Free associations of citizens and scientists with economic and green growth: A computational linguistics analysis

Ivan Savin[a,b,*], Stefan Drews[a] and Jeroen C.J.M. van den Bergh[a,c,d]

[a] Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona, Spain

[b] Graduate School of Economics and Management, Ural Federal University, Yekaterinburg, Russian Federation

[c] ICREA, Barcelona, Spain.

[d] School of Business and Economics & Institute for Environmental Studies, VU University Amsterdam, the Netherlands.

[*] Corresponding author: ICTA-UAB, Edifici Z, UAB Campus, 08193 Bellaterra, Spain; ivan.savin@uab.cat, phone: +34-93-5868779.

Highlights:

- We study associations of citizens and scientists with (green) economic growth.
- Topics are identified using the technique of Structural Topic Modelling.
- Citizens stress problems of corruption, social inequality and poverty.
- Scientists emphasize environmental damage from economic growth.
- We find topic variation among opinion segments in the growth-vs-environment debate.

Abstract

The debate about the relationship between economic growth and environmental sustainability triggers a range of associations. Here we analyze open-ended textual responses of citizens and scientists concerning their associations with the terms "economic growth" and "green growth". We derive from the responses a number of topics and examine how associations differ across distinct opinion segments of people, namely supporters of Green growth, Agrowth and Degrowth. The results indicate that the general public is more critical of the notion of economic growth than academic researchers. Citizens stress problems of corruption, social inequality, unemployment and poverty, with less variation among the three opinion segments compared to scientists. The latter more strongly emphasize the environmental consequences of economic growth. Concerning associations of scientists with the term "green growth", we find topics questioning its feasibility to be more likely expressed by Degrowth supporters, while topics stressing the possibility of sustainable economic growth by Green growth supporters. We find that topic polarization is stronger for scientists than citizens. Our results provide further validation for opinion clusters identified in previous studies and uncover additional insights about related views on growth and sustainability.

Keywords: structural topic modelling, growth-vs-environment debate, public opinion, scientific opinion, green growth.

1. Introduction

Economic growth is widely seen as contributing to improvements in well-being. At the same time, it is questioned from various angles. An old concern, going back to Easterlin (1974), is that GDP and well-being are decoupled in rich countries. Another one, going back at least to Meadows et al. (1972), is that growth contributes to environmental degradation. An updated version of this concern is that limiting climate change to 2°C may not be feasible under a continued trend of global GDP growth (e.g., Jackson, 2011; Anderson & Bows, 2012; Antal & van den Bergh, 2014; Ward et al., 2016). These and other considerations have given rise to research aimed at understanding attitudes and beliefs regarding the relationships between economic growth and the environment, both among the general public (Drews & van den Bergh, 2016; Tomaselli, Sheppard, Kozak, & Gifford, 2019) and specific groups such as scientists (Drews & van den Bergh, 2017). Understanding attitudes and beliefs – or public opinion more generally – is important given their influence on political action to promote environmental and energy policy (Tjernström & Tietenberg, 2008; Anderson et al., 2017).

The majority of quantitative research studies on attitudes and beliefs regarding growth-vs-environment draws on closed-ended survey questions. Recently, some studies have taken a different and more qualitative approach, analyzing freely formulated associations with specific terms or concepts. Such associations may deliver more 'natural' attitudes and beliefs than the responses to pre-formulated, closed-ended questions or statements. Based on this, one can explore more deeply the cognitive content of individuals' attitudes and beliefs. Whereas closed-ended questions easily prime outcomes through word choice, open-ended questions trigger associations by merely offering simple terms, thus minimizing framing or priming contextual terminology. This

avoids limiting survey respondents in their answers as do pre-specified answers or any further information that characterizes closed-ended questions.

The free associations technique has been used to study a variety of environmental and non-environmental topics, such as 'climate change' (Leiserowitz, 2006; Lorenzoni, Leiserowitz, De Franca Doria, Poortinga, & Pidgeon, 2006; Moloney et al., 2014), 'peak oil' (Becken, 2015), 'fracking' (Clarke et al., 2015) and 'financial/economic crisis' (Gangl, Kastlunger, Kirchler, & Voracek, 2012). To our knowledge, there is only one study that has examined associations with 'economic growth' (Mohai, Simoes, & Brechin, 2010). Using data for China and the US collected in 2002, it found that "improvements in standard of living" was the category with the most frequently mentioned associations, though with considerable differences between countries (67% versus 32%).

The data in the above-mentioned studies on free associations have traditionally been manually coded by researchers. An alternative approach is a computer-based analysis using the technique of structural topic modeling (STM). A few studies have used this technique to examine associations with 'climate change' (Tvinnereim & Fløttum, 2015; Tvinnereim, Fløttum, Gjerstad, Johannesson, & Nordø, 2017a), 'air pollution' (Tvinnereim, Liu, & Jamelske, 2017b) and the proposal to introduce a carbon tax (Savin, Drews, Maestre-Andrés, & van den Bergh, 2020). Among the advantages of this technique is that it allows to process large amounts of information in very short time, avoid any systemic bias/inconsistency between human coders working on the same data, and incorporate additional information about the surveyed persons such as their gender, education or political affiliation (Roberts et al., 2014).

The motivation of this study is twofold. First, we want to examine what the general public and scientists associate with the term 'economic growth'. To this end, we draw on two data sets

from surveys among the general public (Drews & van den Bergh, 2016) and scientists with a variety of backgrounds, such as economics, other social sciences or environmental sciences (Drews & van den Bergh, 2017). In addition, we examine associations among scientists only[1] with the term 'green growth' which is often used in academia and public media currently. According to Bowen & Fankhauser (2011), "Green growth has become a buzz word in both policy and academic circles. A clear definition is still lacking, but most analysts would associate the term with environmentally sustainable, biodiverse, low-carbon and climate-resilient growth in human prosperity."

The second main objective is to investigate how associations vary with individual attitudes. With regard to the latter, we build on previous research which found that currently three different population segments exist with respect to attitudes and beliefs regarding economic growth and the environment (Drews, Savin, & van den Bergh, 2019; see also Tomaselli et al., 2019): one that is 'Green growth' believing in the compatibility of growth and environmental sustainability, another is 'Degrowth' expressing a disbelief in such compatibility, while a third is 'Agrowth' which – rather than being pro- or anti-growth – means being disinterested in economic growth.[2] A major difference between supporters of Green growth and Degrowth is that the first are much more convinced about the environmental and social necessity of growth: they agree stronger that growth is required to protect the environment or to create jobs. In contrast, people in the Degrowth cluster disagree that growth is needed for environmental protection or to improve life satisfaction, and they agree that a 'good life' can be achieved without growth. The characterizations of these clusters hold for the general public and are even better distinguishable among scientists (Drews et al.,

[1] The reason is that in the survey conducted by Drews & van den Bergh (2016) among the general public did not include a question on "green growth",

[2] See Drews & Reese (2018) for more discussion of the distinct labels of opinions in the growth-vs-environment debate.

2019). Broadly speaking, these clusters reflect the current positions in the growth-vs-environment debate (van den Bergh & Kallis, 2012; Jakob & Edenhofer, 2014). To further validate these segments, we are interested to study whether free associations with 'economic growth' and 'green growth' differ between these segments. Finally, we also account for the sentiment content of each topic, i.e. whether it exhibits positive, negative or neutral emotions. To this end, we weight the sentiment score of each word in a given topic with the probability of that word appearing in it, using sentiment scores of isolated words from a relevant database.

The remainder of this article is organized as follows. Section 2 describes data and methods. Section 3 presents results for associations by scientists with economic growth and green growth, and subsequently for associations by the general public with economic growth. Section 4 discusses policy implications, while Section 5 concludes.

2. Data and methods

In this study we draw on two questionnaire surveys. The first concerns a worldwide survey among 814 scientists from a variety of academic backgrounds (Drews & van den Bergh, 2017). Based on respondents' self-identified research fields, they were categorized into one of seven groups: economists working specifically on economic growth (*GrowEc*), economists working on growth/environment (*GrowEnv*), other economists (*OthEc*), environmental economists (*EnvEc*), ecological economists (*EcoEc*), environmental social scientists (*EnvSoc*), and environmental scientists (*EnvSci*). Descriptive statistics on these groups as well as other sample characteristics can be found in Table A1 in the Appendix. Data collection was achieved by inviting researchers to express their views on economic growth and the environment in an online English-language

survey between March and May 2015. After cleaning for missing observations[3] 671 responses remained. The survey opened with two open-ended questions, which provide the basis for our computational linguistic analysis:

1. "Before we ask you more specific questions, we would like to know what is the first word, image or thought that comes spontaneously to your mind when you think of 'economic growth'?"
2. "And when you think of 'green growth'?".

