Topic Modeling of Course Content

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Contents

```r
library(tidyverse)
library(tidytext)

library(ggwordcloud) # Word Clouds
library(hunspell)    # Stemmer
library(topicmodels) # LDA
library(lemon)       # fine tune ggplot
library(tm)          # Corpus()
```

1 Introduction

University departments often have little knowledge of the actual content of the programs they offer. Yet, having a good understanding of what each course of a program covers is paramount to maintain the quality of the program.

In this script, I conduct a topic modeling exercise of the curriculum offered by the University College Maastricht (UCM), Maastricht University, the Netherlands. UCM offers a bachelor in Liberal Arts and Science. Its curriculum contains over two hundred courses on virtually every topic conceivable[1], making it a great subject for a topic modeling exercise. The analysis is exploratory in nature: instead of answering a specific research question, I explore the data to obtain a better understanding of the content of UCM's curriculum.

To accomplish this, I conduct three analyses. First, I use the tf-idf to identify the most distcinctive terms of each course and cluster of courses. Then, I compare the content of the 2014-2015 and 2018-2019 course catalogues to identify the themes that have emerged and declined these last few years. Finally, I use the Latent Dirichlet Allocation algorithm to create a topic model of the 2018-2019 curriculum, both at the course- and at the cluster-level. The data I use in the analyses are the course descriptions present in the course catalogues.

2 Data Preparation

2.1 Overview

The data require some preparation before they can be analyzed. We starting by importing a dataset on the courses and the course catalogues (saved as pdf) from the directory. We then extract the descriptions of the courses from the course catalogues. These descriptions are one to two pages long and form the textual data that we will analyze. Lastly, we transform the data into the *tidy text format* and stem the terms.

2.2 Importing

We import two datasets from the directory. `d_course` is a tiblle indicating the code, name and cluster[2] of each course[3]. `corpus` is a corpus containing the five most recent course catalogues of UCM. Course catalogues are published every year and contain a descritpion of each course of one or two pages.

```r
d_course  <- read_csv("Course.csv", col_type = cols())
```

[1] Ranging from artificial intelligence to Shakespeare and terrorism.
[2] Courses are distributed among 17 clusters e.g. International Relation, Cultural Studies, Biomedical Science, etc.
[3] It also includes a variable with a shorter course title (`Title_short`) which we use use in the plots for a better readability.

```r
corpus <- Corpus(x             = DirSource("Catalogues"),
                 readerControl = list(reader = readPDF(control = list(text = "-layout"))))
```

2.3 Extracting Course Descriptions from Course Catalogues

We extract the description of each course from the course catalogues. The code is a little longish and does not add much to the script, so I included it in a seperate appendix.

```
## # A tibble: 831 x 3
##    Code    `Calendar Year` Description
##    <chr>   <chr>           <chr>
##  1 COR1002 2014-2015       "COR1002 - Philosophy of Science\r\nCourse coo~
##  2 COR1003 2014-2015       "COR1003 - Contemporary World History\r\nCours~
##  3 COR1004 2014-2015       "COR1004 - Political Philosophy\r\nCourse coor~
##  4 COR1005 2014-2015       "COR1005 - Modeling Nature\r\nCourse coordinat~
##  5 HUM1003 2014-2015       "HUM1003 - Cultural Studies I: Doing Cultural ~
##  6 HUM1007 2014-2015       "HUM1007 - Introduction to Philosophy\r\nCours~
##  7 HUM1010 2014-2015       "HUM1010 - Common Foundations of Law in Europe~
##  8 HUM1011 2014-2015       "HUM1011 - Introduction to Art; Representation~
##  9 HUM1012 2014-2015       "HUM1012 - Pop Songs and Poetry: Theory and An~
## 10 HUM1013 2014-2015       "HUM1013 - The Idea of Europe: The Intellectua~
## # ... with 821 more rows
```

2.4 Tidying

We save the course descriptions in the tidy text format with one row per course-year-term.

```r
d_description_tidy <- unnest_tokens(d_description, output = word, input = Description)
print(d_description_tidy)
```

```
## # A tibble: 340,594 x 3
##    Code    `Calendar Year` word
##    <chr>   <chr>           <chr>
##  1 COR1002 2014-2015       cor1002
##  2 COR1002 2014-2015       philosophy
##  3 COR1002 2014-2015       of
##  4 COR1002 2014-2015       science
##  5 COR1002 2014-2015       course
##  6 COR1002 2014-2015       coordinator
##  7 COR1002 2014-2015       prof
##  8 COR1002 2014-2015       dr
##  9 COR1002 2014-2015       l
## 10 COR1002 2014-2015       boon
## # ... with 340,584 more rows
```

2.5 Stemming

Lastly, we stem the terms and filter out stop words. We use the stemmer from the `hunspell` package to build a stemming function `stem_hunspell()` which takes a term as input and returns its stem. We prefer the Hunspell stemmer over the usual Snowball stemmer because it offers a more precise stemming.

Trick: dictionary-based approach to stem a large number of terms.

Since it would take too much time to apply our stemming function to all `340.000` terms of `d_description_tidy`, we use a *dictionary-based approach*. We create a dictionnary that provides the stem of the `8,500` unique terms present in the dataset and then `jull_join` the newly created dictionary and `d_description_tidy` to stem all the terms at once. This way, we greatly reduce the number of times we use the stemming function.

```
# Stemming function
stem_hunspell <- function(term) {
  # look up the term in the dictionary
  stems <- hunspell_stem(term)[[1]]

  # identify the stem
  if (length(stems) == 0) { # if no stem in dictionary, use  original term
    stem <- term
  } else { # if multiple stems, use last one (most basic)
    stem <- stems[[length(stems)]]
  }

  return(stem)
}

# Dictionary
my_dictionnary <- d_description_tidy %>%
  distinct(word) %>%
  mutate(word_stem = purrr::map_chr(.x = word,
                                    .f = stem_hunspell))

# Full join
d_description_stem <- d_description_tidy %>%
  full_join(my_dictionnary, by = "word") %>%
  rename(word_original = word,
         word          = word_stem) %>%
  filter(!word %in% stop_words$word,
         !word %in% as.character(1:1e3))
print(d_description_stem) # See humanities (original) - humanity (stem)
```

```
## # A tibble: 172,162 x 4
##    Code    `Calendar Year` word_original word
##    <chr>   <chr>           <chr>         <chr>
##  1 COR1002 2014-2015       cor1002       cor1002
##  2 COR1002 2014-2015       philosophy    philosophy
##  3 COR1002 2014-2015       science       science
##  4 COR1002 2014-2015       coordinator   coordinator
##  5 COR1002 2014-2015       prof          prof
##  6 COR1002 2014-2015       dr            dr
##  7 COR1002 2014-2015       boon          boon
##  8 COR1002 2014-2015       faculty       faculty
##  9 COR1002 2014-2015       humanities    humanity
## 10 COR1002 2014-2015       sciences      science
## # ... with 172,152 more rows
```

3 Analysis

3.1 Overview

Now that the textual data is stored in a tidy text format and is stemmed, we can model the content of the curriculum. We conduct three analyses. First, we identify the most important terms of each course and cluster with the tf-idf. Next, we identify terms that have emerged and declined in the curriculum. Finally, we use the LDA algorithm (a popular technique for topic modeling) to build a topic model of the 2018-2019 curriculum, both at the course- and cluster-level.

3.2 TF-IDF

The tf-idf is a popular measure to identify the most important terms of each document belonging to a corpus. By penalizing terms that occur in many documents, it allows us to focus on the terms that are specific to each document. Terms which appear in a large number of course descriptions such as "learn" or "student" tell us little about the content of the course and therefore have a low tf-idf. This way, we can identify the most *distinctive* terms of each course/cluster and get a feel of the topics that they cover.

