Ratio Bias and Policy Preferences: How Equivalency Framing of Numbers Can Affect Attitudes

Rasmus T. Pedersen
University of Copenhagen

Numbers permeate modern political communication. While current scholarship on framing effects has focused on the persuasive effects of words and arguments, this article shows that framing of numbers can also substantially affect policy preferences. Such effects are caused by ratio bias, which is a general tendency to focus on numerators and pay insufficient attention to denominators in ratios. Using a population-based survey experiment, I demonstrate how differently framed but logically equivalent representations of the exact same numerical value can have large effects on citizens' preferences regarding salient political issues such as education and taxes. Furthermore, the effects of numerical framing are found across most groups of the population, largely regardless of their political predisposition and their general ability to understand and use numerical information. These findings have significant implications for our understanding of framing effects and the role played by numbers in public opinion formation.

KEY WORDS: framing, public opinion, persuasion, ratio bias, numeracy

Words can be a formidable tool for actors trying to shape citizens' attitudes. Within public opinion research, a rich literature on framing effects has demonstrated how the choice of words used by political elites to frame a policy issue can have strong effects on attitudes toward the issue (Clifford & Jerit, 2013; Iyengar, 1991; Nelson, Oxley, & Clawson, 1997; Zaller, 1992). However, while words do matter, and while this literature has contributed substantially to our understanding of citizens' opinion formation, the general perspective of framing as "winning with words" (Schaffner & Sellers, 2010) means that the literature has turned a blind eye to the ways in which framing of *numbers* can move political attitudes.

This present disregard for numbers is curious, as numbers played a key part in the foundational "Asian disease" framing studies (Kahneman & Tversky, 1979, 1984). More importantly, the absence of numbers within current framing studies is at odds with the prominent role played by numbers in modern political rhetoric and news stories, be it unemployment rates, growth rates, tax rates, inflation rates, crime rates, and so on. The increased prominence of numbers in modern politics and public discourse has mostly—somewhat ironically—been described in qualitative terms, but it is evident that numbers and statistics permeate modern politics, news, and society in general (Desrosiéres, 1998; Maier, 2002; Mutz, 1998, pp. 35–38; Prévost & Beaud, 2012). Thus, by disregarding numbers, the field of framing studies has ignored a central component of extant political rhetoric. Because numbers

lend themselves better to logically equivalent framing than words, the literature has also consequently undervalued the relevance of frames that are logically equivalent.

This article demonstrates a novel way in which logically equivalent framing of numbers can have a strong impact on citizens' opinions about political issues. Using a survey experiment, the article shows how numerical framing can substantially affect political attitudes because of "ratio bias," which is a general tendency to pay too much attention to the numerators in ratios and insufficient attention to the denominators (Peters et al., 2006; Reyna & Brainerd, 2008). Specifically, the study shows that numerical framing can be used to considerably increase or decrease support for policies regarding education and taxes and that this effect is found among a majority of voters, largely regardless of their political predisposition and their ability to understand and use numbers.

These results have significant implications for our understanding of framing effects and public opinion formation. First, the results demonstrate that the relevance of logically equivalent frames extends well beyond Kahneman and Tversky's (1979) prospect theory. In fact, the framing effects caused by ratio bias might very well be a more relevant mechanism within the domain of politics. Second, by showing such effects, this study documents the importance of the ever-present numbers in political rhetoric. While some previous studies have found a limited impact of factual numbers on opinion formation (Cohen, 2003; Lawrence & Sides, 2014), this study lends credence to the proposition that citizens indeed use the numbers available to them when forming an opinion on policy issues (Gartner, 2008; Gilens, 2001; Schueler & West, 2015). Third, the results also demonstrate that numbers do not necessarily lead to a more rational public. As the next section will show, there is still plenty of room for irrationality in a quantified world.

The Ratio Bias Phenomenon

To understand the ratio bias phenomenon, imagine that you are faced with two urns containing a mix of red and white jellybeans. The first urn contains 10 jellybeans, of which one is red and nine are white. The second urn contains one hundred jellybeans, of which 10 are red and 90 are white. If you pick a red jellybean, without looking, you will win a prize. If you pick a white jellybean, you will win nothing. Which urn would you prefer to draw from?

Obviously, the likelihood of drawing a red jellybean does not differ between the two urns, but most people will nevertheless prefer the larger urn with 10 red jellybeans (Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999). For many people, this preference for the urn with more jellybeans is so strong that it persists even when it is a nonoptimal choice, for example, when the larger urn contains 7/100 red jellybeans as opposed to the smaller urn with 1/10 red jellybeans (Dale, Rudski, Schwarz, & Smith, 2007; Denes-Raj & Epstein, 1994).

The jellybean experiment illustrates one effect of the ratio bias phenomenon: The perceived likelihood of an event is greater when it is presented as a ratio with a large numerator and denominator than when it is presented as a ratio with a small numerator and denominator (Reyna, Nelson, Han, & Dieckmann, 2009). More generally, the ratio bias phenomenon denotes a tendency to pay too much attention to numerators in ratios and insufficient attention to denominators, and, as such, it is not limited to choices concerning probabilities. Phenomena equivalent or similar to the ratio bias effect have been studied under terms such as "denominator neglect" (Okan, Garcia-Retamero, Cokely, & Maldonado, 2012), "numerosity effect" (Reyna & Brainerd, 2008), "unit effect" (Pandelaere, Briers, & Lembregts, 2011), and "base rate fallacy" (Bar-Hillel, 1980). As shown by these studies, ratio bias is a highly general phenomenon that affects decision making within several different domains (Denes-Raj, Epstein, & Cole, 1995). The bias can influence choices regarding which jobs to apply for (Alonso & Fernandez-Berrocal, 2003), which goods to buy and consume (Burson, Larrick, & Lynch, 2009; Pandelaere et al., 2011), and perceptions of health risks: As demonstrated by Yamagishi (1997),

cancer was rated as riskier when it was described as killing "1,286 out of 10,000 people" than when it was described as killing "24.14 out of 100 people" (p. 495). Similarly, as a consequence of ratio bias, risk perception is also influenced by the temporal frame that is used when describing prevalence or risk: People rate potential cases of deaths as more risky when given the number of deaths per year than when they are given the equivalent number of deaths per day (Bonner & Newell, 2008). This last example also illustrates how ratio bias can work in cases where the denominator is not explicitly spelled out in a number.

