,000 (or more) on a contingent valuation survey in an effort to shift the overall result toward her own value. Conversely, someone who values a nonmarket benefit less than the average person does has an incentive to report an artificially low value—zero, or even negative if that is allowed.

Even individuals who believe they are exactly average have incentives to misreport their valuations if they believe that people who value the good more than them will provide valuations that are skewed to a greater degree than the people who value the good less than them. For instance, if the average person values a good at $10, people who assign higher values to the good might want to provide *much* higher responses (in the thousands of dollars), while people who value it less might be bounded at $0. Even someone who values the good at $10 would have an incentive to report an artificially low value, such as $0, in an attempt to compensate for other respondents' biased values. The overall result is that individuals' stated preferences will diverge wildly from their true preferences, which will greatly complicate regulators' ability to conduct meaningful cost-benefit analysis (CBA).

Some contingent valuation surveys attempt to overcome some of these problems by placing budget constraints on respondents, limiting how much they can value any given good. A budget constraint will prevent individuals from offering the most outlandishly high valuations. But these budget constraints are inherently arbitrary and can be counterproductive. If the budget constraint is too loose, it is meaningless. If it is too tight, it artificially constrains individuals' ability to express intense preferences.

Consequently, contingent valuation studies suffer from several well-known defects. They yield results that are extremely imprecise—for instance, various contingent valuation studies have pegged the value of a statistical life at anywhere from $40,000 to $13 million (Environmental Protection Agency 2010). In addition, contingent valuation surveys are largely impervious to the size of the benefit being analyzed. A very basic test of the reliability of a contingent valuation survey is that it should generate dollar estimates that are roughly proportional to the size of the benefit involved. Individuals should be willing to pay approximately ten times as much to save 10,000 birds as they are willing to pay to save 1,000 birds. And yet this has not proven to be the case. Most contingent valuation studies to not even bother to include this type of validity test, and of those that do, very few pass (Alberini et al. 2004; Cropper et al. 2011). It is little wonder that contingent valuation surveys have attracted such scorn as a means of pricing nonmarket goods. But to date they have been viewed as the best available option. For benefits that are not traded in markets, agencies have either employed

contingent valuation surveys or simply failed to quantify the benefits at all (Masur & Posner 2016).

Instead of relying on unreliable contingent valuation surveys, agencies should use quadratic voting to value non-market goods. That is, the results of quadratic voting should effectively be used as inputs to cost-benefit analysis. To illustrate, consider the regulation described at the beginning of this section. Suppose that the EPA uses standard revealed-preference studies to value the health and safety benefits of the regulation at $9 billion. The question is how much the remaining benefits—preservation of migratory birds—are worth. If (and only if) they are worth at least $1 billion, then the regulation is cost justified. The EPA should hold a quadratic vote, with the question at issue being "Should the EPA protect ten million birds at a cost of $1 billion?" Or, the question could be made even more concrete by linking it to the voter's own finances: "Should the EPA protect ten million birds, if doing so would mean that your electricity bill would rise by approximately $2 per month?" In an era of big data, it is even possible to imagine the precise question being tailored to individual voters using the internet and sophisticated algorithms (Casey & Niblett 2015). If a particular voter logged into a quadratic voting system, the EPA's software would be able to estimate how much more that individual (or firm) would pay each month for electricity if the agency were to promulgate its regulation. For other types of regulation or government project, the agency holding the quadratic vote might be able to estimate how much extra the individual would pay in taxes. This would certainly be possible if the agency were able to access the individual's tax returns, which are kept confidential by the IRS. But it might even be possible using publicly available information regarding the individual's address or Zip code.

Individuals and firms would then participate in the quadratic vote, using their own dollars, to determine whether the EPA should promulgate the regulation. The critical advantage of a quadratic vote over the current method of stated preference surveys is that individuals would vote with their own real dollars, rather than merely stating values that have little connection with reality. Voters would have no incentive to state outlandish and unrealistic preferences (either high or low); as is the case with quadratic voting generally, voters would have the proper incentives to express their own preferences (Lalley & Weyl 2016). And at least in theory, individuals have intrinsic preferences over things such as preservation of the environment and non-human species (Ackerman & Heinzerling 2005). They should have some intuitive sense as to whether they value these non-market goods enough to want significant amounts of money to be spent on them.

