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Transfer Topic Labeling with Domain-Specific Knowledge Base: An Analysis of UK House of Commons Speeches 1935–2014

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Abstract

Topic models are widely used in natural language processing, allowing researchers to estimate the underlying themes in a collection of documents. Most topic models use unsupervised methods and hence require the additional step of attaching meaningful labels to estimated topics. This process of manual labeling is not scalable and suffers from human bias. We present a semi-automatic transfer topic labeling method that seeks to remedy these problems. Domain-specific codebooks form the knowledge-base for automated topic labeling. We demonstrate our approach with a dynamic topic model analysis of the complete corpus of UK House of Commons speeches 1935-2014, using the coding instructions of the Comparative Agendas Project to label topics. We show that our method works well for a majority of the topics we estimate; but we also find that institution-specific topics, in particular on subnational governance, require manual input. We validate our results using human expert coding.

1 Introduction

Political science scholars working with large quantities of textual data are often interested in discovering latent semantic structures in their document collections. Examples include legislative debates, policies, media content, manifestos, and open-ended survey questions. Manual coding of such data is extremely time-consuming and expensive, and does not scale well with the expanding size of the corpora. In practice, document summarization is routinely carried out using variations of probabilistic topic models (Blei, Ng and Jordan, 2003). However, semantic understanding of resulting topics still requires human involvement and thus a set of discretionary decisions that need validation and ensure transparency.

A key feature of political corpora is the evolution of semantic structures over time, which is not fully accounted for in existing methods. Politicians and other decision-makers choose to pay attention to functional areas of specialization, such as health or education policies, which reflect their interests, career experience and goals, and demands for representation. The agenda of the legislature and the content of debates shifts across these topics over time, according to functional pressures and agenda-setting in the media and from public opinion. This is known as concept drift (Gama et al., 2014). In natural language processing (NLP), dynamic topic models are often used to capture the evolution of content structure over time (Blei and Lafferty, 2006). Concept drift in political documents comes from changing content of the texts and presentation style (e.g. compare UN General Debate speeches by Obama and Trump), as well as from the adaptive behavior of politicians (Baturu, Dasandi and Jankin Mikhaylov, 2017). The vocabulary used to express topics may change over time. Human coders are intuitively better placed to pick up the change in meaning in political texts, while machine coding is often faulted with failures to detect semantic change (Albaugh et al., 2014).

We present a method that automatically transfers existing domain-specific knowledge base for topic labeling. We show that our method works well under the concept drift in document summarization. We illustrate the performance of our method applying dynamic

topic modeling of the debates in the UK House of Commons from 1935 to 2014, and labeling the topics using the coding manual of the Comparative Agendas Project (CAP) (Bevan, 2014). We validate our results using human labeling of the topics by the CAP expert coders. Our method applies more generally and can be easily extended to other areas with existing domain-specific knowledge base, such as party manifestos, open-ended survey questions, social media analysis, and legal cases. Using our method, researchers in these fields can be more confident that the building blocks of their models are not an artefact of human coding decisions from within the research process itself.

2 Related Work

In the absence of roll-call data that can be used for ideal point estimation, scholars have turned to legislative speech to estimate policy positions, either by focusing on selected debates (e.g. Laver and Benoit, 2002; Herzog and Benoit, 2015) or through the analysis of all speeches during a legislative term (Lauderdale and Herzog, 2016). A parallel stream of the literature has used topic modeling to estimate the extent to which legislators speak on different topics (Quinn et al., 2010). Topic modeling is a class of models that estimate the underlying themes in a collection of documents. Originally proposed by Blei, Ng and Jordan (2003) in their seminal paper on latent Dirichlet allocation (LDA), various extensions of LDA have been developed in the computing sciences (e.g. Blei and Lafferty, 2007; Teh et al., 2012; Roberts, Stewart and Airoldi, 2016). There have been several recent applications in political science (Grimmer, 2009; Roberts et al., 2014; Mueller and Rauh, 2018).

One of the LDA extensions is the dynamic topic model (DTM) (Blei and Lafferty, 2006), which relaxes the assumption of LDA that documents are unordered. Instead, DTM assumes that documents are grouped into discrete time intervals (e.g., years) that exhibit different mixtures of topics, which allows topics to change over time – both in terms of their prevalence in the corpus and in their word compositions. DTM has not seen extensive practical use

with large volumes of data potentially due to scalability of the inference algorithm (Gropp et al., 2016). In political science there have been very few applications (e.g. Gurciullo et al., 2015; Greene and Cross, 2017).

