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Agent-based modelling in environmental policy analysis

Francesca Cubeddu [1]

Abstract

This paper is a summary of the research developed in the author's Ph.D. programme. The case study deals with the implementation of Energy Efficiency policies in the Building sector of the Lazio Region and carries out an ABM analysis of the impacts of training on the social actors involved. Its purpose is to reproduce the social mechanisms through the study of the actors' actions with ABM in order to evaluate socio-economic impacts by interconnecting the social and economic variables by means of the Social Accounting Matrix (SAM).

Keywords: ABM, interconnection, social action, environment - energy policy, social influence, training.[2]

[1]Department of Social and Economic Sciences (DiSSE), Università Sapienza di Roma, Italy: francesca89cubeddu@gmail.com; francesca.cubeddu@uniroma1.it.

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1 Introduction

Over the years, man has increasingly pursued achievement of energy independence through the use of forms of alternative energy sources permitting autonomous consumption capable of satisfying demand. This pursuit has led to environmental, economic and social problems brought about by different actors adopting different strategies according to their interests. The behaviour and actions of these actors move the system by generating impacts which can be analyzed by means of the Agent Based Model – ABM. Agent Based Models (ABMs) are in fact useful tools for the study of mechanisms leading to the achievement of Energy Independence. The case study focuses on Energy Efficiency policy implementation[3] in the Building sector[4] of the Lazio Region[5], in particular through ABM analysis of the impact of training on the social actors studied [1]. The aim was to reproduce the social mechanisms through a study of the subjects' actions with ABM, and then assess the socio-economic impacts by inter-connecting social and economic variables by means of the Social Accounting Matrix (SAM). The ABM was created by following Boudon's [2] and Coleman's [3] Macro-Micro-Macro mechanical theory. The research activity falls within the methodological branch of local development analysis as it seeks to discern how a policy can lead to growth and development. The study aims to examine the social behaviour of individuals, social influence and social proximity in order to study the interests and decisions of local actors, the way in which influence occurs, and by what means it is transmitted, while at the same time considering the theoretical and methodological plane. An analysis of the local context, the conditions of the area chosen for study and its component network made it possible to define the features to be investigated and subsequently assess their effects [4] [5]. By reproducing the ABM model [6] it was also possible to observe the integration of local analysis in the evaluation of public policy. The model was built first with R and then with NetLogo software. The former makes it possible to describe the model in its mathematical context showing the mathematical equation; in addition, it is a useful support for interconnection with the Social Accounting Matrix (SAM) which shows mainly the economic impacts

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[3] Energy Efficiency constitutes a new energy source fundamental both for the reduction of fuel poverty and socio-economic growth.

[4] The building sector is analyzed because it seems to be the one with the greatest likelihood of implementing the different policy measures as well as the sector which because of the economic crisis exploits all its opportunities. At the same time, this sector makes it possible to study how training can be the driver and facilitator in the diffusion of innovative systems of Energy Efficiency and in stimulating the creation of new jobs.

[5]The Lazio Region was chosen because of its proximity and geographic potential to facilitate travelling, and because it is simpler to gather data in one's own region.

and the consequent social impacts. NetLogo is the ideal software for agent-based simulation because it makes it possible to show the movement of the social actors.

2 The research[6]

In measuring Energy Efficiency, the behaviour and choices of citizens are fundamental since growth and development is possible only when EE measures are put into effect. Training is considered to be the important variable in implementing the measures, starting from the consideration that training is fundamental for social and economic growth and development since it provides the driving force towards change [7].

In order to analyze training within the social model, questionnaires were administered and interviews and direct observations carried out.

The operative field research phase was preceded by an analysis of the sector, defining its production chain and actors, in order to facilitate the construction of the model.

The social model was built with the following actors: 1. Business; 2. Government; 3. Trainers; and 4. Families.

The first actor analyzed was the business sector which with its decisions implements and changes the mentality of the sector. The entrepreneur has the greatest pull [8] since every choice he makes not only affects his own firm but also other actors, the market, the sector and society. In aiming to meet the needs of his business, the entrepreneur, according to Weber [8], acts in accordance with the dictates of a rational action in relation to an objective: growth of wellbeing and increased earnings.

The second actor is Government which with its actions and decisions affects those of entrepreneurs. Policy implementation aimed at increasing social well-being involves development and increased choice in investments for Energy Efficiency measures as well. In addition, in the case under consideration, the Public Administration must respect the 2020 agreements, create incentivizing activities capable of developing the entire sector and lead it to the established objectives.

Trainers are the third actors useful for the realization of Energy Efficiency. Training makes growth and development possible, and continuing education is a

[6] Presented at the 11th Conference of Environmental Sociologists. Acts in the process of being printed with the proposed title: *Training as Driver in Social Decisions for the Application of a Policy. Case Study on Energy Efficiency in the Building Sector in the Lazio Region*. The study has its origins in the author's doctoral research titled *Integration between Social and Economic Models. Development Policies in Energy Efficiency in the Lazio Region*, PhD in *Educational and Social Theory and Research,* Università Roma Tre in co-supervision with Enea Research Board. Presented at Roma Tre on 27 March 2018 and completed in October 2017.

resource because it permits continual evolution which brings growth. The fourth and last actor consists of families which intervene both indirectly and directly since their decisions can stimulate the sector and force businesses to innovate by following social and economic trends.

