Gender Equality in Tertiary Education and Research Institutions: An Evaluation Proposal

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Abstract: Gender inequality in research and innovation is well documented (European Commission, 2016) and tools to measure and monitor it have been proposed and tested within EU funded projects as GenderTime (Badaloni & Perini, 2016) or Effective gender equality in research and academia (EGERA) (http://www.egera.eu/). The evaluation proposal at the heart of this contribution has been developed within EQUAL-IST project (Gender Equality Plans for Information Sciences and Technology Research Institutions) funded under the European Union's Horizon 2020 research and innovation programme that aims at introducing structural changes in research organizations to enhance gender equality within Information System and Technology Institutions. The dimensions and indicators used to measure gender equality are consistent to those that the literature on gender equality in research and academic institutions have shown to be significant. Our contribution shows an innovation in the choice on how to measure gender equality by using Fuzzy Multi Criteria Decision Analysis (FMCDA). We propose a Fuzzy Expert System, a cognitive model that, by replicating the expert way of learning and thinking, allows to formalize qualitative concepts and to reach a synthetic measure of the institution's gender equality (ranging from 0 to 1 increasing with gender equality achievements) that can be then disentangled in its different dimensions. The latter characteristic of the model that we propose can be fruitfully used by policy makers and Equal opportunity officers in order to detect and address the critical elements in the organization and carry out changes to improve gender equality. A first application of the model has been experimented within the EQUAL-IST project and is available for other universities and research institutions wishing to obtain an assessment of their organization in terms of gender equality. Further developments of the model, together with its wider implementation, include the assessment by using fuzzy logic of gender equality policies and institutional factors affecting gender equality within the institution.

Keywords: gender equality, research institutions, fuzzy logic, tertiary education, glass ceiling, Fuzzy Expert System

1. Introduction

The aim of this paper is to provide a gender equality system applied to tertiary education and research institutions. The very intent has been developed within a research project (EQUAL-IST) devoted to introduce structural changes in research organization to enhance gender equality within Information System and technology institutions.[1] It is in this framework that the idea to get a synthetic index of gender equality to be used for comparative analyses within the network of institutions of the consortium has been translated in an operational system.

Here we present the first results of the system that we intend to complete by adding other dimensions affecting the extent of gender equality of a given institution: work-life balance and equal opportunities machineries actions.

The research group has detected a set of variables that define the employment structure of a given institution distinguishing by academic and administrative and technical roles within the institution and evaluating the degree of gender equality in each level (administrative employment, academic composition by level and gender, students enrolled in different level within the institution) and governance.

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[1] A wider description of the intents of the project is in Section 2.

The three universities chosen are located in different countries: Italy (Unimore), Germany (WWU) and Lithuania (KTU) all characterized by under-representation of women in higher academic positions (European Commission, 2016) but by different levels of gender equality index (EIGE, 2017). The latter is on average 66.2 in EU 28 countries, 65.5 in Germany, 62.1 in Italy and 56.8 in Lithuania.

The University of Münster (WWU) is a public university located in the city of Münster, North Rhine-Westphalia in Germany. The WWU is part of the Deutsche Forschungsgemeinschaft, a society of Germany's leading research universities. The WWU has also been successful in the German government's Excellence Initiative. Kaunas University of Technology (KTU) is the largest technical university in Lithuania. The University of Modena and Reggio Emilia (UniMORE) has a longstanding tradition (founded in 1175) and currently offers 80 bachelor and master classes through its ten departments. In compliance with the national laws, Unimore recently established a Unified Committee for the promotion of equal opportunities (CUG) that aims to promote gender equality and fight any kind of discrimination within employees and students population.

We have collected administrative data on the structure of employment by gender and analysed the system of governance within each institution involved.

The methodology used is fuzzy expert system (Section 3) and its application to the data allows us to obtain a crisp indicator on the degree of gender equality in each institution. Preliminary results are commented in Section 4.

2. EQUAL-IST

The EQUAL-IST project aims at introducing structural changes in research organizations to enhance gender equality within Information System and Technology Institutions. The project supports the seven European Research Performing Organizations (RPOs) of the EQUAL-IST consortium in developing and implementing Gender Equality Plans (GEPs) focusing on four main levels: HR practices and management, research design and delivery, student services and institutional communication.