Ratio Bias and Political Attitudes

While ratio bias has been documented across multiple domains, the phenomenon has remained unexplored within the domain of politics and public opinion research. Based on the existing ratio bias studies in other domains, it seems likely that ratio bias can affect citizens' perceptions of the numbers surrounding a policy issue. However, any effect of ratio bias on political attitudes additionally requires that citizens actually use such numbers when forming political attitudes. This assumption is not trivial. Citizens are often ignorant regarding politically relevant numbers on, for example, unemployment, public spending, and population figures (Herda, 2010; Kuklinski, Quirk, Jerit, Schwieder, & Rich, 2000; Lawrence & Sides, 2014), and their opinions can be surprisingly unaffected by such numbers even when they learn about them. Several studies have shown that numbers about, for example, welfare spending, unemployment, and minority populations do not significantly affect people's opinions regarding policies on these issues (Kuklinski et al., 2000; Lawrence & Sides, 2014). If citizens pay no attention to numbers when forming political attitudes, ratio bias should obviously not be expected to exert any influence on such attitudes.

However, numbers are not always disregarded in citizens' opinion formation: Kuklinski et al. (2000) also found that the ostensibly inefficacious numbers on welfare spending did move opinions when presented in a way that drew attention to current misperceptions. Similarly, later experiments have shown that numerical information about crime rates, war casualties, and public spending on issues as diverse as foreign aid, incarceration, and education can move political attitudes in some cases (Gartner, 2008; Gilens, 2001; Mérola & Hitt, 2015; Schueler & West, 2015). In other words, while the results are mixed, numbers do sometimes affect political attitudes. Therefore, if the ratio bias effect can make politically relevant numbers appear larger or smaller, we might also expect that it can affect political attitudes. More specifically, we should expect the following.

H1: Support for a given policy will be higher [lower] when the positive [negative] attributes associated with the policy are presented with a large numerator and denominator relative to a small numerator and denominator.

Numeracy as a Moderator of Ratio Bias

The degree to which individuals' attitudes are affected by ratio bias may be contingent on personal characteristics, both cognitive and attitudinal. Starting with the cognitive factors, the existing literature on the ratio bias effect has often applied the perspective of dual-process theories of judgment and decision making, for example, cognitive-experiential self-theory (Pacini & Epstein, 1999). According to such models, human judgment and decision making can be based on two distinct modes of thought. One is the *experiential system*, which is also termed the *associative system* (Sloman, 1996) or *System 1* (Kahneman & Frederick, 2002), and which operates rapidly, affectively, and relatively effortlessly.

In contrast, the *rational system* (also known as the *rule-based system* or *System 2*) is slow, logical, and effortful. From this dual-process perspective, the ratio bias effect can be seen as a result of the intuitive reasoning of the experiential system. Several specific mechanisms, which are not necessarily mutually exclusive, have been suggested for why the experiential system may exhibit ratio bias. First, the experiential system comprehends smaller numbers better than larger numbers, and it may therefore be easier to realize that a given number is low when it is presented with a small ratio, for example, 1/10 as opposed to 10/100. Second, raw numbers are easier to process than fractions, and the experiential system may therefore be disposed to attend to the numerator as a number and neglect the denominator (Alonso & Fernandez-Berrocal, 2003; Pelham, Sumarta, & Myaskovsky, 1994; Yamagishi, 1997).

An important point related to dual-process explanations of ratio bias is that individuals differ in their reliance on the two systems when solving certain tasks. In tasks involving numbers, individuals may rely more on their experiential system if they have a low level of numeracy, that is, ability to understand and use numerical concepts. Consequently, several experiments have shown that individuals who are low on numeracy exhibit a stronger ratio bias than individuals who are high on numeracy (Reyna & Brainerd, 2008).

It is worth noting that numeracy is only weakly or moderately correlated with level of education and general intelligence and that numeracy is a stronger predictor of performance on number-related tasks than measures of education and intelligence (Låg, Bauger, Lindberg, & Friborg, 2014). It should also be noted that within public opinion research, the term "innumeracy" has sometimes been used as a term denoting ignorance about politically relevant facts and numbers (Lawrence & Sides, 2014; Nadeau, Niemi, & Levine, 1993). However, this article adheres to the definition of numeracy as "the ability to understand and use numerical information" (Reyna et al., 2009, p. 943). Understood in this way, numeracy is so far an almost completely unexplored concept in public opinion research (although see Kahan, 2015; Mérola & Hitt, 2015). Based on existing studies on numeracy and ratio bias, we should expect the following.

H2: Numeracy moderates the ratio bias effect on political attitudes, resulting in stronger ratio bias effects among individuals with a low level of numeracy.

Political Predisposition as a Moderator of Ratio Bias

The existing studies on ratio bias within domains such as health and commerce have not paid much attention to the motivations behind people's decision making. However, when moving into the domain of politics, we need to be cognizant of the fact that reasoning can be motivated by several different goals (Kunda, 1990). The basic premise underlying the theory of motivated reasoning is that the motivations underlying any sort of reasoning can be expected to influence the conclusions reached (Erisen, Lodge, & Taber, 2014; Taber & Lodge, 2006). Specifically, people's reasoning may be driven both by accuracy goals and by directional goals. An accuracy goal motivates people to evaluate the available information in an evenhanded manner with the goal of reaching a conclusion that is accurate (Kunda, 1990). In contrast, reasoning motivated by a directional goal is reasoning that is motivated by a desire to reach a particular conclusion because this conclusion is in line with already held perceptions or attitudes. Hence, in politics, people will often be motivated to reach a conclusion that is in line with partisan directional goals (Bolsen, Druckman, & Cook, 2014).

