Science advocacy in political rhetoric and actions

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Abstract

'Science' is a proportionately small but recurring constituent in the rhetorical lexicon of political leaders. To evaluate the use of science-related content relative to other themes in political communications we undertake a statistical analysis of keywords in U.S. Presidential State of the Union (SOTU) addresses and Presidential Budget Messages (PBM) from Truman (1947) to Trump (2020). Hierarchical clustering and correlation analyses reveal proximate affinities between *'science'* and *'research', 'space', 'technology', 'education'* and *'climate'*. The keywords that are least correlated with *'science'* relate to fiscal *('inflation', 'tax'*) and conflict-related themes (*'security', 'war', 'terror'*). The most ubiquitous and frequently used keywords are *'economy'* and *'tax'*. Science-related keywords are used in a positive (promotional) rhetorical context and thus their proportionality in SOTU and PBM corpora is used to define fields of science advocacy (*public perception advocacy, funding advocacy, advocacy*) for each president. Monte Carlo simulations and randomized sampling of three elements: *language* (relative frequency of usage of science-related keywords), *funding* (proposed funding and allocated discretionary funding of science agencies), and *actions* (e.g., expediency of science advisor appointments, (dis-) establishment of science agencies) are used to generate a *science advocacy score (SAS)* for each president. The *SAS* is compared with independent survey-based measures of political popularity. A myriad of political, contextual and other factors may contribute to lexical choices, policy and funding actions. Within this complex environment '*science*' may have political currency under certain circumstances, particularly where public and political perceptions of the value of science to contribute to matters of priority align.

Keywords

U.S. Presidents; science advocacy; quantitative analysis; science communication; populism; American politics

1 Introduction

This research begins with the following question: *how frequently and variably do 'science' and related keywords appear in the rhetorical lexicon of standardized corpora delivered by leaders?* The leaders chosen to evaluate here are the Presidents of the United States, who regularly make decisions and communicate to the public on complex socioeconomic, political, and other issues. We consider rhetoric in its classical sense, articulated by Aristotle as "*means of persuasion in reference to any subject whatsoever*" (Rapp, 2010). The corpora examined are the President's annual State of the Union (SOTU) address and President's Budget Message (PBM). A variety of statistical techniques are used to investigate the frequency and variability of keyword utility, and to characterise correlations amongst keywords. The 'related keywords' are not defined *a priori*, but rather established through statistical analysis of keyword clustering. Intra- and inter-presidency comparisons are made using these results.

The research then queries, *can a metric for science advocacy be produced, and how does this relate to independent measures of political success?* Statistical approaches are used to combine metrics of science-related language, funding, and actions into a science advocacy score (*SAS*). The *SAS* is compared to mean approval poll ratings and a political greatness metric. The study is used to place science-related rhetoric and actions within a broader societal-political context, full of adjacent, interacting and / or competing themes that may emerge, escalate, and descend in objective and / or perceived importance, at varying spatial and temporal scales. We explore the thesis that '*science advocacy*' may be used as rhetorical tool for reflecting values and beliefs, and may have political advantage in some circumstances.

In undertaking this research, we first acknowledge that '*science*' as a discrete entity may not be unitary, comprehensive, collective, and even readily identifiable within the complex environment of political decision-making and actions (Guston, 2010). We adopt the definition of "science" from the Science Council (2022) (https://sciencecouncil.org/about-science/our-definition-of-science/): "*the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence*". Whilst science inputs can inform many diverse decisions and policies, these ubiquitously reside alongside other relevant beliefs- and values-driven inputs, some of which may be prioritized above science inputs, and some of which might inform the way in which science is utilized in decision-making (Gluckman, 2014; Quigley et al., 2019a,b). As stated by John Gibbons, science advisor to Pres. Clinton (from Pielke Jr. & Klein, 2009):

"*…science is not an overarching national goal for the President. It's only as it serves to help achieve these larger goals that science takes its place in the crown of important activities for the presiden*t"

Science may be pluralistic and partial (Guston, 2010), particularly on matters where divergent scientific opinion is prominent. Some aspects of science exhibit strong partisan and ideological polarization (e.g., *climate change*, where 94% liberal Democrats believe that climate change is a major threat, compared with 19% conservative Republicans) (Kennedy and Hefferon, 2019). Political polarization over science may be associated with *psychological science rejection* (implicit disregard for scientific facts that are inconsistent with one's political identity) and / or *ideological science rejection* (adherence to a political ideology that explicitly contests science) (Rekker, 2021). From their position of influence, U.S. Presidents may influence public perceptions (positively or negatively) of the value and utility of science and other priories, through lexical choices in communications (e.g., Cohen, 1995; Gelderman, 1995), and the relative status of different priorities in federal funding budgetary requests (e.g., Mervis, 2017). President and aspiring presidents may frame science as a fallible entity,

> *"I don't think science knows, actually" [with reference to climate change]*
>
> Fmr. President D. Trump, California Wildfire Briefing, 14 September 2020

or as a symbol of truthfulness and trust,

> *"And I believe in Science"* Hillary Clinton, July 28, 2016 [Democratic Party nominee for U.S. Presidency, with reference to comments by then-Republican party nominee Donald Trump on climate change]
>
> *"I've always said that the Biden-Harris administration, we're going to lead, and we're going to lead with science and truth; we believe in both"* President-elect J. Biden, 16 January 2021 [Democratic Party, pro-science rhetoric at announcement of the new administration's scientific advisers]

and way of 'thinking' and 'knowing',

> *"Now and in the years ahead, we need, more than anything else, the honest and uncompromising common sense of science. Science means a method of thought. That method is characterized by open-mindedness, honesty, perseverance, and, above all, by an unflinching passion for knowledge and truth. When more of the peoples of the world have learned the ways of thought of the scientist, we shall have better reason to expect lasting peace and a fuller life for all*." Pres. Harry S. Truman, "Address to the Centennial Anniversary AAAS Annual Meeting (1948)"

Despite major changes in rhetorical styles, communication technologies (that have changed and diversified the media landscape), predominant methods of communication, and characteristics of the audience (Bennett & Iyengar, 2008; Scacco et al., 2018), 'science' has remained a persistent entity in presidential communications through time (Fig. 1). Whether science-centric rhetoric has true political currency remains an open question.

In this study, we do not seek to disentangle the complexities of how scientific information is sought by, and considered, in presidential communications and policy making. Readers interested in this are encouraged to consult Pielke Jr. & Klein (2010) and the numerous references cited therein. Instead, we seek to develop objective measures for how U.S. Presidents advocate for science based on their lexical choices and actions. This is a challenging task.

Interviews with presidentially-appointed chief science advisors reveal an environment where science and politics are endemically intermingled, where presidential behaviours appear to be variably technocratic, indifferent, and / or contradictory, and where communications between scientists and governing agents have become increasingly specialized and hierarchical (Pielke Jr. and Klein, 2009; Launius and McCurdy, 1997). The context of presidential communications and actions relating to science varies greatly in time and space and is important; emergent issues may enhance or diminish opportunities for science advocacy. Randomized selection and amalgamation of discrete pieces of pro- or anti-science evidence may be subject to various forms of sampling, confirmation and selection biases.

U.S. Presidential communications typically cover a vast range of subjects, including commentary pertaining to actions, policies, and opinions on diverse and constantly changing social, economic, political, technological, and defense-related issues within a complex political ecosystem (Edwards & Howell, 2009). Extensive research focuses on many aspects of presidential communications, including the transitory environment and context within which communications are made (e.g., Scacco et al., 2018), interactions between political rhetoric and the media (e.g., Herbst, 2012), policy (e.g., Beasley, 2010), power and influence (Campbell and Jamieson, 2008), challenges (Denton, 2000), and other rhetoric-related aspects (e.g, Gronbeck, 1996; Stuckey & Antczak, 1998; Kernell, 1986; Tulis, 1987; Hart, 1987).

SOTUs and PBMs are proxy measures of presidential priorities that have a relatively consistent format in approximate speaking duration (SOTU average = 53 minutes and 50 seconds, standard deviation ± 14 minutes; from Pres. Johnson to Trump), communication method (SOTU predominantly orated, PBM written), and audience (SOTU in person to the joint session of the United States Congress, transmitted to the public via the media). We suggest that these attributes make these the most standard and robust corpora for reducing bias in inter-president comparisons; it could be argued that sampling of any of the many other presidential communications (such as commemoration speeches, announcements of new initiatives, etc) could introduce sampling bias, and other interpretive biases associated with the more specialized target audiences of the communications, variations in context, and other factors.

The SOTU gives "*to the Congress Information of the State of the Union, and recommend(s) to their Consideration such measures as he shall judge necessary and expedient*" (U.S. Constitution, Article II, Section 3, Clause 1, 1787). This provides an opportunity for the President to publicly advocate on priority issues, including those that may be informed by science, to Congress, the media, and a large public audience. The SOTU is generally accepted as the best means for assessing the president's policy agenda (e.g., Cohen, 1995, 1997; Kessel, 1974; Light, 1998; Oliver et al., 2011) and thus the endorsement of science in major public communications may considered a form of public science advocacy.