Collections of political documents spanning long periods of time exhibit a problem known as concept drift (Gama et al., 2014). Under ‘not strictly stationary’ data generating processes, the underlying concept that is the target variable of our prediction model may be changing over time thus affecting the predictive decision (for a formal definition, see Webb et al., 2016). In political science, Lowe et al. (2011) develop a measurement model to address the changing nature of left-right ideological dimension. Benoit et al. (2016) present a general approach to data generation using crowdsourcing that can quickly react to change of concepts like the appearance of immigration as a new dimension of party competition. A standard approach to deal with concept drift in political science NLP applications has been to analyze the data from each time interval separately. For example, recent work using annual speech data estimates separate models for each year (e.g. Herzog and Benoit, 2015; Baturu and Jankin Mikhaylov, 2013). DTM is a drift-aware adaptive learning algorithm that adapts to the evolution of topics over time.

Topic labeling is a key post-processing step of all probabilistic topic models. As a general rule labels should be relevant, understandable, with high coverage inside topic, and discriminative across topics. Early research focused on generating labels by hand by using a set of top n words in a topic distribution (so called *cardinality*) learned by a topic model (e.g. Griffiths and Steyvers, 2004). An alternative approach is to implement a supervised topic modeling approach that limits the topics to a predefined set with their word distributions provided *a priori* (Mcauliffe and Blei, 2008; Ramage et al., 2009). The former approach is not scalable, carries a high cognitive load in forming the topic concept and its interpretation (Aletras and Mittal, 2017), and also suffers from a potential bias of the human labeler (Lau and Baldwin, 2016), while the latter is unable to pick up topics unknown beforehand (Wood et al., 2017).

Several automatic labeling approaches have been proposed in the literature that utilize external, contextual information. [Mei, Shen and Zhai \(2007\)](#) minimize the semantic distance between the topic model and the candidate label based on the phrases inside documents. [Lau et al. \(2011\)](#) utilize various ranking mechanisms of the top- n words and candidate labels from Wikipedia articles containing these terms. [Bhatia, Lau and Baldwin \(2016\)](#) use word embeddings to map topics and candidate labels derived from Wikipedia article titles, and then select topic labels based on cosine similarity and relative ranking measures. Word embeddings pre-trained on a large corpus like Wikipedia and deployed for topic labeling of PubMed abstracts as in [Bhatia, Lau and Baldwin \(2016\)](#) is a simple form of general domain knowledge transfer. More generally, a machine learning framework captures the ability to transfer knowledge to new conditions, which is known as transfer learning (for a survey and formal definition see [Pan and Yang, 2010](#)).

3 Unsupervised Topic Modeling with Transfer Topic Labeling

Our main idea is illustrated in [Figure 1](#). The dotted box on the right-hand side illustrates traditional unsupervised topic modeling, which stops with estimated latent topics that need manual labeling. In our approach, we use outside expert codebooks to extract topic labels and associated keywords, which we then use to automatically label the estimated latent topics. Retaining human-in-the-loop allows for adjustment of the labels for specific domains with sparse coverage in the source knowledge base. Hence, we use the term semi-automated topic label in this paper.

In the remainder of this section, we demonstrate the utility of this approach with speeches from the UK House of Commons over the time period from 1935 to 2014. We first explain how we have estimated latent, dynamic topics from the speeches. We then discuss how we have used the codebooks from the Comparative Agendas Project (CAP) ([Bevan, 2014](#)) as