The research hypothesizes that the greater the demand for measures on the part of families, the greater will be business investment and incentives by Public Administrations.

With the theoretical study based on the actions of social agents and their behaviour, the social actors were defined and a sample was selected, utilizing available databanks, contacts with different professional sectors, organizations, authorities[7] and trainers.

The sample of business firms was extracted in different ways and through different procedures. A database of all Italian businesses updated to 2015 was found: AIDA (Analisi Informatizzata delle Aziende Italiane), which is a database of Italian Businesses of the Università Cattolica di Roma. After obtaining the various authorizations necessary, it was possible to compile a complete list of the construction firms in the Lazio Region across its five provinces. The sample was reduced from 197,597 businesses to 543 with a specific filter selected on the basis of the Ateco code, choosing the codes with their respective *subcodes*[8] *and selecting active businesses with over 20 employees.*

To these 543 businesses were added sustainable building and social housing construction firms, whose names were furnished, after a request via email, by the Enti Ance of Rome, Latina, Viterbo and Rieti and Ance Lazio; Confartigianato di Latina; Confindustria Lazio; Fillea (Italian Federation of Construction Workers and Carpenters) both at provincial and national level; Acer; Acer Lazio; Cefmectp; Formedil and CNA (National Confederation of Craft Trades and Small and Medium Businesses)[9] and businesses in the Unindustria registry, for a total of 731 businesses contacted.

The final Sample consisted of the 27 businesses that responded to the questionnaire.

The firms were contacted both by email and telephone. The material was sent through the University webmail with a letterhead attachment describing the research[10]. The letter asked the firms to actively participate in the research by

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[7]These included: Ance, Acea, Enea, Enel, Confartigianato, CNA, Fillea, Lazio Region, Professional Associations and the National Council of Land and Building Surveyors.

[8]41.2 (Construction of residential and non-residential buildings), 43.2 (Installation of plumbing systems and other construction and installation work), 43.3 (Building completion and finishing) and 43.9 (Other works by construction specialists).

[9] Acer Roma and Acer Lazio provided greatest support.

[10] The study was supported with the collaboration of Università Roma Tre and the Enea Research Institute. The letterheads of the two organizations were used to give official status to the research and reassure the firms of its authenticity.

responding to the questionnaire either in person or by email. Only three firms decided to respond online, while the questionnaire was administered to the others *face to face*. Emails were sent requesting confirmation of both receipt and reading. When no such confirmation was received, the firms were also contacted by telephone in order to speed up the process.

The sample of trainers was even smaller than the firms sample; in the Lazio Region 13 questionnaires were distributed. The construction sector has its own training schools through which it seeks to provide its students with a good skills level.

The most important public ones include: Fomedil, Cfmecdp, Ente bilaterale paritetico territoriale for training and construction safety in the Province of Latina, Ente Scuola Edile Frosinone (ESEF), Ente Scuola Edile Viterbo (ESEV) and Lazio Region. Private schools include Lazio Deiconsulting.

The trainers sample was selected from the list of Training Institutions released by the Lazio Region and Cefmectp. Thirty-one Training Institutes and Agencies for businesses and technicians in the building sector were contacted by email following the same procedure used for the building firms.

Twenty training centres responded and of these 16 consented to be interviewed, but ultimately it was actually possible to interview only 13.

Within the government sector, officials from the Lazio Region and the Ministry for Economic Development were interviewed. There were 3 respondents from the Lazio Region and one from the Ministry. The four respondents carry out different tasks and have different political affiliations. The functionaries from the Lazio Region made it possible to study how the Regional system was organized, developed and orientated towards innovation.

2.1 Research tools

Business Firm Questionnaire

A questionnaire consisting of 37 questions was administered to the 27 business firms. Each question had the aim of constructing the interconnection between the social and economic models. Most of the questions analyzed the opinions of the firms, their rational decisions and the actual state of facts. The questionnaire was sub-divided into four parts which made it possible to study both policy impacts and limitations and the actions of the agents:

I. Impacts of the Energy Efficiency measures (from 1 to 6)[11];

[11]The first part or area of the questionnaire, as indicated by questions 1 to 6, studies the impacts of Energy Efficiency measures, focussing on self-evaluation and implementation of imminent measures established by law.

II. Investments (from 7 to 16)[12];
III. Policy limitations (from 17 to 21)[13];
IV. Business, Participation and Communication (from 22 to 37)[14].

The four parts were structured to identify the actions chosen by businesses. The questions were designed to investigate how decisions and motivation of the business sector may influence the implementation of Energy Efficiency measures and at the same time how external actions may modify agents' decision-making. The questions were formulated on the basis of the indicators of the company's development and vitality. The fields analyzed as indices of development and growth included: Training, Participation, Investment (Willingness to Invest), Limitations, Employment and Opportunity. The questionnaire aimed to furnish a complete picture of all three dimensions to be analyzed: political, economic and social; but included questions with social variables which would then feature in the construction of the social model and the SAM.

