eurostat: Eurostat Open Data R Tools DRAFT VERSION IN PROGRESS

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Abstract Governmental institutions are increasingly opening up their data resources for the public as open data. This is providing novel opportunities for research and citizen science, but efficient tools to access and analyze these data sets are needed to realize the full potential of the new information resources. We introduce the **eurostat** R package that provides a suite of tools to access open data from Eurostat, including functions to search, download, and manipulate Eurostat data in an automated and reproducible manner. The online documentation provides detailed examples on how to access, summarize and visualize these spatio-temporal data sets. The package expands previous related work and has been extensively tested by the user community. This contributes to the growing ecosystem of R packages that provide algorithmic tools for reproducible computational research in social science and humanities.

Eurostat, the statistical office of the European Union, provides a rich collection of demographic and economic data through its open data service, which currently includes over 8800 data sets on European demography, economics, health, infrastructure, traffic and other topics. In many cases the statistics are available with great geographical resolution and including time series spanning over several years or decades.

The availability of tools to access and analyse data collections from the public domain can greatly benefit reproducible research (Gandrud, 2013; Boettiger et al., 2015). When the data resources and analysis algorithms are openly available, the complete analytical workflow spanning from raw data to the final publication can be made fully automated and transparent. Standardization of common data analysis tasks via dedicated software packages can help to automate the analysis workflow, greatly facilitating reproducibility and code sharing, and making the data analysis more efficient. The algorithms need to be customized to specific data sources, however, to accommodate variations in raw data formats, access details, and typical use cases so that the end user can avoid repetitive standard programming tasks and spend more time on the actual research tasks. A number of packages to access specific data sources from governmental and other institutions have been consequently designed to meet these demands and to access open data from the Food and Agricultural Organization (FAO) of the United Nations (**FAOSTAT**; Kao et al. (2015)), World Bank (**WDI**; Arel-Bundock (2013)), national statistics authorities (**pxweb**; Magnusson et al. (2014)), Open Street Map (**osmar**; Eugster and Schlesinger (2012)) and many other sources.

A dedicated R package for eurostat open data has been missing, however. We introduce the **eurostat** R package to fill this gap. The package facilitates automated access to open data from Eurostat[1]. This brings together our earlier efforts with the **statfi** (Lahti et al., 2013) and **smarterpoland** (Biecek, 2015) packages. Compared to this earlier work, we have now combined the relevant parts of these two packages and implemented an expanded set of tools with a specific focus on the Eurostat data collection. The first CRAN release of the package was in 2014. Since then it has been actively developed by several contributors and based on community feedback in Github. We are now reporting the first mature version of the package that has been improved and tested by multiple users. The package and its predecessors have been applied in several case studies by us and others[2].

The **datamart** (Weinert, 2014), the **quandl** (McTaggart et al., 2015) and the **pdfetch** (Reinhart, 2015) R packages provide further functions that can be used to access certain versions of Eurostat data. In contrast to these generic database packages, our eurostat package provides functionality that is particularly tailored for the Eurostat open data service. The **eurostat** package greatly benefits from further tools in the **dplyr** (Wickham and Francois, 2015), **knitr** (Xie, 2015), **ggplot2** (Wickham, 2009), **mapproj** (for R by Ray Brownrigg et al., 2015), and **stringi** (Gagolewski and Tartanus, 2015) R packages. The **eurostat** package is part of the rOpenGov collection (Leo Lahti and Kainu, 2013) that provides reproducible research tools for computational social science and digital humanities.

In summary, the **eurostat** package provides custom tools to search, retrieve, modify and visualize data from the Eurostat open data service. The package supports key features such as data cache, date formatting, and tidy data principles (Wickham, 2014) using the the **tidyr** R package (Wickham, 2015c). Here, we provide an overview of the core functionality in the current CRAN release version (1.2.1). For further documentation and the reproducible source code for this article, see the package github site [3].

