LEARNING R PROGRAMMING LANGUAGE FOR ECONOMICS

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Abstract

Worldwide, scientists conduct research finding answers to questions, and that to do this they have to use, measure, and analyze data. Nowadays, more than never, computer programs are intensive used by researchers from various domains in order to ahieve their goals. There are different software helping scholars to get research results. R is currently one of the top programming languages preferred for accomplishing data science. Descending from the S programming language, R is an independent, open-source, and free software environment, which can be used for statistical analysis, visualization and reporting. In present, the R environment has become one of the most used statistical analysis tools, being used in university and academic research environments, but also in the business environment. More and more companies are using R as a data analysis tool. R is also supported by the academic community. The world's major universities support R. R is being used in the disciplines of finance, banking, insurance, economics, stock market, marketing, computer science, and many other disciplines and fields. Specialists in these fields need R knowledge and skills to analyze data. This article promotes learning of R programming language by students, researchers, and teachers from economic field. Learning R programming language is the acquisition of information, knowledge, and skills of R software. It is an ongoing process that takes place throughout whole professional life without an end date. Learning a programming language like R is the same as learning a spoken language? What is the difference between R and RStudio? How can we gain R skills? These are the questions we propose to answer through this research paper. The goal is helping beginners to enter into the R system. Results consist in providing information and sources to help economist and other people interested in starting learning R programming language.

Key words: *R environment, RStudio, learning, research, knowledge, skills*

JEL codes: *C87, L86, A20, I23*

1. Introduction

Learning "consists in adapting our expectations to reality in order to be able to anticipate and control the environment and to maximize our chances of survival" [1]. It is "a relatively lasting change in behavior that is the result of experience. It is the acquisition of information, knowledge, and skills. When you think of learning, it's easy to focus on formal education that takes place during childhood and early adulthood. But learning is an ongoing process that takes place throughout life and isn't confined to the classroom" [2]. A chinese proverb says that "learning is a treasure that will follow its owner everywhere" [3]. A learner is defined in British English as "someone who is learning about a particular subject or how to do something", and as "a person who is learning; student; pupil; apprentice; trainee", in American English [4]. The learning process is "activated as soon as a prediction error occurs, i.e. when reality surprises us by discovering to us something we did not expect" [1]. Henry Ford (1863-1947), the founder of the Ford Motor Company, considers that "anyone who stops learning is old, whether at twenty or eighty. Anyone who keeps learning stays young. The greatest thing in life is to keep your mind young" [5]. Year after year, new concepts and things are coined. In this context, we have to constantly update our knowledge. Alvin Eugene Toffler (1928-2016), an American writer futurist, and businessman, declared that "the illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn" [6]. For Mortimer Jerome Adler (1902-2001), a philospher, educator, and encyclopedist, "the purpose of learning is growth, and our minds, unlike our bodies, can continue growing as we continue to live". Steve Paul Jobs (1955-2011), a business magnate, inventor, and investor, said: "Learn continually. There's always «one more thing» to learn". And Brian Tracy, a motivational public speaker and self-development

author, considers that "continuous learning is the minimum requirement for success in any field" [3].

Nowadays, scholars from different countries and regions of the world, conduct research finding answers to questions, and that to do this they have to use, measure, and analyze data. They use computer programs in order to ahieve their goals. There are different software helping scientists to get research results. R is currently one of the top programming languages preferred for accomplishing data science. What is R? R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and macOS [7]. R descended from the S programming language, which was developed at Bell Labs by experts in statistical computing, including John Chambers, Richard Becker, and Allan Wilks. R is an independent, open-source, and free implementation and extension of the S language, developed by an international team of statisticians, including John Chambers. What evolved into the R Project for Statistical Computing was originated by Ross Ihaka and Robert Gentleman at the University of Auckland, New Zealand. R is the first letter of both Ross and Robert, and it is also the letter before S in the alphabet [8]. "Some languages exist purely to achieve a task within some domain (a specific area of interest such as finance, technical drawing, or machine control) and these are referred to as domain specific languages (DSLs). R is much more flexible than that because you can write your code so that it achieves whichever goal you need" [9].

This article promotes learning of R programming language by students, researchers, and teachers from economic field. The remaining part of the paper is structured as follows. The next section reviews the existing literature on the subject analysed. This is followed by the research methodology section, and the results and discussions. The final section concludes on learning R programming language.

2. Literature Review

R is "used in almost every area where statistics or data analyses are needed. Finance, marketing, pharmaceuticals, genomics, epidemiology, social sciences, and teaching are all covered, as well as dozens of other smaller domains" [10]. One of the more readable languages, R is "used both professionally and recreationally by a fastgrowing number of users. Anywhere you find data, there's a good chance you'll find someone working with R", as Carroll (2018) says [9]. The R environment has become, nowadays, one of the most used statistical analysis tools, being used in university and academic research environments, but also in the business environment. R has the support of the international academic and scientific community, but also of many international companies. More and more companies are using R as a data analysis tool. Among them we mention: Google, Facebook, Mozilla, Twitter, The New York Times, The Economist, NewScientist, Lloyd's, Bing, Johnson&Johnson, Pfizer, Shell, Bank of America, Ford. R is also supported by the academic community. The world's major universities support R, as do other open-source software or initiatives [11]. "R has become the language of choice for use in academic analytics circles because of its sophisticated expressibility for statistical algorithms. It is open source and freely available via download for all common computer operating systems. And thousands of previously contributed and available packages eliminate the need for redeveloping common algorithms from scratch" [12].

Today, R "remains the primary language of academic statisticians, and it also has a prominent place among analysts in business and government as well" [13]. In the book "R for Everyone: Advanced Analytics and Graphics", Lander (2017) has written the following: "R is a wonderful tool for statistical analysis, visualization and reporting. Its usefulness is best seen in the wide variety of fields where it is used. We alone have used R for projects with banks, political campaigns, tech startups, food startups, international development and aid organizations, hospitals and real estate developers. Other areas where we have seen it used are online advertising,

insurance, ecology, genetics and pharmaceuticals. R is used by statisticians with advanced machine learning training and by programmers familiar with other languages and also by people who are not necessarily trained in advanced data analysis but are tired of using Excel" [14].