Trainer Interviews

A questionnaire consisting of 21 questions was administered to the trainers, who were fewer in number than the other agents. The interview was divided into three parts:

I. Opinions regarding Energy Efficiency policy (questions 1 to 4);
II. Specific questions on training, administrative orders and courses offered by the trainer's institution (questions 5 to 15);
III. Questions focussing on the information-participation relation and training.

It is important to consider the trainers' opinions since it is training which permits the implementation and diffusion of energy policy measures. By analyzing the relation between trainers, businesses and technicians, it is possible to study how, on the basis of their opinion of the Energy Efficiency policy, trainers are able to convince firms that it is a good investment in the mid and long term. For the part related to Government[15] comments and opinions were collected of

[12]The second part, *Investments*, consists of questions 7 to 16 investigating all the areas of investment carried out by the businesses and those proposed to them. The questions deal with investments – both actual and potential -, and training. In this area it is possible to observe what relation exists between training and implementation of the measures.
[13]The third part, *Policy Limitations*, questions 17 to 21, studies the limitations of non-diffusion both of Energy Efficiency measures and construction of new sources.
[14]The fourth part, *Business/Participation/Communication*, questions 22 to 37, investigates the relations between business and the sector and government as well as the participation of business in decisions and implementation.
[15]For the Government part, the following people were contacted: for the Ministry for Economic Development (MiSE) Mauro Mallone, and for the Lazio Region 7 political representatives,

political representatives in the environmental, energy and development fields of the Lazio Region, of the director of Division VII "*Energy Efficiency and Energy Savings*" in the Ministry for Economic Development (MiSE), and finally of administrative personnel responsible for different departments in the Lazio Region. The officials contacted were in charge of the following departments: Regional Directorate for Economic Development and Productive Activities; Programmes and Projects for Sustainable Development; Regional Directorate for Infrastructure and Housing Policy – Planning and Public Housing Projects; and Regional Directorate for Training, Research and Innovation, Schools and Universities, Right to Education – Planning Area for Training and Orientation. Political representatives were interviewed in depth in order to analyze the role of the Energy Efficiency policy and training for policy development.

3 Model Description

The model, as mentioned above, was constructed on the behaviour of three agents (Businesses, Trainers and Families), which in practical terms implement the policies emanated by the fourth subject – the political class.

To construct the model the political decision-making processes were translated into numbers: one example of a translation of actions into a numerical measurement is the increase of a defined X percentage of the number of energy upgrading interventions in domestic dwellings within a given geographical region.

The model was built upon the sufficiently detailed description of the behaviour of the actors considered, by selecting the questions from the interviews

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including: 1. The Governor of the Lazio Region Nicola Zingaretti; 2. Fabio Refrigeri, Committee Chairman for Infrastructure, Housing Policies, Local Authorities; 3. Councillor Porrello Devid member of Commission for Environment, Public Works, Transport, Housing and Urban Planning Policies, member of Social and Health Policy Commission; 4. Enrico Forte Vice-president of the Commission for Environment, Public Works, Transport, Housing and Urban Planning policy; 5. Councillor Silvia Blasi, member of the Commission for Environment, Public Works, Transport, Housing and Urban Planning Policy, Commission Member for Agriculture, Artisanal Workers, Commerce, Professional Training, Innovation, Labour, Small and Medium Businesses, Research and Economic Development; ; 6. Enrico Panunzi, President of the Commission for Environment, Public Works, Transport, Housing and Urban Planning Policy, and 7. Adriano Pallozzi, Vice president of the Commission for Environment, Public Works, Transport, Housing and Urban Planning Policy. Governor Zingaretti was contacted but replied that he was not available for interview at the time because of the elections and delegated Councillor Refigeri, but said that if necessary he would be available for interview. Councillor Refrigeri's secretary guaranteed that the Councillor had already been informed that he could be interviewed and assured his availability. The councillors interviewed were Porrello, President Panunzi, Councillor Forte and Committee Chairman Lo Cascio, in lieu of Prof. Fabiani.

and questionnaires relating to training (number of training courses followed in the current year; participation in courses, motivation and the return on investment in training courses over time); policy implementation, both in the application of technology and for motivation; Participation; Investment and Opportunity.

Families were the only agent-group not interviewed. Their data were taken from the Enea database on the number of incentives applied for and from the data of the Ministry for Economic Development, available from 2007 to 2013.

The model was constructed with two software products: R and NetLogo, both with programming language that enables the realization of social models with two different interfaces. The former makes it possible to observe the evolution of the process mathematically; the latter shows the movement of the social agents and their influence. R was used because it more easily permits integration with the economic accounting matrix and also shows social impact. NetLogo makes it possible to observe the movement of social agents and their role during the social influence phase.

Structure of the model built in R[16]

The model is influenced by a research model on social dynamics and collective behaviour and social influence by Nowak, Szamrej and Latanè [9]. In the model, the Energy Efficiency Policy will be indicated with EE.

Four individual factors operate in this model:

1. individual **attitude** in the population, translated into binary terms [0-1 or YES-NO] with a division into two opposite opinions about an issue (in this case whether to do EE or not);
2. **persuasion power** with regard to agents with contrary opinions (variable between 0% e 100%) placed into dynamic relation with attitude, hypothesizing that its intensity would increase with the persistence of an attitude over time;
3. power of external support with respect to agents with similar opinions, structured like the preceding one, with a random attribution to each change in attitude;
4. **social proximity**, given by the spatial localization within the social structure, with a distribution of the agents characterized by a space of 40 x 40 cells.