Several studies have shown that framing effects on political issues are affected by directional goals and that the efficacy of a frame can depend on the political predisposition of the individual exposed to the frame. When a person is exposed to a frame that is clearly congenial to his or hers

political predisposition, this person will tend to follow the frame. In contrast, when exposed to a frame which conflicts with political predispositions, people tend to disregard the arguments in the frame (Druckman & Bolsen, 2011; Druckman, Peterson, & Slothuus, 2013; Leeper & Slothuus, 2014; Nelson et al., 1997; Slothuus & de Vreese, 2010).

While these previous studies have generally investigated frames that are explicitly in favor or in opposition to a specific policy, different ratios used to describe a policy-relevant number are not explicitly or unambiguously arguments in favor or against this particular policy. Imagine, for example, a policy proposal, which entails a tax increase. According to ratio bias theory, we expect people to perceive a tax increase to be relatively larger when described in yearly costs (e.g., $420/year) than when it is described in monthly costs ($35/month), but that does not mean that people would only regard the tax increase of $420/year as an argument against the policy, while an increase of $35/month would be perceived as an argument in favor of the policy. A right-wing voter might tend to regard both these numbers to be arguments against the proposal, whereas a left-wing voter might be more inclined to regard both of these numbers as reasonable costs of the policy proposal.

Nevertheless, the $420/year framing of the tax increase would be relatively more congenial to the position of the right-wing voter, while the $35/month framing would be relatively more in line with the position of the left-wing voter, and the directional goals of these voters may very well make them more likely to disregard or object to a ratio that is uncongenial to their position. However, such motivated reasoning would not by itself result in stronger ratio bias effects among right-wing or left-wing voters. Ratio bias is—by definition—estimated by comparing different reactions to different ratios, and if left-wing voters and right-wing voters exhibit the same degree of politically motivated reasoning when exposed to ratios, this will simply attenuate the effect of the observed ratio bias. Hence, motivated reasoning alone should not lead us to hypothesize that the perceived difference between, for example, $35/month and $420/year has a larger impact on individuals from the left side of the political spectrum or the right side of the political spectrum. Therefore, we pose the open question: *Does political predisposition moderate the ratio bias effect on political attitudes?* (Research Question 1).

Potential Interactions Between Numeracy and Political Predisposition

While motivated reasoning does not, on its own, lead us to expect any observable difference in ratio bias between voters on the left and voters on the right, the perceptions of ratios could potentially be affected by a joint moderating effect of political predispositions and numeracy. For completeness, the study also considers this possibility.

Politically motivated reasoning is often regarded as a consequence of bounded rationality and heuristic thinking associated with System 1 (Lodge & Taber, 2013). It is therefore tempting to assume that System 2 thinking might lessen the impact of politically motivated reasoning and that highly numerate individuals—who are more likely to engage in System 2 thinking when encountering numbers—would therefore rely less on politically motivated reasoning when making up their mind on specific policy issues. However, recent studies suggest that System-level 2 thinking may do the exact opposite, namely *increase* the effect of politically motivated reasoning: According to the *cultural cognition* perspective on motivated reasoning, such reasoning primarily serves as an identity-protecting tool. Thus, processing of information will therefore primarily be guided by an attempt to make this information fit with perceptions that are congruent with the ideological or cultural groups that an individual identifies with (Kahan, 2012). Furthermore, individuals with a high level of cognitive reflection and numeracy will better be able to perform such identity-protecting cognition, and disagreement regarding politically contested facts and numbers will therefore be highest among these individuals (Kahan et al., 2012). In line with this perspective, recent studies have found that conservatives and

liberals which have a high level of science intelligence and numeracy are more likely to disagree and to interpret numbers selectively on issues such as climate change, fracking, and gun control than conservatives and liberals with a low level of science intelligence and numeracy (Kahan, 2015; Kahan, Peters, Dawson, & Slovic, 2013).

If this pattern also holds for ratio bias, we should expect to see that highly numerate individuals would use their numerical skills specifically to overcome ratio bias, when such ratio bias would otherwise pull them away from the decision that best fits with their political identity. In contrast, individuals low on numeracy would not possess the same abilities to process numbers selectively, and they would therefore be relatively defenseless against ratio bias. If there were such an interaction between numeracy, political predisposition, and ratios, this would also mean that:

> *H3*: Numeracy is positively correlated with disagreement between groups of different political predispositions, such that numeracy exacerbates policy disagreements between groups with different political predispositions.

Experiment

A survey experiment was conducted in a commercial online survey panel (YouGov). Members of the panel were invited by e-mail to participate, and among the 1,030 respondents commencing the survey, 1,007 respondents completed it. Survey drop-off after exposure to stimuli was negligible (1.1%). The respondents were approximately representative of the Danish population (see Appendix A for a detailed description of the sample).

Design

The experiment applied a choice paradigm technique where respondents are asked to choose between two alternatives containing trade-offs across two different attributes (Burson et al., 2009). Specifically, respondents were presented with a choice between two different scenarios describing the educational attainment of youths and the respondent's own tax payments. In Scenario A, education rates and taxes remained unchanged relative to status quo, while Scenario B contained improvements in educational attainment but also a tax increase. The experiment employed a 2 × 2 factorial design, such that the first experimental factor varied the ratio used to describe the youths, while the second factor varied the ratio used to describe the taxes. On youths, respondents were randomly exposed to either a description where the problem of youths not completing an education was framed with the relatively small ratio of *8 out of every 100 young people* or a description with the relatively large implied ratio of *5,600/70,000*. On taxes, respondents were randomly exposed to the large numerator and (temporal) denominator of *"DKK 3,000 more in taxes per year"* or to the smaller ratio of *"DKK 250 more in taxes per month."* [1] The exact text of the resulting four experimental conditions is shown in Appendix B.