[1] http://ec.europa.eu/eurostat/data/database

[2] See e.g. http://blog.revolutionanalytics.com/2015/04/financial-times-tracks-unemployment-with-r.html

[3] https://github.com/rOpenGov/eurostat

Search and download commands

To install and load the CRAN release version, just type in R:

```
> install.packages("eurostat")
> library("eurostat")
```

The complete table of contents of the database can be browsed on-line[4], or downloaded in R with the command `toc <-get_eurostat_toc()`. The function `search_eurostat()` is used to make a more focused search over the table of contents. To retrieve data for 'Modal split of passenger transport', for instance, use:

```
> query <- search_eurostat("Modal split of passenger transport", type = "table")
```

The `type` argument limits the search on a selected data set type in the above example. The options for this argument include *'table'*, *'dataset'* or *'folder'*, referring to different levels of hierarchy in the data organization: a `table` resides in `dataset`, which is in turn stored in a `folder`.

Values in the `code` column of the `search_eurostat()` function output provide data sets identifiers that can be used in subsequent download commands. Alternatively, these identifier codes can be browsed at the Eurostat open data service; check the codes in the Data Navigation Tree listed after each dataset in parentheses. Let us look at the data set identifier and title for the first entry of the query data:

```
> query$code[[1]]
[1] "tsdtr210"

> query$title[[1]]
[1] "Modal split of passenger transport"
```

Let us next retrieve the data set with this identifier as follows:

```
> dat <- get_eurostat(id = "tsdtr210", time_format = "num")
```

As the original data is annual in this example, we have selected a numeric time format. This is more convient for annual time series than the default date format. The data sets are provided as standard data frames to support standard tools for data subsetting and reshaping. The above function call returns a table on transport statistics. The first lines of the output are shown in Table 1.

	unit	vehicle	geo	time	values
1	PC	BUS_TOT	AT	1990.00	11.00
2	PC	BUS_TOT	BE	1990.00	10.60
3	PC	BUS_TOT	BG	1990.00	
4	PC	BUS_TOT	CH	1990.00	3.70
5	PC	BUS_TOT	CY	1990.00	
6	PC	BUS_TOT	CZ	1990.00	

Table 1: First lines of output from the `get_eurostat()` function for the data set with the identifier 'tsdtr210'.

	unit	vehicle	geo	time	values
1	Percentage	Motor coaches, buses and trolley buses	Austria	1990.00	11.00
2	Percentage	Motor coaches, buses and trolley buses	Belgium	1990.00	10.60
3	Percentage	Motor coaches, buses and trolley buses	Bulgaria	1990.00	
4	Percentage	Motor coaches, buses and trolley buses	Switzerland	1990.00	3.70
5	Percentage	Motor coaches, buses and trolley buses	Cyprus	1990.00	
6	Percentage	Motor coaches, buses and trolley buses	Czech Republic	1990.00	

Table 2: The output from `get_eurostat()` (Table 1), now converted into human-readable labels by `label_eurostat()`.

[4] http://ec.europa.eu/eurostat/data/database

Utilities

Many entries in Table 1 are not readily interpretable, but a simple call `label_eurostat(dat)` converts the original identifier codes into human-readable versions (shown in Table 2) based on translations in the Eurostat database.

The downloaded data sets are stored in cache by default to avoid repeated downloads of identical data sets. This can speed up the analysis. Storing an exact copy of the retrieved raw data on the hard disk supports also the reproducibility when the source database is constantly updated.

The transport data set in the above example includes three classes of vehicles. Three-dimensional data sets such as this can be conveniently visualized as triangular maps by using the **plotrix** (Lemon, 2006) package.

```
# Select data for the year 2012:
> dats <- subset(dat, time == 2012,
>           select = c(geo, vehicle, values))

# Transform into countries x vehicles matrix and remove NAs
> library(knitr)
> transports <- tidyr::spread(dats, vehicle, values)
> transports <- na.omit(transports)

# Triangle plot
> library(plotrix)
> plotrix::triax.plot(transports[, c("BUS_TOT", "CAR", "TRN")],
>            show.grid = TRUE,
>            label.points = TRUE, point.labels = transports$geo,
>            pch = 19)
```

The Figure 1A illustrates the resulting triangular visualization showing the distribution of vehicle types in different countries. Interestingly, the Eurostat data also reveals a decreasing trend of road accidents in many countries over time (Figure 1B). The Eurostat database includes a variety of demographic and health indicators. We see, for instance, that overweight varies remarkably across different age groups quantified by the body-mass index (BMI) (Figure 2 A).