Shankar (2023) has made a list of 10 best R books in a general way, but also one with other honorable R programming books, which can be found at the address https://hackr.io/blog/best-r-books [15].

Torfs and Brauer (2014) made a (very) short introduction to R. The document contains explanations, examples and exercises on: getting started (install R, install RStudio, RStudion layout, working directory, libraries), some first examples of R commands (calculator, workspace, scalars, vectors and matrices, functions, plots), help and documentation, scripts, data structures (vectors, matrices, data frames, lists), graphics, reading and writing data files, not available data, classes (characters, dates), programming tools (if-statement, for-loop, writing your own functions), and some useful references (functions, keyboards shortcuts, error messages) [16].

Gillespie and Lovelace (2017) recommended resources for learning R: teaching materials, introductory resources, guides, websites, tutorials, books [17]. Buttrey and Whitaker (2017) described some of the resources available to help learning about R: at the command line, the online manuals, on the internet, and further reading [13]. To learn coding in R, Shmueli and Lichtendahl Jr. (2016) listed some coding resources [18]. In a chapter of his book, "Statistical Analysis with R for Dummies", Schmuller (2017) pointed readers to some of the helpful web-based resources the R community has created [19].

In chapter 7 of the book "Computing with Data", entitled "Learning R", Lebanon and El-Geish (2018) describe similarities and differences between R and its close relatives: Matlab and Python [20].

"Why Learn to Program in R?" is a title of a subchapter, written by Fox and Weisberg (2019) in their book "An R Companion to Applied Regression". They explain why someone should learn to program in R, illustrating what he might hope to accomplish using simple examples [8].

3. Research Methodology

R provides "a general language for interactive computations, supported by techniques for data organization, graphics, numerical computations, modelfitting, simulation, and many other tasks. The core system itself is greatly supplemented and enriched by a huge and rapidly growing collection of software packages built on R and, like R, largely implemented as open-source software. Furthermore, R is designed to encourage learning and developing, with easy starting mechanisms for programming and also techniques to help you move on to more serious applications" [21].

Carl Howe, the Director of Education at RStudio, leading a team of professional educators and data scientists at RStudio whose mission to train the next million R users globally, said: "Many students believe that R is obscure, complex, and difficult to write. However, data from a new large-scale survey of R users conducted by RStudio shows that new R users are taking dramatically different learning paths from those who learned R as recently as 2 years ago, and these new learning paths are changing its perception" [22].

Research is "an activity that requires effort, study, time, validating specific hypotheses, invalidating other hypotheses, etc." [23]. The aim of this paper is to promote learning of R programming language by students, researchers, and teachers from economic field. In order to do this, we have formulated the following research questions (RQ):

RQ1: Learning a programming language like R is the same as learning a spoken language?

RQ2: What is the difference between R and RStudio?

RQ3: How can we gain R skills?

These are the questions we propose to answer through this research paper. The goal is helping beginners to enter into the R system. Results consist in providing information and sources to help economist and other people interested in starting learning R programming language.

4. Analysis and Results

RQ1: Learning a programming language like R is the same as learning a spoken language?

Yes, some of the authors agree with an affirmative answer. For Davies (2016), "Learning to use and program in a computing language is much the same as learning a new spoken language. At the beginning, it is often difficult and may even be daunting - but total immersion in and active use of the language is the best and most effective way to become fluent" [24]. Dayal (2015) considers that "we learn R in the same way we would learn a language. The great advantage of R is that it is free, extremely flexible and extensible" [25]. "R has one fairly big advantage over other statistical packages in that it is free. That's right, it's free. Completely and utterly free. People say that there's no such thing as a free lunch, but they're wrong: R is a feast of succulent delights topped off with a baked cheesecake and nothing to pay at the end of it" [26]. Other authors have an opposite opinion. For Adler (2012), "Learning a computer language is a lot like learning a spoken language (only much simpler). If you're just visiting a foreign country, you might learn enough phrases to get by without really understanding how the language is structured. Similarly, if you're just trying to do a couple of simple things with R (like drawing some charts), you can probably learn enough from examples to get by. However, if you want to learn a new spoken language really well, you have to learn about syntax and grammar: verb conjugation, proper articles, sentence structure, and so on. The same is true with R: if you want to learn how to program effectively in R, you'll have to learn more about the syntax and grammar" [27]. "R has a command line interface that offers considerable advantages over menu systems in terms of efficiency and speed once the commands are known and the language understood. However, the command line system can be daunting for the first-time user, so there is a need for concise texts to enable the student or analyst to make progress with R in their area of study" [28].

Every day, no matter the domain or place, people face new challenges and they have to learn new things to solve their problems. Learning R is "a gratifying experience that makes life so much easier for so many tasks" [14]. Since Joseph Adler, a senior data scientist at LinkedIn, was first introduced to R, he has "used R to do many different things: estimate credit risk, analyze baseball statistics, and look for Internet security threats" [27]. He says that he has learned a lot about data and matured a lot as a data analyst. In the forewood of the book "Hands-On Programming with R: Write Your Own Functions and Simulations" written by Grolemund (2014), Hadley Wickham, Chief Scientist at RStudio, explains: "Real challenges are a great way to learn, because you're not memorizing functions void of context; instead, you're learning functions as you need them to solve a real problem. You'll learn by doing, not by reading. As you learn to program, you are going to get frustrated. You are learning a new language, and it will take time to become fluent" [29]. Vikram Dayal, an R economics books writer, has the same opinion on learning R: "We learn by doing and develop an intuitive understanding of quantitative economics, to complement the formal and mathematical approach of textbooks" [25]. Robert and Casella (2010) consider the following: "The best, and in a sense the only, way to learn R is through trial-anderror on simple and then more complex examples. Reading the book with a computer available nearby is therefore the best way of implementing this recommendation" [30].

Learning R programming language is an ongoing process that takes place throughout whole professional life without an end date. Pedro J. Aphalo, Senior University Lecturer of the University of Helsinki and author of R books, confesses to us: "I have been using R since around 1998 or 1999, but I am still constantly learning new things about R itself and R packages. With time, it has replaced in my work as a researcher and teacher several other pieces of software:

SPSS, Systat, Origin, MS-Excel, and it has become a central piece of the tool set I use for producing lecture slides, notes, books, and even web pages. This is to say that it is the most useful piece of software and programming language I have ever learned to use. Of course, in time it will be replaced by something better, but at the moment it is a key language to learn for anybody with a need to analyze and display data" [31].