Unsupervised topic modeling with transfer topic labeling

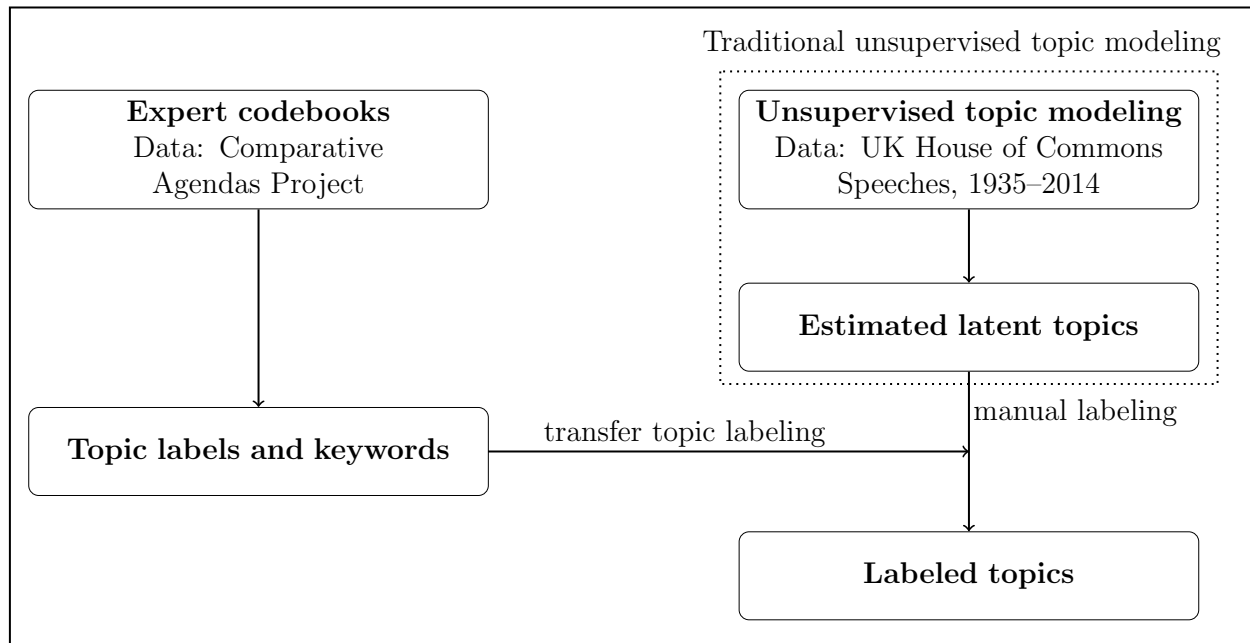


Figure 1: Illustration of the application of transfer learning for semi-automated labeling of estimated topics.

existing knowledge base to transfer topic labels.

3.1 Estimating Dynamic Topics from House of Commons Speeches, 1935–2014

Our data consist of the complete record of debates from the UK House of Commons during the time period 1935–2014. All debates and information about speakers were downloaded from TheyWorkForYou,¹ a transparency website that provides access to parliamentary records and information about MPs. All data were downloaded in XML format and further processed in Python.

The full data set consists of about 4.3 million floor contributions with an average of 49,720 contributions per year (min=17,280, max=118,500, sd=17,596) and a total of 117,914 unique words. Within each session, we combined each MP’s contributions into a single text, excluding contributions that concern the rules of procedure or the business of the House, such

¹<https://www.theyworkforyou.com/>

as the reading of the parliamentary agenda or formal announcements. We also removed the traditional prayer at the beginning of each sitting and all contributions and announcements by the Speaker.

As part of the pre-processing, we applied stemming, removed words that appeared less than 50 times and in fewer than 5 documents, removed punctuation, numbers, symbols, stopwords, hyphens, single letters, and a custom list of high-frequency terms.² The final data set from which we estimate topics includes 47,524 documents (i.e., an MP’s concatenated speeches during a session) and 19,185 unique words.

We used the dynamic topic model (DTM) by [Blei and Lafferty \(2006\)](#) to estimate topics from the speech data. Like any unsupervised topic model, DTM requires setting the number of topics *a priori*. We followed the standard in the literature and picked the number of topics based on semantic coherence and exclusivity (c.f., [Roberts, Stewart and Airoidi, 2016](#)). Based on these two metrics, we selected the model with 22 topics.³

3.2 Extracting Topic Labels and Keywords from Expert Codebooks

We used coding instructions from the Comparative Agendas Project (CAP) ([Bevan, 2014](#)) as external source to extract topic labels and associated keywords. We selected the CAP because we expected the majority of parliamentary speeches to be on topics related to public policy-making. This attention to policy topics is the central interest of the policy agendas set of projects, which have been active since the late 1990s (e.g. [Baumgartner, Green-Pedersen and Jones, 2013](#)). What has been called the policy agendas code frame is a fuller articulation of the policy topics ideas with a larger number of major topic codes, which aims at comprehensive coverage of any topic that is likely to appear.

²We used the fairly extensive MySQL stopword list, which includes more than 500 words. Our custom list includes the following words: hon, mr, member, members, bill, minister, prime, government(s), friend, year(s), gentleman, gentlemen.

³Further details and references regarding model selection are provided in the supplementary materials, Section A.