The average length of responses is 1.94 and 2.34 words, respectively. The distribution of answers is very skewed, with the median being 1 word in both cases, and the maximum 41 and 23 words, respectively. The texts were cleaned, which involved deleting stop words and numbers, words of length less than 3 letters, setting everything to lower case and stemming words, i.e. inflected words were reduced to their word stems, base or root form (e.g., the words 'polluting' and 'pollute' are reduced to the stem 'pollut'). Stemming is necessary to avoid that distinct inflected forms of the same word are considered as different words. Then the words were compared in terms of frequency. As a result, answers to the question regarding economic growth contain 54 (unique) terms and 612 tokens (i.e. total words). Applying the same approach to the term "green growth", we obtain 69 unique terms and 728 tokens.

The second dataset is a public opinion survey undertaken in July 2014 in Spain, in Spanish language. The data was collected by drawing from a panel of the Spanish survey company 'Netquest'. The online sample included 1008 participants and was representative of the general

[3] There was one minor difference between the designs of the two surveys: whereas in the scientist opinion survey respondents could select "no opinion" for each of the 16 statements, in the public opinion survey there was no such option. This difference explains why there are 143 missing observations in the scientists' survey. In Drews et al. (2019) we tested if dropping these observations biases the sample by means of Kolmogorov-Smirnov test and a Wilcox rank sum test and found that both tests indicated no statistically significant bias.

population in terms of income, age, gender and geographical distribution. Further details on sample characteristics can be found in Table A2 in the Appendix (and in Drews & van den Bergh, 2016). The survey opened with the question "Economic growth receives much attention from the media and politics. Could you briefly mention which topics go through your mind when you hear about 'economic growth'?" (translation from Spanish question: "El crecimiento económico recibe mucha atención por parte de los medios de comunicación y la politica. ¿Podrías mencionar brevemente qué temas te pasan por la cabeza cuando se habla sobre 'crecimiento económico'?"). The average length of the response is 10.16 words with the median of 6 words and the maximum of 159 words. The distribution is again very skewed. After the data is processed (no capital letters, no numbers, no stop words) and stemmed, we are left with 267 unique terms and 3468 tokens. As mentioned in Section 1, unfortunately the survey among the general public contained no question on the term "green growth" as it was added only in the later survey among the scientists.

To identify dominant topics in the responses we rely on computational linguistics analysis techniques. To this end, we use the STM method, which - similar to classical topic modelling such as Latent Dirichlet Allocation (LDA) - generates topics using a clustering algorithm based on the co-occurrence of words across documents. The advantage of topic modelling (TM) over simple keyword search is that it considers words not in isolation but together with other words that they appear with. TM reduces the dimensionality of linguistic data from words to topics based on the co-occurrence of words in a collection of responses to infer the underlying topics in those texts and the weight of each topic in each individual response. For example, if we observe the word "resource" in the topic that we label as "GDP", it implies that this word appeared relatively more frequently and exclusively in combination with other words in this topic, and that people associating economic growth with GDP used it more often.

An important difference between STM and LDA is that instead of assuming topical prevalence (i.e. the frequency with which a topic is mentioned by any respondent) and topical content (i.e. words used from any of the topics) to be constant across respondents, we incorporate so-called covariates in which we expect to see variance between responses (Roberts et al., 2014). To this end, we use membership of respondents of opinion clusters in the growth-vs-environment debate as a categorical variable with 1=Green growth, 2=Agrowth and 3=Degrowth. In Drews et al. (2019) we identify these three clusters as having shares of 31%, 44% and 25% in the sample of surveyed scientists, and 32%, 48% and 20% in the sample of Spanish citizens,[4] respectively. Statements used for constructing the clusters, which capture social, economic and environmental aspects related to growth, can be found in Table A3 in the Appendix. Both surveys contained various other questions (e.g., respondents' belief about an end to economic growth or about their favored GDP growth) not used in this paper but which were already analyzed in prior studies (Drews & van den Bergh, 2016/2017; Drews et al., 2019).

The first step in the STM application is to set the number of topics *k*. Defining the number of topics *k*, we consider the so-called 'heldout log-likelihood' of the models (accuracy of the model to predict words from a sample that has been excluded from the estimation step), semantic coherence (how well words from the same topic co-occur within a document) and exclusivity (conditional probability of seeing the topic given the words). We analyze alternative model specifications from three to twelve topics, similar to the approach followed by Tvinnereim et al. (2017a). This way, we seek to form a topic model that not only well predicts the data but also contains semantically interpretable topics that tend to co-occur within responses, and whose top

[4] We dropped 101 out of 1008 answers from the public survey in Spain, as respective respondents answered "neither disagree nor agree" to 90% of the questions and as a consequence, we classified them in an additional, fourth cluster. This means we cannot apply to them the same scale that we use for respondents from the scientific survey.

keywords are unlikely to overlap with keywords from other topics (Roberts et al. (2014). A fourth implicit criterion in selecting *k* is the model's complexity: the larger the *k* the harder it is to interpret the topics. Therefore, when choosing between two models with similar performance we prefer the simpler one.

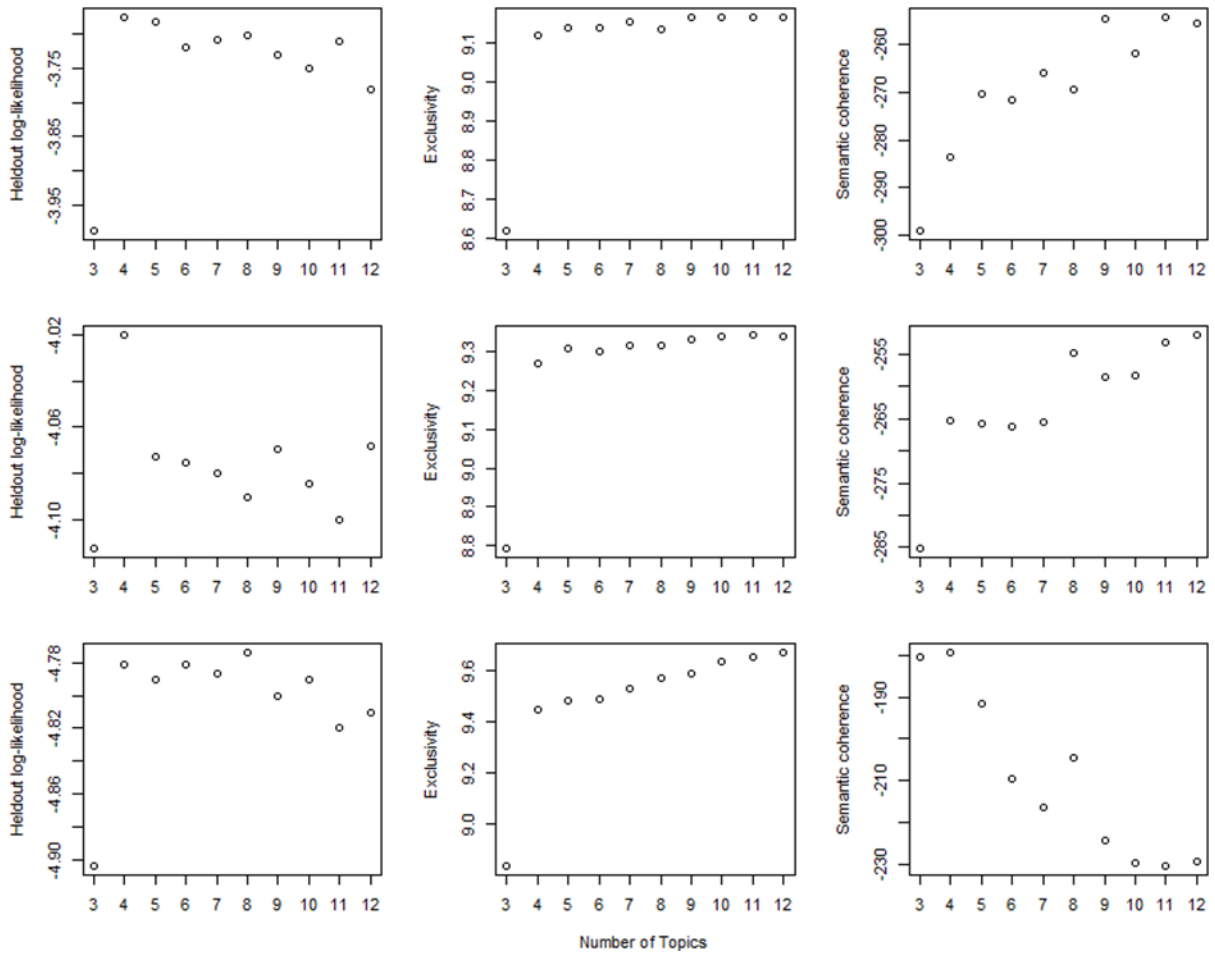

Figure 1. Model performance for different number of topics.
Note: The upper panel is for the topic model responses concerning economic growth among scientists; the mid panel – for responses concerning green growth among scientists; and the lower panel – for economic growth among the general public.