EQUAL-IST kicked off during June 2016 as a challenging 36 months project, involving 9 project partners, 8 universities from 7 countries, with the goal to design and implement Gender Equality Plans (GEPs) for IST Research Institutions. The main objectives of the project include:

- setting up of the scene for the implementation of structural changes in the involves IST research institution towards the promotion of gender equality,

- the enhancement of gender equality at those involved research institutions through the design and implementation of tailored GEPs containing specific measures (activities/practices/interventions) to address gender imbalance,

- the monitoring and assessment of the results of GEPs implementation by refining the gender equality measures and ensuring their effectiveness, efficiency, and sustainability and

- boost of gender equality in research organisations at national and international level.

The design of the EQUAL-IST gender audit methodology has been based on the selection and adaptation of existing methods for gender audit previously developed by other European research projects and qualified international institutions. The outcomes of the State of the Art Analysis evidenced the existence of two main approaches for gender audit: a quantitative approach to the problem, based on measurable indicators, and a qualitative approach, based on participatory techniques and tools. The approaches are complementary in nature and present different advantages with respect to the gender audit process.

Based on the above observations, the developed EQUAL-IST gender audit methodology exploits a mixed strategy integrating both quantitative and qualitative techniques. Existing indicators and participatory tools have been selected and adapted based on the need to customize the gender audit methodology to the specific requirements of IST/ICT research institutions.

The project will combine gender mainstreaming and positive actions on the four target areas considered in the EQUAL-IST project: HR practices and management processes, research design and delivery, student services and institutional communication. For addressing and solving issues of horizontal and vertical segregation in research

and administrative careers, work life balance, gender neutral-blind approaches to IST research, gender gap in students' enrolment, EQUAL-IST will try to operate at the same time on organizational structures, discourses, and behaviours. In addition, EQUAL-IST will promote a participatory approach towards Gender Equality Policies based on co-design and at the same time ensuring the active dialogue with and involvement of top decision makers at the partner RPOs. By setting up a dedicated crowdsourcing online collaborative platform, the project supported both the initial internal assessment of the RPOs and the GEPs design process.

3. A Fuzzy Expert System (FES) a proposal for a multicriteria decision making method (MCDA)

The objective of measuring and monitoring gender equality in research and innovation institutions is pursued by other institutions and in projects proposing different tools as by the EU funded Effective gender equality in research and academia project (EGERA) (http://www.egera.eu/) or GenderTime (Badaloni & Perini, 2016) and in the She Figures platform and reports (EU Commission, 2016). Within the EQUAL_IST project the system of indicators constructed has been designed consistently with the dimensions that the literature show to be relevant in producing gender inequality in academia. The complexity of the dimensions of gender equality requires to build a composite indicator that is a 'synthetic index of multiple indicators'.

Having defined the composite indicator, we have to decide how to measure it and here we propose an innovation in the literature by adopting a new type of logic to measure gender equality. There is a wide literature in this research field that is usually known as Multi Criteria Decision Analysis (MCDA). (Mardani *et al.* 2015, Grabish *et al.* 2009). Since the criteria can have different importance we need to weight them. At this point the methods to follow can be divided in two main area: the weights are decided by experts or by data themselves (Data-Driven). The choice depends also by what is available, in terms of experts available to provide their expertise and whether the data set is sufficiently wide to obtain the information we need to build the weights.

We have then to choose the MCDA method. The usual or traditional MCDA approach works with single or precise values for the inputs, for the weights as well as for the performances of the alternatives in terms of the identified criteria. More recently this wide setting has been enhanced by a new type of logic: Fuzzy Logic and so Fuzzy Multi Criteria Decision Analysis (FMCDA) is born (Chengiz Kahraman, 2009; Kahraman *et al.* 2015). Here we adopt a less demanding approach for the decision-maker (DM), who is able to provide fuzzy numbers instead of single values. The weights should be obtained by flexible rules that let the experts to translate their opinions by verbal judgements. We then need the design of a decision tree that, by a bottom-up procedure, describes the several inputs and the following aggregations that will lead till the higher point, the output.