We use the function `bind_tf_idf()` to obtain the tf-idf of each term for the year 2018-2019. We then identify the most distinctive terms of each cluster and course[4] and display them both as barplots and word clouds. In the latter, the size and the color of a term indicates its tf-idf.

```
tdm_course <- d_description_stem %>%
  filter(`Calendar Year` == "2018-2019") %>%
  count(Code, word, sort = T) %>%
  bind_tf_idf(term = word, document = Code, n = n) %>%
  left_join(d_course, by = "Code")

print(tdm_course)
```

```
## # A tibble: 24,033 x 9
##    Code  word      n     tf   idf tf_idf `Course Title` Cluster Title_sho~
##    <chr> <chr> <int>  <dbl> <dbl>  <dbl> <chr>          <chr>   <chr>
##  1 SSC3~ poli~    34 0.0757  1.82  0.137 Public Policy~ Govern~ Public Po~
##  2 UGR3~ sear~    30 0.101   1.02  0.103 Undergraduate~ Methods Undergrad~
##  3 PRO1~ sear~    27 0.116   1.02  0.119 Research Proj~ Methods Res. Proj~
##  4 SKI3~ conf~    26 0.0716  4.05  0.290 Preparing Con~ Skills  Preparing~
##  5 SSC2~ law      26 0.120   2.10  0.253 Law and Socie~ Sociol~ Law and S~
##  6 SSC2~ conf~    26 0.0992  2.26  0.224 Conflict Reso~ Int. R~ Conflict ~
##  7 SSC3~ trade    26 0.0533  3.54  0.189 International~ Intern~ Internati~
##  8 HUM2~ memo~    25 0.0595  3.36  0.200 Cultural Reme~ Cultur~ Cultural ~
##  9 SKI2~ argu~    25 0.0992  2.51  0.249 Argumentation~ Skills  Argumenta~
## 10 SSC2~ publ~    25 0.112   1.97  0.220 Public Health~ Govern~ Public He~
## # ... with 24,023 more rows
```

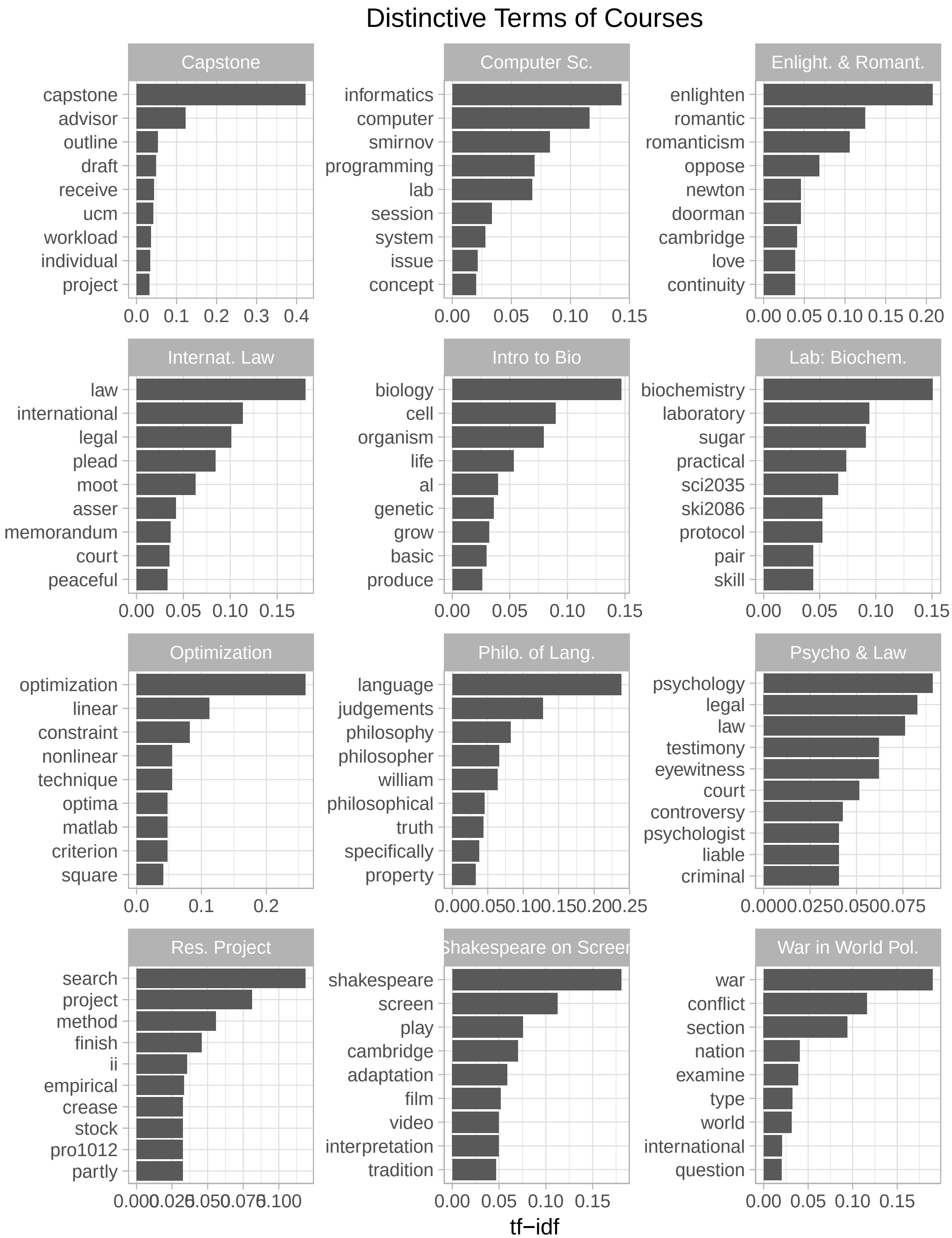
```
tdm_cluster <- d_description_stem %>%
  filter(`Calendar Year` == "2018-2019") %>%
  left_join(d_course, by = "Code") %>%
  count(Cluster, word, sort = T) %>%
  bind_tf_idf(term = word, document = Cluster, n = n)

print(tdm_cluster)
```

[4] We only plot a selection of twelve courses to keep the plots readable.

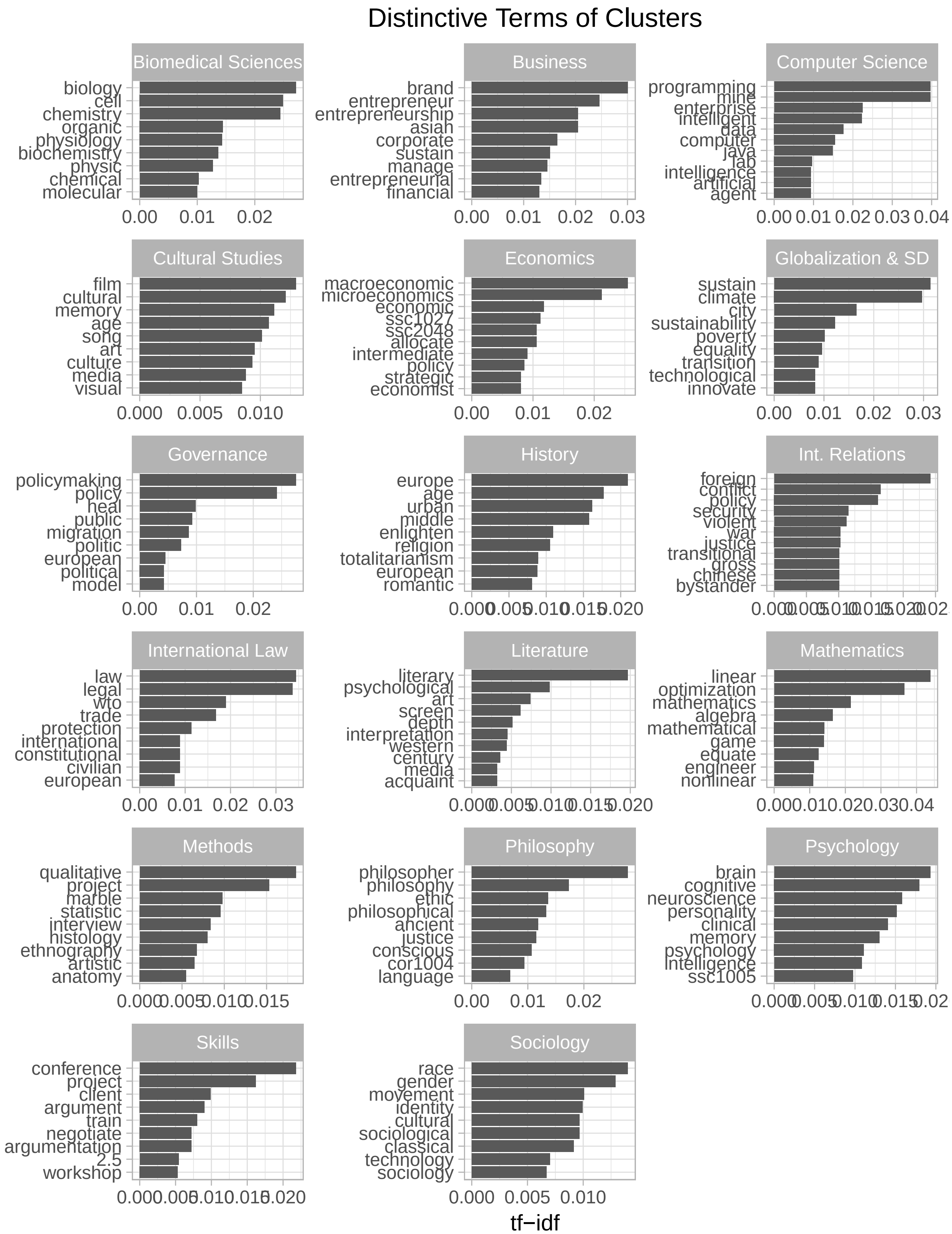
```
## # A tibble: 12,457 x 6
##    Cluster           word         n     tf     idf   tf_idf
##    <chr>             <chr>    <int>  <dbl>   <dbl>    <dbl>
##  1 Skills            student    195 0.0451 -0.0572 -0.00258
##  2 Methods           search     164 0.0472  0        0
##  3 Skills            skill      122 0.0282  0.125   0.00353
##  4 International Law law        102 0.0456  0.754   0.0344
##  5 Sociology         social      99 0.0326  0.0606  0.00198
##  6 Methods           student     86 0.0247 -0.0572 -0.00141
##  7 Economics         economic    81 0.0608  0.194   0.0118
##  8 Skills            project     79 0.0183  0.887   0.0162
##  9 Skills            academic    68 0.0157  0.194   0.00305
## 10 Int. Relations    policy      64 0.0253  0.636   0.0161
## # ... with 12,447 more rows
```