Some individuals may have very strong feelings regarding the value of environmental benefits and be eager to vote; others may be much more apathetic. In order to induce people to participate, the government could increase the amount spent by some multiple before redistributing it to the voters (Posner & Stephanopoulos 2016). This would enable most voters to make money by participating, thereby inducing them to vote, without skewing the incentives for them to vote their preferences. Such a system could become costly to the public fisc if tens of millions of people were participating in each vote, but that is not necessary. Agencies need not survey everyone. They only need to survey an appropriately sized representative sample of potential voters (Mukhopadhaya 2003; Green & Laffont 1977). This will also facilitate the use of multiple, sequential quadratic surveys, which will be helpful to agencies attempting to

pinpoint the value of various benefits. (This issue is discussed in greater detail below.) Alternatively, the government could make it mandatory for citizens to participate occasionally in quadratic surveys, much like jury duty. This would have the advantage of ensuring a random sample and high levels of participation at lower cost. However, it would likely require a change in law, while simply paying participants would not.

Of course, a quadratic vote would not solve all of the problems related to the valuation of nonmarket goods in CBA. Individuals will still be required to pass judgment on issues with which they have little or no experience (Bronsteen, Buccafusco & Masur 2013). As with contingent valuation surveys, even fully understanding the issue might prove difficult. People are not well equipped to imagine what it would mean for a million, or ten million, birds to die because of pollution. Ordinary life does not provide experience with such large numbers (Masur 2007). But the fact of using real money would represent a substantial advance over the untrustworthy contingent valuation surveys on which agencies currently rely.

At the same time, a quadratic vote would introduce other complications. Regulators using quadratic votes can establish floors or ceilings to the value of nonmarket benefits but not point estimates. If a quadratic referendum on saving birds at a cost of $1 billion passes, it establishes that the relevant population places an aggregate value of at least $1 billion on those goods. If the referendum fails, it establishes that the relevant population values the goods at less than $1 billion. But it does not necessarily establish exactly what the aggregate value is, and it is difficult to glean such information from the results of the vote itself. Even if the referendum passes overwhelmingly, with 80% or more of the votes supporting it, this does not necessarily mean that the aggregate value placed on the benefit is greater than $1 billion. Drawing such a conclusion would require strong assumptions regarding the behavior of voters and the extent to which they apply game theoretic concepts when deciding how many votes to cast (Lalley & Weyl 2016). By contrast, a contingent valuation survey will yield an actual number (however unreliable) that the regulator can plug directly into a CBA. While in theory a regulator need only conduct one contingent valuation survey (if it were reliable), the regulator will be required to conduct multiple quadratic votes before it can come close to pinpointing a good's value.

This will be necessary if the regulator plans to impose more than one regulation that will generate the same sort of nonmarket good. And this is entirely likely. For instance, EPA regulations of pollution emitted by power plants, Department of Energy energy-efficiency standards (which diminish the demand for electrical power), and Department of Transportation corporate average fuel economy (CAFE) standards all have the effect of reducing the quantity of sulfur oxides, nitrous oxides, mercury, and particulate matter emitted into the atmosphere (Masur & Posner 2011). Accordingly, all of these types of regulations will provide similar nonmarket goods: preventing wildlife deaths from pollution, protecting habitats, and even reducing the amount of smog in the sky. However, each of these regulations will do so to different degrees, and the costs of providing these benefits will be different. Accordingly, regulators will need to specify a value for these nonmarket benefits with some precision.

One option would simply be to wait until the agency planned to promulgate another regulation and then hold another quadratic vote. Another option would be for the agency to randomly segment the population into different groups and hold multiple quadratic votes related

to the same regulation. For instance, with respect to the hypothetical EPA air pollution regulation, when a voter logged into the quadratic voting system (or went to a quadratic polling place), that voter could be assigned randomly to one of two quadratic voting questions: (1) "Should the EPA protect ten million birds at a cost of $1 billion?"; or (2) "Should the EPA protect ten million birds at a cost of $5 billion?" A "yes" result on the first question and a "no" result on the second would justify promulgating the regulation and establish a floor to the valuation of $1 billion and a ceiling of $5 billion. A "yes" result on both questions would justify promulgating the regulation and set a higher floor valuation of $5 billion. (A "no" result on the first question, and a "yes" result on the second question—implying that voters are willing to spend $5 billion but not $1 billion to obtain a benefit—would serve as a useful indication that something has gone wrong with the quadratic vote.)

Once an agency has established both a floor and a ceiling to the value of the benefit, it could home in on the precise value using binary search. The agency would select the midpoint between the floor and ceiling and test that value with a subsequent quadratic vote. The result of that vote would establish a new floor (if the vote passes) or ceiling (if it fails) on the valuation and cut the possible range of values in half. Because agencies should already be using random samples from the general population, rather than opening quadratic votes to anyone, it should be possible for the agency to simply draw another random sample of individuals for a subsequent vote.