Because both conditions contained information about the total population of youths, respondents in both conditions were given logically equivalent information about both the absolute and the relative

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[1] Both issues are salient in Danish Politics (Dahlgaard, Hansen, & Pedersen, 2014). The numbers for youths was the actual estimate of the Danish Ministry of Education, while the number for the tax increase was based on estimates of the Danish citizens' willingness to pay for sociotropic goals (Hansen, Olsen, & Bech, 2014). The term "8 out of every 100" could also have been written as "8%." However, the percentage format may in itself have an impact on perceptions and decision making (Cuite, Weinstein, Emmons, & Colditz, 2008).

prevalence of the problem with youths not attaining an education. Similarly, a tax increase of DDK 250/month is of course logically equivalent to a tax increase of DKK 3,000/year.

Prior to their exposure to the stimuli, respondents were surveyed on political predisposition, numeracy, and standard demographic variables. *Political predisposition* was measured with two questions, namely the respondents' self-placement on a left-right scale ranging from 0 to 10 and their party choice. Together, these two questions formed a reliable scale, rescaled to range from 0 to 1 ($\alpha = .80$). *Numeracy* was measured with the four items on subjective numerical ability from the Subjective Numeracy Scale (SNS; Fagerlin et al., 2007). Alternatively, numeracy can be measured with questions in which respondents have to perform actual numerical judgments and calculations (Lipkus, Samsa, & Rimer, 2001; Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007; Reyna et al., 2009). However, such objective numeracy scales are time consuming, and some respondents find them to be stressful and frustrating (Cuite et al., 2008). Further, the SNS has been shown to correlate strongly with objective measures of numeracy and to serve relatively well as a predictor of success in numerical tasks (Låg et al., 2014; Zikmund-Fisher, Smith, Ubel, & Fagerlin, 2007), although see, Liberali, Reyna, Furlan, Stein, and Pardo (2012). The SNS was therefore used in order to minimize survey completion time. The scale was translated into Danish and further modified in two ways. First, one of the items was replaced with a new item. The original SNS asks respondents to assess their own ability to calculate a 15% tip. However, in Denmark tipping is relatively rare. Instead, respondents were therefore asked about their ability to convert between currencies. Second, "don't know" was included as a response option. Very few respondents used this option (<3% per item). The four items formed a reliable scale ($\alpha = .90$). Because the SNS scale is negatively skewed, previous research has often used a median split (Peters et al., 2006). However, estimations strategies based on median splits are rarely defensible (Maxwell & Delaney, 1993), and instead scores were squared before being rescaled to range from 0 to 1 ($M = 0.50$, $SD = 0.26$).[2]

Finally, at the end of the survey, respondents were asked to choose the correct number of youths not receiving an education among four alternatives. The correct answer was chosen by 88.2% of the respondents, indicating that most respondents had paid attention to the numbers presented in the scenarios.[3]

Results

As expected, the preference for scenario B differed significantly across the four experimental conditions, $\chi^2(3, N = 1,007) = 19.55$, $p < .001$. Furthermore, the relative placements of the four groups were exactly as expected, although not all of the differences were significant (at $p < .05$). As shown in Table 1 below, the proportion of respondents with a preference for the tax-increase scenario was lowest in the condition where youths were framed with a small ratio and taxes were framed with a large ratio. The proportions were higher in the two conditions where one of these ratios was changed, and, finally, the proportion was highest in the condition where youths were framed with a large ratio and taxes were framed with a small ratio.

The effects were clearly of a nontrivial magnitude. When comparing groups 1 and 4, the difference in support for Scenario B was 17.5 percentage points (95% CI[9.2, 25.7], $z = 4.1$, $p < .001$). This result replicates the findings from a smaller pilot study ($n = 108$), which found a difference of 24.2 percentage points between these two conditions (95% CI[5.9, 42.5, $z = 2.5$, $p = .01$). This pilot study, which also contained a similar experiment with nonsignificant treatment effects, is described in detail in the online supporting information.

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[2] All results remain substantially unchanged when repeating the analyses with nonsquared values of numeracy.

[3] The minority of respondents failing to answer this question correctly was retained in all the analysis, since exclusion of respondents that fail such control questions can lead to serious bias (Aronow, Baron, & Pinson, 2015).

Table 1. Proportion of Respondents Preferring Scenario B

Experimental Conditions	Proportion Choosing Scenario B (95% CI)
Condition 1: Small Youth Ratio (7/100) and Large Tax Ratio (3,000/year)	26.8%$_a$ (21.3–32.3)
Condition 2: Small Youth Ratio (7/100) and Small Tax Ratio (250/month)	30.2%$_{ab}$ (24.5–35.8)
Condition 3: Large Youth Ratio (4,900/70,000) and Large Tax Ratio (3,000/year)	35.7%$_{bc}$ (29.8–41.6)
Condition 4: Large Youth Ratio (4,900/70,000) and Small Tax Ratio (250/month)	44.3%$_c$ (38.1–50.4)

Note: $n = 1,007$. Proportions not sharing a subscript letter differ significantly at the 5% level.

A concern regarding the external validity of the results could be that these large effects might be driven by particularities in the scenario used in the experiments. While this concern is clearly relevant, the 2×2 design of the study allows for additional analyses that can provide some indications regarding the robustness of the effect across different policy issues. Specifically, we can see whether the effects were driven purely by the numerical framing of youths or the numerical framing of taxes. To estimate this, the average effects of the two factors were estimated in a simple logistic regression, with dummy variables for the framing of the two attributes instead of dummies for the four experimental conditions (Model 1 in Appendix C).

An estimation based on this model shows that increasing the denominator used to describe the number of youths increased the preference for scenario B significantly, by 11.5 percentage points (95% CI [5.7,17.3]). Similarly, there was also an effect of lowering the denominator of the tax ratio. This change also increased the preference for scenario B significantly, by 6.0 percentage points (95% CI [0.2,11.8]). This effect of logically equivalent tax ratio framing is even more remarkable given that the price elasticity of tax-funded goods has previously been shown to be much lower than most consumer goods (Green, 1992). Thus, the fact that a ratio bias effect is found across two different factors suggests that the effect might also be reasonably expected to exert some effect on other policy issues and scenarios.