Sometimes the data from the eurostat databse requires more complex pre-processing. Let's consider a question about distribution of sources of renewable energy in different European countries. In order to summarise such sources one needs to first aggregate all possible sources into a smaller number of interesting groups. Then with the use of packages like **dplyr** or **tidyr** one can process data, chop country names, filter countries depending on production levels, normalize the within country production. After a series of such transformations we can finally plot the data to discover that countries vary a lot in terms of sources of renewable energy (Figure 2 B).

```
# All sources of renewable energy are to be grouped into three sets
> dict <- c("Solid biofuels (excluding charcoal)" = "Biofuels",
+          "Biogasoline" = "Biofuels",
+          "Other liquid biofuels" = "Biofuels",
+          "Biodiesels" = "Biofuels",
+          "Biogas" = "Biofuels",
+          "Hydro power" = "Hydro power",
+          "Tide, Wave and Ocean" = "Hydro power",
+          "Solar thermal" = "Wind, solar, waste and Other",
+          "Geothermal Energy" = "Wind, solar, waste and Other",
+          "Solar photovoltaic" = "Wind, solar, waste and Other",
+          "Municipal waste (renewable)" = "Wind, solar, waste and Other",
+          "Wind power" = "Wind, solar, waste and Other",
+          "Bio jet kerosene" = "Wind, solar, waste and Other")
# Some cleaning of the data is required
> energy3 <- get_eurostat("ten00081") %>%
+  label_eurostat(dat) %>%
+  filter(time == "2013-01-01",
+         product != "Renewable energies") %>%
+  mutate(nproduct = dict[as.character(product)], # just three categories
+         geo = gsub(geo, pattern=" \\(.*", replacement="")) %>%
+  select(nproduct, geo, values) %>%
+  group_by(nproduct, geo) %>%
```