RQ2: What is the difference between R and RStudio?

R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS [32]. Can be downloaded from CRAN (Comprehensive R Archive Network): https://cran.r-project.org/. A screen shot of the latest version of R, 4.3.1 (Beagle Scouts) (released on 2023-06-16), is shown in Figure 1.

R is an object-oriented language. How does R work? "At first sight, R environment could seem too complex for a non-specialist or for a non-programmer. In reality, things are different. A major feature of R environment is just its flexibility. While classical software displays the results of an analyze instantly, R stores these results in an object, so an analyze can be performed without displaying any results" [11]. The R console window is useful when the user has a few lines of code to run. It is not anyway the most user-friendly interface of the R environment.

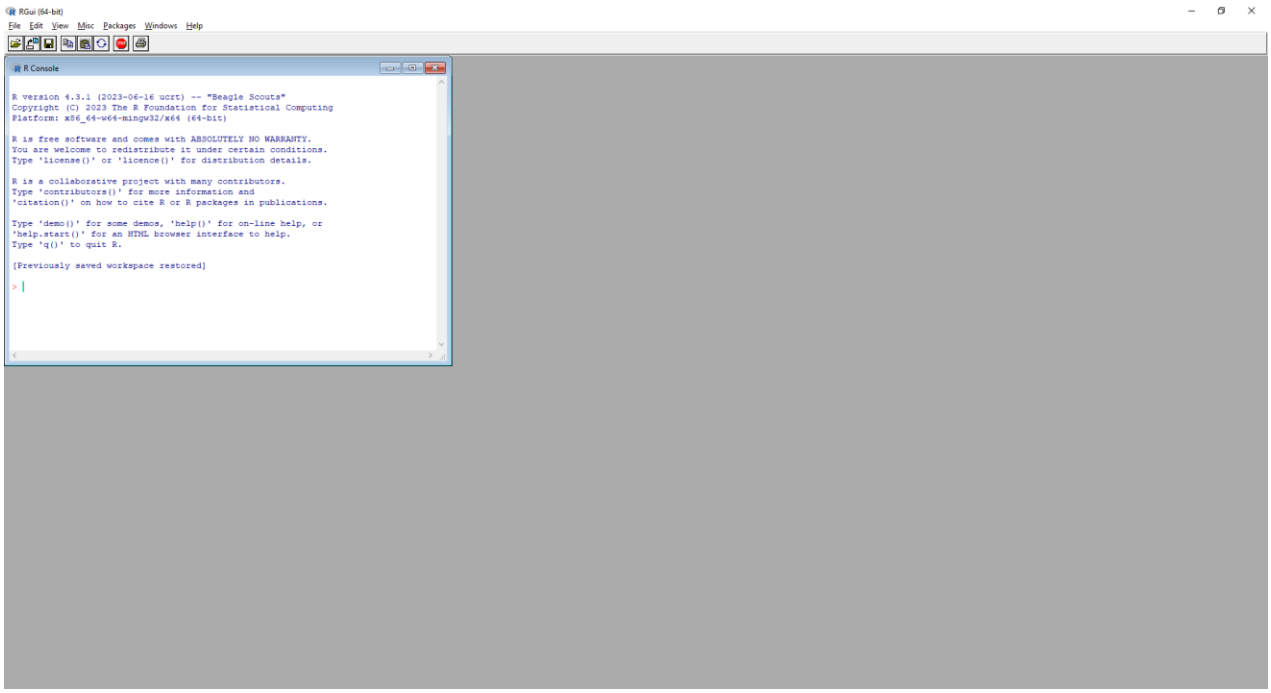

Figure 1: R Main Window [33]

RStudio is an integrated development environment (IDE) for R and Python, one of the most popular ways to run R [27]. It includes a console, syntax-highlighting editor that supports direct code execution, and tools for plotting, history, debugging, and workspace management. RStudio is available in open source and commercial editions and runs on the desktop (Windows, Mac, and Linux) [34]. A screen shot of the latest version of R Studio, 2023.06.1+254 (released on 2023-07-07), is shown in Figure 2.

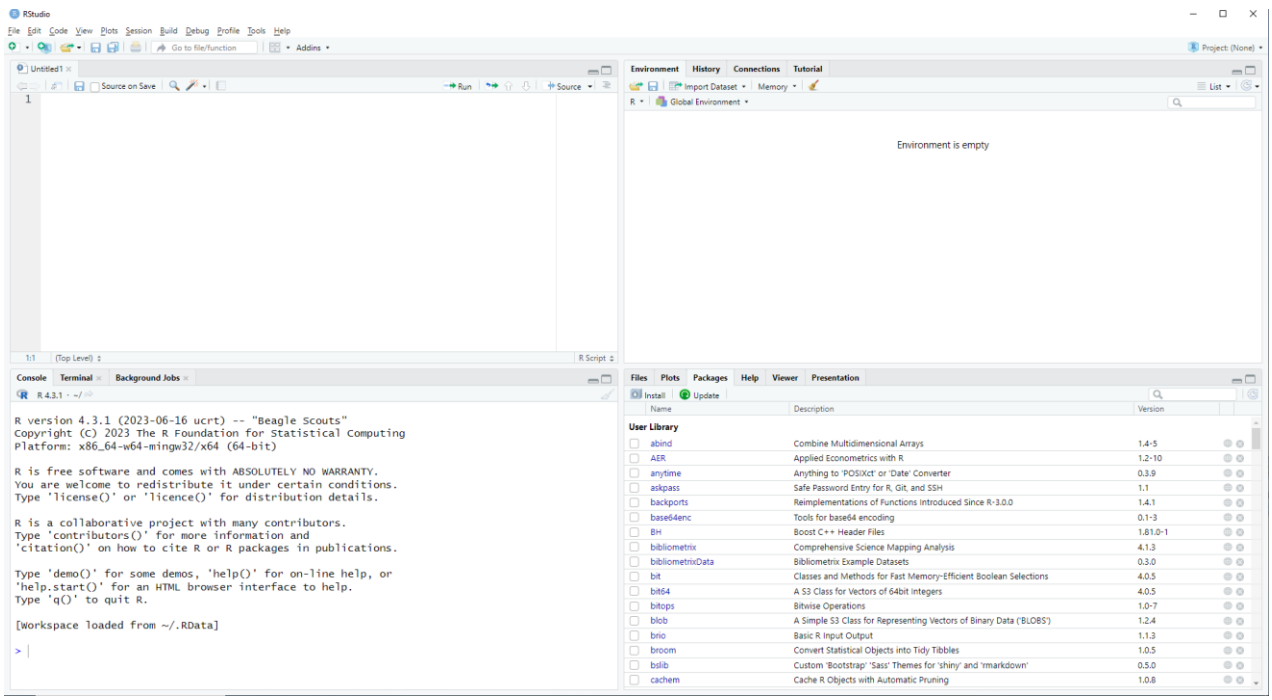

Figure 2: R Studio Main Windows [35]