While our demonstration of transfer topic labeling is limited to the CAP codebooks, we note that our method can be easily extended to other codebooks as long as they include written coding instructions or vignettes. Further, as we will demonstrate below, our method for matching topic labels to estimated latent topics produces goodness-of-fit measures for each match, which allows to evaluate how well the topics derived from a codebook capture the estimated latent dimensions.

The codebook for the UK Policy Agendas Project includes 19 major topics with subtopics.⁴ For each subtopic, the CAP codebook provides written examples of what is being included in each category. For example, category “1. Macroeconomics – 100: General domestic macroeconomic issues” is described as follows:

the government’s economic plans, economic conditions and issues, economic growth and outlook, state of the economy, long-term economic needs, recessions, general economic policy, promote economic recovery and full employment, demographic changes, population trends, recession effects on regional and local economies, distribution of income, assuring an opportunity for employment to every person seeking work, standard of living.

Because the descriptions of CAP subtopics are relatively short, we combine all subtopics under a major topic label into a single document. We then apply *tf-idf* weighting to generate 19 weighted word lists (one for each major topic label), where the weight on each word reflects its importance to a topic label.⁵ Table 1 provides an overview of the 19 topics together with their ten highest ranked words.

⁴This codeframe for the UK is summarized in John et al. (2013) and on the UK project website (<http://www.policyagendas.org.uk/>).

⁵Before calculating *tf-idf* weights, we applied the same pre-processing rules that we applied to the speech data to increase the similarity between the two vocabularies.

Table 1: Overview of CAP Topics

Policy agenda topic	Top ten words based on <i>tf-idf</i> weighting
Macroeconomic Issues	tax, inflat, index, treasuri, fiscal, price, taxat, unemploy, bank, gold
Civil Rights	discrimin, asylum, immigr, equal, right, citizenship, minor, age, refuge, freedom
Health	healthcar, care, health, medic, drug, coverag, nurs, provid, alcohol, mental
Agriculture	agricultur, farm, anim, food, livestock, produc, crop, erad, fisheri, diseas
Labor and Employment	employ, labour, job, migrant, youth, worker, employe, workplac, work, train
Education and Culture	educ, student, school, art, vocat, higher, secondari, teacher, grant, learn
Environment	water, pollut, environment, wast, hazard, conserv, emiss, climat, municip, air
Energy	electr, gas, energi, coal, oil, power, natur, nuclear, fuel, gasolin
Transportation	highway, transport, rail, truck, bus, road, ship, aviat, speed, air
Law and Crime	crime, crimin, drug, justic, traffick, polic, juvenil, sentenc, court, offend
Social Welfare	benefit, elder, volunt, social, food, welfar, incom, contributori, meal, lunch
Community Development, Planning and Housing	hous, mortgag, urban, tenant, veteran, low, homeless, citi, rural, tenanc
Banking and Finance	small, bankruptci, copyright, busi, patent, consum, mortgag, tourism, sport, mutual
Defense	defenc, weapon, arm, intellig, militari, forc, reserv, veteran, armi, war
Space Science	scienc, space, radio, communic, satellit, tv, launch, telecommun, broadcast, research
Foreign Trade	trade, export, tariff, import, invest, exchang, duti, competit, u.k, restrict
International Affairs and Foreign Aid	europ, soviet, east, u.n, africa, u.k, peac, polit, europ, treati
Government Operations	postal, legislatur, execut, minist, employe, elect, census, elector, offici, prime
Public Lands, Water Management	indigen, land, park, convey, histor, water, forest, monument, memori, reclam

3.3 Transfer Topic Labeling

We transfer topic labels from the CAP to the estimated latent topics through a pair-wise matching procedure that finds the most similar CAP topic word list for each latent dimension. For the CAP topics, the word lists are the *tf-idf*-weighted word lists discussed above. For the dynamic topic model, we construct one word list for each of the 22 estimated latent topics.⁶

To identify the best matching topics, we use the Jaccard index, which is a widely used set-based similarity measure.⁷ For two sets A and B , the Jaccard index is defined as

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|} \quad (1)$$

where the numerator is the size of the intersection between A and B , and the denominator is the size of the union of the two sets. The Jaccard index is bound between 0 and 1, with higher numbers indicating greater overlap between two sets. We calculate the Jaccard index for each pair of word lists consisting of one CAP topic and one estimated DTM topic. Using the highest Jaccard value results in 19 unique matches where the CAP label is transferred to the estimated topic.