The PBM is the leading executive statement that accompanies the annual presidential budget request to Congress, and provides insights into presidential budgetary constraints and philosophies, including advocacy for funding priorities (e.g., https://www.whitehouse.gov/wp-content/uploads/2019/03/ap_1_introduction-fy2020.pdf; https://www.everycrsreport.com/reports/R43163.html) such as federal research and development (R&D) funding for executive departments and independent agencies. In addition to budget request, Presidents can make discretionary funding and organizational decisions (Sargent Jr. and Shea, 2014; Lewis, 2017) that may, in part, provide coarse proxies for how they value science relative to other priorities. The budget process is identified as one of the most important avenues through which scientists engage with the President (Pilke Jr. and Klein, 2009),

> *"Most of the decisions that really have technical content get made within the government agencies at a level far below the White House. And it's only rarely that science issues, or issues with technical content, actually come up to the White House for decisions or for policy direction change, but probably the most common way they come up is in the budget process, and that's where a lot of the discussions that I have with my colleagues takes place." John Marburger (science advisor to George W. Bush; as quoted in Pilke Jr. and Klein, 2009)*

We consider that presidential proposals to establish new science agencies, appropriate discretionary funds to science, and increase federal funding to science agencies may be broadly considered as a form of science funding advocacy. As final federal budgetary appropriations are ultimately decided by the U.S. Congress and may not reflect the budgetary recommendations of the President; we thus focus on presidential intent (rather than final science funding outcomes) in this analysis. We acknowledge that linguistic, financial and structural reorganization decisions are likely to be strongly influenced by political factors, including partisanship; the potential underlying motives for science advocacy are briefly discussed but not investigated in detail here.

The data-driven approach undertaken here presents an objective, reproducible metric that is by no means perfect or exhaustive. Our metric intends to complement other types of analyses aimed to investigate science advocacy within the complex socio-political sphere of the U.S. Presidency (Pielke Jr. and Klein, 2009) and stimulate continued research into role of science and affiliated themes in political rhetoric and actions.

2 Materials and Methods

2.1 Keyword counts

Statistical analyses of keywords and keyword groupings provide objective methods for comparing lexical salience between texts (Baker, 2004; Bestgen, 2018). Transcripts for SOTUs (n=71) and PBMs (n=80) from Truman (1947) to Trump (2020) were obtained from the American Presidency Project (http://www.presidency.ucsb.edu/) and FRASER digital library (https://fraser.stlouisfed.org/title/54). SOTUs and PBMs were read in detail to define transcendent topics of presidential communications. From these initial analyses, a suite of frequently-used keywords (‘*science*’, ‘*technology*’, ‘*research*’, ‘*space*’, ‘*environment*’, ‘*economy*’, ‘*energy*’, ‘*natural resource*’, ‘*employment*’, ‘*jobs*’, ‘*housing*’, ‘*inflation*’, ‘*education*’, ‘*tax*’, ‘*health*’, ‘*business*’, ‘*crime*’, ‘*terror*’, ‘*gun*’, ‘*drugs*’, ‘*religion*’, ‘*shooting*’, ‘*military*’, ‘*research*’, ‘*security*’, ‘*climate*’, ‘*space*’, ‘*defense*’, ‘*nuclear*’, ‘*war*’, ‘*racism*’, ‘*pollution*’), including their bound morphemes, derivatives, and related words were identified (Supplementary Information Tables S1, S2). Keywords were counted in all presidential communications using automated scripts (Silver, 2019) and manually cross-checked against

SOTU and PBM transcripts for accuracy and context. Keyword frequencies were measured as a percentage of total keyword frequencies to normalize for large variations in total word counts (SOTU total word counts = $1080 \leq n \leq 9183$; PBM = $294 \leq n \leq 30140$). Only orally-delivered SOTUs were analysed to reduce potential bias arising from cross-comparison of different communication methods (Linnell, 2004). Word counts for presidential communications are provided as a Supplement to this article. Individual keyword counts as a % of total keyword counts in SOTUs and PBMs are presented in Fig. 1A and 1B, respectively. Fig. 2 presents average science keyword usages in combined SOTU and PBMs for each president.

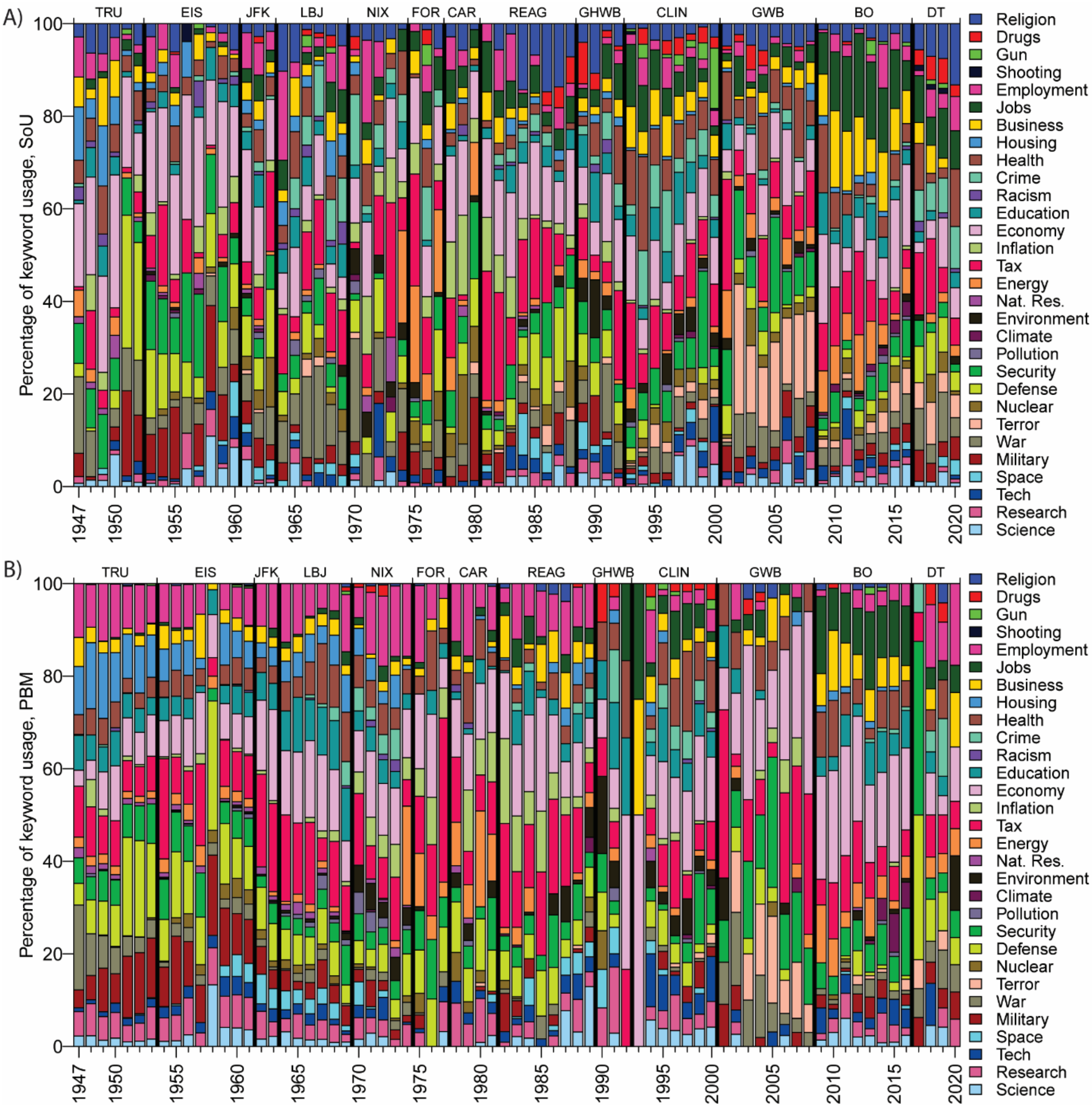

Fig. 1. Keyword utility in presidential messages. (A) Time-series of individual keyword utility as a % of total keywords in individual presidential State of Union (SOTU) addresses. Vertical thick black lines denote presidential transitions. **(B)** Time-series of individual keyword utility as a % of total keywords in individual presidential budget messages (PBM); line and colour labels as in (A).