Since the end of the year 2022, RStudio has become Posit. To learn more about Posit and download a copy, see https://posit.co/.

Beside RStudio, there are other graphical interfaces, as follows [10, 11, 36, 37]:

1. Eclipse StatET™ (https://projects.eclipse.org/projects/science.statet) is an Eclipse-based IDE for R. It offers a set of mature tools for R coding and package building [38].

2. Emacs Speacks Statistics (https://ess.r-project.org/) is a text and code editor which has a statistics add-in called Emacs Speaks Statistics (ESS), famous for having keyboard shortcuts for just about everything one could possibly do.

3. JGR (speak "Jaguar") is a Java-based GUI for R. Can be found at https://github.com/markush81/JGR.

4. NppToR (https://sourceforge.net/projects/npptor/) plugs into Notepad++ to give R integration.

5. PyCharm (https://www.jetbrains.com/pycharm/) offers excellent support for R programming by using the R plugin while being primarily built for Python programming.

6. R commander (https://socialsciences.mcmaster.ca/jfox/Misc/Rcmdr/) is a graphical interface used especially for statistical analyses, having incorporated different functionalities, as: nonparametric tests, dimensional analyzes, regression modelling, continuous/discrete distributions, hypothesis tests. It also provides facilities for importing data from different formats and to make graphs. The package which allow the using of R commander interface is called Rcmdr.

7. Rattle (R Analytic Tool To Learn Easily) (https://rattle.togaware.com/) is a GUI used for data mining, which provides facilities for statistical tests, transformation of data sets, clusters, decision tree models, error matrix, correlation analyses, graphical representations of the models. Figure 3 shows the steps for using the Rattle.

8. Rkward (https://rkward.kde.org/)

9. SciViews-K (https://github.com/SciViews/sciviewsk) an extension for the Komodo IDE to work with R.

10. Tinn-R (https://tinn-r.org/en/) is a modern editor/word processor, that help write R code.

11. Vim-R (https://www.vim.org/scripts/script.php?script_id=2628) is a plug-in for Vim that provides R integration.

12. Visual Studio Code (https://code.visualstudio.com/docs/languages/r)

```
> # Install the rattle package
> install.packages("rattle")

> # Load the rattle package into the memory
> library("rattle")

> # Use the function rattle
> rattle()
```

Figure 3: Steps for using Rattle

RQ3: How can we gain R skills?

To learn the R programming language, an excellent starting point for new R users can be found in "Introduction to R", available from CRAN [39].

At present, R has the following seven reference manuals [40]:

- "An Introduction to R", a manual providing information on data types, programming elements, statistical modelling and graphics. It is based on the former "Notes on R", gives an introduction to the language and how to use R for doing statistical analysis and graphics.

- "R Data Import/Export", a guide to importing and exporting data to and from R. Describes the import and export facilities available either in R itself or via packages which are available from CRAN.

- "R Installation and Administration", a guide to installation and administration for R.

- "Writing R Extensions", a guide to extending R, describing the process of creating R add-on packages, writing R documentation, R's system and foreign language interfaces, and the R API. Covers how to create your own packages, write R help files, and the foreign language (C, C++, Fortran, ...) interfaces.

- "The R Language Definition", an introduction to the R language, explaining evaluation, parsing, object oriented programming, computing on the language, and so forth. That is, the objects that it works on, and the details of the expression evaluation process, which are useful to know when programming R functions.

- "R Internals", a guide to the internal structures of R and coding standards for the core team working on R itself.

- The R Reference Index: contains all help files of the R standard and recommended packages in printable form.

These manuals for R, available at https://cran.r-project.org/manuals.html, were created on Debian Linux and may differ from the manuals for Mac or Windows on platform-specific pages. The correct version of the manuals for each platform are part of the respective R installations. The manuals change with R, hence the R Development Core Team provides versions for the most recent released R version (R-release), a very current version for the patched release version (R-patched) and finally a version for the forthcoming R version that is still in development (R-devel). These manuals are updated with each new release of R [40]. Translations of manuals into other languages than English are available from the contributed documentation section (only a few translations are available), at https://cran.r-project.org/other-docs.html [41]. At this link can be found manuals and tutorials provided by users of R, in English and other languages. "R pentru începători", the Romanian version of "R for Beginners" by Emmanuel Paradis, translated by Ana-Maria Dobre, is the only document available in Romanian, at https://cran.r-project.org/doc/contrib/Paradis-rdebuts_RO.pdf [42].

For an efficient learning, Gillespie and Lovelace (2017) give the following top five tips [17]:

1. Use R's internal help. Try swirl.

2. Read about the latest developments in established outlets such as the Journal for Statistical Software, the R Journal, R lists, and the blogosphere.

3. If stuck, ask for help! A clear question posted in an appropriate place, using reproducible code, should get a quick and enlightening answer.

4. For more in-depth learning, nothing can beat immersive R books and tutorials. Do some research and decide which resources you should use.

5. One of the best ways to consolidate learning is to write it up and pass on the knowledge; telling the story of what you've learned with also help others.