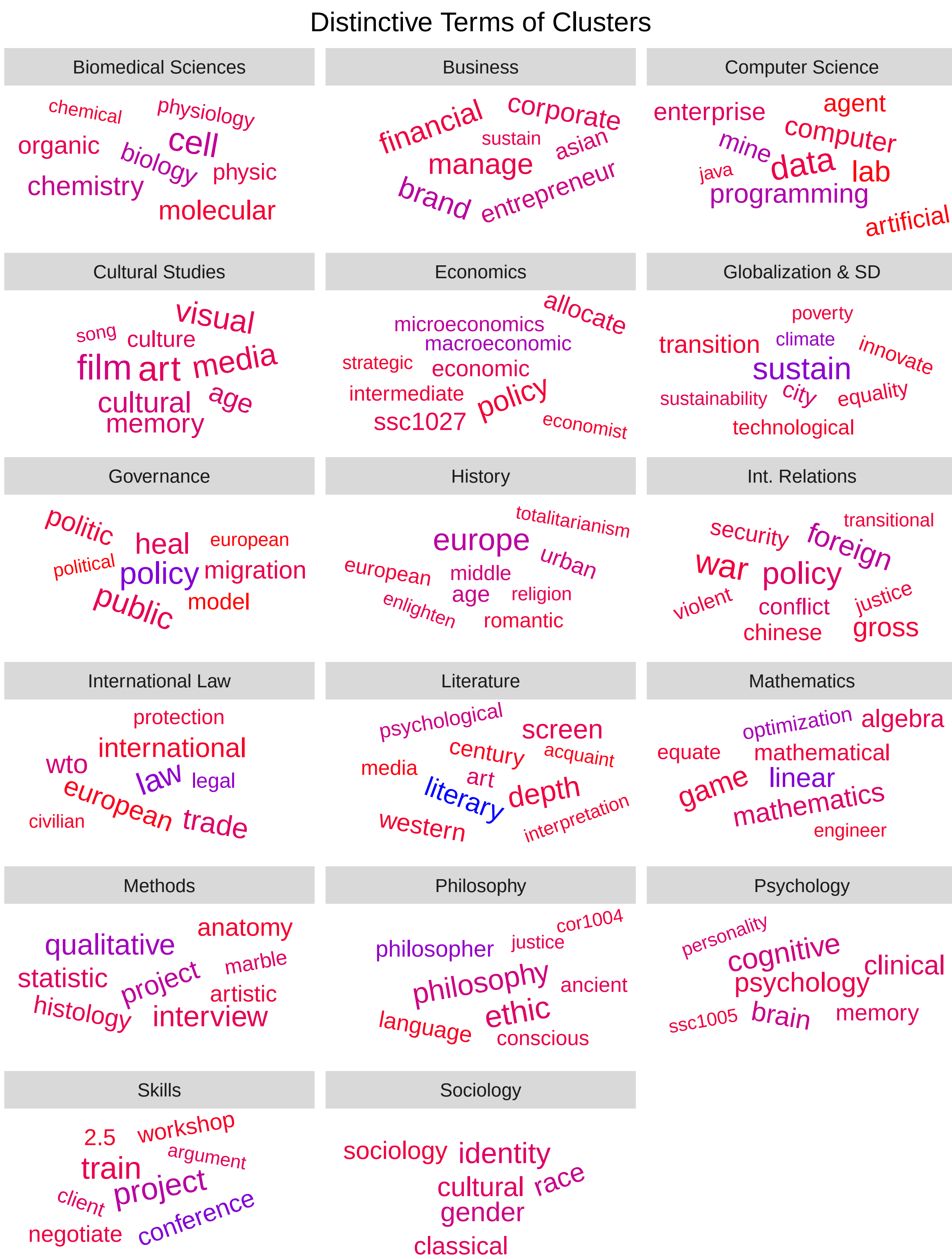
3.2.1 Results

The tf-idf does a pretty good job at isolating the most important terms of the courses/clusters. If the names of the courses/clusters were absent from the plots, it would be fairly easy to guess them from the terms. We also observe interesting elements concerning the content of the clusters. For instance, while the cluster `History` gives a central place to the European continent (with terms like Europe, european), the cluster `International Relations` focuses more on China (chinese).


Distinctive Terms of Courses
Capstone
capstone
advisor
outline
draft
receive
ucm
workload
individual
project
0.0 0.1 0.2 0.3 0.4
Computer Sc.
informatics
computer
smirnov
programming
lab
session
system
issue
concept
0.00 0.05 0.10 0.15
Enlight. & Romant.
enlighten
romantic
romanticism
oppose
newton
doorman
cambridge
love
continuity
0.00 0.05 0.10 0.15 0.20
Internat. Law
law
international
legal
plead
moot
asser
memorandum
court
peaceful
0.00 0.05 0.10 0.15
Intro to Bio
biology
cell
organism
life
al
genetic
grow
basic
produce
0.00 0.05 0.10 0.15
Lab: Biochem.
biochemistry
laboratory
sugar
practical
sci2035
ski2086
protocol
pair
skill
0.00 0.05 0.10 0.15
Optimization
optimization
linear
constraint
nonlinear
technique
optima
matlab
criterion
square
0.0 0.1 0.2
Philo. of Lang.
language
judgements
philosophy
philosopher
william
philosophical
truth
specifically
property
0.000.050.100.150.200.25
Psycho & Law
psychology
legal
law
testimony
eyewitness
court
controversy
psychologist
liable
criminal
0.0000.0250.0500.075
Res. Project
search
project
method
finish
ii
empirical
crease
stock
pro1012
partly
0.000.025.050.075.100
Shakespeare on Screen
shakespeare
screen
play
cambridge
adaptation
film
video
interpretation
tradition
0.00 0.05 0.10 0.15
War in World Pol.
war
conflict
section
nation
examine
type
world
international
question
0.00 0.05 0.10 0.15
tf−idf


Distinctive Terms of Courses
Capstone
receive ucm individual draft capstone advisor outline project workload
Computer Science
programming issue lab smirnov computer session informatics concept system
Enlightenment and Romanticism
continuity romanticism newton enlighten love romantic oppose cambridge
International Law
court international asser law peaceful legal plead moot memorandum
Introduction to Biology
produce organism cell life grow biology genetic basic al
Lab Skills: Biochemistry
laboratory skill protocol biochemistry pair sugar ski2086 practical sci2035
Optimization
optima square constraint technique optimization criterion linear matlab nonlinear
Philosophy of Language
philosophical william property philosophy language specifically judgements truth philosopher
Psychology and the Law
criminal liable legal court psychology testimony law eyewitness controversy psychologist
Research Project
stock partly method empirical ii search finish project crease pro1012
Shakespeare on Screen
interpretation cambridge screen film play video shakespeare tradition adaptation
War in World Politics
world international conflict nation war examine question type section