With regard to maintenance/change of attitude, the basic assumption is that attitude changes according to the power of impact groups. If persuasion P of group y is greater than the power of support S of group x to which the agent belongs it means that if $P_y/S_x > 1$, then the agent's attitude will change. In the

[16] R is a free software program with programming language and specific development ambient for the statistical analysis of data.

work in question, the results show that the dynamics of polarization and resistance often depend on the initial conditions.

The basic equations of the model are:

Equation 1 – Impact of Power of Persuasion (P) in Latanè (1990)

$$\hat{\imath}_p = N_0^{1/2}\left[\sum \left(p_i/d_i^2\right)/N_0\right]$$

Where:

$\hat{\imath}_p$ = impact of the power of Persuasion
N_0 = number of individuals carrying out the persuasion action
d_t = distance between source and recipient

Equation 2 – Impact of Support (S) Power in Latanè (1990)

$$\hat{\imath}_s = N_s^{1/2}\left[\sum \left(s_i/d_i^2\right)/N_s\right]$$

Where:

$\hat{\imath}_s$ = impact of Support power
N_s = number of individuals effecting the Support action
s_i^2 = distance between source and recipient

Equation 1 shows that a group's persuasion impact is the average force exercised by it (persuasion impact / distance squared) multiplied by the square root of the number of members in the group itself. The persuasion of a social group impacts on the actions and behaviour of the individuals.

Following the theoretical model of reference, implementations were carried out to enable the construction of the social model proposed for this study.

Firstly, individual attitude within the population, translated into binary terms [0-1 or YES-NO], with a division into two opposing opinions regarding an issue (in this case, whether to do EE or not) is translated with respect to our problem into the form of "YES, I will implement Energy Efficiency (EE) from this moment)" or "NO, I will not implement EE" and is calculated according to equation 4) shown below. Secondly, the persuasive power regarding agents with opposing opinions (varying between 0% and 100%) produced both internally and externally (all the various subjects urging the realization of EE interventions, which can also be located *within* the family), is placed within a dynamic relation with attitude assuming that its intensity will increase with the persistence of an attitude over time as in Latanè's model. Thirdly, the element of Rational Calculation (RC) has been posited as equal to the Probability of New EE Training by Businesses (PNTB) according to the hypothesis that training is directly correlated with the price indications furnished by the businesses, and this variable is therefore the connecting link between the training policies and the model constructed [10]. In addition, the power of external support, with regard to agents with similar opinions, is set up like the preceding one, with random attribution to each change in attitude (but varying between 0% and 100%). Finally, social proximity, given from spatial localization within the social structure, is not considered in this simplified model. This is an important point: the model did not make use of spatial metrics to examine the diffusion of the phenomena (in this case attitudes towards EE interventions). This is a possible future development. However, in this experiment, the *Persuasion Driver* is also examined within the family nucleus (the atomic element of the Family agent), with a different approach from Latanè's (in which pressure is always exercised from outside the peer group and the support of the group itself). This would be mathematically equivalent to placing $d_i^2 = 0$ into equation 1), with the effect of annulling it completely. The modified functional form of the model proposed is presented below in equation 3. It is assumed that the Political actor has the aim of increasing interventions of energy upgrading in homes and desires to verify the effects of a possible additional intervention to the established one which provides upgrading incentives in the form of tax deductions (the so-called 55% - 65% formula), that is to say the percentages deducted from the value of the investment. In analyzing the role of *Training* in the process of translating Policies into social and economic effects on the system, the training tool is examined with reference to a work previously carried out on the relation between the subjects examined, in which the effect of a training action in Businesses was estimated in terms of price effects [11]. It is assumed that a training action can convince Firms to invest in Energy Efficiency and drive them to lower the prices of goods and services offered to families to create efficiency (a firm convinced of the future of Energy Efficiency can, for example, apply prices lower than the regional or municipal average for window and door fixtures sold to families within its market segment). Two policies are then taken into consideration: *Policy 1* and *Policy 2*, characterized by different costs and results, and the data furnished by the above-mentioned study limited to the PNTB parameter (41% in hypothesis 1, High Skills Training; 23% in hypothesis 2, Low Skills Training, which are the two extreme cases in the work cited).

To summarize the model proposed, the analysis focuses on:

- Government, which enacts/passes regulations;
- Trainers who facilitate awareness in Firms operating in the market;
- Businesses, which it is assumed are competitive within the market in terms of Training;
- Families that respond to the signals of Businesses and integrate them into their decision-making models.

Families are seen not only as actors that give importance to the rational element – represented by the cost of interventions – but also as actors in which two further drivers act: the Persuasion effected both externally and internally on the members of the i-th family nucleus interested in acting in any capacity[17] by investing in interventions; and the Support Force which the external environment, in the form of other subjects with the same orientation as the i-th nucleus, can offer.

As far as the price of interventions is concerned, it is assumed that this is correlated to the level of confidence the firms have in the potential of their market: this level can be rationally correlated directly to their level of training in the potential of the sector technology and is thus identified (posited in proportional relation), with the likelihood of new training.