Are these effects of ratio bias moderated by the respondents' numeracy and political predispositions? To answer this question, model 2 (Appendix C) includes the interactions between these individual-level variables and the experimental manipulations. As is evident from the model, none of the interaction terms have significant coefficients. However, an interaction effect *"cannot be evaluated simply by looking at the sign, magnitude, or statistical significance of the coefficient on the interaction term when the model is nonlinear"* (Ai & Norton, 2003, p. 129). Figure 1 below therefore illustrates the effects of the framing of numbers of youths and the framing of taxes, conditional on the level of numeracy.

The top graph in Figure 1 illustrates the effect of framing youths with a large ratio as opposed to a small ratio. As we would expect, we see large ratio bias effects among respondents low on numeracy, whereas effects are relatively small among the highly numerate respondents. The effect becomes insignificant at numeracy levels above 0.71, a level which just 11.3% of the respondents are above. While this does suggest that numeracy does moderate the effect of ratio, as posited in Hypothesis 2, it is important to note that the differences in effects between respondents high and low on numeracy are not in themselves significant. For example, the estimated effect for a respondent with a numeracy score one standard deviation below the mean is 14.1 percentage points (95% CI [6.4,21.8]), while the estimated effect for a respondent with a numeracy score one standard deviation above the mean is 6.6 percentage points (95% CI [−1.6,14.7]), but the difference between these two effects is not significant ($p = .19$).[4]

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[4] The difference remains insignificant ($p = .19$) when comparing the effects among respondents with numeracy scores of zero (minimum) versus one (maximum).
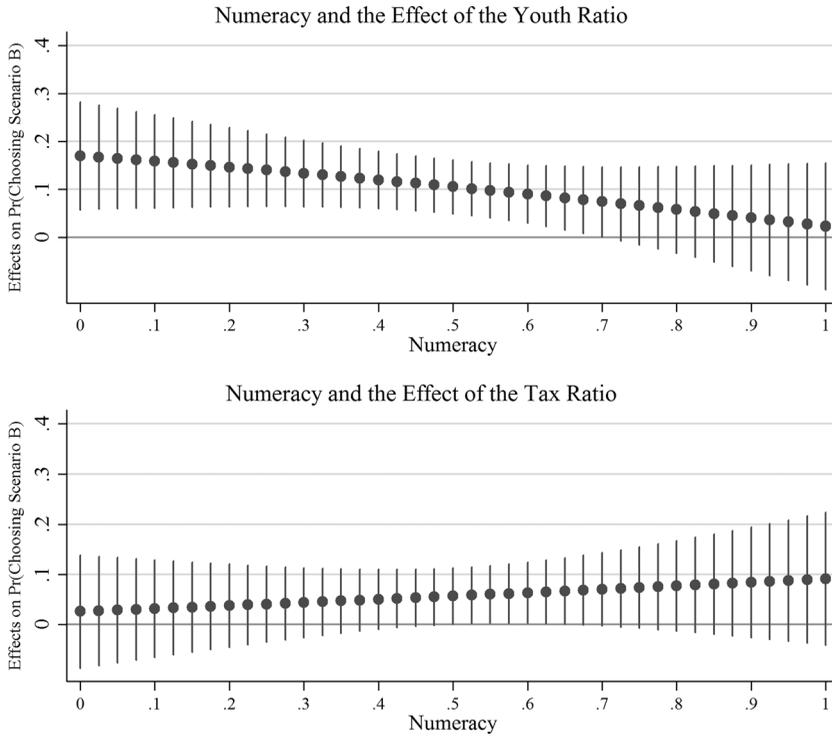
Figure 1. Numeracy as a Moderator (with 95% CI). The graphs illustrate the average marginal effect of experimental conditions, contingent on the respondent's level of numeracy.

Overall then, a reasonably conservative interpretation of the results leads to two conclusions: First, a small group of respondents with very high levels of numeracy may be unaffected by ratio bias, as suggested by the nonsignificant effects for this group. Second, however, we cannot state with certainty that the effects are significantly smaller among the highly numerate than the less numerate. In any case, the vast majority of respondents have levels of numeracy where they are significantly affected by ratio bias.

The marginal effect of the numerical framing of taxes is illustrated in the bottom half of Figure 1. In this model, the marginal effects are insignificant across almost all values of numeracy, and this model can therefore not reveal any significant interactions between experimental conditions and numeracy.

Next, we turn to the question of how political predisposition might moderate the effect of the numerical framing. Before we look at the moderation itself, it is worth noting that there is a strong main effect of political predisposition. The top part of Figure 2 shows the preference for scenario B averaged across all of the experimental groups, across the political spectrum (Based on model 2). As one can see, there is a clear relationship between political predisposition and preferences (the dotted lowess-line confirms an approximately linear relationship). Among respondents on the far left of the political spectrum, a majority of 64.1% (95% CI[57.1,71.0]) preferred the tax increase in scenario B. The preference for this scenario drops substantially as we move to the right on the political spectrum, and among respondents on the far right, only a minority of 17.6% (95% CI [13.9,21.2]) of the respondents preferred this scenario. Clearly, the effects of the experimental manipulation are not a result of the respondents responding indifferently to a politically unimportant issue; rather the respondents are strongly affected by their political predispositions when forming an opinion on this issue.