The instrument we propose is a Fuzzy Expert System (FES) (Bandemer and Gottwald, 1995; Bojadziev and Bojadziev, 2007; Kasabov, 1996; Piegat, 2001). We have used the same approach in several other situations. In all these cases we don't have sufficient data to use data driven methods. (Addabbo et al. 2007, 2009, 2013, Facchinetti et al.2012, 2013, 2018)

FES models are cognitive models that, replicating the human way of learning and thinking, allow to formalize qualitative concepts. They uses blocks of rules to translate the experts' judgments. The experts in charge of codifying the model's operating rules make choices that are visible and manifest, and therefore transformable, in each step for the construction of the model. The model contains an inferential engine to reach a final evaluation. The construction of the model is modular. The evaluation is developed in successive steps (analogous to the decision-making process of individuals) along the branches of the tree until you get to the trunk: the input variables through intermediate output variables lead to the final output of the model. The implementation of the fuzzy expert system in this case has been divided into nine stages (Von Altrock, 1996):

- 1) Analysis of available data
- 2) Initial interview with experts to define the inputs and factors for their aggregation
- 3) Construction of the decision tree
- 4) Subsequent talks to define the range and the blocks of rules
- 5) Technical choices: aggregators and de-fuzzifying
- 6) Selecting complete data from the survey replies and first output

- 7) Comparison with reference cases and calibration
- 8) Calculating new output: if there is not validation of the results by the experts it returns to the previous step
- 9) Analysis of the output.

4. From the system of indicators to gender equality evaluation an application to three research institutions

EQUAL-IST sets a quali-quantitative system of indicators in order to evaluate IST/ICT and tertiary education & research institutions as described in Section 2, the aim of this paper is to get from a wider system of indicators to an implementation by using a specific methodology described in Section 3: Fuzzy Expert System (thereafter FES). As explained FES is particularly fit when it comes to the evaluation of complex and mixed system of indicators to get to a final output that can collect the information without losing its complexity by providing a crispy indicator of the degree of gender equality within the observed institution.

As a first application of the system we restrict ourselves to the quantitative core of the system: the gender equality within different employment groups and students by level and area of tertiary education and the whole governance of the institutions analysed.

Three institutions have been chosen to carry out the application of the Gender evaluation fuzzy expert system:

The University of Münster (WWU): a public university located in the city of Münster, North Rhine-Westphalia in Germany. The WWU is part of the Deutsche Forschungsgemeinschaft, a society of Germany's leading research universities. The WWU has also been successful in the German government's Excellence Initiative. Within WWU the Department of Information System shows a very low number of female students (only 13%) while the Department of Economics within the same University, though characterized by a higher incidence of female students, is still characterized by lower presence of women as professors. The German Research Foundation (DFG) described WWU as being advanced in setting up the Gender Equality Plan.

Kaunas University of Technology (KTU) is the largest technical university in the Baltic States with totally 17 000 thousands students and about 1000 academic staff. There are totally about 2300 persons in the staff of the university, where in the administrative staff there are about 73% of women and between academic staff what is totally 1251 we have 54 % men and 46 % women. The Informatics Faculty is one of the biggest faculties at the university, having about 30 percent students of all the university. In 2015 totally 1166 students joined to the Informatics Faculty, totally 9,9 % women and 90,1 % men. Women representatives of the Informatics Faculty initiated a national movement named "Women and Technology Network (www.mitt.lt) and the "Europe-Central Asia Women and Technology" establishment.

The University of Modena and Reggio Emilia (UniMORE) has a longstanding tradition (founded in 1175) and currently offers 80 bachelor and master classes through its ten departments. In compliance with the national laws, Unimore recently established a Unified Committee for the promotion of equal opportunities (CUG) that aims to promote gender equality and fight any kind of discrimination within employees and students population.