The more important constraint is that agencies should hold quadratic votes only when the results of those votes will be reflected in actual regulation. It should not ask voters to offer what amount to advisory opinions. The agency may not be required to do so legally—more on that below. But if the agency wants voters to participate in its quadratic votes, it must be able to make a credible commitment that the winning side will actually have its preferences enacted. If an agency can establish both a floor and a ceiling to a particular valuation, this is feasible. Imagine a regulation that would require nonmarket benefits worth $1 billion to be cost-benefit justified. Suppose that in the first round of referendums, voters approve a value of $1 billion but reject a value of $5 billion. Regulators could then test a value of $3 billion. If the vote succeeded, the individuals who voted "yes" would believe (correctly) that their votes had been respected. If the vote failed, those people who voted "no" would believe (correctly) that their votes had been respected because the agency would not promulgate the regulation at that cost.[1]

At the same time, agencies are limited in the range of options they may use in quadratic votes. For instance, if the regulation is cost-justified only if the birds are worth $1 billion, the EPA cannot ask some subset of voters whether they value the birds at $500 million or $750 million, even though that would be useful information. If that measure passed, the agency would still be forced to conclude that the regulation is not cost-justified. Failing to promulgate the regulation despite a "yes" result could harm the agency's reputation and dampen participation in future quadratic votes. Similarly, if the initial quadratic referendum regarding a value of $1

[1] If this latter point turns out to be untrue, and voters who reject a valuation of $3 billion feel as though their vote was meaningless when the regulation is later promulgated based on a valuation of $1 billion, then the agency will be required to adjust accordingly. This will become a problem only if voters cease participating because they think their votes are not being respected, but that is a conceivable outcome.

billion does not pass, the agency cannot hold subsequent votes at values of $500 million or $750 million in an effort to obtain a more precise estimate.

The optimal approach for an agency seeking to evaluate its regulations at the lowest administrative cost is a technically complex problem. In some cases, the agency may be best off waiting until subsequent regulations are being considered before holding subsequent quadratic votes; in others, it may benefit from determining a more precise value immediately. The agency's choice depends on a suite of factors, including (a) how precisely it will need to specify the value in order to make regulatory decisions; (b) how many subsequent regulations it plans to issue involving the same benefits; (c) whether it has a belief as to what the value of the benefits will turn out to be, and how confident it is in that belief; and so forth. The agency may need to consult with outside experts in search methodologies, including computer scientists, before choosing a path forward.

One final wrinkle in this analysis is that most regulations do not pose the binary choice of some fixed quantity of benefits in exchange for some fixed costs. Rather, in most cases agencies are faced with a range of regulatory options of varying levels of stringency. For instance, the EPA might require coal-fired power plants to reduce emissions of various pollutants to one of three levels based upon the availability of three different types of scrubbers. In some cases, an agency can regulate across a continuous spectrum. For instance, when it prescribes fuel economy standards, the Department of Transportation could require that manufacturers produce automobiles that average 30 miles per gallon, 30.5 mpg, 31 mpg, 32 mpg, and so forth. As a general (but not universal) rule of thumb, as regulations become more stringent, the costs of those regulations increase non-linearly. That is, if it costs $100 million to reduce the level of some pollutant by X, it will cost more than $200 million to reduce the level of that pollutant by 2X. The agency's objective is to choose the level of regulation that maximizes benefits net of costs.

Imagine, then, that the EPA has three regulatory options of increasing stringency. Table 1 summarizes those options:

{Insert Table 1 here}

The optimal regulation will of course depend upon the value of the non-market benefits. If voters value them at zero, the agency should promulgate Option A. As the value of the non-market benefits increase, the agency should move toward Option B and, later, Option C. To be precise, the breakeven point between Options A and B comes at a value of $2 billion for 1 million birds. If 1 million birds are worth less than $2.0 million, the agency should choose Option A. The breakeven point between Options B and C comes at a value of $3 billion for 1 million birds. If the value of 1 million birds is between $2 and $3 billion, the agency should choose Option B. If it is greater than $3 billion, it should promulgate Option C.