Since in this context it would have been complicated to carry out precise statistical research on average prices in the entire region, it was decided to use the research results in the work of Cubeddu, Rao [12], published by Enea, on the probability of new training for the firms according to a simplified logic of the YES/NO type: it was assumed that the firms receiving most training would apply lower prices, and in the model effectively developed, the input utilized is a percentage value of new training by the firms, which is used in calculating the product of other factors. The level of persuasion and support was allowed to vary from 0% to 100%, in keeping with the model of Nowak, Szamrej, Latanè. The equation which expresses the number of interventions for the i-th policy considered is:

Equation 3 – Impact of Persuasion Power (P) in Cubeddu (2017)

$$\hat{\imath}_p = PNTB_i * N_0^{1/2} * (P_i/S_i)/N_0$$

[17]Valid in one-person households as well, if we consider the decision-making process of a person as resulting from a composite evaluation system..

From this formula can be obtained the number of interventions desired from the model for the link with the Social Accountability Matrix.

Equation 4 – Equation of Action (number of new interventions) in Cubeddu (2017)

$$nint_i = \overline{N_0} * \overline{\hat{\imath}_p}$$

where:

$\hat{\imath}_p$ = Persuasion Power Impact

$PNTB_i$ = Probability of New Training by Businesses in the i-th policy

P_i = level of persuasion external to one's family nucleus

S_i = level of support external to the family nucleus

N_0 = number of people interested in change[18]

$\overline{N_0}$ = average number of people interested in change

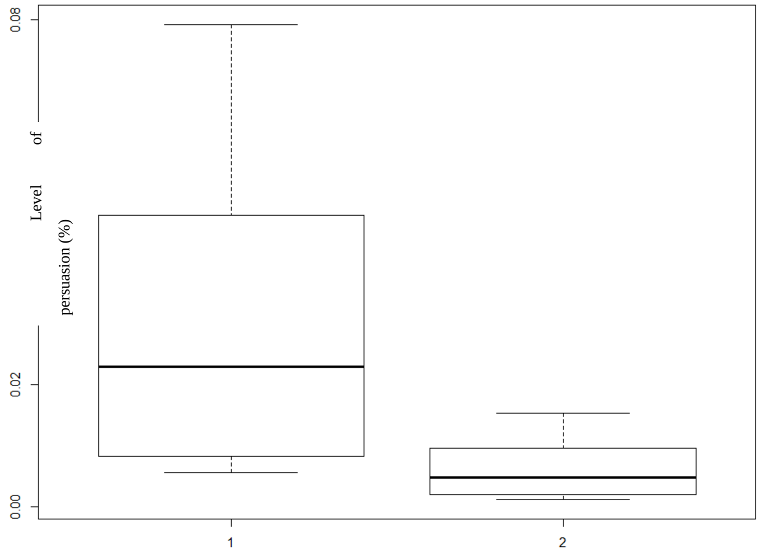
$\overline{\hat{\imath}_p}$ = average pressure resulting from the simulation

The sample not being large, it was decided to carry out a *bootstrap* simulation based on 10,000 repetitions of the model itself. The simulation resulted in an average value of the pressure indicator equalling 8.9% and 4.9% respectively for the two policies of Low and High Training. Multiplying the value of this indicator by the historical average of the number of the Families considered (equal to 14.217 in the period 2007-2013) 1260 and 695 new implementations of the policy

[18] Hypothesized as equal to the historical average of subjects which carried out EE interventions in the period 2007-2013 indicated in the ENEA report [13].

were obtained. In figure 1 a box plot shows the value of the impact of the social pressure expressed in the simulation.

Figure 1- Logical Synthesis of the social experiment carried out simulation



Impact of social pressure

The *box-plot* summarizes the model written in R, presented below. It will be observed that in the model realized the most trained subjects are also those who start up the training. Social pressure involves a spread of training and thus a greater start-up of interventions in Energy Efficiency. The agents affect one another; social persuasion involves an increase in the spread of training.

Policy 1, with greater investments in training, shows that the greater the increase in training the greater the spread of technologies and the more rapid the implementation. As a result, there is an increase in interventions.

Construction of the Social Model in NetLogo

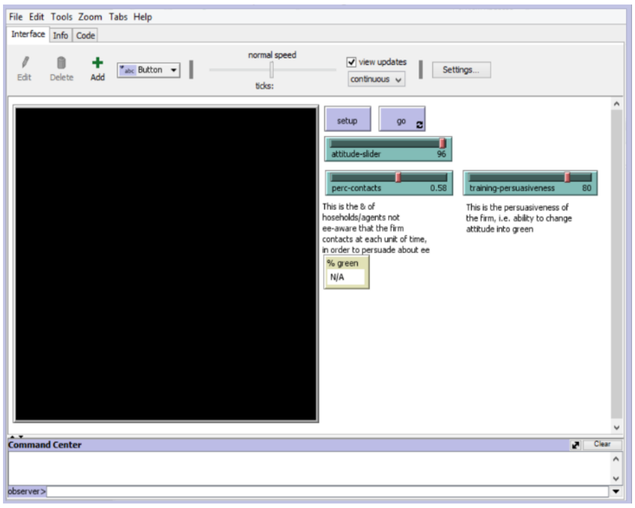
The model analyzed above with R does not permit observation of the movement of the social actors and thus does not graphically effect micro reproduction of the actions.