Defining the optimal number of topics for the question on "economic growth" among scientists we obtain the model performance as demonstrated in upper panel in Figure 1. As one

can see, the held-out likelihood of the model is best for four topics, while model exclusivity for models starting from four topics onwards does not improve much. At last, semantic coherence tends to be larger for larger number of topics. Given, however, that our responses are very short (making coherence a less informative metric here) and the mentioned aim to limit model complexity, we prefer a model with four topics henceforth. Similarly, for associations with "green growth" with 4 topics we reach by far the highest held-out log-likelihood with a good exclusivity score (mid panel in Figure 1). Finally, for the survey among the general public we also compared the performance of the model under different number of topics (lower panel in Figure 1). An important distinction here is that since the responses are longer, the semantic coherence becomes a more relevant metric to look at. The highest semantic coherence is reached for four topics, while held-out log-likelihood is close to its maximum value over the range of considered numbers of topics. Hence, we select four topics again.

After the number of topics *k* is set, the method assigns to each survey response (hereafter referred to as 'document') a vector with *k* values, where each value expresses the degree to which the document belongs to that topic. These values sum up to one. Thus, multiple membership is possible. Topic prevalence is then derived as the degree to which a single response belongs to a given topic, based on the words it contains. We further estimate topic prevalence for the whole dataset to measure relative topic size (see, e.g., Table 1).

To assess sentiment content of each topic, we use the comprehensive database "SentiWords" developed by Gatti, Guerini and Turchi (2016). We chose this database as it contains sentiment scores of more than 155,000 English words taken out of context each associated with a sentiment score between -1 and 1. For example, the word "growth" has a sentiment score 0.27282, while the word "corruption" -0.47726. The average sentiment score of a topic is equal to the

product of the individual sentiment score of each word and the probability of this word belonging to the respective topic. Since sentiment scores are between -1 and 1, while probabilities of words belonging to the topics are between 0 and 1, the average sentiment scores of each topic are bound between -1 and 1 as well.

3. Results

3.1. Economic growth in a survey among scientists

We start with the four topics obtained for the question on "economic growth" among scientists. Table 1 summarizes the most discriminating (i.e. most frequent and exclusive[5]) words from each topic together with the topic prevalence (relative size in the dataset) and descriptive topic label. Furthermore, below we provide five illustrative responses that combine dominant prevalence of a topic in the responses and diversity of responses (i.e. avoiding repetition):

- Topic 1. Social and environmental problems: "environmental and social problems", "environmental destruction", "inequality", "unsustainable", "money".
- Topic 2. Industry and progress: "income increase", "improved standards of living", "factories", "Industry", "development".
- Topic 3. Material wealth: "better (material) life for all", "material wealth", "good trains and good housing stock", "increase in production of goods and/or services", "prosperity".
- Topic 4. GDP: "expansion of economic output and its many measures such as GDP", "resource consumption", "economic expansion", "GDP", "accumulation of capital".

[5] Here and later in the paper we keep the weights of frequency and exclusivity as equal (0.5).

By weighting the sentiment score of each word in a given topic with its probability to appear in that topic, we derive the overall sentiment values as weighted sums presented in the last column of Table 1.[6] The results support the intuition that Topics 1 and 3 are very polarized: the first topic, on social and environmental problems, is quite negative; the second, on material wealth, is rather positive. Topics 2 and 4, in contrast, are neutral. We also derive word clouds for each of the four topics (based on the 30 top words), which are shown in Figure 2.

Table 1. Most discriminating words by topic among scientists for the theme economic growth

Topic	Most discriminating terms (frequency and exclusivity)	Topic label	Topic prevalence	Topic sentiment
1	money, welfar, unsustain, environment, citi, inequ, poverti, destruct, problem, graph	Social and environmental problems	23.4%	-0.182
2	develop, incom, industri, sustain, increas, factori, live, pollut, emiss, standard	Industry and progress	24.9%	0.024
3	prosper, growth, wealth, product, limit, good, materi, exponenti, paradigm, qualiti	Material wealth	24.5%	0.312
4	gdp, capit, consumpt, expans, human, job, econom, resourc, employ, measur	GDP	27.2%	0.003

Notes: The terms shown are those that are the most frequent as well as exclusive to each topic. Labels for each topic are suggested qualitatively on the basis of the content of the terms and associated survey responses. Words are stemmed so that, for example, the term 'inequ' comprises 'inequality' and 'inequity'.

[6] The only stem we could not match here was "unsustain". We assumed it to have the negative sentiment value of the stem "sustain", which is 0.28. Note that even without this assumption Topic 1 would have a very negative sentiment content of -0.147.

Topic 1 has clear negative or critical components and points to environmental problems. Many negative stems appear ("destruction", "smoke", "inequa", "poverti", "problem"), due to their variety, none of them obtain a weight as large as "GDP" in Topic 4 or "prosper" in Topic 3. Topic 3, in contrast, is very positive, pointing to wealth, quality of life and growth. A negative word here is "limit", but it has a small frequency of occurrence. Topic 2 is rather neutral containing positive terms addressing increase in income and better living standards, but also negative ones like "pollut". Topic 4 is also neutral, focusing on GDP as a main association with economic growth.[7]

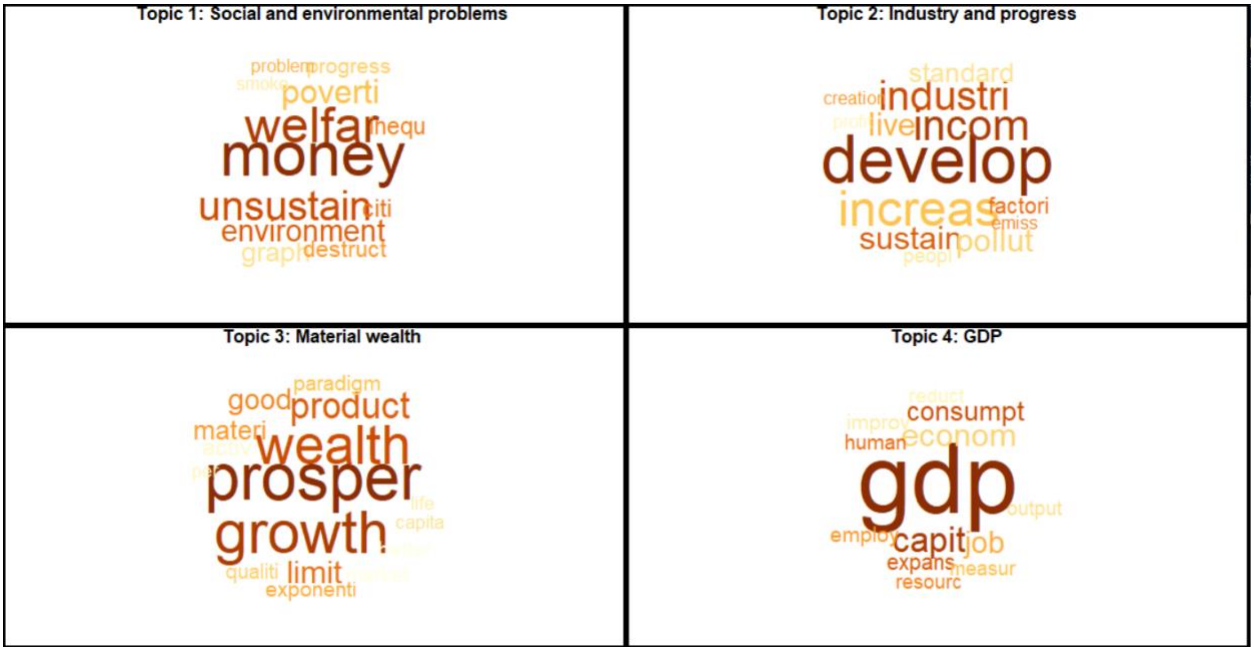

Figure 2. Word clouds of the four topics generated from scientists' associations about economic growth

Note: The font size of a word in a cloud corresponds to the probability (weight) of the respective word given the topic, while the color of the word corresponds to its exclusivity (the darker the color, the more exclusive the words).

[7] The fact that GDP is found so popular in responses from scientists and general public (see Topic 3 in Section 3.3) is not surprising given its dominant role as an economic indicator. It also responds to the behavioral requirement to simplify complex issues, such as economic performance, to a simple (single) metric (van den Bergh, 2009).

Setting the color of the words in Figure 2 according their FREX rank (frequency + exclusivity, Roberts et al. 2014) with more exclusive words having darker color, we also see that some popular words, like "increase" in Topic 2 are not as exclusive as "incom" or "sustain".