R has a number of ways of getting help to learners. Typing `help()` R console is for on-line help, and `help.start()` for an HTML browser interface to help. Figure 4 shows different commands users can type to get help for a function or object (e.g. mean, the generic function for the arithmetic mean), or for a package (e.g. ggplot2, a package entitled "Create Elegant Data Visualisations Using the Grammar of Graphics"). A feature of the R help system is the facility it provides to execute most examples in the help pages via the `example()` command. Some packages contain vignettes, discursive documents describing the use of the package. To find out what vignettes are available in the packages installed on R system, one should enter the command `vignette()`. The command `vignette(package="package-name")` displays the vignettes available in a particular installed package, and the command `vignette("vignette-name")` or `vignette("vignette-name", package = "package-name")` opens a specific vignette [8].

```
> # Get help for mean function
> help(mean)
> # or, for short
> ?mean

> # The function help.search is helpful for searching within manual pages
> help.search("mean")
> # or, for short
> ??mean

> find("mean") # returns where mean can be found

> # Get examples for mean function
> example(mean)

> # Get help for package ggplot2
> help(package = "ggplot2")
> library(help = ggplot2)

> # Get the vignettes available for package ggplot2
> vignette(package = "ggplot2")
> vignette("ggplot2-in-packages") # opens the vignette ggplot2-in-packages

> # Browse all the vignettes
> browseVignettes()
```

Figure 4: Commands of getting help in R

Figure 5 shows RStudio's help window, where beginners can find information structured on the following categories: R Resources, RStudio, Manuals, Reference, and Miscellaneous Material. A click on Learning R Online from R Resources takes us on the page

https://education.rstudio.com/ [43], where anyone who wants to learn R can find a learning path to choose: beginners, learners, teachers. For beginners there are 6 ways to begin learning R, listed at the address https://education.rstudio.com/learn/beginner/.

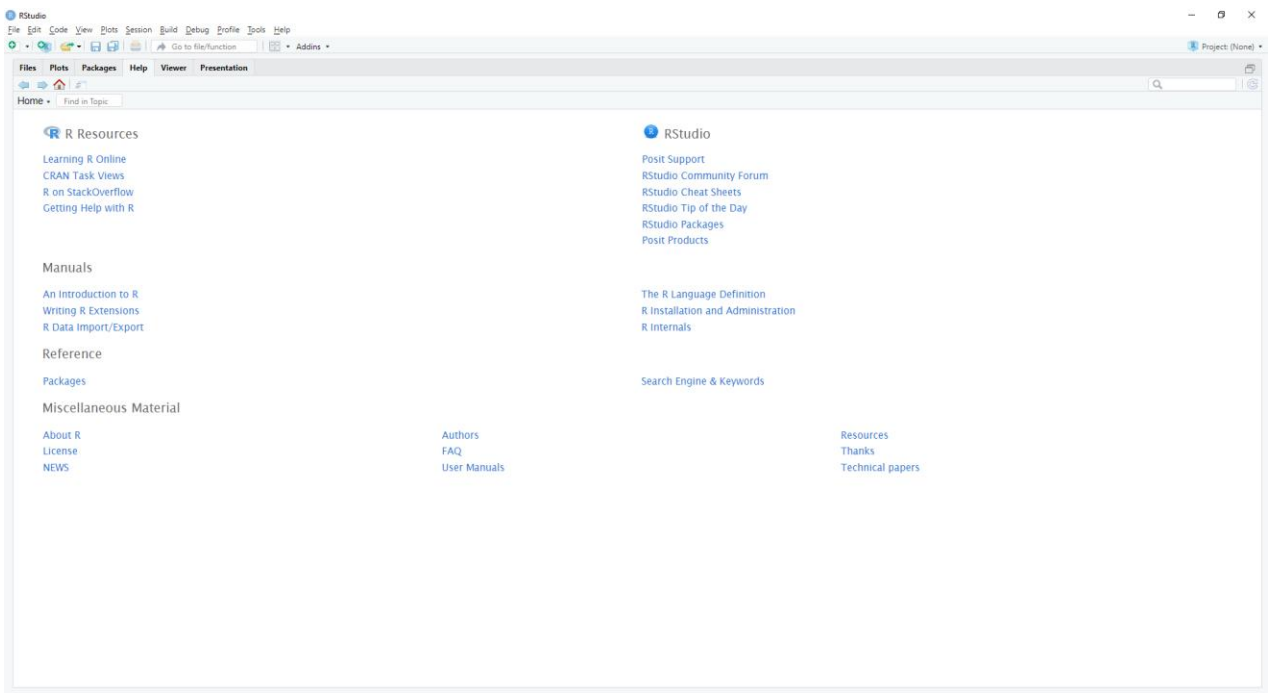

Figure 5: RStudio's Help Window [35]