Recent data on employment at the University of Modena and Reggio Emilia (Unimore) show phenomena of occupational gender segregation that are particularly relevant at the Department of Engineering Enzo Ferrari (DIEF). Data clearly show that some sectors, like the administrative area, are characterized by a prevalence of women (71% at the university level and 53% at the department level), but the situation drastically changes if we consider the academic employees, where the percentage of women drops to 38% for Unimore and 22% for the DIEF department. Moreover, disaggregated data on the academic members show that the female presence decreases passing from the category of researchers to highest positions of associate and full professors, indicating the existence of the so called 'glass ceiling' problem. In compliance with Law 183/2010, the former Equal Opportunity Commission has been merged with the Committee for protection against mobbing in the Unified Committee for the rights of the employees [Comitato Unico di Garanzia (CUG)]. Members of Unimore CUG have been elected to represent each employees group and students. CUG is a machinery of Unimore that aims to promote gender equality and fight discrimination, including gender discrimination. Since its recent

establishment, CUG has been very active in promoting actions to fight gender inequality and to prevent sexual harassment.

The system structure (Figure 1) identifies the fuzzy logic inference flow from the input variables to the output variables. The fuzzification in the input interfaces translates analog inputs into fuzzy values. The fuzzy inference takes place in rule blocks which contain the linguistic control rules. The output of these rule blocks are linguistic variables. The defuzzification in the output interfaces translates them into analog variables.

The following figure shows the whole structure of this fuzzy system including input interfaces, rule blocks and output interfaces. The connecting lines symbolize the data flow.
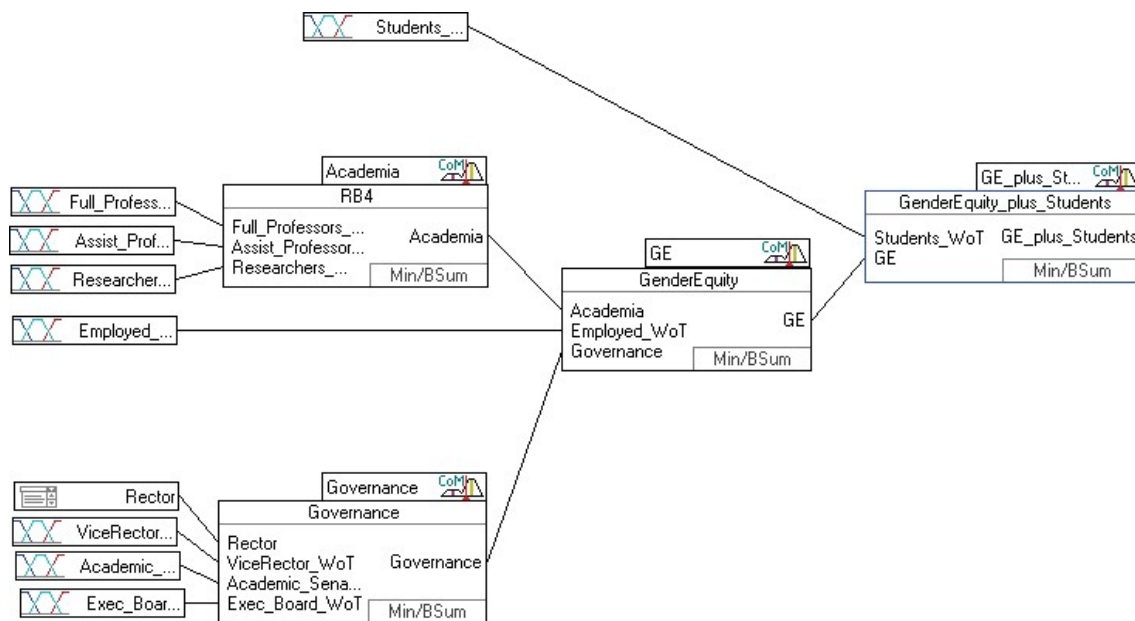

Figure 1: Fuzzy expert system of gender equality within tertiary education/research institutions

The final gender equality indicator takes the value of 1 (maximum gender equality) and 0 maximum inequality.

The intermediate variables are:

- Gender equality within the academic and administrative staff and Governance

- Gender equality in the distribution by level and area of education (Students)

By each level within academic and administrative and technical employment the ratio of women to men has been constructed and a system of rules has been specified assigning a higher weight on women's under-representation in the apical levels.