In this scenario, the EPA's path forward is clear. It should select (at least) two randomized survey groups and hold (at least) two quadratic votes: one that asks whether it is worth $2 billion to save 1 million birds, and another that asks whether it is worth $3 billion to save 1 million birds. (Again, it would be preferable to phrase these questions in terms of the

money that each individual would be required to pay.) If both referendums are rejected, the agency should promulgate Option A; if the first passes and the second is rejected, it should promulgate Option B; if both pass, it should promulgate Option C. More generally, in this context an agency should be able to decide which version of the regulation to promulgate with only a few quadratic votes.

The situation becomes more complicated if we drop the assumption that the marginal benefit of protecting land and wildlife from pollution does not decline. That is, people might rationally value the first million birds saved more than the fourth or fifth million birds saved. After all, some individuals might care primarily about preserving the species; after a certain number of birds are saved, the remainder become less important. (It is worth noting that nonlinearity in responses to contingent valuation studies is one of the principal pieces of evidence used to reject those surveys as unreliable. If in fact individuals *actually* value nonmarket benefits nonlinearly—as opposed to being unable or unwilling to give meaningful answers to contingent valuation surveys—then perhaps contingent valuation studies are not quite as unreliable as previously thought.)

In any event, if the EPA does not assume that the value of benefits scales linearly, it cannot treat the environmental benefits involved as multiples of the basic unit of 1 million birds. It must determine the value of 1 million birds, 2 million birds, and 3 million birds as if they were separate entities, and then it must compare those values against one another in order to select the regulatory option that produces the greatest net benefits. Again, without making strong assumptions regarding the behavior of voters, a quadratic vote can yield only a binary yes/no answer regarding the value of a set of benefits. Accordingly, the agency will need to conduct several different votes before it can select the net-benefit-maximizing option. The same principle applies if a regulation will create multiple nonmarket benefits. For instance, a regulation might prevent the deaths of birds, otters, and turtles, and also protect sensitive wetlands. In such a case, the agency would be forced to value the various goods separately, which raises the issue detailed here.

One option would be to hold multiple quadratic votes with respect to each of the three options. The EPA might segment the population into nine groups and ask whether saving 1 million birds is worth $1 billion, $5 billion, or $10 billion; whether saving 2 million birds is worth $3 billion, $7 billion, or $12 billion; and so forth. The problem with this approach is that some of the votes might wind up being advisory only. For instance, suppose that the referendum on saving 1 million birds for $5 billion passes. If the referendum on saving 2 million birds for $3 billion passes, but the one on saving the same number for $7 billion does not, then the welfare-maximizing regulation is Option A.[2] Some voters will have successfully voted to save 2 million birds for $3 billion, yet the agency will not promulgate a regulation that does so. For all of the reasons detailed above, that is not desirable.

Instead, the agency should sequence its quadratic votes. It can employ one shortcut, which is to assume that the marginal benefits of saving more birds do not *increase*. Accordingly, Option A is preferable so long as 1 million birds is worth less than $1 billion. The EPA should

[2] The net health and safety benefits of Option A exceed those of Option B by $2 billion, and so Option B is preferable only if it produces at least $2 billion more in environmental benefits.

first test that proposition. If a referendum on that value passes, the agency can use subsequent referendums to home in on the value of the benefit. Once it has roughly identified the value that individuals place on 1 million birds, it can run the same process for 2 million birds to test whether greater environmental benefits have sufficient value to warrant more stringent regulation. For a regulation with a large number of options, an extended series of quadratic votes might be required. However, the rulemaking process is already so long—most major regulations take years to promulgate—that agencies should have ample time to complete a suite of quadratic votes without causing additional delays. Again, selecting the precise sequence and number of votes will be technically complicated and will depend upon a host of factors, including the agency's future regulatory plans. It may be sensible for the agency to consult with outside experts before settling on a path forward.

In the alternative, one could imagine agencies using a system of quadratic voting with credits, rather than dollars, as in Posner and Stephanopoulos (2016). Each voter would be issued some number of credits which could then be spent on any agency-related quadratic vote of the voter's choice. Yet this approach is inferior to using real dollars in quadratic elections in several ways, as Posner and Stephanopoulos explain. A system of credits would only allow voters to trade off their preferences for one public good against another, instead of trading off public goods against private goods. This problem is particularly acute in the regulatory context because the universe of potential public goods is unconstrained. Voters (and agencies) cannot know what regulatory benefits might be at issue in subsequent years, which will complicate voters' efforts to make tradeoffs. In addition, the government might issue too few credits to allow voters with intense preferences to express them. Individuals will likely end up casting roughly similar numbers of votes because there is no benefit to saving credits. But when it comes to valuing nonmarket goods, it is likely that some individuals have much more intense preferences than others. CBA should reflect this. Given the disadvantages of QV systems involving credits, agencies should incorporate quadratic votes using real dollars whenever possible.