As a validation exercise we recruited a group of CAP experts to label the word lists for each topic according to the CAP categorization. Seventeen experts who participated in this exercise could submit two choices of the labels (most appropriate and second most appropriate). We assess the quality of expert labeling using Fleiss' kappa measure of inter-coder agreement. We also calculate proportion of experts who agree with the automatically selected topic label as their first or second choice. We provide additional information on our expert coding validation exercise in the supplementary materials, Section C.

Table 2 provides an overview of the 22 estimated dynamic topics together with their Jaccard index, the matched CAP topic label, topic label selected by experts, proportion

⁶Additional information on our implementation of transfer topic labeling is provided in the supplementary materials, Section B.

⁷We also used an alternative approach using the ROUGE F1 metric frequently used in document summarization and machine translation literature. The results using Jaccard and ROUGE were identical.

of experts who selected the same topic label as the transfer-learning approach with the first or second choice, Fleiss' kappa inter-coder agreement, and the top 20 words from each DTM topic. Three CAP categories from Table 1 have not been matched: Environment, Space Science, and Public Lands and Water Management. It should also be noted that the lists of words conform to common understandings of what the categories mean, for example agriculture has words such as milk and meat in the list.

Table 2: DTM topics with Matched Policy Agenda Topic Labels and Comparison to Expert Coding

#	Topic Label Selected by Transfer-Learning Approach	Topic Label Selected by Experts	Prop. Experts		Jaccard Index	Fleiss' Kappa	Top 20 Words from Estimated Dynamic Topics
			1st	2nd			
1	Agriculture	Agriculture	1.00	0	0.62	0.81	price, agricultural, food, suppli, ask, ration, milk, water, farmer, ministri, market, industri, fisheri, consum, sugar, beef, meat, fish, rural, increas
2	Labour and Employment	Labour and Employment	0.94	0	0.47	0.54	employ, industri, polic, men, labour, worker, union, work, unemploy, area, women, trade, law, wage, crime, home, court, factori, train, case
3	International Affairs and Foreign Aid	International Affairs and Foreign Aid	0.88	0.06	0.23	0.82	hous, european, question, matter, eu, committe, order, union, communiti, discuss, statement, europ, made, treati, constitut, countri, debat, point, answer, make
4	Defense	Defense	0.88	0	0.42	0.61	air, defenc, forc, ministri, civil, aviat, ireland, aircraft, aerodrom, servic, northern, broadcast, imperi, airway, afghanistan, televis, Iraq, corpor, offic, fl
5	Community Development, Planning and Housing Issues	Community Development, Planning and Housing Issues	0.81	0.06	0.52	0.68	local, hous, author, council, build, road, work, rent, charg, plan, home, region, area, counti, rate, communiti, land, london, peopl, develop
6	Government Operations	Government Operations	0.75	0.12	0.27	0.40	scotland, scottish, state, vote, elect, elector, secretari, hous, parliament, commiss, regist, parti, assembl, system, ask, gallant, peopl, glasgow, awar, devolut
7	Foreign Trade	Foreign Trade	0.69	0.06	0.32	0.60	trade, hous, question, committe, industri, board, matter, export, countri, import, duti, answer, discuss, refer, presid, agreement, made, film, hope, british
8	Health	Health	0.56	0.44	0.52	0.52	school, educ, health, servic, care, author, hospit, evacu, nhs, children, patient, local, board, adopt, medic, peopl, teacher, area, univers, doctor
9	Transportation	Transportation	0.56	0.25	0.32	0.46	busi, london, steel, product, industri, ship, war, suppli, constitu, british, ministri, transport, research, peopl, aircraft, work, rail, vessel, firm, factori
10	Energy	Energy	0.56	0.19	0.52	0.43	agricultur, coal, industri, energi, land, farmer, board, oil, farm, miner, gas, subside, power, water, scheme, climat, british, committe, elect, carbon
11	Labour and Employment	Labour and Employment	0.50	0.12	0.13	0.54	question, pension, peopl, sir, figur, work, benefit, answer, increas, million, inform, rate, refer, repli, report, cent, part, gallant, committe, matter
12	Energy	Energy / Labour and Employment ¹	0.38	0.19	0.37	0.48	coal, industri, employ, unemploy, board, area, mine, job, peopl, fuel, develop, train, electr, miner, transport, region, men, work, east, north
13	Government Operations	Law, Crime, and Family Issues	0.31	0.25	0.18	0.51	peopl, home, ask, point, speaker, hous, constitu, case, offic, polic, order, general, agre, debat, secretari, prison, man, awar, post, public
14	Social Welfare	Macroeconomics	0.25	0.06	0.42	0.18	secretari, state, tax, chancellor, peopl, benefit, pension, exchequ, cut, war, incom, social, hous, purchas, problem, profit, minist, compani, duti, govern
15	Banking, Finance, and Domestic Commerce	Social Welfare	0.06	0.06	0.23	0.30	pension, nation, price, unemploy, industri, case, assist, insur, increas, busi, benefit, compani, british, peopl, age, offic, man, widow, board, allow
16	Macroeconomics	Transportation	0	0.25	0.32	0.46	secretari, transport, state, railway, tax, road, industri, compani, price, bank, subside, commiss, vehicl, trade, nationalis, control, servic, chancellor, union, privat
17	Foreign Trade	International Affairs and Foreign Aid	0	0	0.37	0.82	countri, state, commonwealth, coloni, leagu, british, intern, unit, india, foreign, sec-
18	Social Welfare	Government Operations	0	0	0.18	0.40	retari, majesti, ask, syria, develop, german, south, peopl, rhodesia, world
19	Social Welfare	Education	0	0	0.27	0.53	beg, line, act, deal, provis, make, legis, law
21	International Affairs and Foreign Aid	Transportation	0	0	0.18	0.46	ask, secretari, state, school, educ, awar, offic, statement, war, armi, servic, make, teacher, children, men, admiralti, view, step, forc, releas
22	Social Welfare	Government Operations	0	0	0.27	0.40	east, railway, learn, author, step, region, number, local
23	Civil Rights, Minority Issues, and Civil Liberties	Government Operations	0	0	0.23	0.40	matter, question, case, sir, answer, sport, made, act, local, author, fund, inform, report, point, time, nation, person, concern, regul, servic
		Government Operations	0	0	0.23	0.40	ireland, northern, countri, point, peopl, polic, war, hous, speech, great, time, parti, irish, speaker, debat, issu, order, opposit, state, agreement

