Teaching Methodologies and Open Source Software: Empirical Application to Econometrics and Mathematics

Alcina Nunes and Carlos Balsa

Abstract — Nowadays, the software open source represents an important teaching resource. However, it is not sufficiently explored as an higher education teaching methodology. In subjects with a very specific goal, applied contents and attended by a small number of students, the commercial software is still preferred to the open source software. Aware of this reality, this paper presents a reflection about the use of open source software in Applied Econometrics and Mathematics. The adoption of two different software programmes – Gretl and Octave – allows the discussion about a comprehensive set of pedagogical, economical and technical advantages and some observed practical limitations. In practice, the refereed advantages are stressed when the students' results are analysed. Their academic results benefit from the adoption of software which is executed, distributed and improved freely.

Index Terms — Econometrics, Mathematics, *Open-Source software*, Teaching methodologies.

1 Introduction

The access to open source software is nowadays a rather unexplored source of academic pedagogic tools. Software tools which are crucial to the promotion of, both theoretic and practical, learning processes in higher education teaching institutions.

Along with commercial labels it is possible to find a large diversity of high quality free software. An excellent example of this software is the software gathered in the Free Software Foundation (FSF), established in 1985 to promote the use, study, change and redistribution of software (Free Software Foundation, 1985). The mentioned institution encourages the use of free software that results from individual and group contributions, especially those connected with an academic or scientific background. The requirements are that each user should follow the GNU General Public Licence which defines all the aspects related to the application of open source software (see http://www.fsf.org).

However, in spite of the advantages of the open source applications, as the freedom of execution, distribution and improvement, it is possible to find in our high education schools some resistance to abandon the use of commercial software with which the teachers seem to have created strong personal and professional links.

In the *Escola Superior de Tecnologia e de Gestão do Instituto Politécnico de Bragança (ESTiG-IPB*) the use of open source software is not uncommon. Indeed, the commercial software is being substituted by open source software concerning operative systems, internet navigation, e-mail management and word processing programmes. Still, when the application of software tools, in the teaching methodological processes, is analysed more carefully it is possible to verify that the use of commercial software is preferred to the use of free software. Such observation is true, essentially, when such methodological processes reach specific scientific areas targeted to a particularly small number of students.

The relative independence of higher education teachers concerning certain commercial software, associated with the methodological processes adopted in the classroom and the development of a strong customer loyalty, seems to constitute an obstacle to the adoption of open source software as a teaching methodological instrument. The non adoption of such tools seems to result from: (i) embedded teaching practices achieved by the use of specific software to answer specific scientific and/or pedagogical issues; (ii) resistance to learn and/or experiment a now software tool and; (iii) to some suspicion about what is available gratuitously in the web. In short, it is possible to state that such resistance to the adoption of open source software, as an instrument of

- *Alcina Nunes. Escola Superior de Tecnologia e Gestão de Bragança, Apartado 1134, 5301-857 Bragança. E-mail: alcina@ipb.pt.*
- *Carlos Balsa. Escola Superior de Tecnologia e Gestão de Bragança, Apartado 1134, 5301-857 Bragança. E-mail: balsa@ipb.pt.*

methodological processes enrichment, results not only from technical difficulties but also from cultural scepticism. Only like this it is possible to explain the persistence of such resistance even when the free tools approach the commercial tools in the sense that both are user friendly.

Econometrics and numerical methods are among the examples of scientific areas which specificity and empirical applicability demands the adoption of software programmes as teaching and knowledge transmission tools. Software like Eviews, Stata, SPSS, Matlab, Maple or Matemática have nowadays an ample diffusion into academic contexts. However, although the majority of property companies perform special prices to teaching institutions, not always their acquisition is seen as a priority by institutions facing budget constrains. Especially if the number of target students is not vast enough to justify the investment. Therefore the advantages presented by the open source software associated with to the strong budget constrains, experienced by the public teaching institutions, lead to the substitution of the commercial software by the free software.

In the subject Applied Econometrics lectured in the Management course the use of the traditional econometrical software (Eviews, Stata, SPSS) was replaced by GRETL (http://gretl.sourceforge.net/gretl_portugues.html). No other subject of the course adopted open source software as a teaching methodological tool. In the institution, at all, only other subject adopted open source software as an methodological tool. The subject of Numerical Methods lectured to Electrical Engineering and Mechanical Engineering courses adopted the OCTAVE (http://www.gnu.org/software/octave/) as an alternative to the commercial software Matlab produced by MathWorks, Inc. (www.mathworks.com). Since the open source software language is *quasi* totally compatible with the commercial software language, the previous mentioned software present themselves as an exceptional alternative in a context of budget constrains.