3. Legal authority

While applying QV to many areas of law or policy would require a statute or even a constitutional amendment (Posner & Stephanopolous 2016; Posner & Weyl 2015), administrative agencies already have the authority to employ quadratic votes as part of the regulatory processes. There are two potential mechanisms. First, agencies could use quadratic votes as research tools, just as they might conduct contingent valuation studies or engage in other types of research. Agencies already have budgets and mandates to conduct research, as the next sections will describe in greater detail.

The downside of using a quadratic vote as a research tool is that the referendum itself is not legally binding; the agency would conduct the vote and then separately promulgate the regulation afterwards. This does not present a legal problem, but it may present a practical problem if voters are reluctant to participate in a non-binding referendum. As noted above, the agency can partially solve this problem by committing itself publicly to abiding by the results of the quadratic vote and acquiring a reputation for reliability. Still, this strategy will never be 100% successful. The agency's action might be vetoed by another executive branch actor, such as OIRA or the president. A new president might be elected and withdraw the regulation before

the agency can complete it. Some unforeseen event, such as an economic downturn, might intervene and change the cost-benefit calculus, forcing the agency to rethink its plans. Even if Congress blocked the agency from regulating by passing a statute, voters might mistakenly blame the agency even though it was not the agency's fault (Stephanopoulos 2016). A failure to regulate for any reason could prevent the EPA from successfully holding non-binding quadratic votes in the future.

This provides an incentive for the agency to attempt to make its quadratic votes legally binding. The best way to do so would be to promulgate a regulation that is contingent upon the result of a quadratic vote or series of votes. The regulation would go into effect only if a particular quadratic referendum reached a particular result; or, if multiple regulatory options are on the table, the regulatory outcome would depend upon which referendums passed and which failed.

It seems quite likely that such an approach would be lawful, although there is very little law on this point (Watts 2012). So far as can be determined, no statute explicitly addresses whether an agency may promulgate a regulation that relies upon an external trigger and no reported cases evaluating the practice exist. However, there are examples of regulations, promulgated under a number of different statutes that automatically spring into force or are suspended based upon some external triggering event. For instance, the Department of Labor has promulgated regulations that automatically extend eligibility for unemployment benefits in a state when that state's unemployment rate hits 5% or when the state satisfies other criteria (20 C.F.R. § 615.11-13). Many other regulations can be suspended or reinstated at the discretion of the executive. For instance, when the president or a governor declares a state of emergency, that declaration automatically suspends a wide range of regulations, including rules governing automobile and transportation safety (49 C.F.R. § 390.23(a)(1)(i)). States have promulgated regulations containing automatic triggers as well. For instance, regulations issued by the EPA require the states to devise their own plans to reduce greenhouse gas regulations. In the course of complying with that requirement, seven states issued regulations that automatically suspend if a court of appeals or the Supreme Court strikes down the underlying EPA regulation (e.g., Tenn. Comp. R. & Regs. 1200-03-09-.02). The EPA, which has the authority to approve or disapprove of state plans, has permitted states to use these automatic triggers (Environmental Protection Agency 2012).

Automatic triggers are sometimes built into statutes as well. For instance, the EPA's duty to regulate is triggered when the agency finds that a particular pollutant "endanger[s] public health or welfare" (42 U.S.C. § 7521(a)(1)). Even more generally, many regulations take effect only on a future date certain. That is a type of trigger, although a very formal one. Again, there are no reported cases testing such provisions, and so it is hard to assess their legality with any confidence. But the fact that agencies are allowed to use triggering provisions regularly and without comment indicates that a trigger based on a quadratic vote may well be allowed.

Certain types of regulations, promulgated by certain agencies, are far more likely to create nonmarket benefits than others. In particular, the most common—and perhaps most significant—types of nonmarket benefits are environmental ones, as in the example from the previous section. When the EPA regulates under the Clean Air Act or Clean Water Act, the

regulations will almost always affect wildlife and the environment, along with the lives and health of human beings. Any pollutant that reaches the air or the water supply, and is thus relevant to human health, will almost certainly affect the health of animals and their habitats as well. Contrast this with regulation by other agencies such as the Occupational Safety and Health Administration (OSHA) or the range of agencies with authority over the financial markets, such as the Commodities Futures Trading Commission or the Securities and Exchange Commission. OSHA's regulatory authority extends to workplace injuries and deaths, which are traded in the marketplace for labor. And with respect to the financial markets, essentially all of the costs and benefits of regulation are quintessentially market-related. Accordingly, in considering the legal framework for agencies to incorporate QV, the sections that follow will first focus on the Clean Air Act and Clean Water Act, as well as the Energy Independence and Security Act, which has been the source of significant energy efficiency regulation.