Governance has been built by using the gender composition of the University Executive Board and the Senate (measuring the under-representation of women) and whether the institution has a male or female Dean or Deputy Dean.

The weight that has been given to each dimension is specified in Table 1 and reflects the judgements of the experts in terms of the higher power of governance, followed by the academic body and their structure in terms of gender equality in affecting the whole gender equality of the institution.

Table 1: Weights

Academia:	
Full Professor	Very positive
Associate Professor	Very positive
Researcher	Slightly positive
Governance	
Rector	Very positive

Vice Rector	Very positive
Academic Board	Slightly positive
Executive Board	Slightly positive
GE	
Academia	Positive
Administrative	Slightly positive
Governance	Very positive
GE + Students	
GE	Very positive
Students	Slightly positive

Source: Gender equality experts' judgements

We have then evaluated the FES by using the available system of indicators built within the EQUAL-IST project by using administrative data for the University of Modena and Reggio Emilia (Unimore), the University of Münster (WWU) and Kaunas University of Technology (KTU).

Before turning to the results of our Fuzzy Expert System on Gender Equality within tertiary education and research institutions let us comment upon the system of indicators results on different dimensions of gender equality.

Our elaborations on administrative data confirm the severe under-representation of women within the Academic Body in the highest level consistently with what can be found at national level (European Commission, 2016). Women represent 20% of the 124 full professors enrolled in WWU, 25% of the 205 full professors in Unimore and 27% of 175 full professors in KTU. In associate professor positions women share ranges from 20% in WWU to 45% in KTU while women share in researcher and temporary researcher positions ranges from 38% in WWU to 48% in Unimore (Table 2).

Table 2: Percentage of women by level of academic position in University of Modena and Reggio-Emilia (Unimore), Kaunas University of Technology (KTU), University of Münster (WWU) Year 2015.

	Unimore		KTU		WWU	
	F%	N.Obs.	F%	N.Obs.	F%	N.Obs.
Full Professor	25%	205	27%	175	20%	124
Associate Professor	38%	318	45%	401	20%	12
Researcher,Temporary Researcher	48%	260	43%	169	38%	377

Source: Our elaborations from administrative data

On the other hand the administrative staff, though recording women's under-representation within the highest managerial positions, shows on average more equality than in the Academic body in the three universities analysed. The University of Modena and Reggio Emilia indicators on governance show the absence of women in Rector or ViceRector positions and a severe under-representation in the Senate and in the Executive Board. On the other hand the higher presence of women in ViceRector positions in University of Münster (WWU) and Kaunas University of Technology (KTU) mitigates the under-representation of women in Senate and Executive Board at KTU and in the Senate in WWU (Table 3).

The implementation the Fuzzy Expert System described in Figure 1 with the weights reported in Table 1 on the set of indicators related to each institutions commented above show a synthetic Gender Equality Index for each one of the three institutions analysed by 0.67 (Table 4). The higher gender equality within non academic staff has a positive impact on the degree of gender equality at Unimore. The gender equality of the University of

Modena and Reggio Emilia, not taking into account the gender equality in the distribution of students by level of education, is 0.50 well below the maximum gender equality achievable.

Table 3: Percentage of women Rector or ViceRector, in Senate and Executive Board.

University of Modena and Reggio-Emilia (Unimore)
Kaunas University of Technology (KTU)
University of Münster (WWU)

	Unimore		KTU		WWU	
Governance	F%	N.Obs.	F%	N.Obs.	F%	N.Obs.
Senate	28%	25	27%	49	43%	23
Executive Board	36%	11	0	11	50%	6
Rector	0	1	0	1	0	1
ViceRector	0	2	100%	2	75%	4

Source: Our elaborations from administrative data

KTU University shows a higher than Unimore and WWU degree of gender equality in academic positions though still with a very low record (0.32). WWU shows the higher inequality by gender in the academia dimension, however, its lower achievement in terms of gender equality in academia is compensated by a better score in the non academic staff dimension and by the higher (than Unimore) record achieved in gender equality in the governance dimension (Table 4).