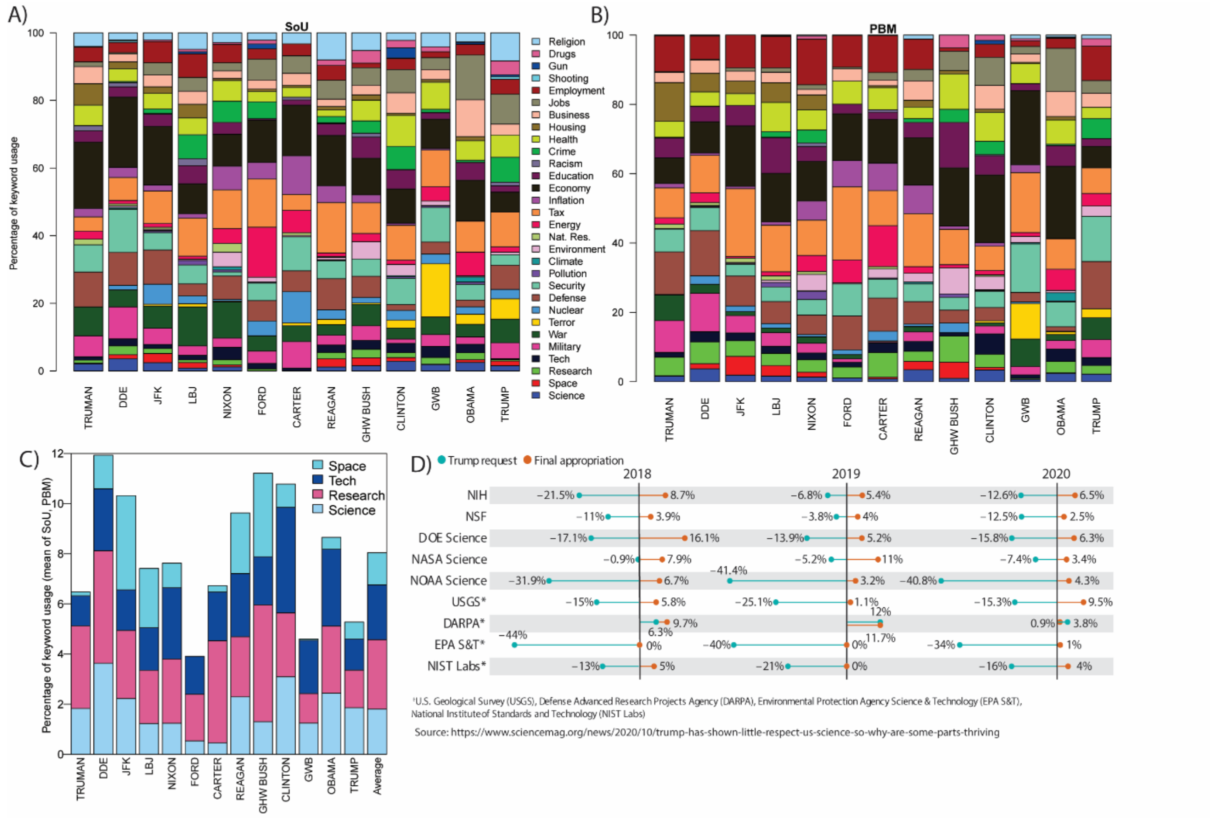

Fig. 2. A) Average keyword average utility and science advocacy in SOTU, by president. **(B)** Average keyword average utility and science advocacy in PBM, by president. (C) Combined (SOTU and PBM) science-related keyword utility (see Fig. 3 for clustering analysis) by president. **(D)** Example of U.S. Presidential Budget Message requests and Congress-approved final appropriations for major science agencies as a % of the previous year's Congress-approved final appropriations. From 2018 to 2020, Trump proposed funding reductions for almost all science agencies but final federal budgetary appropriations resulted in increased funding. See https://www.science.org/content/article/trump-has-shown-little-respect-us-science-so-why-are-some-parts-thriving for further commentary.

2.2 Dimension-reduction and clustering analysis

Unsupervised clustering was used to investigate keyword frequency data (Kaufman & Rousseeuw, 1990). The averaged % keyword usage for each president was normalized across Presidents to have mean zero and unit variance; this was done separately for SOTUs and PBMs. Agglomerative hierarchical clustering was then performed on the Euclidean distance between columns (each column represented one keyword), agglomerating clusters by assuming distances to between a cluster and node (keyword) to be the furthest distance between that the outlying node and the nodes within the cluster. This yielded a clustering over keywords (Fig 3A,C).

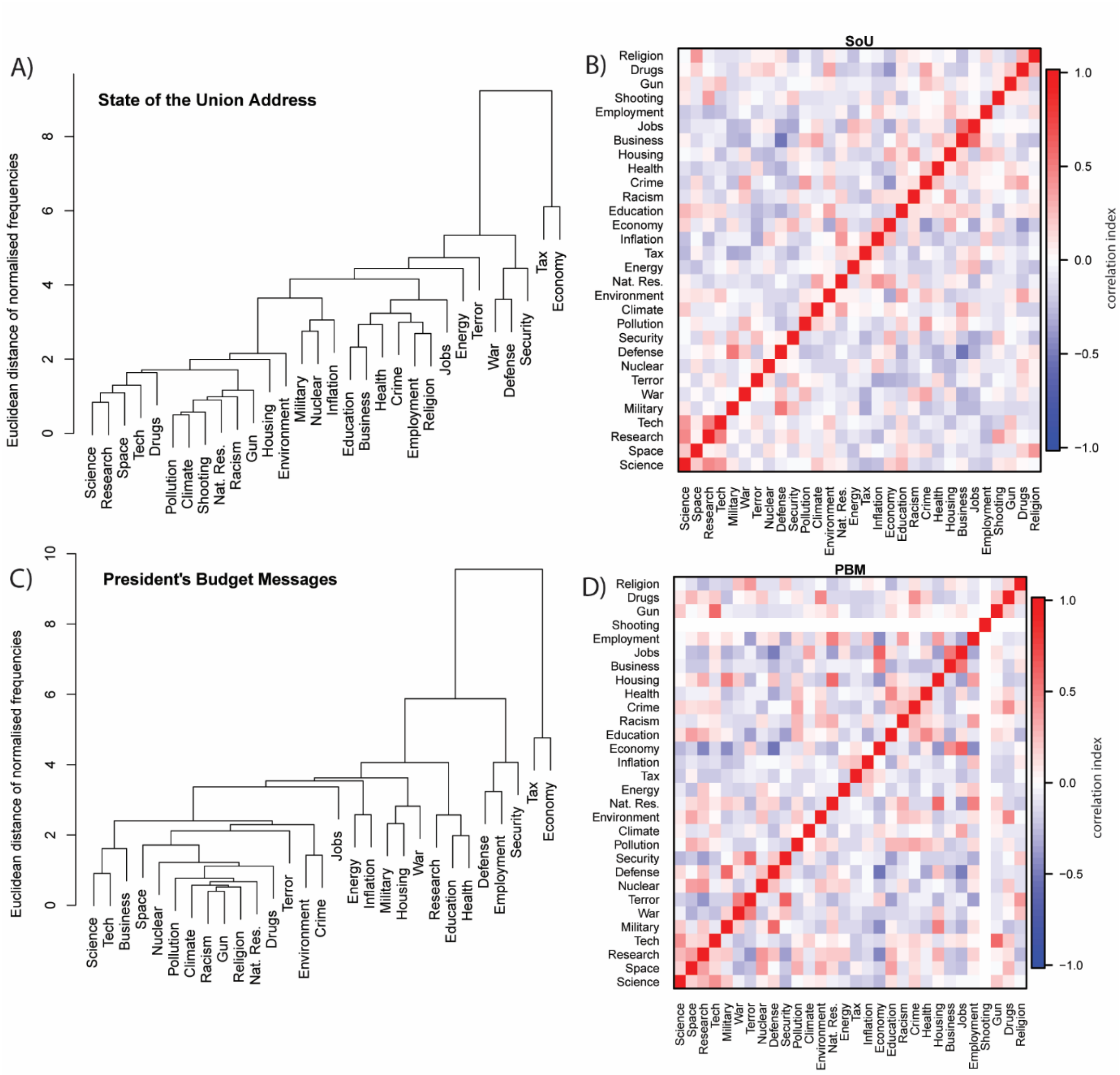

Fig. 3. Clustering and correlation analyses of keywords in presidential messages. (A) Dendrogram of keywords in SOTUs. **(B)** Correlations between pairs of keywords, comparing their mean % usage in SOTUs. **A)** Dendrogram of keywords in PBMs. **(D)** Correlations between pairs of keywords, comparing their mean % usage in PBMs. 'Shooting' did not appear PBMs and is shown as having zero correlations.