3.1 Clean Air Act

The Clean Air Act permits the EPA to set limits on the level of a given pollutant that factories or other sources may release into the atmosphere. The agency must set national ambient air quality standards (NAAQS) that cap emissions for a wide variety of pollutants (42 U.S.C. § 7410); it also has separate authority to regulate new pollution sources (42 U.S.C. § 7411) and especially hazardous pollutants (42 U.S.C. § 7412). Across all of these statutory provisions, the EPA's authority is phrased in terms of its ability to set "emissions limitations"—binding standards for how much of a given pollutant the source may emit (Masur & Posner 2015).

But while the statute constrains the type of regulation the agency may promulgate, it imposes no such constraint on the methodologies the agency may use when selecting the appropriate level of regulation. If the EPA uses QV as a research tool and input to CBA, the form of EPA regulation would not change. The agency would still promulgate standard regulations based upon standard emissions limitations. This could even become part of the notice-and-comment period: the agency could propose a regulation with the ultimate parameters contingent on a quadratic vote and then hold the quadratic vote during the comment period. When it comes to research tools such as this, the Clean Air Act is not merely permissive but actually mandates that the agency conduct research:

> The Administrator shall establish a national research and development program for the prevention and control of air pollution and as part of such program shall . . . conduct, and promote the coordination and acceleration of, research, investigations, experiments, demonstrations, surveys, and studies relating to the causes, effects (including health and welfare effects), extent, prevention, and control of air pollution (42 U.S.C.A. § 7403).

QV as an input to CBA would thus fall squarely within the EPA's authority to conduct "research, investigations, experiments, surveys, and studies" into the "health and welfare effects" of air pollution.

Similarly, there would be nothing novel or controversial about the EPA using the results of a quadratic vote to price environmental and other benefits. The Clean Air Act describes the emissions standards the EPA should establish in a number of different ways. With respect to

National Ambient Air Quality Standards, it instructs the EPA to provide "the maximum degree of reduction of each pollutant . . . which the permitting authority . . . taking into account energy, environmental, and economic impacts and costs, determines is achievable" (42 U.S.C. § 7479(3)). With respect to new sources of pollution, it directs the agency to set standards for pollution emissions "achievable through the application of the best system of emission reduction" while "taking into account the cost of achieving such reduction" (42 U.S.C. § 7411(a)(1)). Both of these sections invoke economic considerations, and thus both directly implicate the pricing of nonmarket benefits that QV is meant to facilitate. Accordingly, courts have consistently permitted agencies regulating under the Clean Air Act to use cost-benefit analysis (Masur & Posner 2010), and in recent cases they have even pushed the agency to rely more explicitly on comparisons of benefits and costs (Masur & Posner 2016; *Michigan v. EPA* 2015).

3.2. Clean Water Act

Like the Clean Air Act, the Clean Water Act is framed largely in terms of pollution standards. The statute gives the EPA the authority to set "effluent limitations," in parallel with the Clean Air Act's emissions limitations (33 U.S.C. § 1311(b)(1)(A)). The most salient difference between the two is that the Clean Water Act instructs the EPA to require that regulated firms install particular pollution-reducing technology—the "best available technology economically achievable" (33 U.S.C. § 1311(b)(1)(A)(i)) for some pollutants, and the "best practicable control technology" for others (33 U.S.C. § 1311(b)(2)(A)(i)). Regardless, this language should raise no additional hurdle to the incorporation of QV. The form of regulation will be the same: the agency will set an effluent limit and require a particular type of pollution control technology. If anything, the connection with cost-benefit analysis, and thus with the use of QV to price nonmarket goods, is even tighter. The statutory requirement that the EPA select the best technology "economically achievable" appears to call directly for something resembling CBA, as does the requirement that the technology be "practicable," if practicable is understood in economic terms (Masur & Posner 2010). The courts have allowed agencies particularly wide latitude in employing CBA under these Clean Water Act provisions (*Entergy Corp.* v. *Riverkeeper, Inc.* 2009).