The comparative analysis of the implementation of different open source programmes to different subjects in different courses allows to infer about the effectiveness of their adoption and the pertinence of extend the use of free software to other subjects which use software tools as teaching methodological instruments.

The pedagogical, economic, technical and institutional consequences confirm that the adoption of open source software is a valuable option to the traditional software programmes adopted in the public higher education institutions.

The present paper is divided as fallows. Next section presents the open source software adopted mentioning their general features. Section 3 presents the advantages and disadvantages of their adoption as a methodological tool, in general and in each one of the particular subjects mentioned. After a section where the empirical results are discussed the final considerations will be presented.

2 GRETL AND OCTAVE PRESENTATION

Open source software is the designation of a set of operative systems which enjoy four characteristics universally accepted as essential for each user. These four characteristics are divided in four types of freedoms (which are never compulsory for the users). Freedom to: (i) execute the software for any kind of application; (ii) study and adapt its functioning to particular needs; (iii) redistribute an unlimited number of copies, and; (iv) improve and to make public the modifications introduced in the software allowing that everyone benefit from the introduced improvements. The above mentioned freedoms characterize, generically, the GRETL and OCTAVE software.

The GRETL software (Cottrell e Lucchetti, 2007) can be described as a computer programme aiming to perform econometric analysis and that uses a C programming language. It is possible to find GRETL versions available for Windows and Linux operative systems.

The OCTAVE software (Eaton, 2002) can be understood as a high level language aiming to perform numeric computation. Its interface, in the form of command lines, allows “to call” functions aiming to solve numerous linear and no-linear problems. The language is very intuitive making it easily overcome by students. The software also contains a large number of pre-programmed mathematical functions and numeric methods which allow rapidly achieve the desired results, even in the case of complex problems. Although there is an OCTAVE version available to function in Windows the software is mainly developed to function in Linux being a part of the Debian Linux or SuSe Linux.

3 ADVANTAGES AND LIMITATIONS OF THE OPEN SOURCE SOFTWARE

The use of econometrical and mathematical software in the classroom, as a teaching methodological tool, is of great importance to the transmission of contents and the acquisition of empirical competences.

The designation of the subject Applied Econometrics points out that the knowledge goals depend of the empirical application of mathematical and statistical concepts in the field of the economical measurement. In particular, it is intended that the students achieve skills in the management of statistical data which allow them to test and validate theoretical hypothesis and take scientifically grounded management decisions. This desired acquisition of competences process needs, therefore, the adoption of computer programmes suitable to reach the above mentioned goals.

The use of econometric software was not a novelty, still, the difficulties felt by the students when using the commercial software adopted and the financial cuts for the acquisition of academic licences led to the adoption of GRETL. The use of traditional commercial software in English language and its non availability outside the classroom turn into a deficient programme comprehension, by the students, and in a wrong perception about the degree of difficulty of the empirical applications. Other disadvantage of the commercial econometric programmes referred to the limitation of its use outside the context of the normal classroom. This disadvantage represented a practical impossibility to continuously evaluate the student's progresses. The student could not develop self-leaning work outside the classroom and could not present more extended papers and reports.

In the more empirical subjects of the engineering courses the adoption of computer software allows to focus the attention in physical phenomena and not only in the programming of mathematical methods used in modelling. In other cases, when the intention is to illustrate the potential of certain mathematical tools, the use of computer programmes allows a quick return of results. In the study plans of the Electrical Engineering and Mechanical Engineering courses appears the subject of Numerical Methods where it was decided to introduce the use of the computer to solve the classroom proposed problems.

The use of the computer with the software OCTAVE solved difficulties related with several different limitations. Previously the numerical methods problems should be solved "by hand" with the help of a calculator. This was a severe limitation to the number and dimension of problems proposed. It was necessary to chose only a small number of problems, which should be the most representative, not allowing to stress particular cases of numerical methods. Another limitation was the dimension of the proposed problems. They could only include a small number of variables which do not allowed the representation of real study cases. Finally the disparity of calculator models, more or less sophisticated, among students originated some disparity in the available tools.

Each software application advantages and limitations are presented in Tables 1, 2 and 3. The presented advantages are divided in three essential parts: pedagogical, economical and technical advantages.

Many of the software GRETL and OCTAVE advantages are generic and transversal to any open source software so they are common between the two programmes (Table 1).