The y-axis of the keyword dendrograms (Fig 3A,C) shows the "dissimilarity" between pairs of keywords. The dissimilarity between a pair of keywords was taken to be the Euclidean distance between the vector of normalized frequencies, comprising one element per president (averaging over the keyword percentage usages across all their messages of a given type). These vectors were normalized to have mean 0 and variance 1. The height of the horizontal line shows the dissimilarity between pairs of clusters or nodes (keywords). The dendrogram was incrementally constructed by agglomerating pairs of nodes and/or clusters; once agglomerated, distances between the new cluster and other nodes or clusters was taken to be the maximum distance in the comparison in question (this is termed agglomeration via ‘complete linkage’). Correlation plots (Fig. 3B,D) characterise the normalized vector variances between individual keywords (highest possible correlation = 1, lowest possible correlation = -1). Keyword clustering and correlation plots delineate ‘science-related’ keywords that are most closely associated (i.e., proximate) with ‘*science*’; these are ‘*research*’, ‘*technology*’, ‘*space*’, and to a lesser extent ‘*climate*’ and ‘*education*’. Keywords that are least correlated with ‘*science*’ relate to fiscal (‘*inflation*’, ‘*tax*’) and conflict-related challenges (‘*security*’, ‘*war*’, ‘*terror*’). A sample of contextual time-series data is presented in Supplementary Information Fig. S1.

2.3 Science advocacy plots

Selected keyword average % usage for individual presidents in SOTUs vs. PBMs are presented in Fig. 4. The fields are defined as (i) ‘*Public Perception Advocates*’: higher-than-average % SOTU counts, low % PBM counts, (ii) ‘*Funding Advocates*’: higher-than-average % PBM counts, low % SOTU counts, (ii) ‘*Advocates*’: higher than average % SOTU counts and % PBM counts), and (iv) ‘*Non-advocates*’ (low % SOTU counts and low % PBM counts). The boundaries between advocacy fields are indicative, rather than representing substantive thresholds.

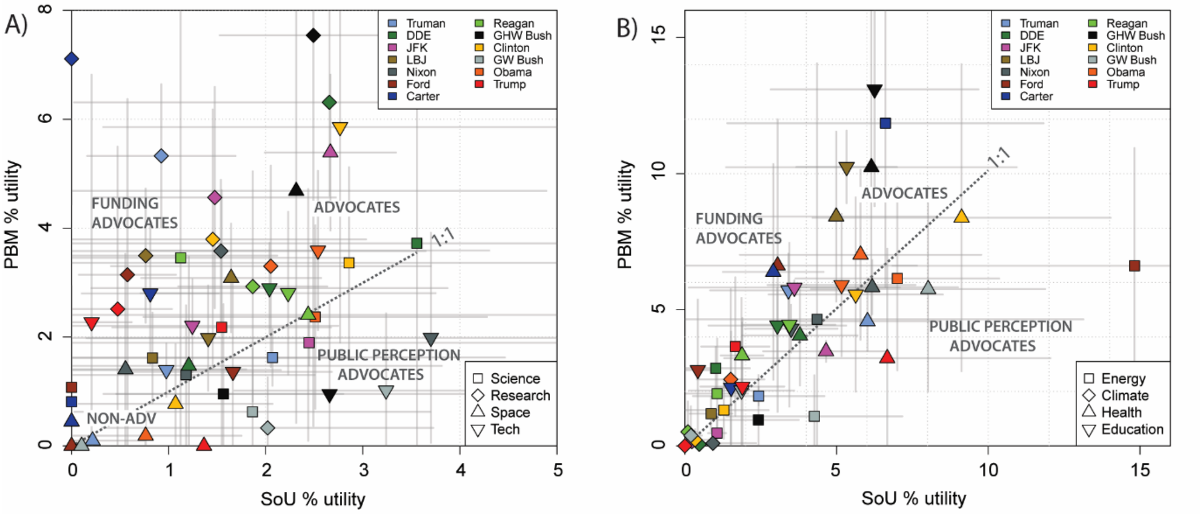

Fig 4. Keyword % usage in the two message types and science advocacy. (A) Comparison of average % usage of individual, most-proximate (i.e. shortest Euclidean distances, largest correlation indices in Fig. 3) science-related keywords in SOTUs and PBMs for each president. Symbol shape corresponds to keyword, symbol colour corresponds to president. Labelled 'advocacy fields' correspond to higher-than-average science keyword utility % in SOTUs only ('public perception advocacy'), higher-than-average science keyword utility % in PBMs only ('funding advocacy'), higher-than-average science keyword utility % in PBMs and SOTU addresses ('advocacy') and lower-than-average science keyword utility % in PBMs and SOTU addresses ('non-advocacy'). Advocacy fields are for intended for conceptual purposes; boundaries between each field are not distinctly defined. **(B)** Comparison of average % utility of other science-related keywords in SOTU addresses and PBMs for each president. The 'climate' data points (Fig. 2B) amalgamate 'climate', 'environment', 'natural resources', and 'pollution' data, since these terms are commonly topically grouped in PBMs and SOTUs. As with (A), the selected keywords have the shortest Euclidean distances and largest correlation indices in Fig. 3.

2.4 Presidential science advocacy score and political popularity

The time-series of Gallup poll approval rating % data from 29 May 1945 (Truman) to 16 June 2019 (Trump) are shown in Supplementary Information Fig. S2. Gallup reports a ~3% uncertainty in up-scaling results from the sampled population (~1000 people) to the larger population the survey is intended to represent. There is uncertainty in using the mean approval rating value for a president for comparative purposes, partly because of the large variations in the relative timing and frequency of the polls (conducted up 100 days apart with significant variability over 1938-2008, then daily over 2009-2017, then weekly in 2018). To address this aspect, we fitted a smoothing spline through the approval rating data for each president, used this to interpolate to daily frequency, then calculated a mean Gallup poll approval rating (y axis; Fig. 5A) from the daily averages.

The 2018 Presidential Greatness poll results shown on the y-axis in Fig. 5B (Vaughn and Rottinghaus, 2018) are presented as a mean and range. This metric was established via a presidential-greatness survey of current and recent members of the Presidents and Executive Politics Section of the American Political Science Association conducted in 2017-2018. Respondents were asked to rate each president on overall greatness on a scale from 0 to 100 (0=failure, 50=average, and 100=great); 170 usable responses were tabulated. The Presidential Greatness poll data is presented as the mean value ratings from survey respondents identifying as the Democrat, Republican and Independent/Other. The survey respondents were skewed towards Democrat and Independent-affiliated voters beyond the US average, thus we summarised the Presidential Greatness poll as a weighted mean of the three ratings, with weightings taken as the average over 2004-2019 of Gallup Polls of party affiliation across US voters (https://news.gallup.com/poll/15370/party-affiliation.aspx); these indicate 29.5% Republican, 32.9% Democrat and 37.6% Independent. The range presented for the Presidential Greatness score was taken as the minimum and maximum greatness score among the three party/non-aligned groups.

For Fig. 5A and 5B, the 'science advocacy score' *(SAS)* is based on three components: actions, funding and language. Each of these categories is comprised of a series of factors that are outlined below. In developing this method, we recognize that there is no objective measure of a President's support for science (or lack thereof) that is free from subjective and interpretive bias. Others approaching this topic may assign different weights to these components and factors. Given this epistemological uncertainty, we considered a range of different possible realisations of the *SAS*, randomly sub-sampling the factors comprising the three components (*actions, funding, language*). One advantage of this approach is that it provides some insight into the uncertainty of the *SAS* (i.e., the range of possible views that may be adopted for a given President's public support for science). In the manner defined below, there were 44,100 equiprobable science scores under this sampling scheme. Fig. 5A and 5B show the median and inter-quartile range of 5000 random samples (with replacement).

The '*actions*' component was based on eight factors (Supplementary Information - Table S3): 1) the presence of a science representative within the Executive Office of the President, 2) inter-agency coordination organizations, 3) science-related advisory committees, 4) independent science-related agencies, 5) multi-agency science-related initiatives, 6) other non-defence Federal research agencies, 7) defence research agencies, and 8) the promptness of the appointment of a director for the Office of Science and Technology Policy (OSTP). For each component, points were evaluated for establishment (+1), abolition (-1) or continuation (0) of an agency or representative, or for the last factor the appointment (+1) or otherwise (-1) of a director of the OSTP within 100 days of assuming office. The total number of points was adjusted for time-in-office by dividing by the length of the presidency (in years). Each random sample selected four of these eight factors, and the resultant scores were normalized to have zero mean and unit variance. We acknowledge that more extensive lists of 'anti-science' actions are available (e.g., https://www.ucsusa.org/resources/attacks-on-science?_ga=2.145380413.863759956.1612999703-1619096890.1612999703) but that variations in the extent to which past presidents have been analysed following this approach preclude unbiased inclusion of these analyses into our research framework.