As noted above, in an earlier study we identified three opinion clusters, namely Green growth, Agrowth and Degrowth (Drews et al., 2019). We want to understand now whether these clusters help to explain the differences in associations by the respondents. To do so, we fit a linear model where the dependent variable is the topic prevalence (proportion of each document dedicated to each topic) of a particular academic, and the explanatory variable is a categorical variable taking values 1 (Green growth), 2 (Agrowth) and 3 (Degrowth). This categorical variable has been also used as the only covariate in our STM topic model allowing topical prevalence to vary across groups. Figure 3 shows that respondents belonging to the Degrowth cluster devote significantly more words in their responses to environmental problems (Topic 1) and to the topic dominated by neutral association of GDP indicator with economic growth (Topic 4). Conversely, people from the Green growth cluster tend to talk more about growth, prosperity and living standards (Topics 2 and 3). The slopes of all four regression lines are significant at the 1% level as confirmed by in Table A4 in the Appendix.

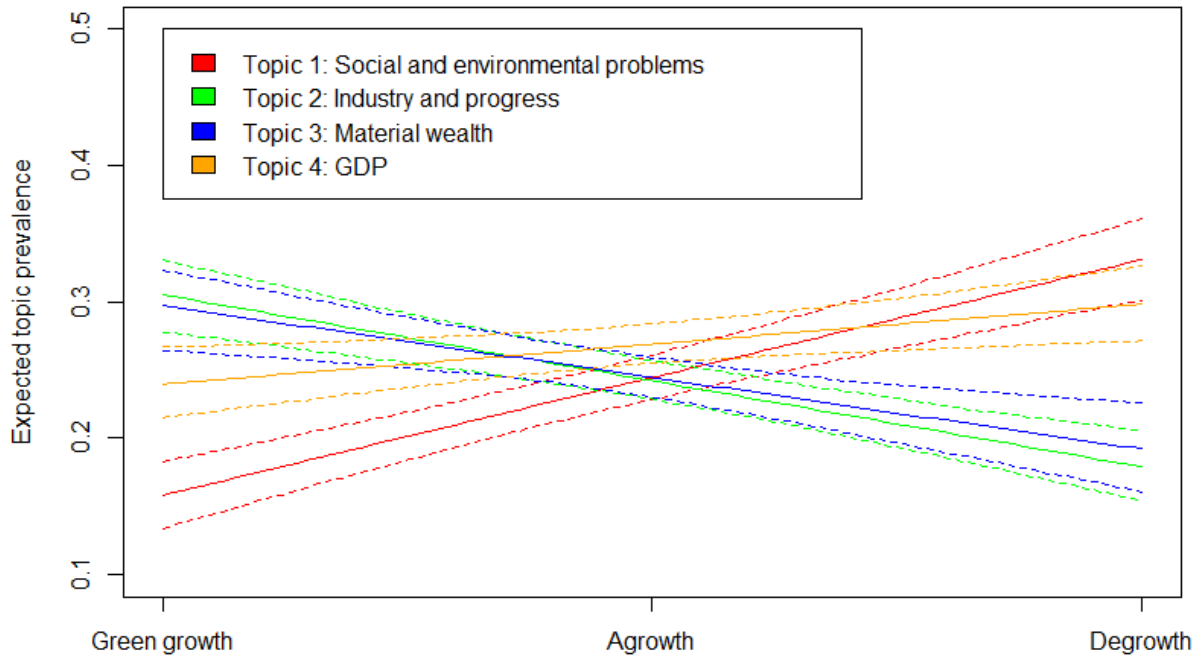

Figure 3. Effect of opinion with regard to growth-vs-environment debate on topic prevalence for associations with economic growth by scientists.
Note: Values generated by a regression where the outcome variable is the proportion of each document dedicated to each topic, given the selected STM model. The explanatory variable is a categorical variable taking values 1 (Green growth), 2 (Agrowth) and 3 (Degrowth). Confidence intervals plotted as dashed lines indicate the 95% uncertainty range and include both regression and measurement uncertainties associated with the STM model.

3.2. Green growth in the survey of scientists

The topic prevalence and their most frequent and exclusive words are shown in Table 2. Topic 1 contains terms referring to a better reality (green tech, forests, green industry) but at the same time is fairly skeptical about it, as reflected by terms like greenwashing and oxymoron. Topic 2 instead puts considerable emphasis on the idea of growth and development compatible with preservation of the environment. Topic 3 emphasizes the concept of sustainability, but also questions the possibility of sustainable growth ("impossible", "paradox"). Topic 4 is again positive with emphasis on environment, better life and renewable energy. Note that topics 2 and 4 are very

similar in their overall meaning, though they use distinct words, which explains why they are recognized as distinct topics. Here again we provide a list of five illustrative responses per topic:

- Topic 1. Green ambiguity: "necessary for future, but not defined well yet", "green industry, "green energy and green urban spaces", "greenwashing", "oxymoron".
- Topic 2. Green technologies: "growth that lacks or minimizes pollution or negative environmental consequences", "increase of income without environmental damages for next generations", "a field of solar panels", "firms, limited pollution", "services rather than goods".
- Topic 3. (Non-)Sustainability: "ecological capitalism (not necessary sustainable, not social/fair)", "an illusion to try to make the impossible possible", "wildlands, lots of open space, half the space occupied by people and their artifacts, no/little pollution, PV, windmills, etc", "sustainability", "paradox".
- Topic 4. Environment and energy: "beautiful environment and economic development", "renewable energy", "better than just economic growth", "high income in pristine climate and environment", "renewables".

Next, we also undertook a sentiment content analysis for each topic. This indicates that none of the topics has a very negative sentiment content. Topic 1, for example, contains positive stems like "prosper" and "green" next to "oxymoron" which also has a positive sentiment value of 0.12. "Greenwash" could not be matched in the SentiWords database, and we assume it to have the same value as a very negative word "lie" (-0.62). Topic 2 combines both positive stems ("good", "growth") with negative ones ("pollut", "limit"), which explains its rather neutral sentiment score. Finally, Topics 3 and 4 also are dominated by positive stems. All in all, it appears that even if scientists raise doubt about the possibility of green growth and precision of its concept,

the words they use do not easily allow distinguishing between positive and negative sentiment without further context. The associated word clouds are presented in Figure 4.

Table 2. Most discriminating words by topic among scientists for the theme green growth

Topic	Most discriminating terms (frequency and exclusivity)	Topic label	Topic prevalence	Topic sentiment
1	green, oxymoron, forest, greenwash, wind, industri, carbon, possibl, defin, prosper	Green ambiguity	23.6%	0.133
2	tree, solar, pollut, technolog, good, panel, environment, limit, growth, extern	Green technologies	27.2%	0.044
3	sustain, ecolog, windmil, imposs, natur, economi, effici, paradox, gdp, illus	(Non-) Sustainability	26.0%	0.187
4	environ, energi, renew, climat, chang, develop, better, live, econom, power	Environment and energy	23.2%	0.167

Note: The terms shown are those that are the most frequent as well as exclusive to each topic. Labels for each topic are suggested qualitatively on the basis of the content of the terms and associated survey responses. Words are stemmed so that, for example, the term 'pollut' comprises 'pollute' and 'pollution'.

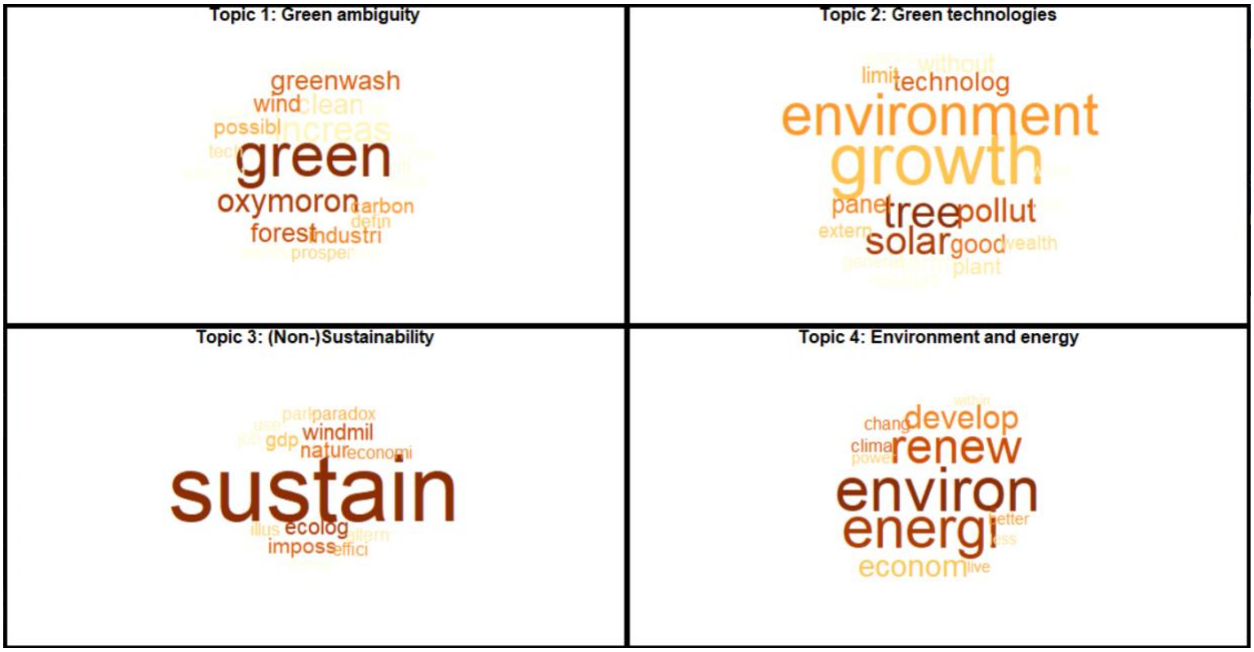

Figure 4. Word clouds of the four topics generated from scientists' associations with green growth
Note: The font size corresponds to the probability (weight) of the respective word given the topic, while the color of the word corresponds to its exclusivity (the darker the color, the more exclusive the words).