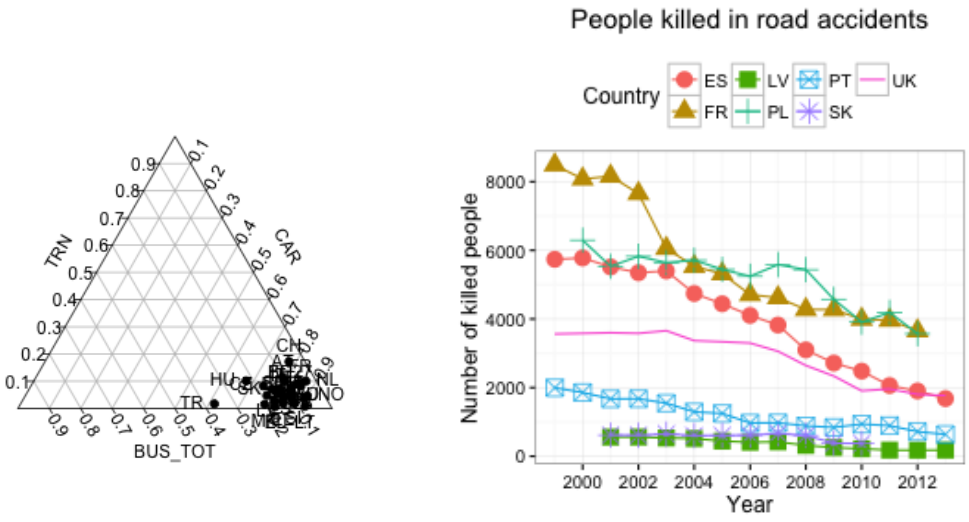

Figure 1: Example visualizations of data sets retrieved with the **eurostat** package. **A** The distribution of the three unique passenger transport vehicle types in different countries (country codes shown) visualized on a triangular **plotrix** map. The three vehicle types are 'Motor coaches, buses and trolley buses' (BUS_TOT), 'Passenger cars' (CAR), and 'Trains' (TRN). **B** Timeline indicating the number of people killed in road accidents in various countries.

```
+  summarise(svalue = sum(values)) %>%
+  group_by(geo) %>%
+  mutate(tvalue = sum(svalue),
+         svalue = svalue/sum(svalue)) %>%
+  filter(tvalue > 1000,
+         !grepl(geo, pattern="^Euro")) %>% # only large countrie
+  spread(nproduct, svalue)
# Triangle plot
> library(plotrix)
> par(cex=0.75)
> plotrix::triax.plot(as.matrix(energy3[, c(3,5,4)]),
+                     show.grid = TRUE,
+                     label.points = TRUE, point.labels = energy3$geo,cex.ticks=0.75,col.symbols = "red4",
+                     pch = 19)
```

Geospatial information

Map visualizations

The indicators in the Eurostat open data service are typically available as annual time series grouped by country, and sometimes at more refined temporal or geographic levels. Eurostat provides complementary geospatial data on the corresponding administrative statistical units to support visualizations at the appropriate geographic resolution. The geospatial data sets are available as standard shapefiles[5]. As an example, let us look at disposable income of private households (data set identifier tgs00026[6]). This information is provided at the geographic level of NUTS2 regions. This is the intermediate level of territorial units in the Eurostat regional classifications, and roughly corresponds to provinces or states in each country[7] (Figure 3). The example demonstrates how the Eurostat data sets and geospatial data, retrieved with the eurostat package, can be combined with additional visualization tools and other utilities including **grid** (R Core Team, 2015), **maptools** (Bivand and Lewin-Koh, 2015), **rgdal** (Bivand et al., 2015), **rgeos** (Bivand and Rundel, 2015), **scales** (Wickham, 2015a), and **stringr** (Wickham, 2015b).

[5]http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units
[6]http://ec.europa.eu/eurostat/en/web/products-datasets/-/TGS00026
[7]http://ec.europa.eu/eurostat/web/nuts/overview

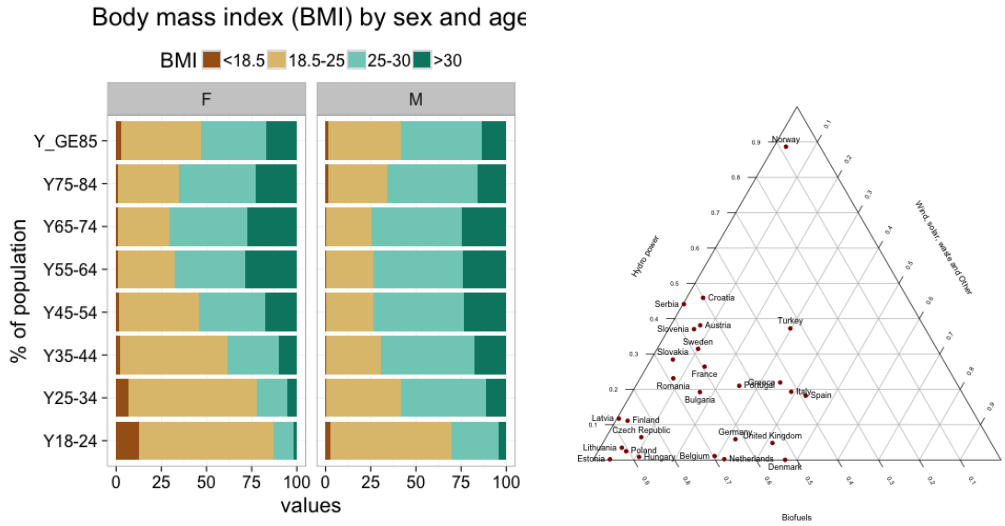

Figure 2: A The body-mass index in different age groups based on Eurostat open data. **B** Sources of production of renewable energy in the year 2013 based on Eurostat table `ten00081`.