The Clean Water Act also mirrors the Clean Air Act in its promotion of research into the causes and effects of water pollution. The Act obligates the EPA to "conduct, and promote the coordination and acceleration of, research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of pollution" (33 U.S.C. § 1254(a)(1)). The statute anticipates that such research will take place inside and outside of the EPA. It advises the agency to partner with states, municipalities, and other organizations. It also permits the EPA to award research grants to a number of different types of organizations, including state and local agencies (33 U.S.C. § 1255(a)) and "institutions of higher education" (33 U.S.C. § 1259(a)). This authority is technically unnecessary for holding a quadratic vote, which is revenue-neutral (except for the administrative costs of arranging the vote itself, or if it becomes necessary to pay participants). Nonetheless, it provides yet another indication that the statute envisioned the agency engaging with outside groups and individuals, including financially.

3.3. Energy Independence and Security Act

The Energy Independence and Security Act (EISA) provides the Department of Transportation with the authority to mandate more stringent fuel economy standards for automobiles and light duty trucks (49 U.S.C. § 32902). Because fuel economy standards affect the consumption of fossil fuels, they impact the environment and have the potential to provide a number of nonmarket benefits that are difficult to value through traditional means. Accordingly, the fuel economy regulations promulgated by the DOT are prime candidates for the use of quadratic voting.

The EISA is explicit in requiring the Department of Transportation to consider the economic effects of its fuel economy standards. The statute mandates that "each standard shall be the maximum feasible average fuel economy level" (49 U.S.C. § 39202(a)), with "feasible" defined in part with reference to "economic practicability" (49 U.S.C. § 39202(f)). When the agency has regulated under this statute, it has done so according to a cost-benefit analysis that takes into account extensive nonmarket benefits to the environment (Masur & Posner 2011).

Furthermore, the Department of Transportation is not merely permitted but required to conduct studies and engage in outside consultation in formulating its regulations. The statute directs the DOT to consult with both the Department of Energy and the Environmental Protection Agency when formulating fuel economy standards, given the overlap with those agencies' jurisdictions (49 U.S.C. § 39202(b)(1)). The DOT likewise is required to "adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible" (49 U.S.C.A. § 32902(k)(2)).

Perhaps most interestingly for present purposes, the EISA requires the Department of Transportation to partner with the National Academy of Sciences to produce a report on fuel economy standards, including "an analysis of existing and potential technologies that may be used practically to improve automobile and medium-duty and heavy-duty truck fuel economy" (121 Stat. 1492, Sec. 107). It might be premature for the National Academy of Sciences to hold quadratic referendums in the course of preparing this report; the statute requires that the National Academy begin writing the report "as soon as practicable," which might predate the agency's regulatory efforts. But it raises the more general possibility that the National Academy of Sciences could become a centralized clearinghouse for quadratic voting. Individual agencies possess expertise in their particular areas of regulation, but they may not acquire significant expertise in running quadratic votes. Some agencies may need to administer quadratic referendums only quite rarely if relatively few of their regulations involve nonmarket benefits. (The EPA may be an exception.) At the same time, holding quadratic referendums will require both technological infrastructure—the voting booths, electronic or physical—and expertise in presenting questions and information in accessible fashion. There is an analogy to CBA itself. Agencies such as the EPA that frequently engage in cost-benefit analysis appear to have become relatively proficient in it, and their CBAs are relatively more comprehensive. By comparison, agencies that conduct cost-benefit analysis only very rarely, such as the Department of Agriculture or the Patent and Trademark Office, struggle with the methodology and produce CBAs that are highly incomplete and riddled with errors (Masur & Posner 2016; Masur 2016).

An argument can thus be made for centralizing authority over quadratic voting within a single agency. That agency could be OIRA, the usual repository for centralized authority in the American administrative state. But OIRA does not typically conduct external studies or generate external data; what studies it does conduct usually pertain to the regulations that other agencies have promulgated. By contrast, the National Academy of Sciences (NAS) frequently is tasked with conducting studies and preparing reports on technical topics of importance to the executive branch, and using quadratic voting to price regulatory benefits is well within the range of typical NAS activity (Benjamin & Rai 2008). Agencies could approach the National Academy with the issues on which they require data; the National Academy could determine how to translate those requests into quadratic votes.

3.4. Other areas of regulation

In addition to the statutes summarized above, numerous other statutes, administered by a variety of agencies, are likely to create substantial nonmarket benefits. None of these statutes contains a legal barrier to using quadratic voting, and thus the agencies that administer them should consider immediately employing quadratic votes to value the relevant nonmarket benefits. Here is a sampling:

3.4.1 Endangered Species Act (16 U.S.C. § 1531)

The ESA affects the work of a number of federal agencies, none more directly than the Department of the Interior, which is charged with promulgating land use regulations to protect the habitats of endangered species. A typical effort is the agency's 1994 regulation protecting the Mojave habitat of the endangered desert tortoise (Environmental Protection Agency 1994). The principal benefit of this regulation is the saved tortoises themselves, but the agency was unable to quantify that benefit using traditional methods.