R has a package called swirl (Statistics with Interactive R Learning), with the title "Learn R, in R". The swirl system is a collection of interactive courses to teach R programming and data science within the R console [44]. swirl is "an interactive teaching platform for R. It offers a number of extensions and, for the pioneering, the ability for others to create custom extensions. The learning curve and method will not work for everyone, but this package is worth flagging as a potent self-teaching resource. In some ways, swirl can be seen as the ultimate internal R help as it allows dedicated learning sessions, based on multiple choice questions, all within a usual R session" [17]. It requires the installation of the swirl package, then use of the install from swirl() function to download courses. In Figure 6 we introduced the steps for installing the swirl package and loading it into the memory, and the first lines of discussion from lesson 1.

```
> # Install the swirl package in RStudio
> install.packages("swirl")

> # Load the swirl package into the memory
> library(swirl)

| Hi! I see that you have some variables saved in your workspace. To keep things
| running smoothly, I recommend you clean up before starting swirl.

| Type ls() to see a list of the variables in your workspace. Then, type
| rm(list=ls()) to clear your workspace.

| Type swirl() when you are ready to begin.

> # Remove all the objects from memory
> rm(list=ls())
```

```
> swirl()

| Welcome to swirl! Please sign in. If you've been here before, use the same
| name as you did then. If you are new, call yourself something unique.

What shall I call you? Sorin

| Thanks, Sorin. Let's cover a couple of quick housekeeping items before we begin our
| first lesson. First of all, you should know that when you see '...', that means you
| should press Enter when you are done reading and ready to continue.

...  <-- That's your cue to press Enter to continue

| Also, when you see 'ANSWER:', the R prompt (>), or when you are asked to select from
| a list, that means it's your turn to enter a response, then press Enter to continue.

Select 1, 2, or 3 and press Enter

1: Continue.
2: Proceed.
3: Let's get going!

Selection: 1

| You can exit swirl and return to the R prompt (>) at any time by pressing the Esc
| key. If you are already at the prompt, type bye() to exit and save your progress.
| When you exit properly, you'll see a short message letting you know you've done so.

| When you are at the R prompt (>):
| -- Typing skip() allows you to skip the current question.
| -- Typing play() lets you experiment with R on your own; swirl will ignore what you
| do...
| -- UNTIL you type nxt() which will regain swirl's attention.
| -- Typing bye() causes swirl to exit. Your progress will be saved.
| -- Typing main() returns you to swirl's main menu.
| -- Typing info() displays these options again.

| Let's get started!

...

| Please choose a course, or type 0 to exit swirl.

1: R Programming
2: Take me to the swirl course repository!

Selection: 1

| Please choose a lesson, or type 0 to return to course menu.

 1: Basic Building Blocks      2: Workspace and Files        3: Sequences of Numbers
 4: Vectors                    5: Missing Values             6: Subsetting Vectors
 7: Matrices and Data Frames   8: Logic                      9: Functions
10: lapply and sapply         11: vapply and tapply         12: Looking at Data
13: Simulation                14: Dates and Times           15: Base Graphics

Selection: 1
```

```
  |                                                                      |   0%

| In this lesson, we will explore some basic building blocks of the R programming
| language.

...

  |=====                                                                 |   3%
| If at any point you'd like more information on a particular topic related to R, you
| can type help.start() at the prompt, which will open a menu of resources (either
| within RStudio or your default web browser, depending on your setup). Alternatively,
| a simple web search often yields the answer you're looking for.

...

  |=========                                                             |   5%
| In its simplest form, R can be used as an interactive calculator. Type 5 + 7 and
| press Enter.

> 5 + 7
[1] 12

| Nice work!

  |==============                                                        |   8%
| R simply prints the result of 12 by default. However, R is a programming language
| and often the reason we use a programming language as opposed to a calculator is to
| automate some process or avoid unnecessary repetition.

...

  |===================                                                   |  11%
| In this case, we may want to use our result from above in a second calculation.
| Instead of retyping 5 + 7 every time we need it, we can just create a new variable
| that stores the result.

...

  |=======================                                               |  13%
| The way you assign a value to a variable in R is by using the assignment operator,
| which is just a 'less than' symbol followed by a 'minus' sign. It looks like this:
| <-

...

  |============================                                          |  16%
| Think of the assignment operator as an arrow. You are assigning the value on the
| right side of the arrow to the variable name on the left side of the arrow.

...

  |================================                                      |  18%
| To assign the result of 5 + 7 to a new variable called x, you type x <- 5 + 7. This
| can be read as 'x gets 5 plus 7'. Give it a try now.

> x <- 5 + 7
```

```
| Keep working like that and you'll get there!

  |=================================                                     |  21%
| You'll notice that R did not print the result of 12 this time. When you use the
| assignment operator, R assumes that you don't want to see the result immediately,
| but rather that you intend to use the result for something else later on.

...

  |=========================================                             |  24%
| To view the contents of the variable x, just type x and press Enter. Try it now.

> x
[1] 12

| You got it right!

  |=============================================                         |  26%
| Now, store the result of x - 3 in a new variable called y.

> y <- x - 3

| All that practice is paying off!

  |=================================================                     |  29%
| What is the value of y? Type y to find out.

> y
[1] 9

| Perseverance, that's the answer.
```

Figure 6: Steps for using swirl and starting the first lesson [45]

At the address https://www.youtube.com/watch?v=olOJfAjzdO8, can be found the tutorial "Learning R with Swirl" [46].

swirl courses is a collection of interactive courses for use with the swirl R package. Anyone interested can find instructions for installing these courses at web address https://github.com/swirldev/swirl_courses. Some of these courses are still in development. Further down are the current offerings [47], organized by level of difficulty:

1. Beginner

- R Programming: The basics of programming in R
- R Programming E: Same as the original, but modified slightly for in-class use. R Programming E is identical to R Programming, except the eliminated prompts for Coursera credentials at the end of each lesson and instead give students the option to send an email to their instructor notifying them of completion.
- The R Programming Environment

2. Intermediate

- Regression Models: The basics of regression modeling in R
- Getting and Cleaning Data: dplyr, tidyr, lubridate, oh my!

3. Advanced

- Statistical Inference: This intermediate to advanced level course closely follows the Statistical Inference course of the Johns Hopkins Data Science Specialization on Coursera. It introduces the student to basic concepts of statistical inference including probability, hypothesis

testing, confidence intervals and p-values. It concludes with an initiation to topics of particular relevance to big data, issues of multiple testing and resampling.

- Advanced R Programming

"There are many excellent R resources about topics such as visualization (e.g., Chang 2012), data science (e.g., Grolemund and Wickham 2016), and package development (e.g., Wickham 2015). There are even more resources on how to use R in particular domains, including Bayesian statistics, machine learning, and geographic information systems. However, there are very few unified resources on how to simply make R work effectively. Hints, tips, and decades of community knowledge on the subject are scattered across hundreds of internet pages, email threads, and discussion forums, making it challenging for R users to understand how to write efficient code" [17].

Users of the R environment inevitably interact with the large online community. The main online resources are as follows [11]:

- On-line support pages for each package (vignette). These represent a description of the documentation that is the basis for each package, accompanied by examples.
- Documentation available on CRAN website: https://cran.r-project.org/
- R-FAQ: https://cran.r-project.org/doc/FAQ/R-FAQ.html
- RSeek, a search engine created on Google platform: https://rseek.org/
- Website with news and tutorials: https://www.r-bloggers.com/
- Quick-R: https://www.statmethods.net/
- R for SPSS and SAS users: https://www.statmethods.net/
- R Journal: https://journal.r-project.org/

There are also a number of specialized websites and forums where questions can be asked [11]:

- R-help mailing list: https://www.r-project.org/mail.html
- Stackoverflow: https://stackoverflow.com/questions/tagged/r
- Stat Exchange https://stats.stackexchange.com/
- Talk Stats: http://www.talkstats.com/
- CrossValidated: https://stats.stackexchange.com/

On its official Web site, many free contributed documents are also available. The page https://www.r-project.org/doc/bib/R-books.html gives a partially annotated list of books that are related to R and may be useful to the R user community [48]. In addition, over 100 books related to R have been published and they are available at online bookstores. In particular, we recommend the books from Table 1.