Not surprisingly perhaps, Topic 4, and to a lesser extent Topic 2 – both highlighting the compatibility of "growth" with "environment" and "economy" – tend to be more present among people in the Green growth cluster, and less among those in the Degrowth cluster (Figure 5). The other two topics (1 and 3) stress sustainability but also criticize the concept of "green growth" through words like "illus", "paradox", "greenwash", "imposs" and "oxymoron". These are used more frequently by people in the Degrowth cluster. The slopes of regression lines for all topics but Topic 2 are significant at the 1% level (for Topic 2 significance is at 5%) as confirmed by Table A5 in the Appendix.

v

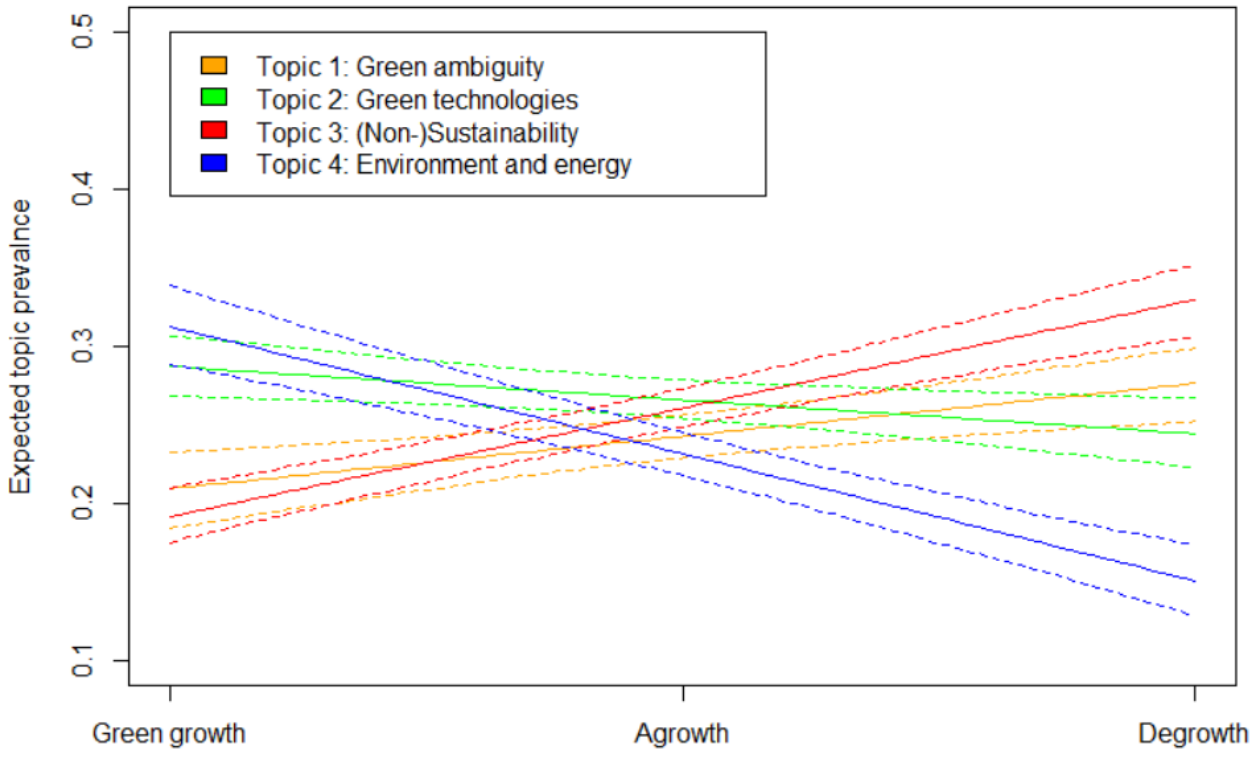

Figure 5. Effect of opinion with regard to growth-vs-environment debate on topic prevalence for associations with green growth by scientists

Note: Values generated by a regression where the outcome variable is the proportion of each document dedicated to each topic, given the selected STM model. The explanatory variable is a categorical variable taking values 1 (Green growth), 2 (Agrowth) and 3 (Degrowth). Confidence intervals indicate the 95% uncertainty range and include both regression and measurement uncertainties associated with the STM model.

3.3. Economic growth in a public survey

Now we look on the topics based on responses from the general public. Table 3 presents the topic labels, their prevalence and the most discriminative words.

Table 3 Most discriminating words by topic on economic growth by the general public

Topic	Most discriminating terms (frequency and exclusivity)	Topic label	Topic prevalence	Topic sentiment
1	crisis, lie, more, corruption, politics, peopl, benefit, are, missing, europe *crisi, mentira, mas, corrupcion, politica, gent, beneficio, estan, falta, europa*	Crisis, lies and corruption	25.2%	-0.171
2	growth, economic, spain, single/only, government, rich, poor, think, year, believe *crecimiento, economico, españa, solo, gobierno, rico, pobr, creo, año, pienso*	Disbelief in economic growth and government	24.2%	0.095
3	employment, increase, gdp, consumption, creation, tax, premium, risk, salary, debt *empleo, aumento, pib, consumo, creacion, impuesto, prima, riesgo, salario, deuda*	Employment and economic recovery	26.6%	0.042
4	work, poverty, tourism, development, purpose, economic, country, rate, unemployment, help *trabajo, pobreza, turismo, desarrollo, fin, economica, pai, tipo, paro, ayuda*	Unemployment and poverty	24.0%	-0.157

Note: The terms shown are those that are the most frequent within as well as exclusive to each topic. Labels for each topic are suggested qualitatively on the basis of the content of the terms and associated survey responses. Words are stemmed so that, for example, the term 'inequ' comprises 'inequality' and 'inequity'. Translations are best approximations based on readings of representative entries.

Below we provide one illustrative response per topic (with original formulation in Spanish in parentheses):

- Topic 1. Crisis, lies and corruption: "Political lies, enrichment of those who have achieved the absolute majority and those who are waiting to get there. Corruption, shamelessness and lack of scruples." ("Mentira politica, enriquecimiento de los que han logrado la mayoria absoluta y de los que estan a la espera de llegar a ella. Corrupcion, desvergüenza y falta de escrúpulos.").
- Topic 2. Disbelief in economic growth and government: "There is no such economic growth today in Spain. In any case, it only affects big companies and fortunes, and politicians. It is a utopia, constant growth, destroys the planet's resources and people. The system is not solidary, for some to win others have to lose." ("No existe ese crecimiento economico hoy por hoy en España. En todo caso solo afecta a las grandes empresas y fortunas, y a los politicos. Es una utopia el crecimiento constante, destruye los recursos del planeta y a las personas. El sistema es insolidario, para que unos ganen otros tienen que perder.")
- Topic 3. Employment and economic recovery: "Consumption, creation of employment, entrepreneurship, credit, creation of companies" ("Consumo, creacion de empleo, emprendeduria, credito, creacion de empresas").
- Topic 4. Unemployment and poverty: "Economic policy, unemployment, retirements, evictions, poverty ..." ("La politica economica, el paro, las jubilaciones, los desahucios, la pobreza....").

Considering the illustrative responses of each topic we find that Topic 1 is most critical, focusing on the issues of crisis, lies and corruption. Topic 2 is also critical, but with a stronger focus on disbelief in the government and economic growth and on social injustice. Topic 4 in turn

concentrates on economic problems such as unemployment and poverty. Topic 3 is the only cluster of responses with clearly optimistic views, focusing on wellbeing, consumption and investments. If we measure the sentiment score of the stems contained in the topics, topics 1 and 4 are most negative, which is to be expected. Topic 2 has a positive sentiment score, which seems inconsistent with its critical nature, but can be explained by dominance of positive terms out of context, notably "growth", and to a lesser extent, "economic" and "rich"; assessing the context, however, demonstrates that the respondents do not believe in that growth is feasible. Topic 3 is positive. The related word clouds are presented in Figure 6.