Do these strong predispositions then moderate, perhaps even eliminate, the effects of ratio bias? As shown in the middle graph of Figure 2, framing the number of youths as
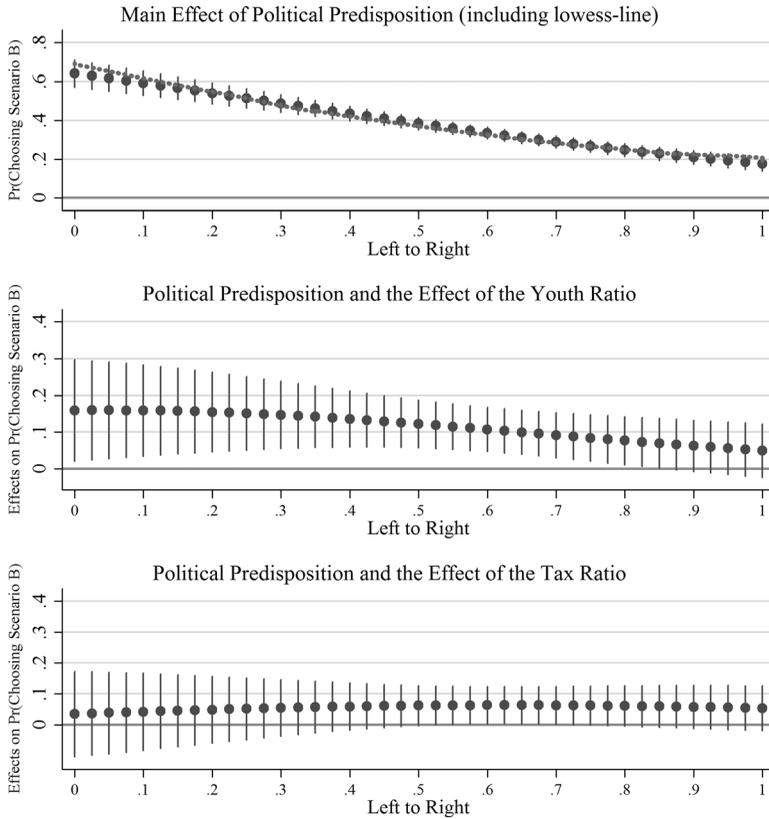
Figure 2. Political Predisposition as Main Effect and Moderator (with 95% Cl). The graphs illustrate the probability of choosing Scenario B (scenario with tax increase), contingent on the respondent's political predisposition and experimental condition.

4,900/70,000 instead of 7/100 increases the preference for scenario B among respondents across most of the political spectrum. The effect becomes insignificant once left-right position reaches 0.86, a level which 20.3% of the respondents are above. While left-leaning respondents thus seem to respond more to this framing than respondents on the center and on the right, contrasts show, however, that the difference in effects between respondents one standard deviation to the left of the mean versus one standard deviation to the right of the mean is not significant ($p = .16$).[5]

The effect of the framing of taxes is shown in the three graphs at the bottom of Figure 2. As we can see from the figure, the effect of framing the tax increase as "DKK 250 per month" instead of "DKK 3,000 per year" does not differ much across the political spectrum. When estimating effects across the political spectrum, the effect is insignificant, except for a small part of the center of the left-right scale. In sum, while the analyses demonstrate strong ratio bias effects for left-leaning but not for the most right-leaning respondents, the analysis does not reveal strong or significant moderating effects of political predisposition.[6]

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[5] The difference remains insignificant ($p = .25$) when comparing the effects among respondents with left-right positions of zero (minimum) versus one (maximum).

[6] One could easily imagine nonlinear moderating effects of political predisposition, for example, stronger ratio effects for centrist individuals. However, a Box-Tidwell test for nonlinearity shows no significant effects of adding polynomial terms to the model.
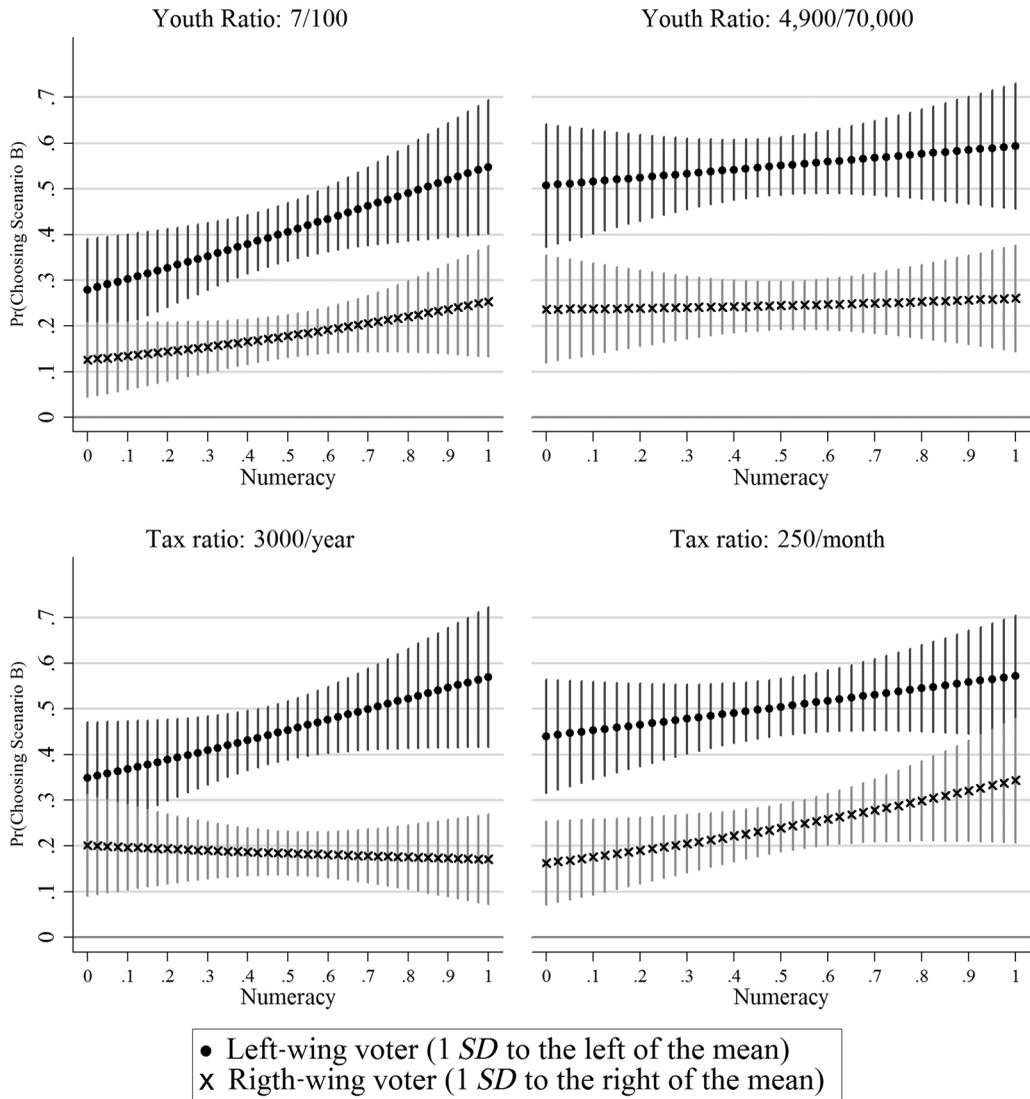
Figure 3. The Joint effects of numeracy and political predisposition (with 95% Cl). The graphs illustrate the probability of choosing Scenario B (scenario with tax increase), contingent on respondent's numeracy, political predisposition, and experimental condition.