Table 1. Suggested Readings

Book Title	Author(s)/ Reference	Published by	Year
A Data Scientist's Guide to Acquiring, Cleaning, and Managing Data in R	Samuel E. Buttrey and Lyn R.Whitaker [13]	John Wiley & Sons	2017
Advanced Object-Oriented Programming in R: Statistical Programming for Data Science, Analysis and Finance	Thomas Mailund [49]	Apress	2017
Advanced R	Hadley Wickham [50]	Chapman and Hall/ CRC	2019
Advanced R Statistical Programming and Data Models: Analysis, Machine Learning, and Visualization	Matt Wiley and Joshua F. Wiley [51]	Apress	2019
An Introduction to R for Quantitative Economics. Graphing, Simulating and	Vikram Dayal [25]	Springer	2015

Computing			
An Introduction to Statistical Learning with Applications in R	Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani [52]	Springer	2013
An R Companion to Applied Regression	John Fox and Sanford Weisberg [8]	SAGE	2019
Beginning Data Science in R: Data Analysis, Visualization, and Modelling for the Data Scientist	Thomas Mailund [53]	Apress	2017
Beyond Spreasheets with R: A Beginner's Guide to R and RStudio	Jonathan Carroll [9]	Manning	2018
Computational Finance: An Introductory Course with R	Argimiro Arratia [54]	Atlantis Press	2014
Data Mining and Business Analytics with R	Johannes Ledolter [55]	John Wiley & Sons	2013
Data Mining with R: Learning with Case Studies	Luís Torgo [56]	Chapman and Hall/ CRC	2017
Data Science with R: A Step By Step Guide With Visual Illustrations & Examples	Andrew Olesky [57]	Andrew Olesky	2018
Data Visualization: A Practical Introduction	Kieran Healy [58]	Princeton University Press	2019
Discovering Statistics Using R	Andy Field, Jeremy Miles and Zoë Field [26]	SAGE	2012
Efficient R Programming: A Practical Guide to Smarter Programming	Colin Gillespie and Robin Lovelace [17]	O'Reilly Media	2017
Empirical Research in Economics: Growing up with R	Changyou Sun [59]	Pine Square	2015
Financial Analytics with R: Building a Laptop Laboratory for Data Science	Mark J. Bennett and Dirk L. Hugen [12]	Cambridge University	2016
ggplot2 – Elegant Graphics for Data Analysis	Hadley Wickham [60]	Springer	2016
Hands-On Programming with R: Write Your Own Functions and Simulations	Garrett Grolemund [29]	O'Reilly Media	2014
Introduction ro R for Quantitative Finance	Gergely Daróczi, Michael Puhle, Edina Berlinger, Péter Csóka Dániel Havran, Márton Michaletzky, Zsolt Tulassay, Kata Váradi, and Agnes Vidovics-Dancs [61]	Packt Publishing	2013
Introduction to Time Series Modeling with Applications in R	Genshiro Kitagawa [62]	Chapman and Hall/ CRC	2021
Learn ggplot2 Using Shiny App	Keon-Woong Moon	Springer	2016

	[63]		
Learn R for Applied Statistics: With Data Visualizations, Regreesions, and Statistics	Eric Goh Ming Hui [64]	Apress	2019
Learn R: As a Language	Pedro J. Aphalo [31]	Chapman and Hall/ CRC	2020
Learning Base R	Lawrence M. Leemis [65]	Ascended Ideas	2021
Learning Microeconometrics with R	Christopher P. Adams [66]	Chapman and Hall/ CRC	2021
Learning Quantitative Finance with R	Param Jeet and Prashant Vats [67]	Packt Publishing	2017
Learning R Programming	Kun Ren [68]	Packt Publishing	2016
Learning R: A Step-by-Step Function Guide to Data Analysis	Richard Cotton [10]	O'Reilly Media	2013
Learning RStudio for R Statistical Computing	Mark P.J. van der Loo and Edwin de Jonge [69]	Packt Publishing	2012
Metaprogramming in R: Advanced Statistical Programming for Data Science, Analysis and Finance	Thomas Mailund [70]	Apress	2017
Multivariate Time Series Analysis: With R and Financial Applications	Ruey S.Tsay [71]	John Wiley & Sons	2013
Numerical Methods and Optimization in Finance	Manfred Gilli, Dietmar Maringer, and Enrico Schumann [72]	Academic Press	2019
Panel Data Econometrics with R	Yves Croissant and Giovanni Millo [73]	John Wiley & Sons	2019
Practical Data Science with R	Nina Zumel and John Mount [74]	Manning	2020
Quantitative Economics with R. A Data Science Approach	Vikram Dayal [75]	Springer	2020
R Cookbook: Proven Recipes for Data Analysis, Statistics, and Graphics	J.D. Long and Paul Teetor [76]	O'Reilly Media	2019
R for Data Science: Import, Tidy, Transform, Visualize, and Model Data	Hadley Wickham and Garrett Grolemund [77]	O'Reilly Media	2016
R for Dummies	Andrie de Vries and Joris Meys [37]	John Wiley & Sons	2015
R for Everyone: Advanced Analytics and Graphics	Jared P. Lander [14]	Pearson Education	2017
R for Microsoft Excel Users: Making the Transition for Statistical Analysis	Conrad Carlberg [78]	Pearson Education	2017
R Graphics	Paul Murrell [79]	Chapman and Hall/ CRC	2019
R Graphics Cookbook: Practical Recipes for Visualizing Data	Winston Chang [80]	O'Reilly Media	2018
R Guide to Accompany Introductory Econometrics for Finance	Robert Wichmann and Chris Brooks [81]	Cambridge University	2019