Distinctive Terms of Clusters
Biomedical Sciences
biology
cell
chemistry
organic
physiology
biochemistry
physic
chemical
molecular
Business
brand
entrepreneur
entrepreneurship
asian
corporate
sustain
manage
entrepreneurial
financial
Computer Science
programming
mine
enterprise
intelligent
data
computer
java
lab
intelligence
artificial
agent
Cultural Studies
film
cultural
memory
age
song
art
culture
media
visual
Economics
macroeconomic
microeconomics
economic
ssc1027
ssc2048
allocate
intermediate
policy
strategic
economist
Globalization & SD
sustain
climate
city
sustainability
poverty
equality
transition
technological
innovate
Governance
policymaking
policy
heal
public
migration
politic
european
political
model
History
europe
age
urban
middle
enlighten
religion
totalitarianism
european
romantic
Int. Relations
foreign
conflict
policy
security
violent
war
justice
transitional
gross
chinese
bystander
International Law
law
legal
wto
trade
protection
international
constitutional
civilian
european
Literature
literary
psychological
art
screen
depth
interpretation
western
century
media
acquaint
Mathematics
linear
optimization
mathematics
algebra
mathematical
game
equate
engineer
nonlinear
Methods
qualitative
project
marble
statistic
interview
histology
ethnography
artistic
anatomy
Philosophy
philosopher
philosophy
ethic
philosophical
ancient
justice
conscious
cor1004
language
Psychology
brain
cognitive
neuroscience
personality
clinical
memory
psychology
intelligence
ssc1005
Skills
conference
project
client
argument
train
negotiate
argumentation
2.5
workshop
Sociology
race
gender
movement
identity
cultural
sociological
classical
technology
sociology
tf−idf


Distinctive Terms of Clusters
Biomedical Sciences
chemical physiology organic cell biology physic chemistry molecular
Business
financial corporate sustain asian manage brand entrepreneur
Computer Science
enterprise agent computer mine java data lab programming artificial
Cultural Studies
visual song culture film art media cultural age memory
Economics
allocate microeconomics macroeconomic strategic economic intermediate policy ssc1027 economist
Globalization & SD
poverty transition climate innovate sustain sustainability city equality technological
Governance
politic heal european political policy migration public model
History
totalitarianism europe urban european middle age religion enlighten romantic
Int. Relations
transitional security foreign war policy violent conflict justice chinese gross
International Law
protection international wto law legal european civilian trade
Literature
psychological screen century acquaint media art literary depth western interpretation
Mathematics
optimization algebra equate mathematical game linear mathematics engineer
Methods
qualitative anatomy marble statistic project artistic histology interview
Philosophy
cor1004 philosopher justice philosophy ancient language ethic conscious
Psychology
personality cognitive clinical psychology ssc1005 brain memory
Skills
2.5 workshop argument train client project negotiate conference
Sociology
sociology identity cultural race gender classical

3.3 Topic Emergence

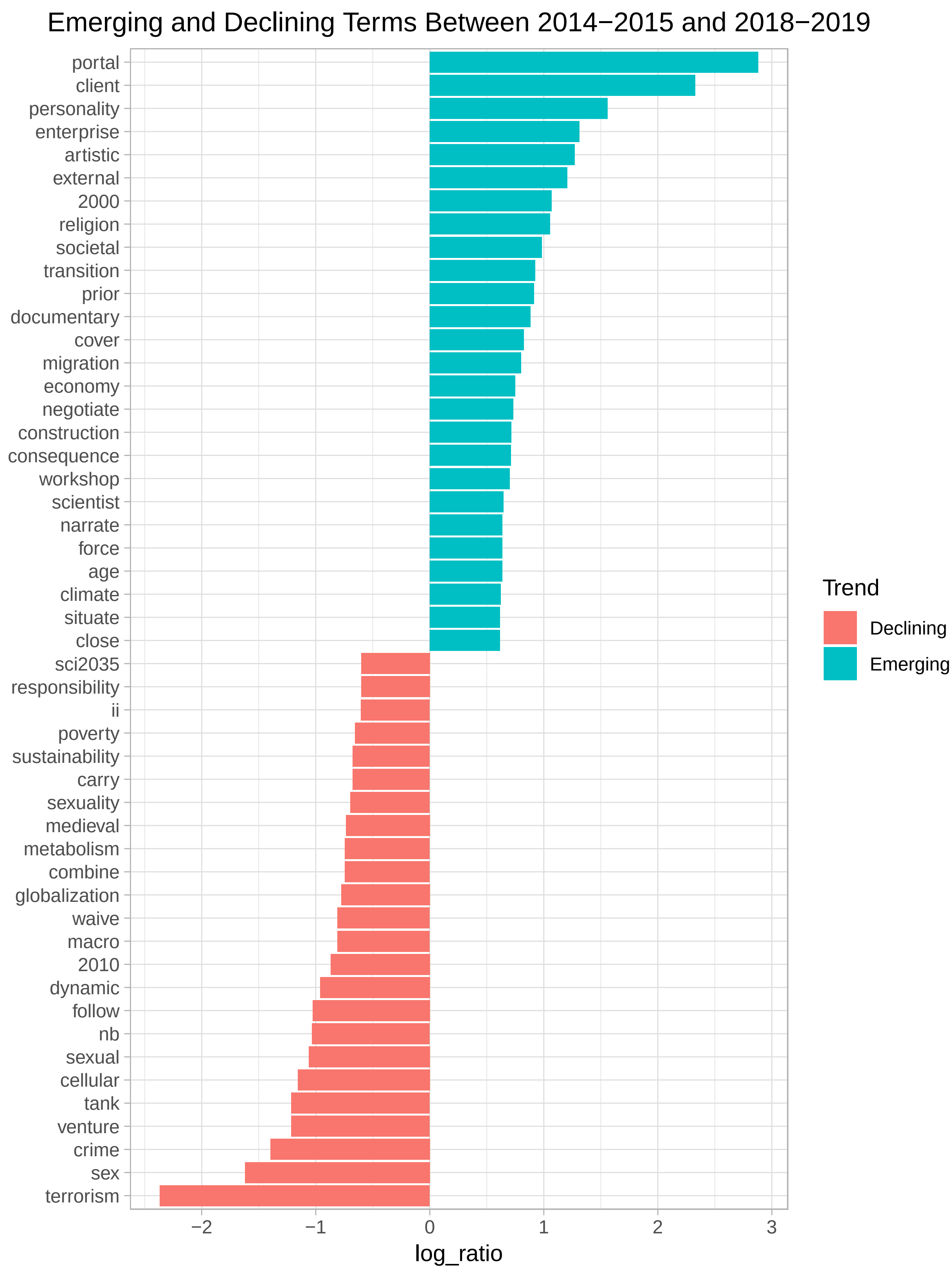
We compare the content of the 2014-2015 (oldest available) and 2018-2019 (most recent) course catalogues to identify terms and themes that have declined and emerged these last few years. To accomplish this, we compare the frequency of the terms in the two catalogues by taking their `log ratio`. A positive value indicates that the term has become more frequent since 2014-2015 and a negative value indicates a decline in the use of the term. We plot the forty terms with the highest absolute `log ratio`. Again, we display the information both as a barplot and wordcloud.

```
d_emergence <- d_description_stem %>%
  filter(`Calendar Year` %in% c("2014-2015", "2018-2019")) %>%
  count(`Calendar Year`, `word`) %>%
  spread(key = `Calendar Year`, value = n, fill = 0) %>%
  rename(new = "2018-2019", old = "2014-2015") %>%
  mutate(n         = old + new,
         log_ratio = log( ((new+1) / (sum(new)+1)) /
                          ((old+1) / (sum(old)+1)) ),
         Trend     = case_when(log_ratio<0 ~ "Declining",
                               log_ratio>0 ~ "Emerging")) %>%
  filter(n > 15) %>%
  top_n(50, abs(log_ratio))

print(d_emergence)
```