Note: Column "Prop. Experts" is the proportion of experts who selected the same topic as the transfer-learning approach with their first or second choice.

¹ Experts were tied between topic label "Energy" and "Labour and Employment". The Fleiss' Kappa reported in this row is the average of the kappas for each label.

A majority of experts agreed with the automatic approach on 12 topic labels. The clearest example being the topic of agriculture (#1) where transfer labeling and all the experts identified farming and agriculture related terms. Further four topics show sufficiently large agreement between experts across two choices and automatic labeling (#13 government operations and #14 social welfare). Banking topic is labeled in total by 12% of experts, but it also shows significant disagreement across experts with Fleiss' kappa at 0.3. For macroeconomics (# 16) a majority of experts labeled it as transport, while 25% of the experts agreed with the automatic labeling of this topic as macroeconomics as their second choice (kappa = 0.46).

The remaining six entries in the table show complete disagreement between our automatic approach and experts. Not a single expert assigned the same label as the transfer-learning approach. These cases are difficult to explain as they both contain varied values for Jaccard and Fleiss' kappa. The topics morph into concerns about representation and territorial identity, not in ways that are solely about these political topics, but are still connected to the policy issues that MPs talk about. With transportation the match is for regional policies in Wales and England which is an amalgam of keywords on transport. Another crossover is for social welfare that combines with legislative procedures, which reflects the extent to which MPs focus on social welfare in asking parliamentary questions. The importance of this topic is that it comes up four times with different word formations. The experts are possibly using the government operations label for catch-all procedural issues (e.g. in #18 and #22), or fitting a label to a topic that is not represented in CAP like Northern Ireland (# 23). In the latter case, the algorithm arguably more correctly applies the label of civil rights and minority issues. We provide additional validation results in the supplementary materials.

4 Conclusion

Treating text as data is an approach of increasing importance in political science. NLP techniques developed in the computing sciences are routinely added to methodological toolkits. Topic modeling is a favorite tool of document summarization. Political scientists often have to be creative in interpreting and labeling estimated topics; yet such labeling is also often difficult to replicate – a *sine qua non* of modern political science.

To address the deficiency of current labeling and to have a better way of accommodating changes over time, we present a new method for topic labeling. Our approach provides an automatic labeling method that transfers the wealth of substantive knowledge accumulated in political science into labeling topic models. Our transfer labeling approach is also fully transparent and replicable that allows to bring in human expertise to bear on difficult cases. Hence we call it a semi-automatic transfer labeling approach with a human-in-the-loop.

The method can be extended to party manifestos, open-ended survey questions, social media data, and legal documents, in fact all research domains where topic models have made advances in recent years.

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