TABLE 1

GENERIC ADVANTAGES OF THE OPEN SOURCE SOFTWARE

Pedagogical
* Freedom of execution (they can be installed in any compute and any place). Students can download and use the software in their personal computers outside the classroom. * Promotion of a responsible and legally accepted attitude towards the utilization of computer software. Avoiding the illegal copy of commercial software students are stimulated to perform ethical actions concerning the intellectual and industrial property rights. * The open source software allows to each teacher and student to study and improve it. The constant improvements allow to teachers and students to be up to date relating to the scientific advances.
Economical
* Budget saving for both institutions and students.
Technical
* Possibility to use in several platforms and the consequent availability to different operative systems (*Microsoft Windows, Apple Macintosh, Linux*). * Larger software warranty, security and stability and a larger immunity to virus and worms.

As it was referred, the advantages of the GRETL and OCTAVE adoption are common between them. They only distinguish in the pedagogical aspects (Table 2). This difference shows, however, another advantage of the open source software – its adaptability to the scientific and pedagogic specificities of each subject and to the teaching methodology. This last presented advantage is fundamental in higher education teaching systems.

TABLE 2
ADVANTAGES OF THE ADOPTED SOFTWARE

GRETL	OCTAVE
Pedagogical	
* Possibility of continuous evaluation implementation through the realization of empirical papers. by the students * Possibility to use econometric software in Portuguese language. * Availability of the software and the respective manual. * User friendly. Knowledge of computer programming is not needed. This advantage is particularly important to Management students not familiar with computer science. * Good compatibility with traditional Word and data processors as Word and Excel. * Easy manipulation of statistical data generated in different types of econometric software. * Availability of data bases coming from well known econometric manuals.	* Possibility of resolution of real exercise problems. * Possibility of resolution of ample exercises without a great amount of effort. * Possibility of resolution of a bigger number of exercises and, consequently, of a bigger number of particular cases. * Substitution of a large number of different calculator models by a unique tool of computation. * Availability of a great number of elementary pre-programmed mathematical functions which allow a quick achievement of results. * Inclusion of numerical algorithms coming from scientific “libraries” as LAPACK (Anderson et al, 1999). * Possibility to focus on the resolution methods and not on programming. Programming these methods in C or Fortran is fastidiously and subject to errors which result in a large lost of time.

The more specific advantages, presented by each one of the mentioned open source software, concern to the specific goals and aims of the subjects were the software is adopted. Therefore the differences among the advantages presented by GRETL and OCTAVE refer to pedagogical advantages.

The limitations of each one of the software, presented in Table 3, result from the teacher’s perception. The limitations of each one of the software analysed are, therefore, subjective and, again, result from the pedagogical specificities and needs of the subject were it was applied.

TABLE 3
LIMITATIONS OF THE ADOPTED SOFTWARE

GRETL	OCTAVE
The teacher must study with detail the features and applicability of the software if he/she not possesses elementary knowledge related to computer science. * Short number of support books in a particular national language (In this case, Portuguese).	
	* Idiom of the programme – Only English. * User interface is not so user-friendly or visually appealing compared with commercial software.

The Gretl and Octave adoption specific limitations are almost concerned with the traditional limitations of the open source software. Namely the user interface of the open source software is not so user friendly or visually attractive as some commercial software. Although the previous limitation was, in practice, observed only for Octave. The number of academic/scientific publications concerning the use of open source software is very scarce. The manual are essentially restricted to each open source software web page. For example, it is possible to find the manual for Gretl using the link http://ricardo.ecn.wfu.edu/pub//gretl/manual/. Additionally, the few manuals provided are restricted to English language and are not available in a particular national language. For instance, the only book, in Portuguese, about Numerical Methods that refers to Octave as supporting tool is mentioned in reference [5]. However, theses limitations can be easily compensated by some additional pedagogical effort.

4 EMPIRICAL RESULTS

In the pedagogical advantages of the open source software was stressed the importance of the software application as a way to allow the student continuous knowledge evaluation. A continuous evaluation carried out through the execution of empirical applications. Such

advantage can be confirmed, in practice, by the analysis of the student's results. In particular, the results of the students subjected to the introduction of the open source software Gretl and Octave as pedagogical tools.

The comparative analysis of the statistical data from each one of the above mentioned subjects – Applied Econometrics and Numerical Methods – and the open source software programmes, GRETL and OCTAVE, respectively, is presented in Table 4.