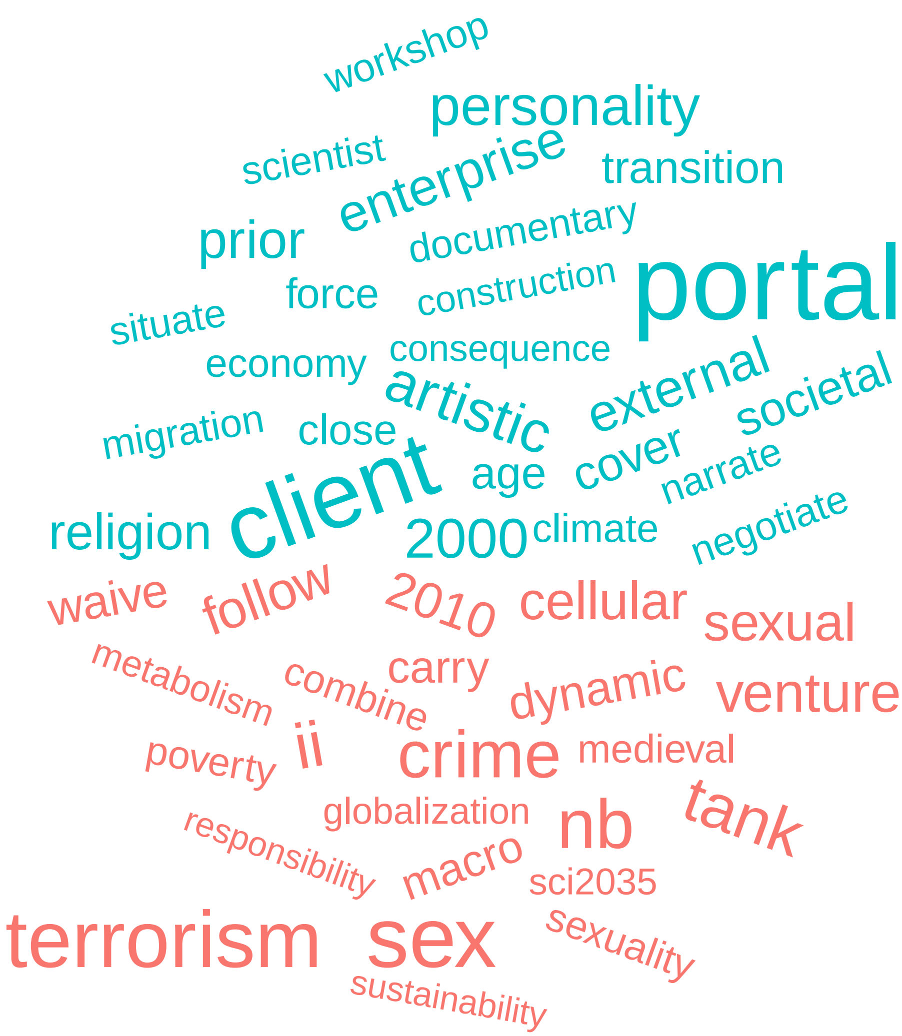
```
## # A tibble: 50 x 6
##    word       old   new     n log_ratio Trend
##    <chr>    <dbl> <dbl> <dbl>     <dbl> <chr>
##  1 2000        10    35    45     1.07  Emerging
##  2 2010        16     7    23    -0.870 Declining
##  3 age         24    52    76     0.636 Emerging
##  4 artistic     4    19    23     1.27  Emerging
##  5 carry       13     7    20    -0.675 Declining
##  6 cellular    16     5    21    -1.16  Declining
##  7 client       1    22    23     2.33  Emerging
##  8 climate     10    22    32     0.622 Emerging
##  9 close       12    26    38     0.615 Emerging
## 10 combine     14     7    21    -0.744 Declining
## # ... with 40 more rows
```

3.3.1 Results

From the two plots, we can observe that topics that have made the news these last few years such as religion, migrationa and climate have become more important in the catalogues. This shows that the college has done a godd job at adapting its curriculum to the development of the world. We also observe that the themes of sexuality (with terms like `sex`, `sexual` and `sexuality`) and terrorism (`terrorism`, `crime`) have declined. It is interesting to note that the terms `globalization`, `poverty` and `sustainability` have become less important. As for the term `portal`, its "emergence" is due to the introduction of a new online student *portal* system at the college. The terms is not mentioned once in 2014-2015 and appears `19` times in 2018-2019. This shows that human interpretation and a good knowledge of the data is crucial to avoid false alarms in such analysis.


Emerging and Declining Terms Between 2014−2015 and 2018−2019
portal
client
personality
enterprise
artistic
external
2000
religion
societal
transition
prior
documentary
cover
migration
economy
negotiate
construction
consequence
workshop
scientist
narrate
force
age
climate
situate
close
sci2035
responsibility
ii
poverty
sustainability
carry
sexuality
medieval
metabolism
combine
globalization
waive
macro
2010
dynamic
follow
nb
sexual
cellular
tank
venture
crime
sex
terrorism
−2
−1
0
1
2
3
log_ratio
Trend
Declining
Emerging

Emerging (blue) and Declining (red) Terms Between 2014−2015 and 2018−2019



3.4 LDA

Finally, we use the Latent Dirichlet Allocation (LDA) algorithm to conduct a topic analysis of the college's curriculum at the course- and the cluster-level. Given a corpus of documents and a predetermined number of topics, the LDA algorithm outputs a topic model which gives the importance of each term to the topics (beta distribution) and the importance of each topic to the documents (gamma distribution). In other words, the LDA find the mixture of words associated with each topic and the mixture of topics associated with each document. The advantage of the LDA over regular clustering methods is that is allows for overlap of terms across topics and of topics across documents, thereby offering a model that is closer to natural language.

3.4.1 Fitting Model

In the LDA algorithm, the number of topics has to be determined in advance. We build four models with respectively `5`, `12`, `17` and `25` topics. For

TODO: use package `ldatuning` to determine best number of topics. (https://cran.r-project.org/web/packages/ldatuning/vignettes/topics.html)

```
d_cast <- d_description_stem %>%
  filter(`Calendar Year` == "2018-2019") %>%
  count(Code, word) %>%
  cast_dtm(Code,word, n)
```

```
LDA_5  <- LDA(d_cast, k = 5 , control = list(seed = 123))
LDA_12 <- LDA(d_cast, k = 12, control = list(seed = 123))
LDA_17 <- LDA(d_cast, k = 17, control = list(seed = 123)) # There are 17 clusters
LDA_25 <- LDA(d_cast, k = 25, control = list(seed = 123))
```

3.4.2 Results

We present the output of a topic model with three plots which respectively show (i) the most important terms for each topic (ii) the main courses/clusters of each topic and (iii) the most important topics of each course/cluster. For each model, we present the results at the course- an the cluster-level. To keep the script concise, we only include a selection of plots for the model with `12` topics. In the first four plots, the topics are unlabelled; in the last three, the topics are labelled. The complete output of each model (two triplets of plots with unlabelled topics) can be found in the directory.

Firstly, the third plot shows that most topics are covered in several clusters. Fot instance, `topic 10` is covered in several clusters of the humanities (`History`, `Literature` and `Philosophy`) and social sciences (`International Relations`, `International Law` and `Economics`). For a liberal arts program this is a desirable outcome since it encourages students interested in a particular topic to take classes in different clusters, thereby broading their acadmeic horizon[5]. At the same time, this pattern may be artificially created by the fact that there are much more than twelve topics present in the curriculum, meaning that the LDA algorithm combines unrelated themes into the same topic. This is for instance the case for `topic 3` which combines the themes of law (`law`, `legal`) and international (`european`, `international`) (see first plot). Increasing the number of topics in the model should solve this issue.

We also observe that the distribution of topics is very different at the course and the cluster level. While courses are usually heavily dominated by a single topics, clusters contain several major topics. Looking at the second plot, we observe that the courses `Computer Science`, `Optimization` and `Philosophy of Language` for instance are heavyly dominated by `topic 7`. The fourth plots shows that most clusters contain several topics. Interestingly, this graph shows that the same topic (`topic 10`) dominates the clusters `History`,

[5] One of the objectives of the program.