As a final step in the analyses, we investigate the possibility of a joint moderating effect of numeracy and political predisposition, as posited by Hypothesis 3. The graphs in Figure 3, which are based on model 3 in Appendix C, shows the predicted probabilities of choosing Scenario B, contingent on experimental treatment, numeracy, and political predisposition.[7]

Looking at the two top graphs in Figure 3, which illustrates how respondents react to the framing of youths, we see a pattern among left-leaning respondents that is consistent with Hypothesis 3: Numeracy plays a particularly large role for these respondents, when they are exposed to a ratio that

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[7] Left-wing respondents are set to a left-right position one standard deviation to the left of the mean, while right-wing respondents are set to one standard deviation to the right of the mean. Setting these values to minimum and maximum possible values does not change the conclusions.

is relatively uncongenial to their predisposition (a ratio of 7/100). When exposed to this ratio, respondents with a high level of numeracy (1 *SD* above the mean) are significantly ($p = .03$) more likely to choose Scenario B than respondents with a low level of numeracy (1 *SD* below the mean). However, the right-leaning respondents with a high level of numeracy does not conversely use their numeracy to reject Scenario B. Regardless of the ratio presented to them, highly numerate right-wing respondents are (nonsignificantly) more likely to choose Scenario B than right-wing respondents with a low level of numeracy. Overall, the results show that when respondents are exposed to the small youth ratio, the gap between highly numerate left-wing and right-wing respondents is 26.3 percentage points, whereas the corresponding gap between respondents with low numeracy is just 18.9 percentage points. While this difference could suggest a polarizing effect of numeracy, it is, however, not significant ($p = .34$). Similarly, when exposed to the large youth ratio, the marginal effect of numeracy is clearly nonsignificant ($p = .70$)

The lower graphs in Figure 3, illustrating how respondents react to the framing of taxes, shows a pattern that is similar to the pattern found when looking at the framing of youths: While the pattern among left-leaning respondents is as expected, right-wing respondents do not behave as expected. Further, the polarizing effect of numeracy is insignificant for both tax ratios ($p > .10$).

Finally, an aggregate test across all experimental conditions shows that while the left-right gap in preferences among individuals with a high level of numeracy is higher than the gap among respondents with a low level of numeracy (29.2 versus 23.9 percentage points), this difference is nonsignificant ($p = .35$).

General Conclusion and Discussion

As demonstrated by this study, the framing of numbers can clearly affect opinion formation and policy preferences through ratio bias. The manipulations of the numerical formats yielded an effect of a substantial magnitude, the effect was successfully replicated across two studies using different samples, and the effect was found across two different dimensions, namely the numerical framing of money (taxes) and the numerical framing of people (youths). Furthermore, the results of this study suggest that ratio bias is a highly general phenomenon that can have an effect across most groups of voters. Ratio bias effects were significant among all but the most right-wing respondents and among all but the most numerate respondents.

Manipulation of the numerator and denominator of a politically relevant number will not necessarily always be as efficacious as in the experiments presented in this study. We should therefore be careful not to naively assume identical effect sizes in real life. Similar to other framing effects, the effects of ratio bias may be attenuated by, for example, counterframing (Chong & Druckman, 2013) and party cues (Druckman et al., 2013). However, the effects may also be amplified by repetition (Chong & Druckman, 2013), and future studies may want to investigate the degree to which such factors impact the ratio bias effect.

The impact of ratio bias on real-life politics is of course also related to the question: To what degree do political actors actually utilize this ratio bias to their advantage? This question is unanswered by this study. However, it is not necessarily a coincidence that then presidential candidate Al Gore reframed the $1.6 trillion tax cut plan of his opponent George W. Bush as a plan in which "the average family would get about enough money to buy one extra Diet Coke a day" (Krishna & Slemrod 2003, p. 193). Similarly, it is not necessarily a coincidence that a controversial plan to substantially increase working hours in Denmark was temporally framed by the sponsoring political parties as an increase of just "12 minutes a day" (Hutcheson, 2012, p. 341). In any case, because every rational number can be transformed into a ratio, political elites can potentially attempt to exploit the ratio bias effect practically every time they use numbers in their persuasive messages.

Therefore, the results also have implications for the field of framing studies within public opinion research because they suggest that the field has been too quick to disregard the empirical relevance of equivalence framing and, thus, numbers. In much of the literature, equivalence framing has been narrowly identified with the frames on losses and gains originally used by Kahneman and Tversky (1979, 1984; see, e.g., Borah, 2011; Vraga, Carr, Nytes, & Shah, 2010). Consequently, frames of equivalence have generally been disregarded in favor of "emphasis frames," which are not logically equivalent, based on the argument that equivalency frames are rare in policy discourse and political news (Chong & Druckman, 2007; Druckman, 2001; Scheufele & Iyengar, 2014; Slothuus, 2008; Sniderman & Theriault, 2004). However, as demonstrated in this study, frames of equivalence and numbers can affect us through other mechanisms than the one suggested by Kahneman and Tversky's (1979) prospect theory. Thus, equivalency framing is not necessarily rare in policy discourse and news. In fact, because essentially all policy-relevant numbers are amenable to manipulation of the numerator and denominator, ratio bias might therefore turn out to be a highly relevant mechanism through which equivalency framing can have significant effects on public opinion.