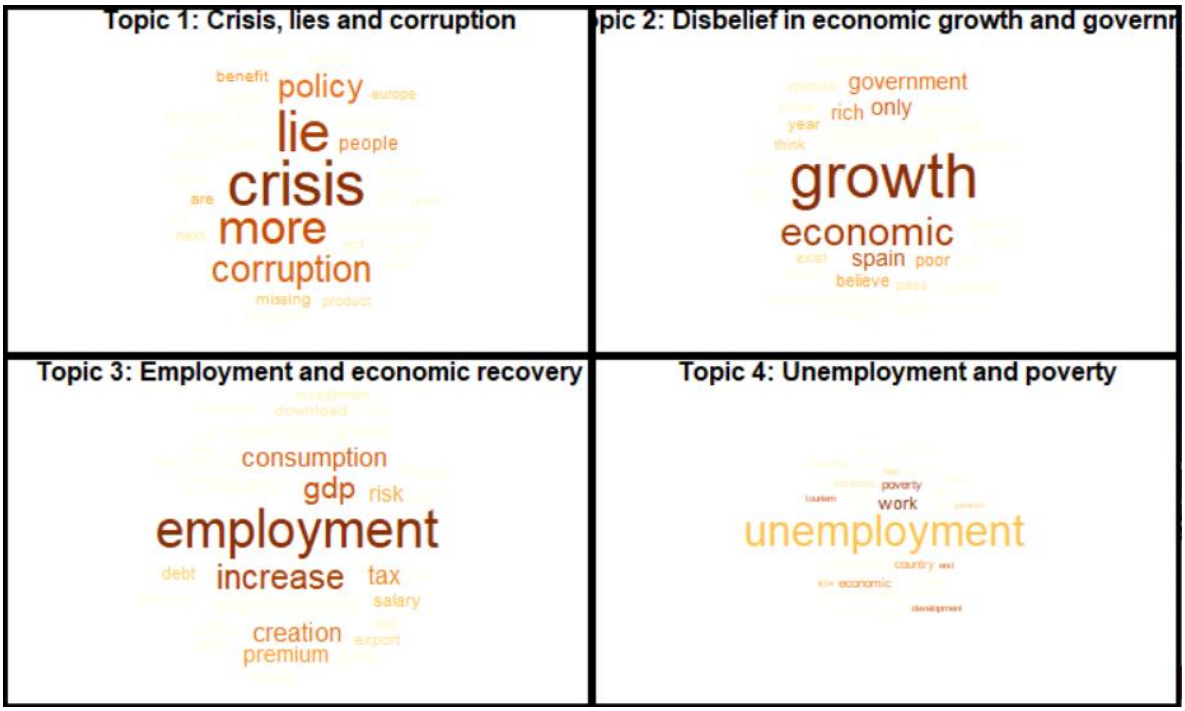

Figure 6. Word clouds of the four topics generated from associations with economic growth by the general public

Note: The font size corresponds to the probability (weight) of the respective word given the topic, while the color of the word corresponds to its exclusivity (the darker the color, the more exclusive the words).

As one might expect, the topics showing strongest disbelief in economic growth and the government (Topic 1 and Topic 2) are more popular among the Degrowth cluster (Figure 7). This

is particularly true for Topic 1 as the slope is significant at the 1% level (see Table A6 in the Appendix). In sharp contrast, Topic 3, most positive and focused on consumption, investments and wellbeing, is better present among the Green growth segment. Topic 4 focusing on unemployment and poverty is also slightly better present among this cluster. The slopes of the latter two topics are significant at the 5% level.

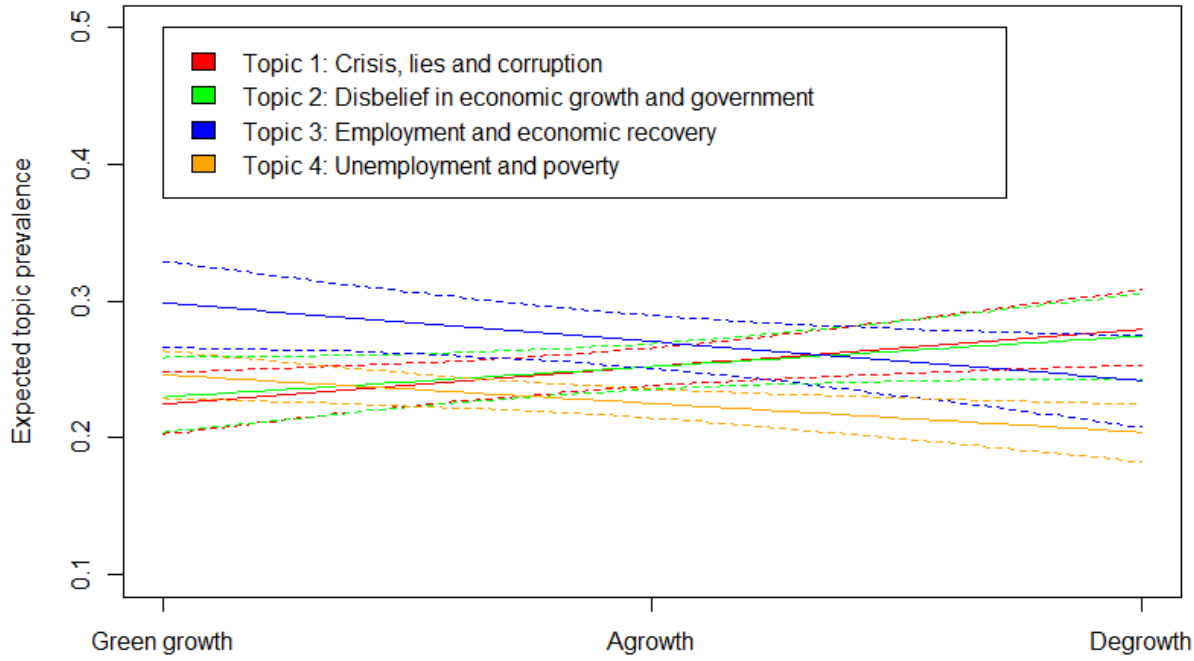

Figure 7. Effect of opinion with regard to growth-vs-environment debate on topic prevalence on economic growth by general public

Notes: Values generated from a regression where the outcome variable is the proportion of each document dedicated to each topic, given the selected STM model. The explanatory variable is a categorical variable taking values 1 (Green growth), 2 (Agrowth) and 3 (Degrowth). Confidence intervals indicate the 95% uncertainty range and include both regression and measurement uncertainties associated with the STM model.

When comparing the surveys of scientists and general public, one can notice that topic prevalence differing stronger for the former (compare Figures 3 and 7). An explanation for this may be the lower polarization of opinions in the growth-vs-environment debate as shown in Figure

5 in Drews et al (2019). Indeed, comparing the Green growth, Agrowth and Degrowth clusters with respect to their growth skepticism, the authors find much larger spread among the clusters in scientific opinion compared to public opinion. In particular, while among the scientists Green growth, Agrowth and Degrowth opinion segments scored 3.4, 4.6 and 5.8 on the index of aggregate growth skepticism, respectively, among the general public these values were 3.5, 3.9 and 4.9, respectively. The present study shows that people exhibiting larger differences in their anti-growth position, as expressed through responses to closed-ended questions, also exhibit larger differences in their responses to open-ended questions that result in (textual) associations to economic growth.

4. Discussion

We have measured and analyzed scientists' and citizens' associations with economic and green growth using structural topic modeling. The advantage of this technique compared to simply counting word frequency is that by clustering words into topics based on their co-occurrences we considerably reduce dimensionality of the problem (from 50-250 words to just four topics). This contributes to a better understanding of the context in which those words are used. For example, take the topic "material wealth": it combines words like "wealth", "prosperity", "quality" and "life". The topic "crisis, lies and corruption", in turn, connects the three keywords from the title of the topic to "politics". The particular advantage of structural topic modelling is that in formulating the topic models we assume people belonging to different opinion groups concerning the growth-vs-environment debate to have different topical prevalence and topical content, that is, they speak about different topics and use different words. By applying the method, we identify four distinct topics in the responses to each of the three survey questions, as summarized in Table 4, with prevalence of the topics indeed significantly varying among the three opinion groups.