The '*funding*' component was based on three factors: 1) changes to research and development funding as a percentage of discretionary outlays during tenure, 2) changes to non-defence research and development funding as a percentage of non-defence outlays, and 3) changes to funding for the OSTP. As with the 'actions' component, points were assigned for each factor for increases (+1), reductions (-1), no change (0), with half-points assigned for minor changes. Each random sample selected two of these three factors, with the resultant scores normalized as above. Because of the complexity of the U.S. Federal Budget (https://www.aaas.org/news/federal-budget-process-101), including incumbent's revisions of budgets developed by their predecessors and complex inter-agency interactions, interpreting monetary assignments as a proxy for presidential priorities is challenging. OSTP funding is by no means a perfect proxy for the value a given president places on science advice but it is perhaps one of the simplest objective measures available as its administering organization is the Executive Office of the President. In theory, a president that values science advice from the OSTP might assign a higher % of discretionary funding to this office than a president who does not. The history and contributions of OSTP and its affiliates (President's Council of Advisors on Science and Technology; National Science and Technology Council) and their predecessors are available at https://obamawhitehouse.archives.gov/administration/eop/ostp/about, Pielke Jr. and Klein (2009), and Sargent Jr. and Shea (2017).

The '*language*' component was based on the SOTU and PBM word counts. Eight keywords were considered ('science', 'research', 'space', 'tech', 'energy', 'climate', 'health', 'education') on the basis of contextual reading of the corpora and the results of the hierarchical clustering analyses. Each random sample included a selection of four of these keywords. Also selected at random was the source: the SOTU only, the PBM only, or both the SOTU and PBM. The counts of each keywords were converted to the average percentage keyword use for each president across messages. We then took the ratio of each President's average percentage keyword use to the average percentage keyword usage across presidents. This ratio was normalized in the same manner as the two components described above.

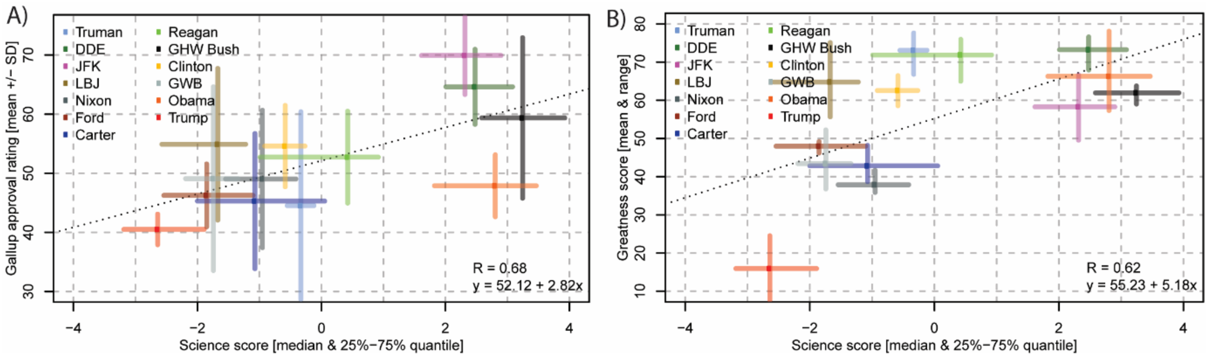

Fig. 5. Presidential approval, presidential greatness, and science advocacy scores (*SAS*). **(A)** Presidential mean daily Gallup poll approval rating vs. *SAS* ("science score"). Mean daily approval rating determined by interpolating data between successive polls assuming linear inter-poll trajectories. Vertical error bars represent 1 standard deviation for all discrete polling data results for the president listed. Coloured horizontal error bars represent 68% epistemic uncertainty in science score. Equation for linear best fit line (with R) to central data points as shown. (C) 2018 Qualtrics Presidents & Executive Politics Presidential Greatness Survey mean rating vs. science score. Vertical error bars represent mean ratings differentiated by party of survey respondents. Coloured horizontal error bars represent 68% epistemic uncertainty in science score. Linear best fit line with R is fit to central data points.

3 Results

3.1 Keyword usage in presidential communications

The most frequently used keywords in SOTUs and PBMs (Fig. 1) are '*economy*', '*tax*', '*security*', and '*defense*'. The least frequently used words are '*shooting*', '*climate*', '*pollution*', '*racism*' and '*gun*'. Some keywords show significant temporal trends in usage that transcend presidential changes, such as '*jobs*' and '*health*' (average ascendency through time), '*housing*', '*employment*', and '*natural resources*' (average diminishing use through time), and '*inflation*' (ascendency to highest usage in the 1970s to early 1980s followed by descent).

The % usage of the most proximate science-related keywords (*'science', 'research', 'technology', 'space'*; as defined from the hierarchical clustering) has no statistically significant temporal trends and is highly variable about mean % usage (coefficient of variation >1). '*Science*' and '*technology*' are the most frequently used keywords in SOTUs and '*research*' is the most used keyword in PBMs. '*Science*' usage varies significantly through time (0 to >10% usage) but is ubiquitously used in a positive, promotional sense (i.e., there is no evidence in SOTUs or PBMs of anti-science rhetoric). Positive spikes in usage are observed for many presidents. Some can be confidently interpreted as contextual evidence concurrent with the emergence of important events in U.S. science policy (e.g., the establishment of the National Science Foundation in 1950 (Truman; SOTU), the ascendency of science advice to priority status in the White House following the 1957 Soviet Union launch of Sputnik (Eisenhower; SOTU and PBM in 1958). Some presidents primarily speak of '*science*' as a valued entity in health, educational, and technological contexts (Clinton, Obama), others to advocate for funding (Reagan), and others to recount U.S. historical achievements (Trump, 2019 SOTU). Eisenhower, Clinton, and Obama are the highest average users of '*science*'; Ford and Carter did not mention '*science*' in any SOTUs and are amongst the lowest users in PBMs. '*Research*' and '*technology*' commonly positively correlate with '*science*' usage, although exceptions exist (e.g., Carter; PBM). '*Space*' usage is highest during the height of the "Space Race" (ca. 1960 to 1970), re-emerges in usage (concomitant with increases in '*defense*' usage) during Reagan's Strategic Defense Initiative or "Star Wars" agenda (Krug 2004), and was prominent during GHW Bush's Space Exploration Initiative (1989), before declining to minimal utility. Presidents considered to have advocated most strongly for NASA funding in Congress (JFK, Reagan, GHW Bush) (Conley and Cobb, 2012) are clear outliers in '*space*' usage in PBMs. The largest combined users for science-related keywords are Eisenhower, GHW Bush, Kennedy and Clinton; the lowest are Ford, GW Bush, and Trump (Fig. 2). There is complementary evidence to suggest that the most frequent users of science-related keywords in SOTUs and PBMs also placed value on science in other communications,

> *"Love of liberty means the guarding of every resource that makes freedom possible—from the sanctity of our families and the wealth of our soil to the genius of our scientists."* Dwight D. Eisenhower, January 20, 1953 [Republican Party, First Inaugural Address]

Figure 4 examines the relationships between keyword use in SOTU vs. PBM for science-related keywords (see also Fig. 3). Science keyword % usage for SOTU vs. PBM is plotted by president and used to estimate generalized fields of science advocacy ('public perception advocates', 'funding advocates', 'advocates' and 'non-advocates' = non-adv). In Fig. 4A, approximately 2/3 of the data points reside above the 1:1 line, indicating the most proximate science-related keywords are typically used more frequency in PBMs than SOTUs (i.e. Presidents tend to act more as funding advocates than public perception advocates on these topics). The most frequent users of science keywords (i.e. science 'advocates') are Eisenhower, Kennedy, Clinton, GHW Bush, and Reagan. GW Bush used science keywords in SOTUs more frequently than many of his compatriots, but rarely used them in PBMs ('public perception advocate'). Several presidents (e.g., Carter, Truman, Ford, Johnson) advocated significantly more for 'research' in PBMs than SOTUs (i.e. 'funding advocates').

Fig. 1, 2, and 4 present insights into presidential advocacy for a diversity of priorities, some of which could be considered science-related, depending on context. Notable advocates are Carter and Ford for '*energy*', Clinton for '*health*', Johnson for '*education*', and Nixon and Clinton for '*climate*' (including: '*environment*', '*natural resources*', and '*pollution*'; see Fig 2 caption). Obama, Clinton, and Nixon are the largest advocates of the potentially science-related keywords shown in Fig. 4B; Eisenhower, Reagan, Truman and Trump are the least. Relationships between keyword usage and historical presidential actions and agendas are addressed in the Discussion.

Keyword % usage of ‘*war*’ is highest in Truman’s communications following World War II, during the peak of the Vietnam War (Johnson and Nixon), and in the lead-up-to and commencement of military action during the Iraq war (GHW Bush) and the ‘war on terror’ (GW Bush) (See Supplementary Information Fig. S1). Excluding its heightened usage during the Korean War and escalation of Cold war tensions during Truman’s tenure, the keyword ‘*defense*’ has been most frequently used outside of periods of major military conflicts, and may reflect the emergence of real or perceived international threats, and presidential priority initiatives and values (e.g., Eisenhower’s communications may reflect his military-based employment history and value system, the Cuban Missile Crisis during JFK presidency, nuclear threats during Carter presidency, advocacy for the Strategic Defense Initiative during Reagan presidency, advocacy for defending America’s borders during Trump presidency). ‘*Military*’ usage was highest in the Truman and Eisenhower presidencies and spiked during denouncements of emerging Soviet military action in Afghanistan by Carter, during intermittent military engagements during the Reagan presidency, and at the commencement of military conflicts in Afghanistan and Iraq during the GW Bush presidency.