Table 4: Index of Gender Equality (GE) within the institution

University of Modena and Reggio-Emilia (Unimore)
Kaunas University of Technology (KTU)
University of Münster (WWU)

	Academic G.E. (intermediate index)	Administrative staff (Women over total ratio)	Governance (intermediate index)	Gender Equality Index	Students (Women over total ratio)	Gender Equality index (including students)GE_plus_Students
Unimore	0.26	0.7	0.25	0.50	0.58	0.67
KTU	0.32	0.66	0.5	0.55	0.51	0.67
WWU	0.17	0.75	0.5	0.50	0.50	0.67

Source: Our elaboration based on FES implementation on the system of indicators collected for Unimore, KTU & WWU

By implementing the FES on the microdata collected for the other research institutions in the network and for each IST/ICT department within tertiary education institutions involved in the project we will be able to carry out comparative analyses and put the outcomes in terms of gender equality in relation to the FES on work life balance and equal opportunity machineries that we are currently building to study the factors affecting gender equality across institutions.

First results on this line of research have shown that the three institutions involved in the analysis are characterized by similar gender equality in the institution though determined by quite different personnel and governance structure. In particular the University of Münster (WWU) shows a fairly low gender equality in Academia matched with a higher gender equality within the administrative component and governance while the University of Modena and Reggio-Emilia shows amongst the trhee components a worse situation in terms of gender equality in governance (0.25 out of 1) followed by gender equality in Academia (0.26) whereas the degree of gender equality in the non academic staff is higher (0.70). Turning to the Kaunas University of Technology (KTU) the implementation of our Fuzzy expert system detects a worse situation, in terms of gender equality in Academic staff (0.32 out of 1) followed by governance (0.50) and non academic staff (0.66) (Table 4).

5. Conclusions and further developments

In the evaluation of gender equality within academia and research institutions the methodology proposed and applied in this study can be considered an innovation since it uses fuzzy logic to measure the composite indicator.

The gender equality fuzzy expert system evaluation that we have built (GEFES_EV) in this paper focus is on the gender equality achievement in the structure of employment by gender and level, on the students' enrollment by gender and on the gender equality in the governance of the institution.

The application to three universities within the EQUAL-IST project network has allowed to detect a similar gender equality output though determined by different dimensions of the index.

One of the powerful characteristics of fuzzy expert systems is connected to the ability to go backwards in searching for the dimensions that contributed more to the observed outcome in order to address the issue with proper policies.

Several factors have been shown to be related to this gender inequality in the access to further step in the academic career. They range from lower integration into the scientific community and in networks, to interrupted work profile connected to childbearing and rationing on childcare services.

Further developments involve the extension to all the institutions partners of the project and the inclusion of country variables referred to the situation in the country in terms of gender equality (including also the EIGE gender equality indicator) and equal opportunity norms at country level with a special focus on the existing micro and meso-level policy measures addressing gender equality in Sciences and Research.[2]

To take into account the possible interaction of the measures of gender equality within research institutions the system will also be extended to capture two further dimensions:

- the extent of work life balance within the institution and in the region/country where the institution is located
- equal opportunity machineries at work within the institutions.

Further developments can regard the use of the output of the system in the information set within a participatory process of gender auditing to develop awareness and discussion since the system allows comparison across departments of the same Academic institution, across different institutions in the countries that are willing to undertake the evaluation process. The availability of intermediate results, as the case shown in the application of the system to three universities in the EQUAL-IST network, can then be used by each institution and at different steps of the gender audit process to allow the implementation of policies to contrast gender inequality in different fields and monitor their impact on each dimension of gender equality. The evolution of the index and its components over time can then be used to represent the gender equality evolution in the academia and/or research institution detecting also the interaction with policies implementation or relevant changes in norms and policies at country or regional level.

Acknowledgements

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[2] Multilevel analyses can be performed across the institutions analysed taking into account the different policies on gender equality in Sciences and Research within each country. Meta analyses of these policies can be found in Muller et al. (2011) and European Commission (2008) and have been updated within the EQUAL-IST project with reference to the network countries.