3.4.2 Outer Continental Shelf Lands Act (43 U.S.C. § 1332)

The Department of the Interior (DOI) also has authority to promulgate regulations to enforce this statute, which is designed to safeguard the outer continental shelf against environmental degradation. The DOI uses its authority under the Act to make rules regarding, among other things, the safety of offshore oil drilling platforms. In the wake of the Deepwater Horizon oil spill in the Gulf of Mexico, the DOI promulgated new regulations that tightened safety rules for offshore drilling and mandated more advanced equipment and training (Department of the Interior 2010). Quadratic voting could aid the agency in monetizing many of the benefits from avoiding another oil spill, including damage to the ocean ecosystem and deaths of marine life. Here, the DOI did not even begin to attempt to quantify this or other benefits.

3.4.3 National Environmental Policy Act (42 U.S.C. § 4321)

NEPA is another statute that impacts numerous agencies, among them the Department of Agriculture, which has regulatory authority over forests and logging. For instance, in 2003 the agency promulgated a regulation to block the building of roads in large swaths of Alaskan forest

in the interest of protecting native wildlife from being disturbed by automobiles (Department of Agriculture 2003). The agency did not attempt to quantify the nonmarket benefits that the regulation would produce.

3.4.4 Prison Rape Elimination Act (42 U.S.C. § 15601)

The Department of Justice (DOJ) has authority under this statute to promulgate regulations designed to reduce the incidence of prison rape. In 2012, it issued a regulation that mandated greater security and monitoring in federal prisons (Department of Justice 2012a). In monetizing the benefit of reducing the incidence of prison rape, the DOJ relied upon both contingent valuation surveys and jury verdicts in actual cases (Department of Justice 2012b). Neither involves an individual actually putting his or her own money at stake; although jury verdicts involve real dollars, they are someone else's dollars. The DOJ would have been better off using a quadratic vote.

3.4.5 Immigration and Nationalization Act (8 U.S.C. § 1103)

Under this statute and the Homeland Security Act (6 U.S.C. § 112), the Department of Homeland Security (DHS) has substantial authority to establish procedures governing visas and immigration. Many of the costs and benefits related to immigration are involved in market transactions. But in some cases, benefits may not be market-based and elude easy quantification. For instance, for many years a noncitizen living in the United States who was applying for a visa was forced to leave the country while the visa was being processed. In 2013, DHS promulgated a regulation allowing noncitizens to remain in the country while their visas were being reviewed, sparing them the hardship of being separated from their jobs and families (Department of Homeland Security 2013). Some of the benefits are market-based (the noncitizen may be able to continue working), while others, such as avoiding being separated from one's family, represent non-market benefits. DHS could have used a quadratic vote to determine the value of the latter, which it could not quantify.

3.4.6 Vietnam Era Veterans' Readjustment Assistance Act (38 U.S.C. § 4212)

The Department of Labor has rulemaking authority under this and a variety of related statutes, all of which allow the agency to promulgate rules to reduce the incidence of discrimination against various classes of workers. In 2013, the DOL promulgated regulations designed to prevent workplace discrimination against disabled veterans (Department of Labor 2013). Some of the benefits from preventing such discrimination are market-based (via the employer-employee relationship) and easier to monetize. But the DOL also cited benefits related to dignity and equity, which it was not able to monetize, and which would be ripe for consideration through a quadratic vote.

4. Conclusion

Quadratic voting should be used as a complement to CBA and used to improve agencies' ability to value nonmarket benefits that are typically difficult to monetize. Unlike many areas of law and policy, where implementing quadratic voting would require legislation, agencies already

have the power under their existing organic statutes to employ quadratic votes in regulation. A wide variety of regulatory areas exist wherein QV could improve regulatory outcomes, and the relevant statutes offer nothing but encouragement. Administrative agencies can and should move immediately to incorporate quadratic voting into the regulatory process.

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Table 1: The EPA's Three Regulatory Options

	Option A	Option B	Option C
Health and safety benefits (cancer and emphysema cases avoided)	$3 billion	$4 billion	$6 billion
Costs:	$2 billion	$5 billion	$10 billion
Non-market benefits:	1 million birds saved	2 million birds saved	3 million birds saved

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