Table 4. Summary of topic labels for the sample/question combinations

Topic label growth for scientists	Topic label green growth for scientists	Topic label growth for general public
Social and environmental problems (-0.182)	Green Ambiguity (0.133)	Crisis, lies and corruption (-0.171)
Industry and progress (0.024)	Green technologies (0.044)	Disbelief in economic growth and government (0.095)
Material wealth (0.312)	(Non-) Sustainability (0.187)	Employment and economic recovery (0.042)
GDP (0.003)	Environment and energy (0.167)	Unemployment and poverty (-0.157)

Note: aggregate sentiment scores are provided in parentheses.

Our results are broadly comparable with those of the only prior study on associations with economic growth by Mohai et al. (2010), given that the latter also found few mentions of environmental issues among the general public. It suggests that expressing skepticism or opposition to economic growth by citizens can result not only from preferences for environmental protection, but also from considerations about social and political problems.

A further contribution of this study is that it analyzed how respondents' associations differed between three clusters, namely Green growth, Agrowth and Degrowth. The results show meaningful differences between clusters in both surveys. For example, researchers of the Green growth cluster were less likely to mention social and environmental problems when thinking about economic growth than those of the Degrowth cluster. Although differences were less strong, also

in public opinion one could observe that social problems and corruption were more likely to be mentioned by respondents in the Degrowth than the Green growth cluster. Overall, such results can be considered as further validation of the existence of these three opinion clusters. For example, (un)employment was one of the dimensions on which public opinion clusters showed clearly distinguishable opinions in prior research (Drews et al., 2019), which is supported by the topic prevalence of the present results (topics 3 and 4).[8] Furthermore, our results can be viewed as an extension of prior findings that provide deeper insights into public opinion. A good example is a closed-ended survey question on excessive political attention to economic growth. While we know from Drews et al. (2019) that people from the Degrowth opinion segment expressed significantly stronger agreement to the statement "politicians are too concerned about economic growth" than the other opinion segments, now we may understand some of the major reasons underlying these views: people do not put much trust in the government or official statistics, and they lack personal experiences of improved living standards, thinking that benefits of growth accrue mostly to big companies and politicians (note the higher prevalence of Topic 2 in Figure 7 among people with Degrowth opinion). Comparing the surveys of scientists and general public, we found that topic differences are stronger among scientists than citizens. This is in line with Drews et al. (2019) who already demonstrated the lower degree of polarization between the Green growth versus Degrowth clusters in the debate about growth-vs-environment by the general public.

With regard to the experts' associations with 'green growth', the results somewhat question Bowen Fankhauser's (2011) claim that "most analysts would associate the term with environmentally sustainable, biodiverse, low-carbon and climate-resilient growth in human prosperity". While many respondents indeed associated the term with such positive notions, there

[8] See also significant coefficients of the regression slopes for these two topics as shown in Table A4 in the Appendix.

was also considerable skepticism about it, as can be derived from frequent terms such as "greenwashing", "oxymoron" or "paradox". The latter might be consistent with a recent review of the empirical evidence underlying green growth, which suggests that green growth is practically impossible and a misguided policy objective (Hickel & Kallis, 2020). Further research involving more recent data samples can help to better understand whether, how and by whom the narrative of green growth is increasingly questioned.

Some limitations of this study are as follows. The questions on economic growth in the two surveys had somewhat different question wordings, which might have a slight effect on responses. Next, since most of researchers participating in the scientist survey came from an environmental discipline, it is not surprising that they more frequently associate economic growth with environmental issues (particularly in topic 1 and 2). Moreover, they were invited to the survey knowing that it would be about growth and the environment. In contrast, members of the general public did not know what the survey was about, and the first survey question they had to answer was the one about associations with growth. This may partly explain why 'the environment' was not at the top of their mind. In addition, Spanish participants of the public opinion survey responded during a particular socio-economic context, namely the economic-financial crisis starting in 2008, possibly explaining a stronger concern by the citizens than scientists about unemployment and dishonest politicians. Although after several years of recession, Spain started to experience low economic growth at the time of conducting the survey in 2014, the negative effects of the crisis on unemployment and real incomes were still clearly present. These and possibly other differences between the two samples suggest that one needs to see their findings in a complementary rather than directly comparable way.

Another limitation of our study concerns the sentiment analysis. While we used sentiment scores of words taken out of context, words' meaning tends to depend on the specific context, and our approach does not account for that. Furthermore, to use the same SentiWords database for responses provided by the general public in Spanish, we had to translate the words in English, which could affect the results.[9]

5. Conclusions

In this article, we assessed the old debate about the relationship between economic growth and environmental sustainability from a different angle, namely by analyzing open-ended textual responses of the general public and scientists. We find that the general public is very critical of the notion of economic growth, much more on average than academic researchers. People stress problems of corruption, social inequality, unemployment and poverty. These topics dominate in the associations of the majority of respondents with relatively little variation among segments of people that reflect the three main opinions in the growth-vs-environment debate. Researchers, in contrast, stress more the role of environmental problems associated with economic growth and show greater variation in topics between the three segments of people. For example, people from the Green growth segment are more likely to stress the benefits associated with economic growth and the role of renewable energy for sustainable development, while people from the Degrowth segment mention more environmental and social (poverty, corruption) problems related to economic growth, while questioning the very possibility of sustainable growth (using a term like "greenwashing").

[9] Unfortunately, no database with similar scores for Spanish words is available to our knowledge.

Our study shows that the technique of structural topic modeling is useful to determine important concerns of different stakeholders, such as general public, voters, academics, other experts, or policy makers. Moreover, STM allows us to classify the problems raised by people with distinct views on the growth-vs-environment debate. This might help to better frame environmental communication and policy initiatives targeting those specific groups with the aim to increase political and voter support. For example, it is evident from our findings that those arguing for alternatives to the growth model need to pay attention not just to the environmental but particularly to the social aspects of the growth critique, e.g. beliefs that the benefits of growth are unequally distributed.

Regarding future research, it would be interesting to examine associations with economic growth in countries that do not experience serious economic and social crises as Spain did at the time of the data collection for this study. In addition, one might study associations of the general public with the term “green growth”, given that it is increasingly appearing now in popular media.

Acknowledgements

This study has received funding through an ERC Advanced Grant from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n° 741087). Ivan Savin acknowledges financial support from the Russian Science Foundation [RSF grant number 19-18-00262].

References

Anderson, B., Böhmelt, T., & Ward, H. (2017). Public opinion and environmental policy output: A cross-national analysis of energy policies in Europe. Environmental Research Letters. https://doi.org/10.1088/1748-9326/aa8f80

Anderson, K., & Bows, A. (2012). A new paradigm for climate change. *Nature Climate Change*, *2*(9), 639–640. doi:10.1038/nclimate1646

Antal, M., & van den Bergh, J. C. J. M. (2016). Green growth and climate change: Conceptual and empirical considerations. *Climate Policy*, 1–13. doi:10.1080/14693062.2014.992003

Becken, S. (2015). Peak Oil: A hidden issue? Social representations of professional tourism perspectives. *Journal of Sustainable Tourism*, 1–21. doi:10.1080/09669582.2015.1042484

Bowen, A., & Fankhauser, S. (2011). The green growth narrative: Paradigm shift or just spin? *Global Environmental Change*, *21*(4), 1157–1159. doi:10.1016/j.gloenvcha.2011.07.007

Clarke, C. E., Hart, P. S., Schuldt, J. P., Evensen, D. T. N., Boudet, H. S., Jacquet, J. B., & Stedman, R. C. (2015). Public opinion on energy development: The interplay of issue

framing, top-of-mind associations, and political ideology. *Energy Policy*, *81*, 131–140. doi:10.1016/j.enpol.2015.02.019

Drews, S., & Reese, G. (2018). "Degrowth" vs. Other Types of Growth: Labeling Affects Emotions but Not Attitudes. Environmental Communication, 12(6), 763–772. https://doi.org/10.1080/17524032.2018.1472127

Drews, S., Savin, I., & van den Bergh, J. C. J. M. (2019). Opinion Clusters in Academic and Public Debates on Growth-vs-Environment. *Ecological Economics*, *157*, 141–155. doi:10.1016/j.ecolecon.2018.11.012

Drews, S., & van den Bergh, J. C. J. M. (2016). Public views on economic growth, the environment and prosperity: Results of a questionnaire survey. *Global Environmental Change*, *39*, 1–14. doi:10.1016/j.gloenvcha.2016.04.001

Drews, S., & van den Bergh, J. C. J. M. (2017). Scientists' views on economic growth versus the environment: A questionnaire survey among economists and non-economists. *Global Environmental Change*, *46*, 88–103. doi:10.1016/j.gloenvcha.2017.08.007

Easterlin, R. A. (1974). Does economic growth improve the human lot? Some empirical evidence. *Nations and Households in Economic Growth*, *89*, 89–125.