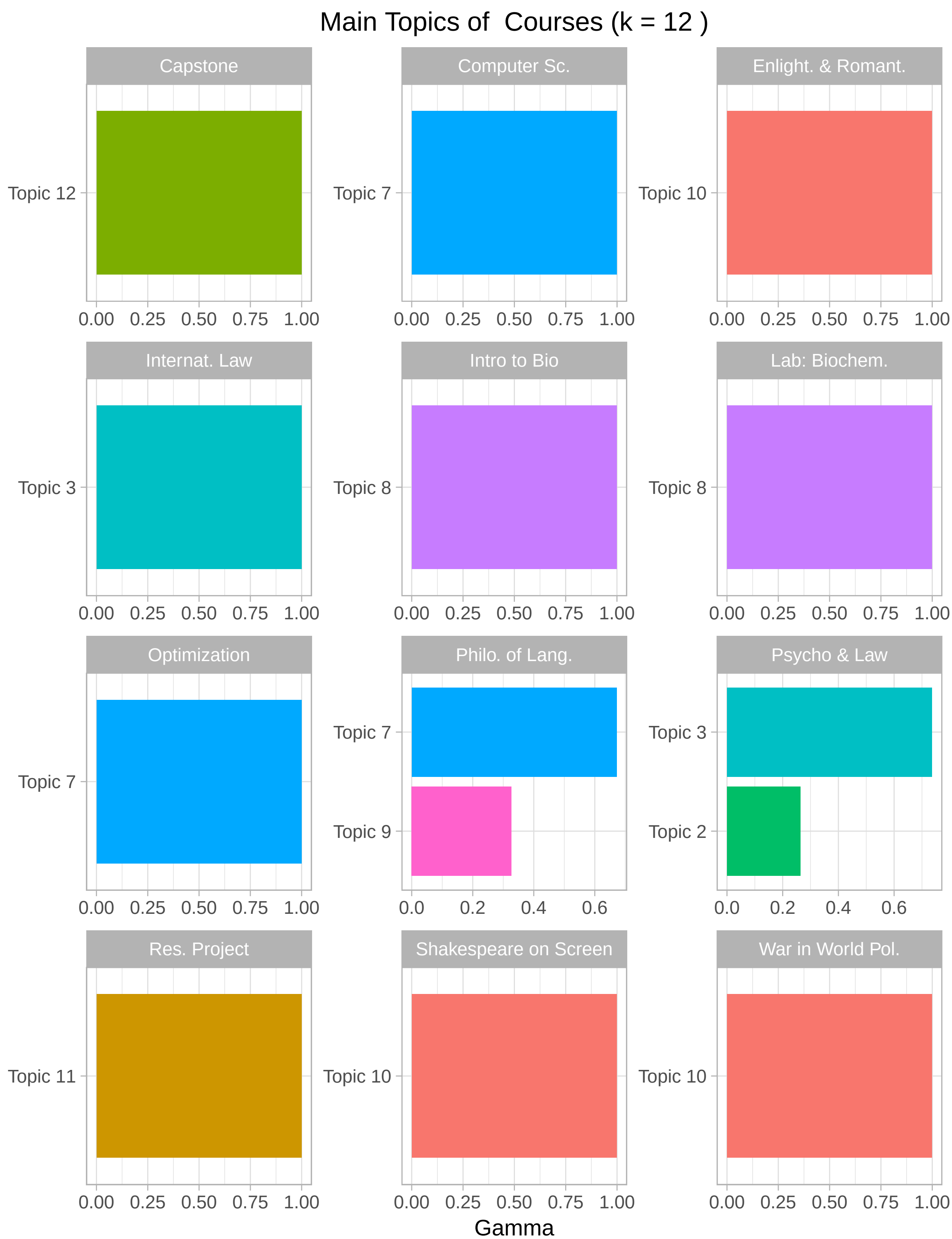
International Relations and Literature. This indicates either that the content of the three clusters share some similarity or that topic 10 contains several different themes.

So far, we have only analyzed models with unlabelled topics. In order to give more substance to our analysis, we assign labels to the topics. To accomplish this, we look at the first plot and identify the common theme(s) among the terms. Some topics are easier to label than others. topic 6 is for instance pretty straightforward: it is dominated by the term search and also contain the terms qualitative, read, interview and study: topic 6 corresponds to qualitative research skills and we therefore label it Qual. Res.[6]. Labelling topic 7 on the other hand is more trick. The best label I could find is Engineering. I have labelled each topic and present the results in the last three plots.

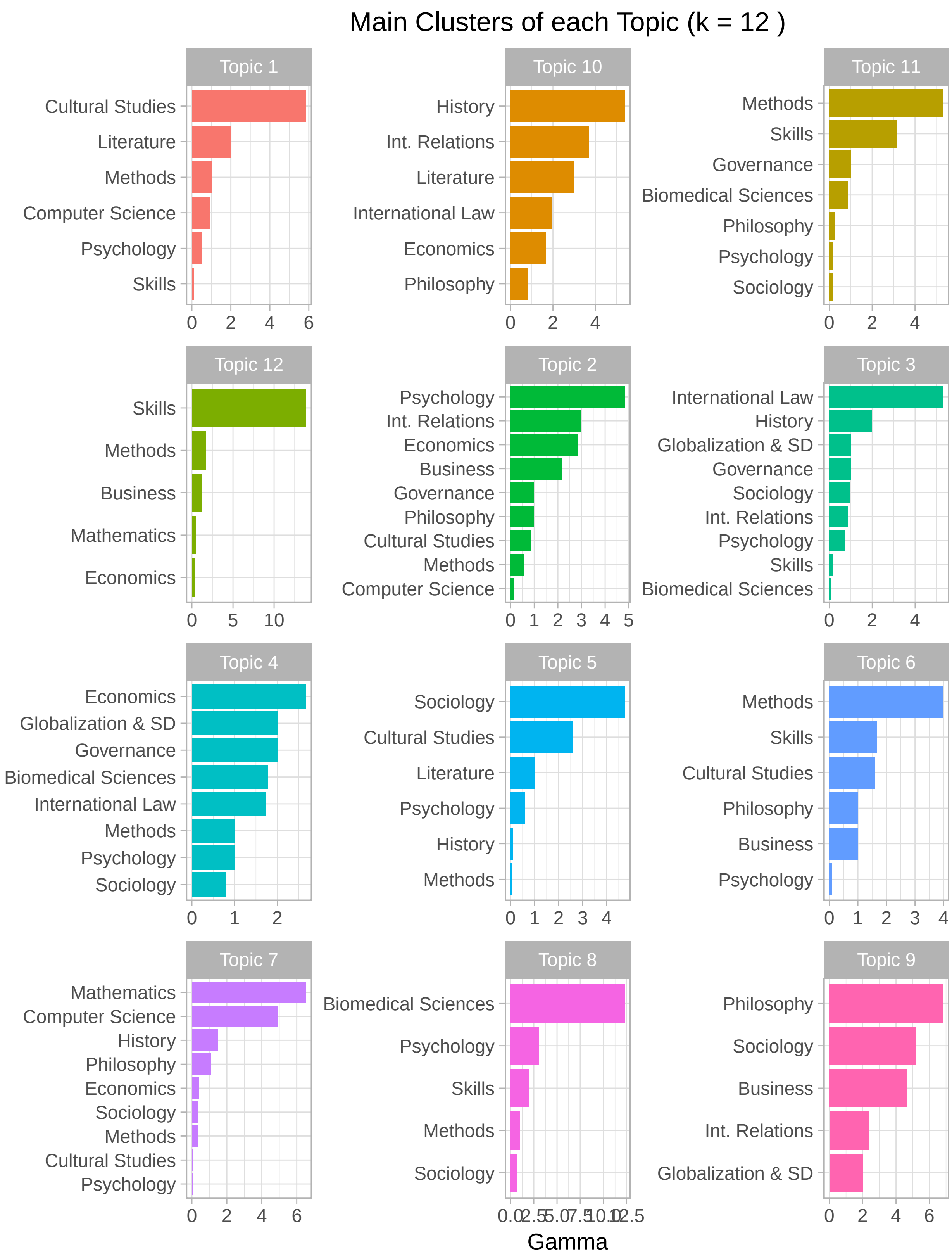
The labels give us a better image of the actual content of the courses and the clusters. The last plot indicate sthta most clusters cover the topics that we expect them to cover, indicating that the current division of courses in clusters is backed up by the content of the courses. As expected, the cluster Sociology covers the topics of Society and Culture and the cluster Cultural Studies covers the topics of Arts, Culture and Qual. Res.. Yet, I am surprised by the absence of certain topics in some clusters. For instance, the cluster history lacks the topics of culture and society and the topic of research is also barely present in Biomedical Sciences. The former shows the heavy focus of the history cluster on war and conflicts (Foreign Policy) and the latter reflects the absence of research projects in the classes of the biomedical cluster.

[6]This is a subjective choice and the reader may find a more fitting label.