‘*Economy*’ is the most utilized keyword for both SOTU and PBMs. The two-year moving average % usage typically fluctuates between 10-20% for all presidents except for Trump. Temporal variability in the use of ‘*economy*’ is complex. There is a tendency for ‘*economy*’ to be used more frequently during times of stronger domestic economic performance (higher % annual change in real GDP per capita) and less during economic recessions, suggesting that a large fraction of its usage is primarily related to gaining political advantage from economic prosperity or recovery rather than to advocate for economic change during reduced economic performance. Divergent usage of this keyword is also evident in the different message formats; during the 2007-2009 global financial crisis GW Bush used ‘*economy*’ frequently in PBMs to advocate for economic stimulus, but reduced usage in

SOTU presumably due to the potential for adverse political ramifications of further escalating this issue in the public eye, while Obama particularly increased % usage of ‘*economy*’ in early SOTU addresses to advocate for economic stimulus and policy reform, and to gain political advantage from economic recovery. The % usage of ‘*inflation*’ tends to correlate with % annual changes in consumer price index (CPI); peak usage in SOTUs and PBMs is concurrent with large CPI increases (and more frequent recessions) during the 1970s to early 1980s.

‘*Science*’ and ‘*research*’ commonly exhibit positive correlations (as evident from Eisenhower, GHW Bush, Clinton and Obama communications), which are sometimes accompanied by increases in the usage of ‘*technology*’ (Nixon, Clinton, Obama) and ‘*space*’ (Reagan, Eisenhower). This is consistent with results from the clustering analyses. There is a tendency towards more less frequent usage of ‘*science*’ and ‘*research*’ during economic recessions and periods of heightened inflation and more frequent usage during periods of economic stability or growth (Fig. S1). This is also evident in the strong negative correlations between science-related keywords and ‘*economy*’, ‘*inflation*’ and ‘*tax*’. There is a tendency for increased ‘*science*’ and ‘*research*’ usage outside of periods of military conflict. We hypothesize that ‘*science*’ and ‘*research*’, and to a lesser extent ‘*technology*’ and ‘*space*’, may be considered as optional linguistic components of political messaging, where their usage at a given time is highly subject to the prevalence of other non-optional socioeconomic and militaristic issues and presidential priorities. Put more brazenly, perhaps some leaders consider ‘science’ as a luxury item, to feature more prominently in times of peace and prosperity, with reduced rhetorical usage when urgent economic and militaristic matters ascend in priority. Of the presidents with positively performing economies and declining or low levels of military engagement, Clinton was the most prolific user of science keywords, and Trump the least.

3.4 Science advocacy and political popularity

The behaviour of presidential polling data is reasonably well understood (e.g., Mueller, 1973; Erikson et al., 2002; Eichenberg et al., 2006). Presidential polling data tends to show a 'honeymoon' period of elevated approval ratings following election or re-election, a subsequent decline approval rating with time (although this is not ubiquitous, e.g, Clinton), longer-term variations in polling trends (that could be related to economic performance, and / or involvement in costly wars with large accumulations of fatalities, for example Truman decline during Korean War and Kennedy and Johnson declines during Vietnam war; Hibbs, 2000) and episodic perturbations (i.e., 'rally events', such as surge in approval for GW Bush after declaration of the 'war on terror' following the 11 September 2001 terrorist attacks) (Eichenberg et al., 2006). Almost every president begins their tenure with sustained, elevated approval levels compared to their predecessor. Intra-presidency approval ratings commonly vary by >30%. The presidents with the highest mean approval ratings are Kennedy, Eisenhower, GHW Bush, and Clinton; the lowest are Trump, Truman and Carter. Truman, GW Bush, and GHW Bush have the highest standard deviation in mean approval rating. The presidential greatness survey scores (derived from Vaughn & Rottinghaus, 2018 and modified for poll respondent party affiliation) are highest for Eisenhower followed by Truman and Reagan, and lowest for Trump (lowest), Nixon, Carter, and GW Bush (Fig. 5B). The science advocacy scores are highest for GHW Bush, Obama, Eisenhower, and Kennedy and lowest for Trump, GW Bush, and Ford (Fig. 5). The science advocacy scores show a positive correlation with both the contemporary and historical approval ratings (Fig. 5).

4 Discussion

Although political parties may sometimes take partisan approaches to science-related issues, presidential communications and actions relevant to science issues and funding may be challenging to analyse objectively and may be difficult to characterise as pro- or anti-science (Fisher, 2013). To gain objective insights into presidential communications using a standardized framework, we analysed a uniform set of *corpora* (Presidential SOTU and PBMs) using uniform criteria (keyword counts) that are internally normalized to account for variations in *corpora* length (keyword as a % of total keywords used). Our objective was to undertake an objective analysis that is easily reproducible and immune from many potential forms of cognitive bias, partisanship and heuristics (Kuklinski & Quirk, 2000).

Several key observations pertaining specifically to the relative frequency of science keyword use in presidential communications warrant discussion here. There is no clear association between political party and the % usage of '*science*', '*research*', '*space*', or '*technology*' in either SOTUs or PBMs. Eisenhower (Republican), Kennedy (Democrat), GHW Bush (R), Clinton (D), and Reagan (R) are the most frequent users of science-related keywords, while Trump (R), Carter (D), Ford (R), and Johnson (D) are the least (Fig. 2A). All presidents have delivered at least one SOTU or PBM communication where each of the science-related keywords are less than the presidential average % usage. There is also no clear relationship between political party and other selected science-related keywords shown in Fig. 4B. Care must be taken to view the collective of their messages to evaluate science advocacy during their presidency rather than focusing on a single message (hence keyword % usage averaged over messages was used in the PC analysis and clustering), and any suggestion that a specific presidential message enables characterisation of a long-term prevailing political party view is not evidenced in these data (Fig. 1). An emergent pattern is that many presidents occupy an outlier-type position in at least one specific science-related keyword, and their linguistic advocacy for this theme is independently supported by their presidential actions. A prime example of this is Nixon, whose advocacy in the combined *'climate'* + *'environment'*+ *'natural resources'* + *'pollution'* field (Fig. 4B) is consistent with his track record in environmental policy and advocacy that includes establishment of the National Environmental Policy Act (1969), Environmental Protection Agency (1970), National Oceanic and Atmospheric Administration (NOAA, 1970), Clean Air Act (1970), Earth Week (1971), Clean Water Act (1972), and Endangered Species Act (1973). Clinton's advocacy for *'technology'* and *'health'* is similarly supported by actions including establishment of the Climate Change Technology Initiative (2000), the E-rate and the Technology Literacy Challenge Fund (1996), National Nanotechnology Initiative (2000) the Clinton Health Access Initiative (2002), amongst others (see Supplementary Information) (https://clintonwhitehouse5.archives.gov/WH/Accomplishments/eightyears-09.html). The absence of advocacy may also be supported by actions in some instances; for example one of the lowest Presidential users of '*science'* and *'research'* (Pres. Trump, particularly in 2017-2018) proposed large science budget cuts (Malakoff & Korwall, 2017; Mervis, 2017) (Fig. 2D), delayed appointments of chief science advisors (Goldman et al., 2017), and dissolved science advisory councils (Sargent Jr. and Shea, 2017). GW Bush was described as engaging in a "war on science" (Mooney, 2005)

We cannot fully understand the extent to which science advocacy might be entirely politically motivated, or if some emergent issues demanded a role for science whether the President was interested in advocating for science or not. We acknowledge that once science institutions were established (e.g, National Science Foundation by Truman in 1950) future presidents could not score advocacy points in this aspect, even if supportive of these science agencies, but could score advocacy points in PBM messaging and proposed funding for these agencies. The absence of advocacy (e.g., for science) may be a simple manifestation of attendance to more urgent priorities, even if a President had a personal and vested interest in science. Our probabilistic, resampling approach to the construction of a science score represents our best effort at trying to objectively address these types of potential interpretative concerns.

We endeavour to minimize potential bias associated with word selection, word omission, and weighting of words, actions, and funding (e.g., *should other keywords have been counted? Are the metrics used to calculate the science advocacy score sufficient in volume and representation?*) by (i) applying the same criteria to all presidential communications wherever possible, so that an emphasis is placed on comparative analysis amongst the presidential cohort, and (ii) applying Monte Carlo simulations and randomized sampling of possible combinations of language, funding, and actions metrics to develop science advocacy scores and associated error bounds for each president. Due to the low population of science-related keyword counts (25^{th} and 75^{th} quartile values of $0 \leq x \leq 4$ counts in SOTUs with median values of 0 to 2), the data are highly sensitive to small fluctuations in usage. Multiple mentions of '*science*' and science-related keywords in SOTUs, given the size of the attendant audience and competition to address many priorities, is assumed to represent an agenda that is linguistically distinct from one that does not mention these words.