Finally, the results of this study also have implications for our understanding of how facts and numbers affect opinion formation. As noted previously, prior studies have sometimes found a limited impact of factual numbers on political attitudes (e.g., Kuklinski et al., 2000; Lawrence & Sides, 2014). It is tempting to interpret and lament this absence of impact as a sign of deficient rationality in citizens' opinion formation and conversely regard political attitudes that are based on or affected by factually correct numbers as somehow more rational or well founded. Indeed, this perspective on numbers as a way to rational decision making is widely shared: Historically, the quantification of public discourse, and the world at large, has often been hailed as a development toward a more rational form of politics and debate (Prévost & Beaud, 2012, p. 44). However, while this study shows that individuals indeed use the numbers that are available to them when forming their opinions on policy issues, the results also demonstrate that even when factually correct numbers have an impact, they do not necessarily lead to a more rational public. Understanding how numbers affects opinion formation requires that we pay attention to the fact that logically equivalent numbers can be framed in a number of ways and that our perception of numbers is affected by such numerical framing.

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Appendix A: Sample Characteristics

	Sample (*n* = 1,007)	Danish Population (ages 18–85)[a]
GENDER (female)	50%	50%
AGE, YEARS (*SD*)	46 (16)	48 (18)
AGE GROUPS		
18–29	20%	20%
30–45	27%	26%
46–59	29%	25%
60+	24%	29%
EDUCATION[b]		
High School or Less	32%	32%
Vocational Education	37%	36%
Some College	31%	32%
VOTE[c]		
Left-to-Center Parties	39%	44%
Center-to-Right Parties	61%	56%

[a]Population data are from Statistics Denmark (www.danmarksstatistik.dk), except vote intention.
[b]Data for Educational level of Danish population is based on ages 20–69.
[c]Data for population vote intentions based on poll 7. January 2014 (Epinion.dk).

Appendix B: Question Wordings

[Condition 1]	[Condition 2]	[Condition 3]	[Condition 4]
In Denmark, approximately *70,000* young people are attending the 9th grade. Among this group, *8 out of every 100* young people will not complete an education at the level of a high school degree. Imagine that the state of society in Denmark three years from now is as described below in either alternative A or alternative B:	In Denmark, approximately *70,000* young people are attending the 9th grade. Among this group, *8 out of every 100* young people will not complete an education at the level of a high school degree. Imagine that the state of society in Denmark three years from now is as described below in either alternative A or alternative B:	In Denmark, approximately *70,000* young people are attending the 9th grade. Among this group, *5,600* young people will not complete an education at the level of a high school degree. Imagine that the state of society in Denmark three years from now is as described below in either alternative A or alternative B:	In Denmark, approximately *70,000* young people are attending the 9th grade. Among this group, *5,600* young people will not complete an education at the level of a high school degree. Imagine that the state of society in Denmark three years from now is as described below in either alternative A or alternative B:
A: Among the youths, *8 out of every 100* young people will not complete an education, and I pay the same amount of taxes as I do today.	A: Among the youths, *8 out of every 100* young people will not complete an education, and I pay the same amount of taxes as I do today.	A: Among the youths, *5,600* young people will not complete an education, and I pay the same amount of taxes as I do today.	A: Among the youths, *5,600* young people will not complete an education, and I pay the same amount of taxes as I do today.
B: Among the youths, *7 out of every 100* young people will not complete an education, and I pay DKK *3,000 more in taxes per year*.	B: Among the youths, *7 out of every 100* young people will not complete an education, and I pay DKK *250 more in taxes per month*.	B: Among the youths, *4,900* young people will not complete an education, and I pay DKK *3,000 more in taxes per year*.	B: Among the youths, *4,900* young people will not complete an education, and I pay DKK *250 more in taxes per month*.
Would you prefer alternative A or B? (Prefer A; Prefer B)	Would you prefer alternative A or B? (Prefer A; Prefer B)	Would you prefer alternative A or B? (Prefer A; Prefer B)	Would you prefer alternative A or B? (Prefer A; Prefer B)

Note: The numbers were not italicized in the survey.

Appendix C: Logistic Regression Models

Predicting Support for Scenario B

	Model 1	Model 2	Model 3
Large Youth Ratio	0.52***	1.10**	1.11
	(0.13)	(0.41)	(0.67)
Small Tax Ratio	0.27*	0.03	0.79
	(0.13)	(0.41)	(0.67)
Numeracy		0.89	1.99
		(0.52)	(1.13)
Large Youth Ratio $\times$ Numeracy		-0.80	-0.84
		(0.56)	(1.22)
Small Tax Ratio $\times$ Numeracy		0.26	-1.30
		(0.56)	(1.23)
Left-Right Position		-2.12***	-1.14
		(0.46)	(1.00)
Large Youth Ratio $\times$ Left-Right		-0.33	-0.38
		(0.50)	(1.10)
Small Tax Ratio $\times$ Left-Right		0.21	-1.18
		(0.51)	(1.10)
Numeracy $\times$ Left-Right			-2.00
			(1.83)
Large Youth Ratio $\times$ Numeracy $\times$ Left-Right			0.12
			(1.96)
Small Tax Ratio $\times$ Numeracy $\times$ Left-Right			2.81
			(1.97)
Constant	-1.06***	-0.27	-0.79
	(0.12)	(0.36)	(0.60)
Model χ^2	18.91***	103.45***	105.64***
Pseudo R^2	0.01	0.08	0.08
N	1007	996	996

Note. Logistic regression coefficients (and standard errors).
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Appendix: Pilot Study on Ratio Bias and Policy Preferences

Table 1: Sample Characteristics

Table 2: Experiment 1 in Pilot Study

Table 3: Experiment 2 in Pilot Study

Results