R in a Nutshell: A Desktop Quick Reference	Joseph Adler [27]	O'Reilly Media	2012
R in Action: Data Analysis and Graphics with R	Robert I. Kabacoff [82]	Manning	2015
R in Finance and Economics: A Beginner's Guide	Abhay Kumar Singh and David Edmund Allen [83]	World Scientific	2016
R Markdown Cookbook	Yihui Xie, Christophe Dervieux, and Emily Riederer [84]	Chapman and Hall/ CRC	2021
R Packages: Organize, Test, Document, and Share Your Code	Hadley Wickham [85]	O'Reilly Media	2015
Reproducible Research with R and RStudio	Christopher Gandrud [86]	Chapman and Hall/ CRC	2020
Statistical Analysis with R for Dummies	Joseph Schmuller [19]	John Wiley & Sons	2017
Text Mining with R: A Tidy Approach	Julia Silge and David Robinson [87]	O'Reilly Media	2017
The Analysis of Time Series: An Introduction with R	Chris Chatfield and Haipeng Xing [88]	Chapman and Hall/ CRC	2019
The Art of R Programming: A Tour of Statistical Software Design	Norman S. Matloff [89]	No Starch Press	2011
The Book of R: A First Course in Programming and Statistics	Tilman M. Davies [24]	No Starch Press	2016
The Environment in Economics and Development. Pluralist Extensions of Core Economic Models	Vikram Dayal [90]	Springer	2014
The Essentials of Data Science: Knowledge Discovery Using R	Graham J. Williams [91]	Chapman and Hall/ CRC	2017
The R Book	Elinor Jones, Simon Harden, and Michael J. Crawley [92]	John Wiley & Sons	2022
The R Primer	Claus Thorn Ekstrøm [93]	Chapman and Hall/ CRC	2016
Time Series Analysis and Its Applications: With R Examples	Robert H. Shumway and David S. Stoffer [94]	Springer	2017
Time Series Analysis: Forecasting and Control	George E.P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, and Greta M. Ljung [95]	John Wiley & Sons	2015
Time Series in Economics and Finance	Tomas Cipra [96]	Springer	2020
Using R And RStudio for Data Management, Statistical Analysis, and Graphics	Nicholas J. Horton and Ken Kleinman [39]	Chapman and Hall/ CRC	2015
Using R for Introductory Econometrics	Florian Heiss [97]	Florian Heiss	2020
Using R for Principles of Econometrics	Colonescu [98]	CreateSpace	2018

For Romanian learners who want to use R program in economics, there are published two books in Romanian:

- "R cu aplicații în statistică", written by Adrian Dușa, Bogdan Oancea, Nicoleta Caragea, Ciprian Alexandru, Nicolae Marius Jula, and Ana Maria Dobre, published in 2015, in Bucharest, by Bucharest University Publishing House [11];

- "Econometrie cu aplicații în R", author Dănuț-Vasile Jemna, 2017, Iași, Editura Universității Alexandru Ioan Cuza [99].

Also there is a web page, "Invata R", at https://www.r-project.ro/invatar/intro/#gsc.tab=0 [100].

In his book, "Learn R: As a Language", covering different aspects of the use of the R language, Aphalo (2020) noted: "Explanations are concise but contain pointers to additional sources of information, so as to encourage the development of a routine of independent exploration. This is not an arbitrary decision, this is the normal modus operandi of most of us who use R regularly for a variety of different problems. Some have called approaches like the one used here «learning the hard way», but I would call it «learning to be independent»" [31]. Davies (2016) tells us: "As a beginner, you must not only learn to use R for your specific data analysis goals but also learn to think like a programmer. This is partly why R has a bit of a reputation for being «hard» – but rest assured, that really isn't the case" [24].

R has "a steep learning curve - it does take a while to get used to the power of R - but no steeper than for other statistical languages" [101]. Alfredo (2011) considers that the learning curve for R software is "steeper than the learning curve of most commercial packages" [102]. Williams (2011) noted that "direct interaction with R has a steeper learning curve than using GUI based systems, but once over the hurdle, performing operations over the same or similar datasets becomes very easy using its programming language interface" [101].

5. Conclusions

Today, more than never, data science became "an indispensable tool for any organization, allowing for the analysis and optimization of decisions and strategy. R has become the preferred software for data science, thanks to its open source nature, simplicity, applicability to data analysis, and the abundance of libraries for any type of algorithm" [103]. R is used in many fields and has a long history. "R is freedom. R allows scientists to conduct statistical computing and draw graphs in a completely new way. It reflects the inner desire of all human beings for freedom: free to speak, free to dance, free to move, and now, free to do programming" [59]. Jonathan Carroll thinks that R "it's a great language that makes many tasks simpler and that has a nice way of doing things" [10]. "Out of the box, R has a lot of functionality but where the real power comes in is through its package mechanism and the large collection of packages available for download and use" [53]. "R has a number of packages that extend its capabilities. There are thousands of R packages on the web. By installing, and then loading a specific package we can extend R to tackle our specific problem" [25]. R has over 19000 packages.

"With the explosion of «Big Data» problems, statistical learning has become a very hot field in many scientific areas as well as marketing, finance, and other business disciplines. People with statistical learning skills are in high demand" [52]. R is being used in the disciplines of finance, banking, insurance, economics, stock market, marketing, computer science, and many other disciplines and fields. Specialists in these fields need R knowledge and skills to analyze data. Using it in education and research, the R programming language can bring increased

facilities to achieve results compared to other sotware tools; in this way it is suitable for researchers, data scientists, and teachers. In addition, with the help of the R programming language, research becomes reproducible; the condition is that both the data and the results of the data analysis in a research paper are available to readers via an R file.

Learning R programming language is the acquisition of information, knowledge, and skills of R software. "We all want to learn. No one is born a data scientist. Every person who works R today was once a complete beginner" [43]. "Learning a computer language like R can be either frustrating, fun, or boring. Having fun requires challenges that wake up the learner's curiosity but also provide an emotional reward on overcoming them" [31]. Anyone who wants to learn R programming language, will need a computer and the R software, a desire to learn something, and R sources (books, manuals, tutorials, forums, etc). Adler (2012) said that "there's no better way to learn something than by trying it yourself" [27]. Anyone can learn R language. For Amos A. Folarin, from University College London, "lucid and engaging – this is without doubt the fun way to learn R!" [82]. For all who want to learn R, we just say: "Learn the R language as a child would: Do not struggle, just play! If going gets difficult and frustrating, take a break! If you get a new insight, take a break to enjoy the victory!" [104].

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