The analysis of political language by automated content methods is generally intended to supplement, rather than replace, thoughtful reading and contextual analysis of communications (Grimmer & Stewart, 2012). A detailed analysis of the historical political and socioeconomic contexts of each keyword is well beyond the scope of this study (however some contextual analysis is presented in the time-series plots, see Supplementary Data). Instead, we focused primarily on science-related keywords and their most obvious relationships to other keywords. We acknowledge that many keywords that appear to have the highest divergence from science-related keywords (e.g., economy, security, defense, drugs) relate to issues that can be informed by science and could be lexically used within a science context, but our reading and interpretations of samples from the SOTU and PBM transcripts indicates that the clear majority are not. Instead, they are primarily used to communicate on socioeconomic, health, and/or foreign or domestic policy and security issues, for which the contextual relevance of science is commonly unstated. While we acknowledge the same keyword may be used for different purposes, for example, to lobby support for political action on an emerging challenge (e.g., avoiding an 'economic' recession) or to claim success from measures taken for political benefit (e.g., a strong 'economy') science-related words are not used in an anti-science context. Some keywords may multiple meanings (e.g., illegal '*drugs*' as narcotics vs. '*drugs*' as prescription medications; '*health*' care vs. '*health*' of the economy - see Supplementary Information); we identify this as an additional source of uncertainty in word data. Given the various assumptions and uncertainties inherent to this analysis, we caution against over-interpreting these results.

The foregoing invites consideration of Donald Trump's science advocacy and comparison with that of his predecessors. Such an analysis is of benefit because Trump sought and realised political capital thorough populism that included rhetorical anecdotes (excluding SOTUs and PBMs) that could be considered negative towards science, scientists, and experts more generally. According to some analyses, Trump's 'impulsive' 'failure' in response to COVID-19 pandemic (https://www.washingtonpost.com/elections/interactive/2020/trump-pandemic-coronavirus-election/), which included anti-mask sentiment, anti-science advice sentiment, and other populistic rhetoric aimed at diminishing the role of science and scientists, may have been a critical factor in his loss of the 2020 election (https://www.politico.com/f/?id=00000177-6046-de2d-a57f-7a6e8c950000). In important respects, Trump's populism built on a scepticism towards scientific expertise and his elevation of instinct (his own) as the essential commodity in decision-making.

Trump ranked lowest in science keyword usage and science advocacy in the analysed SOTU and PBMs. Trump also proposed significant reductions in funding to almost every major governmental science agency throughout his presidency (Fig. 2D). Ironically, Congress countered these proposed funding reductions with funding increases to many U.S. science agencies (Fig. 2D). The National Institutes of Health (NIH), the biggest federal supporter of academic research, has increased its budget by 39% in the past 5 years despite budget cuts proposed by Trump, and the budget of the National Science Foundation (NSF) has gone up by 17% over the past 3 years.

Numerous studies have investigated the 'success' of U.S. Presidents from diverse perspectives and using distinct proxy measures, including election success (Hibbs, 2000) success in Congress and legislation (Rogowski, 2016; Barrett and Eshbaugh-Soha, 2007), and success in supreme court appointments (Segal et al., 2000). Here we use simple polling-based metrics for success: average public approval rating and expert-opinion-derived Greatness scores. Neither metric captures the complete and coherent picture of presidential success; Truman and Obama are amongst the least popular presidents in average approval rating but score amongst the highest in Greatness, for example. However, when the presidential cohort is considered *en masse*, there is in general a positive correlation between science advocacy scores and (i) approval rating and (ii) Greatness score. These relationships need not imply direct causation; other economic indicators (e.g., growth of real disposable personal income per capita) and cumulative military fatalities are more indicative predictors of popularity (Hibbs, 2000; Eichenberg et al., 2006). Presidential Greatness could hardly be uniquely attributed to science advocacy given the relatively low use of science keywords in presidential communications, the small (typically <1.2%) of federal funding for research and development as a % of gross domestic product (https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd), and the near-continuous emergence of domestic and international issues that feature more prominently in U.S. political and public discourse. However, scientific and technological achievements rank 3rd behind America's armed forces and its history in a survey of nationalist pride (96% of respondents stated they were proud of these achievements) (Bonikowski and DiMaggio, 2016). Is it possible that Trump's 2019 SOTU, where 'science' usage was associated with a historical pride-in-achievement context and was anomalously high relative to his preceding SOTU's, sought advantage from this relationship? Could future presidents and political strategists seek to capitalize on this? It remains possible that the prioritization of science-related issues within the complex environment of democratic politics, regardless of the motive or context, may yield subtle political advantages that are not yet well captured or understood. Indeed, President Biden's early 'pro-science' agenda has included rapid action on COVID-19, climate change, and appointment of scientists into key roles in his administration (https://www.scientificamerican.com/article/biden-elevates-science-in-week-one-actions/). Regardless of the potential causal chains between science and political success, we hope this paper will assist in stimulating further research in this area.

Our analysis provides intriguing insights into the utility and variations in how science features in presidential communications. Different methodologies (e.g., topic analyses, text dispersion keyness - Grimmer & Stewart, 2000; Jacobi et al., 2016; Egbert & Biber, 2019) could be used to further interrogate the results presented herein. We hope this study contributes quantitative evidence to inform contemporary debates on issues such as presidential attitudes towards science (Fisher, 2013; Lane and Riordan, 2018), and contributes to other studies of U.S. Presidents (e.g., Thoemmes & Conway III, 2007; Watts et al., 2013; Roediger & DeSoto, 2014).

5 Conclusions

- *'Science'* and related keywords (*research, space, technology*) constitute a proportionately small (ca. 5-10%) but persistent element in the rhetorical lexicon of U.S. Presidents from Truman to Trump, transcending time and political party.
- Fiscal terms ('*economy*', '*tax*') are the most used keywords in presidential communications; *inflation', 'tax', 'security', 'war',* and *'terror'* are the keywords least correlated with science keywords
- '*Science*' and related keywords are used in a positive (promotional) rhetorical manner and thus their proportionality in SOTU and PBM corpora is a proxy measure for science advocacy
- Monte Carlo simulations of U.S. Presidential language, funding proposals and allocations, and actions are used to estimate a science advocacy score (*SAS*) for each president that is compared with independent measures of political success
- Positive correlations between the *SAS* and measures of presidential popularity and greatness do not constitute causation, but suggest that science advocacy could have political currency in some contexts, as potentially evident in the most recent U.S. Presidential election campaign (Pres. Biden)

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Supplementary Information (Text and Figures)

Scripts used for keyword counting of SOTU and PBM transcripts are provided in Silver (2019). The keyword counts are available in Silver & Quigley (2019). Below is the list of keywords that match when the search is applied to a dictionary file containing over 99,000 US English words:

energy: 'energy'; **tax:** 'nontaxable', 'overtax', 'overtaxed', 'overtaxes', 'overtaxing', 'surtax', 'surtaxed', 'surtaxes', 'surtaxing', 'surtaxs', 'tax', 'taxable', 'taxation', 'taxations', 'taxed', 'taxes', 'taxing', 'taxpayer', 'taxpayers', 'taxs'; **defense:** 'defend', 'defense'; **education:** 'education'; **employment:** 'employ', 'employable', 'employe', 'employed', 'employee', 'employees', 'employer', 'employers', 'employes', 'employing', 'employment', 'employments', 'employs', 'underemployed', 'unemployable', 'unemployed', 'unemployeds', 'unemployment', 'unemployments'; **research:** 'research', 'researched', 'researcher', 'researchers', 'researches', 'researching', 'researchs'; **shooting:** 'shooting'; **space:** 'space'; **nuclear:** 'nuclear'; **natural resources:** 'natural resources'; **racism:** 'racism', 'civil rights'; **crime:** 'crime', 'crimes', 'criminal', 'criminally', 'criminals', 'decriminalization', 'decriminalizations', 'decriminalize', 'decriminalized', 'decriminalizes', 'decriminalizing'; **environment:** 'environment', 'environmental', 'environmentalism', 'environmentalisms', 'environmentalist', 'environmentalists', 'environmentally', 'environments'; **religion:** 'faith', 'god', 'prayer', 'religion'; **health:** 'health', 'healthful', 'healthfully', 'healthfulness', 'healthfulnesss', 'healthier', 'healthiest', 'healthily', 'healthiness', 'healthinesss', 'healths', 'healthy', 'unhealthful', 'unhealthier', 'unhealthiest', 'unhealthy'; **terror:** 'terror', 'terrorism', 'terrorisms', 'terrorist', 'terrorists', 'terrorize', 'terrorized', 'terrorizes', 'terrorizing', 'terrors'; **war:** 'war', 'warrior', 'warriors', 'wars'; **economy:** 'economic', 'economical', 'economically', 'economics', 'economicss', 'economy', 'economys', 'microeconomics', 'microeconomicss', 'socioeconomic', 'uneconomic', 'uneconomical'; **jobs:** 'jobs'; **business:** 'agribusiness', 'agribusinesses', 'agribusinesss', 'business', 'businesses', 'businesslike', 'businessman', 'businessmans', 'businessmen', 'businesss', 'businesswoman', 'businesswomans', 'businesswomen'; **drugs:** 'drugs', 'narcotics'; **inflation:** 'inflation'; **climate:** 'climate'; **science:** 'science', 'sciences', 'scientific', 'scientifically', 'scientist', 'scientists'; **gun:** 'gun', 'gunfire', 'gunman', 'guns', 'handgun', 'rifle', 'shotgun'; **tech:** 'biotechnology', 'biotechnologys', 'technical', 'technological', 'technologically', 'technologies', 'technologist', 'technologists', 'technology', 'technologys'; **military:** 'military'; **security:** 'security'; **housing:** 'housing'; **pollution:** 'pollution'