Gangl, K., Kastlunger, B., Kirchler, E., & Voracek, M. (2012). Confidence in the economy in times of crisis: Social representations of experts and laypeople. *The Journal of Socio-Economics*, *41*(5), 603–614. doi:10.1016/j.socec.2012.05.018

Hickel, J., & Kallis, G. (2020). Is Green Growth Possible? *New Political Economy*, 25(4), 469–486. https://doi.org/10.1080/13563467.2019.1598964

Jackson, T. (2009). *Prosperity Without Growth: Economics for a Finite Planet*. Routledge.

Jakob, M., & Edenhofer, O. (2014). Green growth, degrowth, and the commons. *Oxford Review of Economic Policy*, *30*(3), 447–468. doi:10.1093/oxrep/gru026

Leiserowitz, A. (2006). Climate Change Risk Perception and Policy Preferences: The Role of Affect, Imagery, and Values. *Climatic Change*, *77*(1–2), 45–72. doi:10.1007/s10584-006-9059-9

Lorenzoni, I., Leiserowitz, A., De Franca Doria, M., Poortinga, W., & Pidgeon, N. F. (2006). Cross-National Comparisons of Image Associations with "Global Warming" and "Climate Change" Among Laypeople in the United States of America and Great Britain. *Journal of Risk Research*, *9*(3), 265–281. doi:10.1080/13669870600613658

Meadows, D.H., Meadows, D.L., Randers, J., and Behrens, W.W. (1972). *The Limits to Growth: A Report for the Club of Rome's Proyect on the Predicament of Mankind.* Universe Books, New York.

Mohai, P., Simoes, S., & Brechin, S. R. (2010). Environmental Concerns, Values and Meanings in the Beijing and Detroit Metropolitan Areas. *International Sociology*, *25*(6), 778–817. doi:10.1177/0268580910378138

Moloney, G., Leviston, Z., Lynam, T., Price, J., Stone-Jovicich, S., & Blair, D. (2014). Using social representations theory to make sense of climate change: What scientists and nonscientists in Australia think. *Ecology and Society*, *19*(3). doi:10.5751/ES-06592-190319

Roberts, M. E., Stewart, B. M., Tingley, D., Lucas, C., Leder-Luis, J., Gadarian, S. K., … Rand, D. G. (2014). Structural Topic Models for Open-Ended Survey Responses. *American Journal of Political Science*, *58*(4), 1064–1082. doi:10.1111/ajps.12103

Savin, I., S. Maestre-Andrés, S. Drews and J. van den Bergh (2020). Public views on carbon taxation and its fairness: A computational linguistics analysis. EVOCLIM working paper, ICTA-UAB

Tjernström, E., & Tietenberg, T. (2008). Do differences in attitudes explain differences in national climate change policies? Ecological Economics, 65(2), 315–324. https://doi.org/10.1016/j.ecolecon.2007.06.019

Tomaselli, M. F., Sheppard, S. R. J., Kozak, R., & Gifford, R. (2019). What do Canadians think about economic growth, prosperity and the environment? *Ecological Economics*, *161*, 41–49. doi:10.1016/j.ecolecon.2019.03.007

Tvinnereim, E., & Fløttum, K. (2015). Explaining topic prevalence in answers to open-ended survey questions about climate change. *Nature Climate Change*, *5*(8), 744–747. doi:10.1038/nclimate2663

Tvinnereim, E., Fløttum, K., Gjerstad, Ø., Johannesson, M. P., & Nordø, Å. D. (2017a). Citizens' preferences for tackling climate change. Quantitative and qualitative analyses of their freely formulated solutions. *Global Environmental Change*, *46*, 34–41. doi:10.1016/j.gloenvcha.2017.06.005

Tvinnereim, E., Liu, X., & Jamelske, E. M. (2017b). Public perceptions of air pollution and climate change: Different manifestations, similar causes, and concerns. *Climatic Change*, *140*(3–4), 399–412. doi:10.1007/s10584-016-1871-2

van den Bergh, J. C. J. M., & Kallis, G. (2012). Growth, A-Growth or Degrowth to Stay within Planetary Boundaries? *Journal of Economic Issues*, *46*(4), 909–920. doi:10.2753/JEI0021-3624460404

van den Bergh, J. C. J. M. (2009). The GDP paradox. *Journal of Economic Psychology*, *30*(2), 117–135. https://doi.org/10.1016/j.joep.2008.12.001

Ward, J. D., Sutton, P. C., Werner, A. D., Costanza, R., Mohr, S. H., & Simmons, C. T. (2016). Is Decoupling GDP Growth from Environmental Impact Possible? *PLOS ONE*, *11*(10), e0164733. doi:10.1371/journal.pone.0164733

Appendix

Table A1. Key characteristics of the survey respondents among scientists (N = 671)

Variable	*n*	Variable	*n*	Variable	*n*
Age		**Research field**		**Political ideology**	
<30 years	19	GrowEc	34	Very left	46
30-39	218	GrowEnv	31	Left	206
40-49	200	OthEc	75	Slightly left	190
50-59	113	EnvEc	228	Center	108
≥60	87	EcoEc	131	Slightly right	50
Gender		EnvSoc	156	Right	28
female	162	EnvSci	16	Very right	3
male	498	**# publications grow/env**		Don't know	31
Education		0	213	**Citizenship**	
PhD	586	1-3	187	North America	160
Other	85	4-10	185	EU	337
Professional affiliation		11-29	54	Asia	65
Academia	553	≥30	32	Africa	16
Government	36	**# publications growth**		Australia and Oceania	27
Private	33	0	355	Central and Southern America	15
Other	47	1-3	77	Other	51
Income of country of origin[a]		4-9	40		
High	589	10-19	23		
Middle/low	82	≥20	19		

Notes: [a] We use the classification of The World Bank for high and middle/low income countries:http://data.worldbank.org/about/country-and-lending-groups. The research fields are described in Section 2. Not all numbers add up to N = 671 due to missing data.

Table A2. Key socio-demographic characteristics of the public opinion survey

Variables	**Description**	**Mean (SD) or %**
Gender	female	50.7%
Age	18 to 64 years	40.14 (12.57)
Household income	1 (≤ 1000 €) to 5 (≥ 3000 €)	2.88 (1.34)
Educational attainment	1 (primary education) to 4 (postgraduate degree)	2.60 (0.76)

Table A3. Statements of both surveys serving as input to the cluster analysis

Statement label	**Statement wording**
Life satisfaction	Continued economic growth is essential for improving people's life satisfaction.
Public services	Economic growth is necessary to finance public health and pension systems.
Stability	Without economic growth the economy will become less stable.
Environmental protection	Economic growth is necessary to finance environmental protection.
Full employment	Full employment can be achieved without economic growth.
Good life	A 'good life' without economic growth is possible.
Energy rebound	Energy savings due to technological advances are partly undone by further economic growth.
Environmental damage	Economic growth always harms the environment.
Development space	In view of limited natural resources, rich countries may have to give up their economic growth to assure that all poor people in the world can reach a fair standard of living.
Techno-fix	Technology can solve all environmental problems associated with economic growth.
Recovery	Future economic growth will recover and again be as high as in the past.
Post-materialism	Economic growth raises incomes which in turn make people care more about the environment.
Excessive political attention	Politicians are too concerned about economic growth.
Income inequality	Making the income distribution more equal should get a higher priority than economic growth.
Flawed welfare measure	The GDP is a flawed measure of social welfare.
Governmental control	Economic growth can be controlled by the government.

Table A4. Results of the regression analysis for the STM model on economic growth among scientists

	Topic 1 Social and environmental problems	Topic 2 Industry and progress	Topic 3 Material wealth	Topic 4 GDP
Intercept	0.07659***	0.36330***	0.35044***	0.20978***
Cluster membership	0.08309***	-0.06107***	-0.05174***	0.02969***

Note: Asterisks ***, **, and * denote 1%, 5%, and 10% significance, respectively. Coefficients indicate whether prevalence of respective topics changes with the value of the covariates.

Table A5. Results of the regression analysis for the STM model on green growth among scientists

	Topic 1 Oxymoron	Topic 2 Green technologies	Topic 3 (Non-) Sustainability	Topic 4 Environment and energy
Intercept	0.17573***	0.30894***	0.12212***	0.39346***
Cluster membership	0.03346***	-0.02169**	0.06914***	-0.08102***

Note: Asterisks ***, **, and * denote 1%, 5%, and 10% significance, respectively. Coefficients indicate whether prevalence of respective topics changes with the value of the covariates.

Table A6. Results of the regression analysis for the STM model on economic growth by general public

	Topic 1 Crisis, lies and corruption	Topic 2 Disbelief in economic growth and government	Topic 3 Employment and economic recovery	Topic 4 Unemployment and poverty
Intercept	0.19423***	0.20833***	0.33482***	0.26283***
Cluster membership	0.02922***	0.02173*	-0.03246**	-0.01859**

Note: Asterisks ***, **, and * denote 1%, 5%, and 10% significance, respectively. Coefficients indicate whether prevalence of respective topics changes with the value of the covariates.