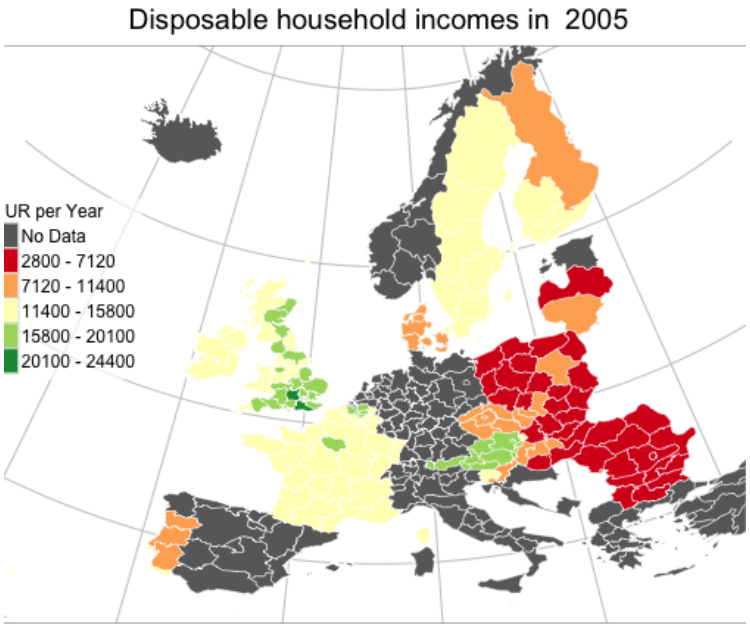

Figure 3: Disposable income of private households across NUTS2-level national regions in European countries visualized based on geospatial data available from Eurostat.

Default country groupings

To facilitate further analysis and visualization of standard European country groups, we have included ready-made country code lists. The list of EFTA countries is retrieved, for instance, with:

```
data(efta_countries)
```

This provides the EFTA country listing in Table 3. Similar lists are available for Euro area (ea_countries), EU (eu_countries) and the EU candidate countries (candidate_countries). These auxiliary data sets facilitate the selection of specific country groups in the analysis. The full name and a two-letter identifier are provided for each country as provided by the Eurostat database. The country codes follow the ISO 3166-1 alpha-2 standard, except that GB and GR are replaced by UK (United Kingdom) and EL (Greece) in the Eurostat database, respectively. Linking these country codes with external data sets can be facilitated by conversions between different country coding standards with the **countrycode** package (Arel-Bundock, 2014).

Summary

The **eurostat** R package provides convenient tools to access open data from Eurostat. Combining programmatic access to the data sets with further analysis and visualization tools allows a seamless and reproducible automation of the complete data analytical workflow from accessing the raw data to statistical analysis and final publication. The source code and installation instructions for the latest development version of the eurostat package are available at the github site, as well as the full source code of the figures and tables of this manuscript[8], where the Rmarkdown document provides reproducible documentation with full algorithmic details on the analyses, and can be updated when new versions of the Eurostat data become available.

The eurostat package provides one example of automated data retrieval from institutional data repositories, featuring options such as search, subsetting and cache. Possible future extensions and improvements include implementation of specific data representation formats to harmonize the data representation across similar data sources and to facilitate subsequent tool development. In particular, we should take further advantage of the existing spatiotemporal data structures available in R, such as those provided by the **spacetime** package (Pebesma, 2012), and construct wrapper functions to speed up routine operations such as visualizing the temporal and geospatial data sets from Eurostat. The package source code can be freely used, modified and distributed under the BSD-2-clause (modified FreeBSD) license. We welcome issues, bug reports and other feedback.

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[8] https://github.com/rOpenGov/eurostat
[9] https://github.ropengov.io

	code	name
1	IS	Iceland
2	LI	Liechtenstein
3	NO	Norway
4	CH	Switzerland

Table 3: The EFTA country listing from the eurostat R package.

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