Two extra phrases, which do not appear in the dictionary file, are added to the list: 'civil rights' (under the 'racism' keyword) and 'natural resources' (under the 'natural resources' theme). The dictionary file used is a standard file among Linux systems, and the version used was provided with version 7.1-1 of the Ubuntu 'wamerican' package.

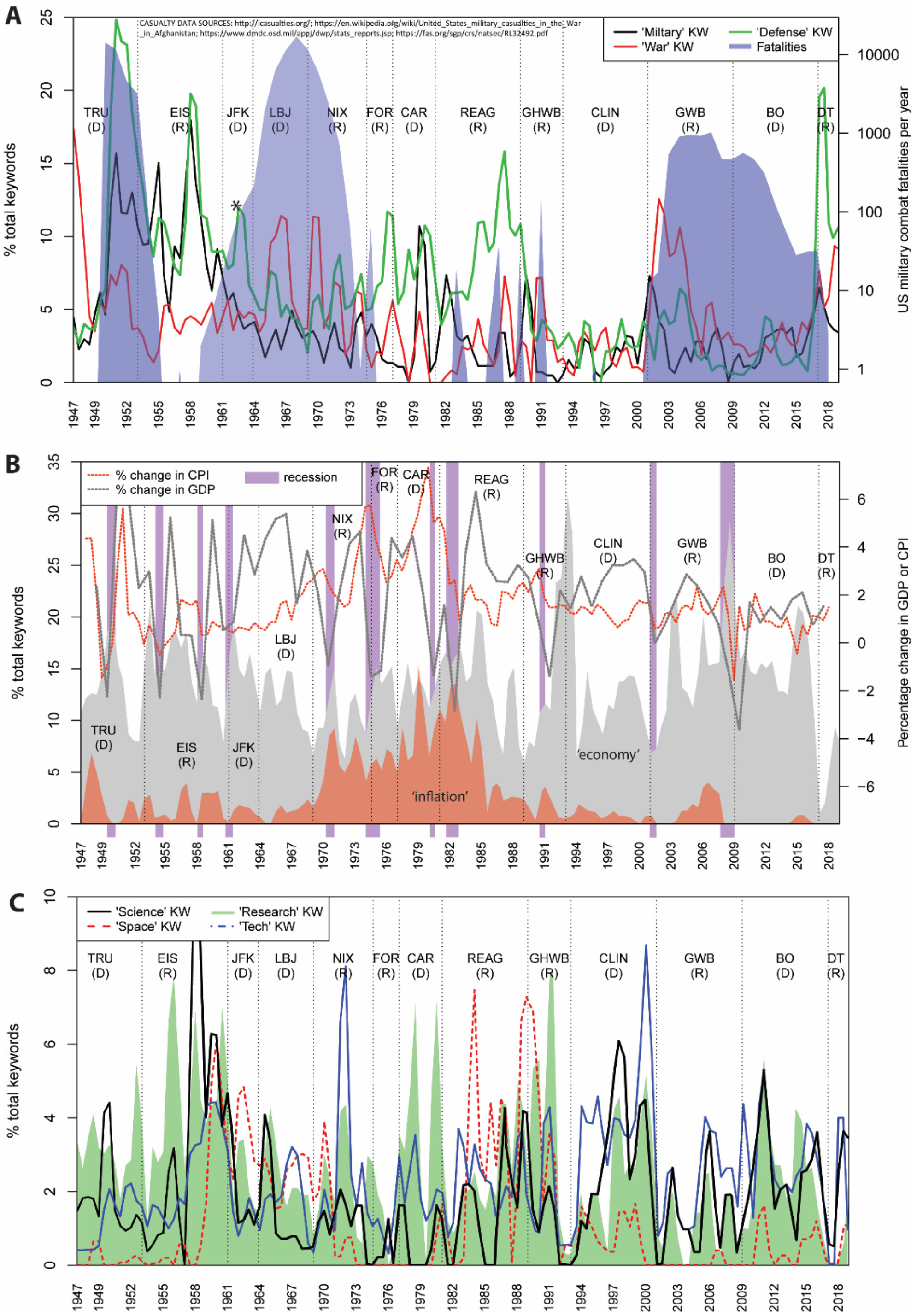

Fig. S1. Examples of time-series of average keyword utility % versus significant military and socio-economic data. (A) Time-series of 'military', 'war', and 'defense' average % keyword utility in SOTU and PBMs plotted with the log of U.S. military combat casualties per year (SOURCES: http://icasualties.org/; https://en.wikipedia.org/wiki/United_States_military_casualties_in_the_War_in_Afghanistan; https://www.dmdc.osd.mil/appj/dwp/stats_reports.jsp; https://fas.org/sgp/crs/natsec/RL32492.pdf). Keyword utility lines correspond to a 2-pt moving average of SOTU and PBMs, for distinct values see Fig. 1. Symbol * denotes the timing of Cuban Missile Crisis. Light grey lines denote presidential inauguration dates. **(B)** Time-series of 'inflation' and 'economy' keyword % utility (lines), shown with annual % change in U.S. Consumer Price index

(CPI) and U.S. real gross domestic product (GDP) per capita (shaded areas), and timing of economic recessions (purple bars). Sources of CPI and GDP data shown in top right of figure. **(C)** Time-series of ‘science’, ‘space’, ‘technology’ (lines) and ‘research’ (shaded) % keyword utility averaged over the SOTU and PBMs.

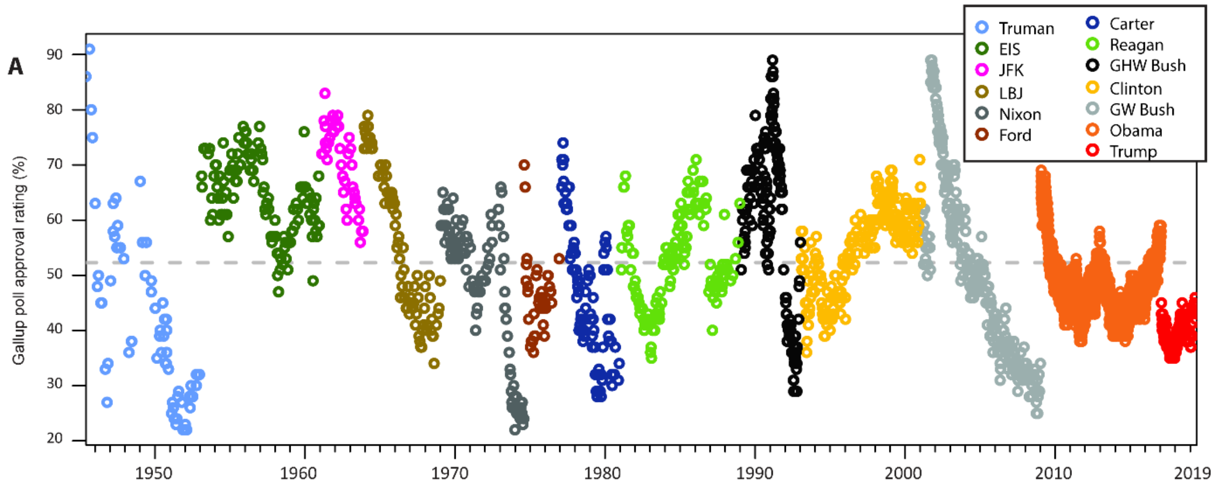

Fig. S2 Time-series of presidential approval % Gallup poll data from 29 May 1945 to 16 June 2019. Gallup poll data was obtained from https://news.gallup.com/interactives/185273/presidential-job-approval-center.aspx (last accessed 20 June 2019). The y-axis is the Gallup poll % of survey participants that answered “Approve” to the question "*Do you approve or disapprove of the way [president’s name] is handling his job as president?*” in the corresponding poll survey. The horizontal grey dashed line shows the average approval rating for the sampled Presidents.