The ABMs follow Boudon and Coleman's Micro-Macro-Micro process, but in order to be able to observe it, Netlogo software [14], whose settings permits such a representation, was used.

NetLogo reproduces the simulation of the real system showing: the movements of the social agents (Business, Government, Trainers and Families), how the spread of Energy Efficiency policy measures (ee in this graphic representation) occurs, and what happens when investments in training are made.

The Nowak, Szamrej, Latanè Model [15] is represented with the ABM in NetLogo, showing that training carried out in the firms has effects on the families: 100 firms correspond to 1000 families which as a result of persuasion and influence are in their turn trained. NetLogo, as shown in Figure 2, appears with an interface consisting of: *Setup*, *Go* and three *Sliders* which are: *attitude*, *perc-contacts* and *training-persuasiveness*. The *green %* button shows the percentage of the agents/families that have an *attitude* towards implementing Energy Efficiency measures.

Figure 2 – Interface of Cubeddu NetLogo Social Model



The settings were chosen and created to permit the movement of agents: specifically, the *attitude slider* makes it possible to see the decision of families to adopt energy efficiency systems; the *perc-contacts slider* represents the number of subjects/families that have not been influenced and on which the firms apply persuasion, and *training-persuasiveness* is the persuasion carried out both by the firms and subjects in proximity which have the capacity to change *attitude* (to implement energy efficiency measures) in relation to training.

First of all, on the basis of the social model shown above, a *code* is written in which the functions of the actors and their actions are made explicit, permitting representation of the simulation. The functions written in the code simulate the movements of the agents in the software.

From this point all the actions shown are referred to the graphic simulation. In fact, it will also be necessary to graphically illustrate the software interface in order to show the reproduction of the ABM, theoretically the Macro-Micro approach that in its representation becomes Micro-Macro.

Going back to the theoretical model, the opinion on the application of tools in Energy Efficiency is observed with *attitude*, based on both the persuasion and support variables.

The model indicating *attitude = 1 (green)* shows that the agent decides to implement Energy Efficiency interventions. Families are influenced by *neighbours*, as in the Nowak, Szamrej and Latanè model. In addition, it can be observed that the effect of persuasion and support is determined by the firms and the training exercised on the firms:

1. one (or more) firms that train and persuade the agents to change their minds about Energy Efficiency;
2. the power of persuasion, given by the training of the firms.

In the model the firms come into contact as a result of proximity with a variable number of non-trained agents who do not have any knowledge about Energy Efficiency (*perc-contacts slider*) and to which the process of persuasion is applied. In other words, the firms exercise on the subjects a force given by the relation of persuasion and support on the subjects in their vicinity

$$(\hat{\imath}_p = PNTB_i * N_0^{1/2} * (P_i/S_i)/N_0).$$

The agents near both the firms and the agent/family exercise a capacity of persuasion (which is variable, can be defined with the *training-persuasiveness slider* and has a distance of zero). In addition, it can be stated that, as a result of contact with the firms (which have clearly explained all the advantages of ee to the other agents), the people who come into contact and exchange influence about the implementation of Energy Efficiency systems (*ee-friendly*) inherit the firm's power. Their capacity of persuasion and support increases significantly, because they have been more informed. Therefore, their capacity to contribute to the diffusion of the policy becomes greater and greater.

The effects of training, persuasion and spatial vicinity among all the agents makes it possible to observe that if we start from the original model (launched with Setup) from a situation of low green (if no training has been exercised on the firm and thus there is no knowledge of the policy), the result will be that the greens, the agents trained, are forced to disappear – as though a culture of anti-development, anti-investment and anti-efficiency were being spread in society (Figures 3a and 3b).When the level of persuasion of the firms is introduced into the model with the *perc-contacts slider* the opposite effect is observed – that is, the firms contribute to inverting the tendency thanks to the action of influence practised on the agents and families. This influence generates agent spreaders with a high persuasion capacity. The result is evident: starting from the same situation, green energy spreads (Figures 4a and 4b).

Figure 3a – Cubeddu Setup Model with low level of persuasion and presence of agents with knowledge of EE measures.

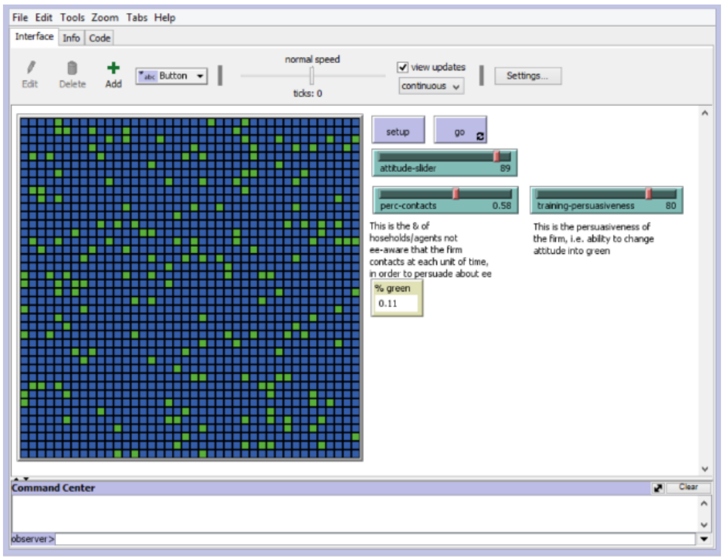


Figure 3b – Cubeddu Go Model movement of agents with low level of persuasion and training; the agents increasingly have no knowledge of EE and measures and do not put them into practice.