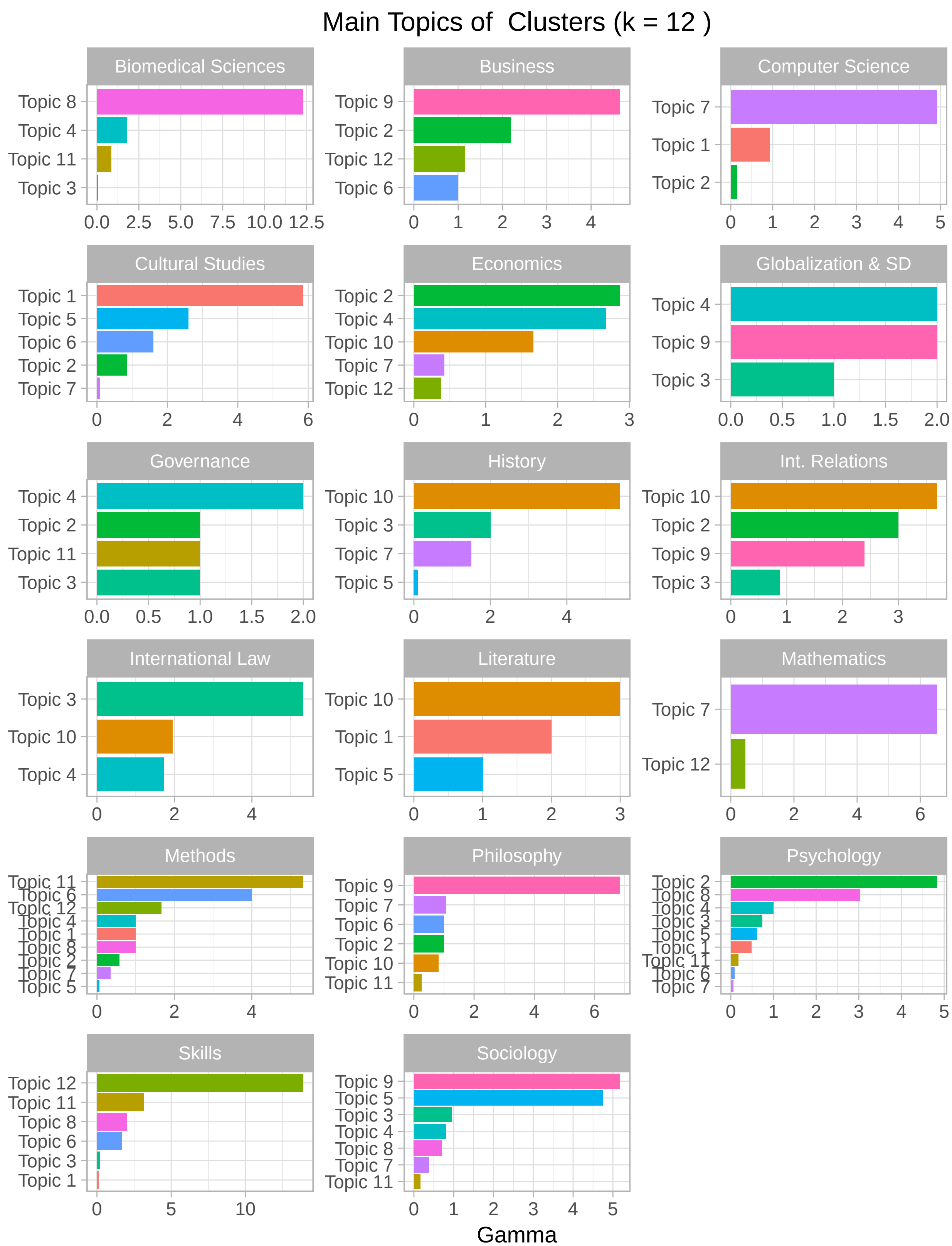
3.4.2.1 Unlabelled Topics



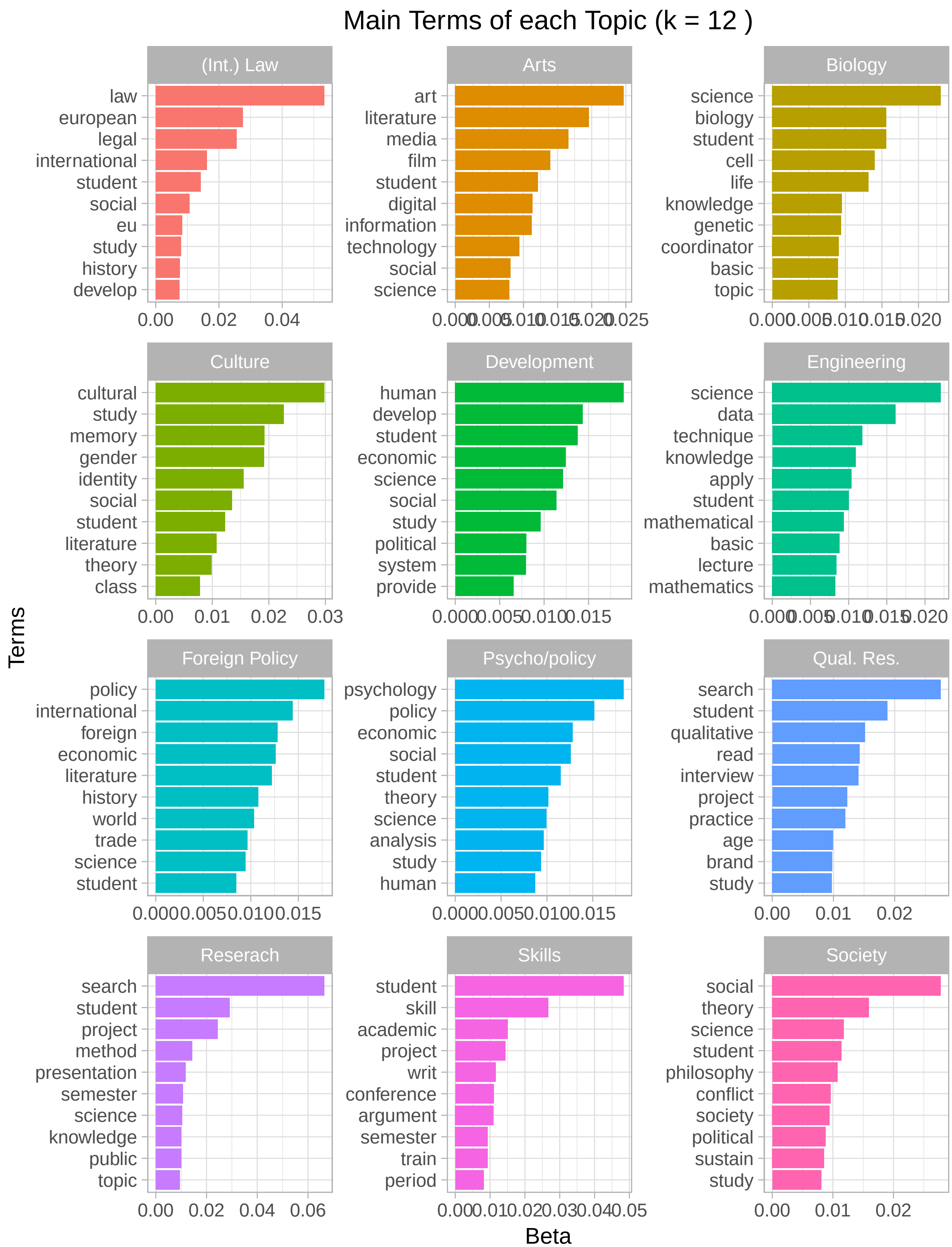
Main Topics of Courses (k = 12)
Capstone
Topic 12
Computer Sc.
Topic 7
Enlight. & Romant.
Topic 10
Internat. Law
Topic 3
Intro to Bio
Topic 8
Lab: Biochem.
Topic 8
Optimization
Topic 7
Philo. of Lang.
Topic 7
Topic 9
Psycho & Law
Topic 3
Topic 2
Res. Project
Topic 11
Shakespeare on Screen
Topic 10
War in World Pol.
Topic 10
0.00 0.25 0.50 0.75 1.00
0.0 0.2 0.4 0.6
Gamma