TABLE 4

STATISTICAL DATA – STUDENTS RESULTS

Course	**Management**	**Electrical Engineering**	**Mechanical Engineering**
Subject	**Econometric Methods**	**Numerical Methods**	
Software	**GRETL**	**OCTAVE**	
Number of students	14	50	33
Presence	14	29	19
No Ordinary Students	4	8	3
$\frac{\text{Presence}}{\text{Number of Students}}$	43%	58%	58%
Evaluated Students	14	31	24
Continuous Evaluated Students	11	31	24
Approved Students	14	25	16
$\frac{\text{Approved Students}}{\text{Evaluated Students}}$	100%	81%	67%
$\frac{\text{Approved Students}}{\text{Total Number of Students}}$	100%	50%	48%
$\frac{\text{Approved Students}}{\text{Continous Evaluated Students}}$	127%	81%	67%

Before presenting the results expressed in Table 4 is important to mention two significant notes: (i) the presence in classes was mandatory for the ordinary students in both Electrical Engineering and Mechanical Engineering courses; (ii) the continuous evaluation was not a mandatory evaluation method for the Applied Econometrics subject.

As could observed in the previous table, the pedagogical advantage of Gretl's and Octave's software use, which refers to the continuous evaluation of students, is notorious and represents an added-value in terms of academic success. This perception is more evident in the Applied Econometrics subject for the Management Course. The presence in classes was not mandatory for this subject students. Indeed, in average, only 43% of the students had attended the classes and 29% were not ordinary students. 79% of the total number of students had chosen the continuous evaluation method, thought.

The simplicity of the software installation and use were the main reasons for the choice of the alternative non mandatory evaluation method. This evaluation method was even chosen for a great number of non ordinary students who could not be present during classes.

The results, measured in terms of academic results are obvious – 100% of the students were evaluated positively. The observed result surpassed one's expectations in such a way that the application of the software as a pedagogical tool persists in the classes.

In the Numerical Methods subject is also possible to verify equally good approval rates. It is important to notice the Electrical Engineering course with 81% of academic success. In opposition to these course students the students of Mechanical Engineering had showed fewer skills related to the use of computers. That is due to the less usual adoption of computer programmes in other subjects of the course. It was also observed a major resistance in the use of the Linux operative system and consequently a major resistance to the use of the Octave software. It is believed that could be the reason for the inferior approval rate – 67%. Nevertheless, such positive results were possible due to the adoption of a continuous evaluation methodology.

The students satisfaction concerning the use of open source software was not formally evaluated – was not made a formal questionnaire about their perception regarding the adoption of open source software as a teaching methodological tool – still, it seemed to the teachers involved that they were pleased with the use of this kind of software.

In particular, in the Econometric Methods subject, the easy execution of the Gretl programme in the students personal computers, its simplicity, the fact that the

software presents a Portuguese version and its compatibility with Word text processor were the fundamental aspects for students (even the less willing to adopted the use of new software) be satisfied during classes. It was not perceived any resistance to the adoption of the software.

For the Numerical Methods subject, although it was verified some reluctance in some student less familiarized with computers (the reason were explained in last section), it was observed a great motivation to use the Octave. The enthusiasm was due to its great potential concerning numerical computation and to its simplicity.

8 CONCLUSION

The practical application of specific open source software in scientific areas such applied econometrics or mathematics have shown to be an option with a high degree of pedagogical potential. The cost/benefit relation is insignificant. The advantages presented by the open source software are clearly superior to the possible specific limitations of its adoption in some scientific areas.

In theory, all the learning process implicated actors – students, teachers and institutions – can withdraw benefits from the replacement of proprietary software for open source software. In practice, such benefits are observed by high academic success rates.

The above presented conclusions have conducted to the maintenance of the Gretl and Octave applications and to advise its adoption as a pedagogical tool in higher education institutions.

ACKNOWLEDGMENT

The authors wish to thank the helpful comments of the participants on the 18th Luso-Spanish Conference in Management, Porto, 2008.

REFERENCES

[1] E. Anderson, Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney and D. Sorensen, "LAPACK Users' Guide - 3rd Edition", *Society for Industrial and Applied Mathematics, 1999.*

[2] A. Cottrell and R. Lucchetti, "Gretl Users' Guide", available on http://gretl.sourceforge.net/, 2007.

[3] J.W., Eaton, "GNU Octave Manual", *Network Theory Ltd*, 2002.

[4] Free Software Foundation, "Articles of Incorporation", *The Commonwealth of Massachusetts*, 1985.

[5] A. Quarteroni and F. Saleri, "Cálculo Científico com Matlab e Octave", Springer –Verlag, 2007.

Nunes. Alcina has a PhD degree in Economics, concluded in 2008, and is currently an Assistant Professor in the *Instituto Politécnico de Bragança*, Portugal. Her research interests and publications concern to public policy evaluation, econometrics and microeconomics.

Balsa. Carlos has a PhD in Computational Sciences, concluded in 2006, and is currently an Assistant Professor in the *Instituto Politécnico de Bragança*, Portugal. His research interests and publications concern to Numerical Methods applications.

.