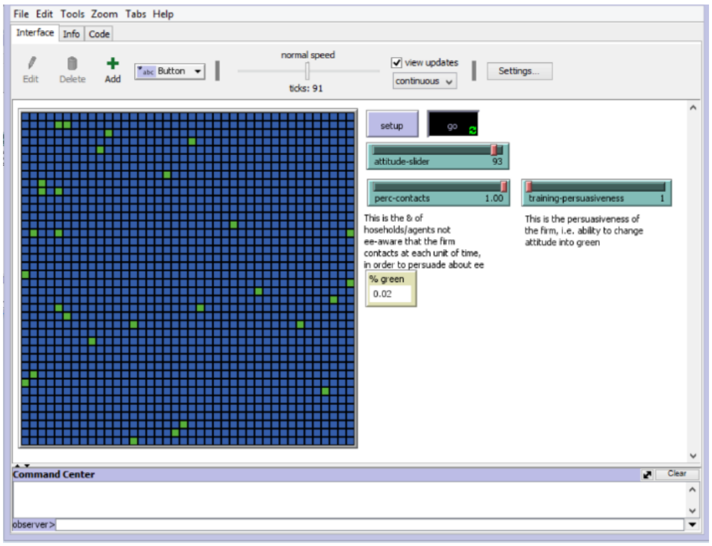


Figure 4a – Cubeddu Setup Model with high level of persuasion and training and agents who have knowledge of EE measures.

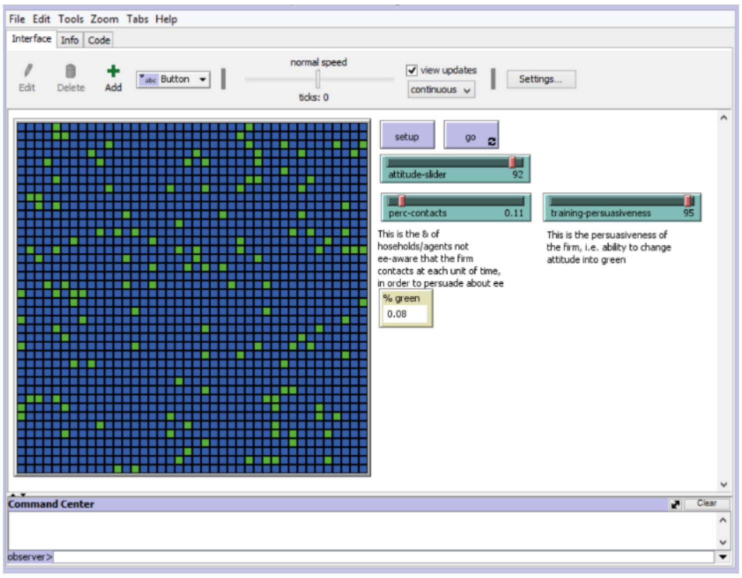
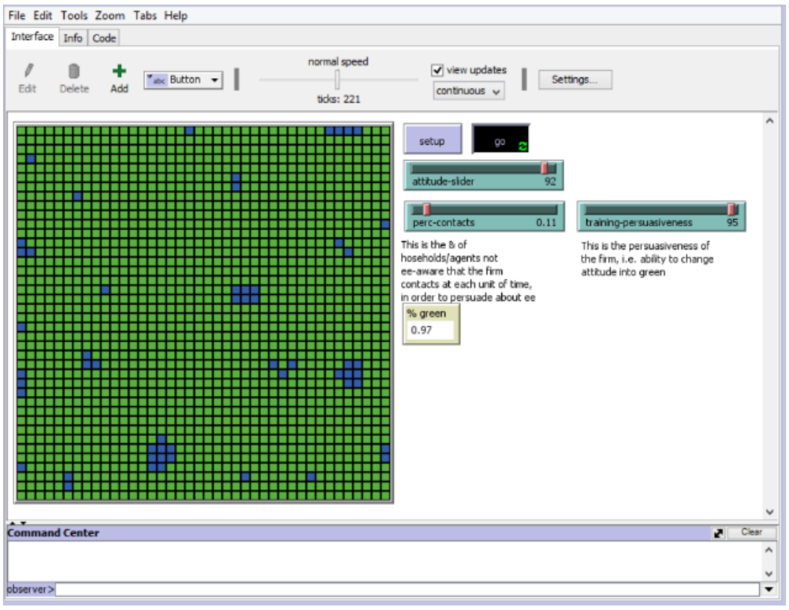


Figure 4b – Cubeddu Go Model movement of the agents who with a high level of persuasion and training increasingly have knowledge of EE measures, put them into practice and spread knowledge.



The model shows that once a critical level is reached, the policy spreads itself, through the persuasion of the agents who live in close proximity.

With training, the firms exercise a stimulation force leading to activation of the process.

The ABM model presented in NetLogo makes it possible to see what impacts a training policy has in the spread of – in this case – Energy Efficiency measures[19].