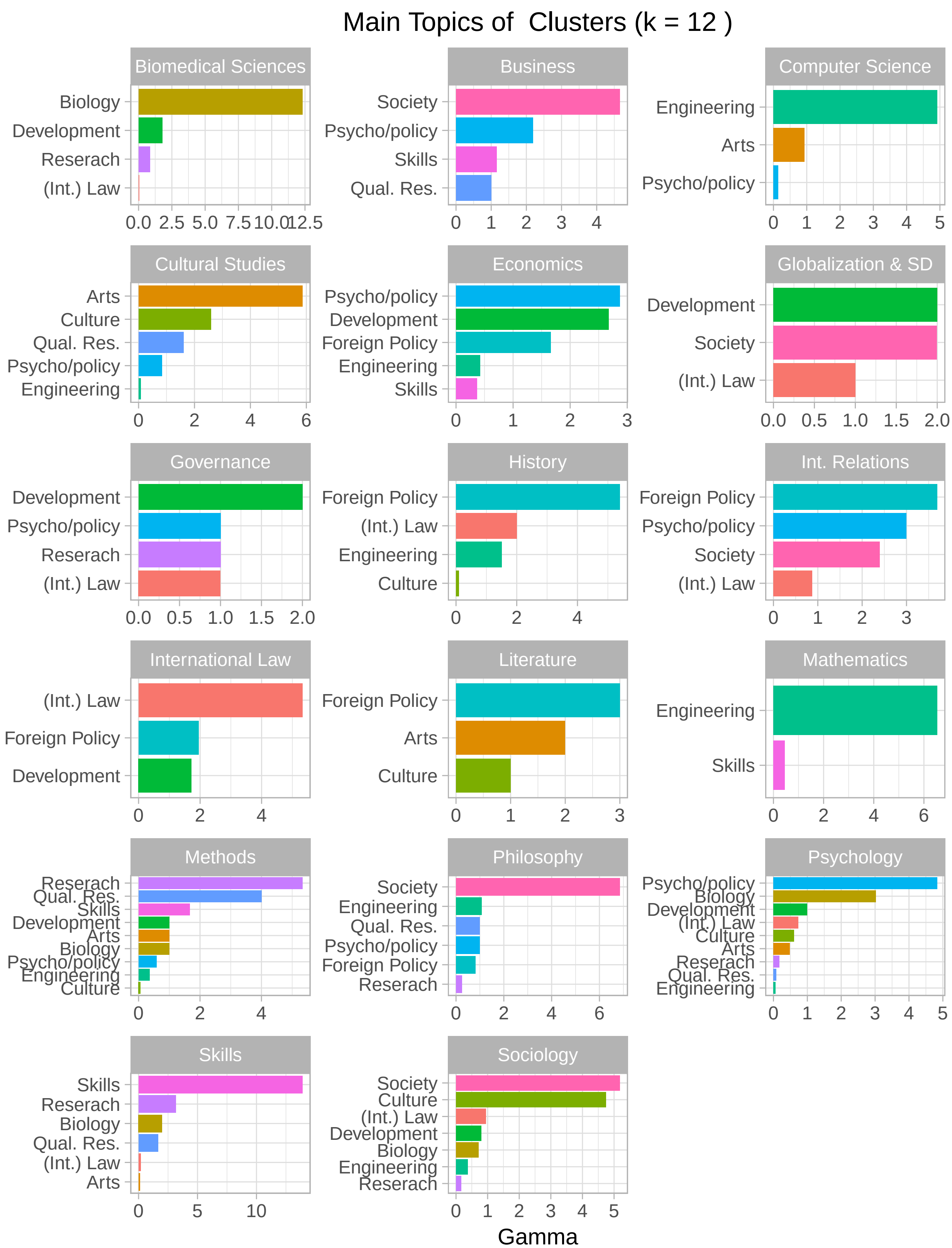
Main Clusters of each Topic (k = 12)
Topic 1
Cultural Studies
Literature
Methods
Computer Science
Psychology
Skills
Topic 10
History
Int. Relations
Literature
International Law
Economics
Philosophy
Topic 11
Methods
Skills
Governance
Biomedical Sciences
Philosophy
Psychology
Sociology
Topic 12
Skills
Methods
Business
Mathematics
Economics
Topic 2
Psychology
Int. Relations
Economics
Business
Governance
Philosophy
Cultural Studies
Methods
Computer Science
Topic 3
International Law
History
Globalization & SD
Governance
Sociology
Int. Relations
Psychology
Skills
Biomedical Sciences
Topic 4
Economics
Globalization & SD
Governance
Biomedical Sciences
International Law
Methods
Psychology
Sociology
Topic 5
Sociology
Cultural Studies
Literature
Psychology
History
Methods
Topic 6
Methods
Skills
Cultural Studies
Philosophy
Business
Psychology
Topic 7
Mathematics
Computer Science
History
Philosophy
Economics
Sociology
Methods
Cultural Studies
Psychology
Topic 8
Biomedical Sciences
Psychology
Skills
Methods
Sociology
Topic 9
Philosophy
Sociology
Business
Int. Relations
Globalization & SD
Gamma


Main Topics of Clusters (k = 12)
Biomedical Sciences
Topic 8
Topic 4
Topic 11
Topic 3
0.0 2.5 5.0 7.5 10.0 12.5
Business
Topic 9
Topic 2
Topic 12
Topic 6
0 1 2 3 4
Computer Science
Topic 7
Topic 1
Topic 2
0 1 2 3 4 5
Cultural Studies
Topic 1
Topic 5
Topic 6
Topic 2
Topic 7
0 2 4 6
Economics
Topic 2
Topic 4
Topic 10
Topic 7
Topic 12
0 1 2 3
Globalization & SD
Topic 4
Topic 9
Topic 3
0.0 0.5 1.0 1.5 2.0
Governance
Topic 4
Topic 2
Topic 11
Topic 3
0.0 0.5 1.0 1.5 2.0
History
Topic 10
Topic 3
Topic 7
Topic 5
0 2 4
Int. Relations
Topic 10
Topic 2
Topic 9
Topic 3
0 1 2 3
International Law
Topic 3
Topic 10
Topic 4
0 2 4
Literature
Topic 10
Topic 1
Topic 5
0 1 2 3
Mathematics
Topic 7
Topic 12
0 2 4 6
Methods
Topic 11
Topic 6
Topic 12
Topic 4
Topic 1
Topic 8
Topic 2
Topic 7
Topic 5
0 2 4
Philosophy
Topic 9
Topic 7
Topic 6
Topic 2
Topic 10
Topic 11
0 2 4 6
Psychology
Topic 2
Topic 8
Topic 4
Topic 3
Topic 5
Topic 1
Topic 11
Topic 6
Topic 7
0 1 2 3 4 5
Skills
Topic 12
Topic 11
Topic 8
Topic 6
Topic 3
Topic 1
0 5 10
Sociology
Topic 9
Topic 5
Topic 3
Topic 4
Topic 8
Topic 7
Topic 11
0 1 2 3 4 5
Gamma

3.4.2.2 Labelled Topics



Main Topics of Courses (k = 12)
Capstone
Skills
Computer Sc.
Engineering
Enlight. & Romant.
Foreign Policy
Internat. Law
(Int.) Law
Intro to Bio
Biology
Lab: Biochem.
Biology
Optimization
Engineering
Philo. of Lang.
Engineering
Society
Psycho & Law
(Int.) Law
Psycho/policy
Res. Project
Reserach
Shakespeare on Screen
Foreign Policy
War in World Pol.
Foreign Policy
0.00 0.25 0.50 0.75 1.00
0.0 0.2 0.4 0.6
Gamma


Main Topics of Clusters (k = 12)
Biomedical Sciences
Biology
Development
Reserach
(Int.) Law
0.0 2.5 5.0 7.5 10.0 12.5
Business
Society
Psycho/policy
Skills
Qual. Res.
0 1 2 3 4
Computer Science
Engineering
Arts
Psycho/policy
0 1 2 3 4 5
Cultural Studies
Arts
Culture
Qual. Res.
Psycho/policy
Engineering
0 2 4 6
Economics
Psycho/policy
Development
Foreign Policy
Engineering
Skills
0 1 2 3
Globalization & SD
Development
Society
(Int.) Law
0.0 0.5 1.0 1.5 2.0
Governance
Development
Psycho/policy
Reserach
(Int.) Law
0.0 0.5 1.0 1.5 2.0
History
Foreign Policy
(Int.) Law
Engineering
Culture
0 2 4
Int. Relations
Foreign Policy
Psycho/policy
Society
(Int.) Law
0 1 2 3
International Law
(Int.) Law
Foreign Policy
Development
0 2 4
Literature
Foreign Policy
Arts
Culture
0 1 2 3
Mathematics
Engineering
Skills
0 2 4 6
Methods
Reserach
Qual. Res.
Skills
Development
Arts
Biology
Psycho/policy
Engineering
Culture
0 2 4
Philosophy
Society
Engineering
Qual. Res.
Psycho/policy
Foreign Policy
Reserach
0 2 4 6
Psychology
Psycho/policy
Biology
Development
(Int.) Law
Culture
Arts
Reserach
Qual. Res.
Engineering
0 1 2 3 4 5
Skills
Skills
Reserach
Biology
Qual. Res.
(Int.) Law
Arts
0 5 10
Sociology
Society
Culture
(Int.) Law
Development
Biology
Engineering
Reserach
0 1 2 3 4 5
Gamma