The true model is not so much the one represented with the software but the one outlined in the theoretical part, since only by studying the network, the actors and their movements over the territory is it possible to generate opinions and functions that are translatable mathematically and graphically.

In the social model it is clearly shown that training involves the diffusion of the policy, with the application of its mechanisms, only if there is a real interest in investment in training. Social persuasion is thus exercised on the families and support comes into play. Investments in training are among the tools used to incentivize policy implementation and diffusion, which is fundamental because it brings the economic dimension into social behaviour. In fact, a concrete method to illustrate how the adoption of Energy Efficiency policy comes about is to observe the number of interventions carried out and participation in training courses.

The results of the case study integrated into the SAM[20]

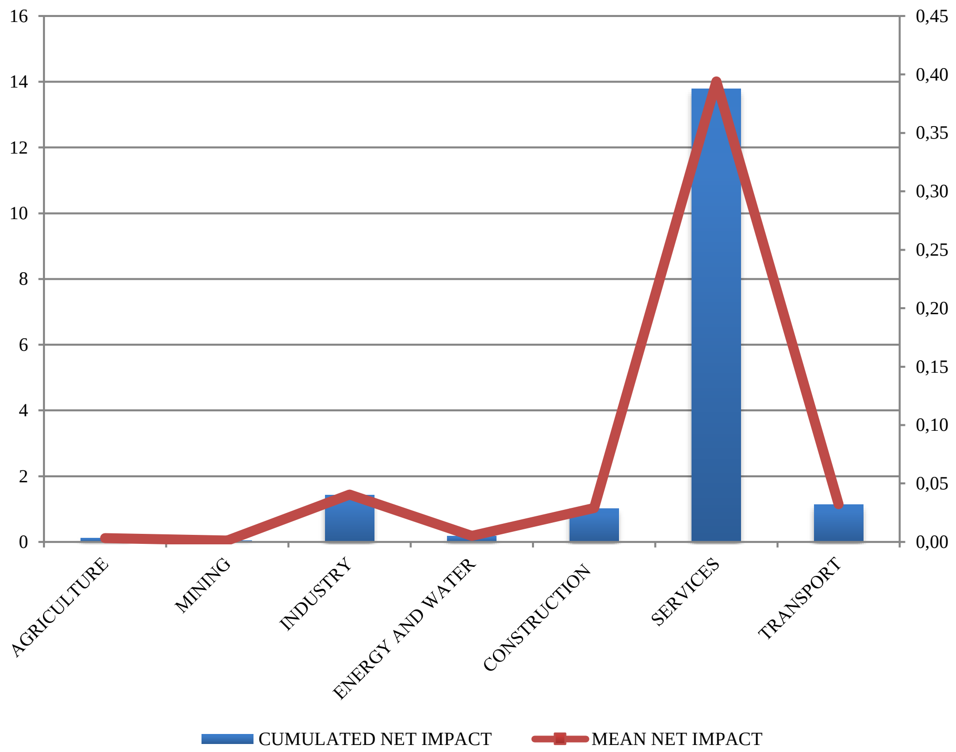
Once the social model was built and realized with the two types of software, it was possible to go on to the second phase of the research: the insertion of the social variables into the Social Accounting Matrix.

The Social Accounting Matrix – SAM from now on – [16] permits observation of all the social impacts deriving from the social model. The data of the social model examined are fed into the Matrix constructed in Excel. The data on training and investment in incentivizing activities for the Energy Efficiency measures show that with increased information and education there is an increase in human capital employed, in addition to the economic capital possessed by the subjects. Figure 5 shows average annual effects on added value and employment deriving from the adoption of the Policy (of training) simulated in the Social Model. The effects are clear, since the values calculated for the Policy scenario have been subtracted from those relating to the contra-factual scenario. This

[19] The effects of Training can be analyzed and studied according to different themes and policies.
[20] Matrix used at Enea, designed and patented with Tor Vergata University.

makes it possible to have a realistic and concise picture of the effects derived from investments in training.

Figure 5 – Net results of the evaluation of macroeconomic impact of the scenarios under consideration (Policy - contra-factual– annual average – data in millions of euros (added value) and thousands (JC).



The SAM results confirm that an aggressive policy on training would (if the result furnished by the Social Model created is accepted as a given) produce a positive effect both in terms of added value and number of jobs. The complete results expressed by macro-sector are contained in Table 1. The table shows the impacts in the macro-sectors of economic activity. Closer examination of the data makes it possible to observe some characteristics of the type of impact considered, relating to the nature of the activities connected with interventions of building upgrading.

Table 1- Complete evaluation results of the Policy and contra-factual scenarios by means of SAM – data in millions of euros (added value) and thousands (number of jobs)

	POLICY 1		**POLICY 2**		**NET**	
ADDED VALUE	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**
EMPLOYMENT	2,34	0,07	1,87	0,05	0,47	0,01
CAPITAL	2,89	0,08	2,31	0,07	0,58	0,02
FAMILIES	6,08	0,17	4,86	0,14	1,22	0,03
ENTERPRISE	1,39	0,04	1,11	0,03	0,28	0,01
AGRICULTURE	0,15	0,00	0,12	0,00	0,03	0,00
MINING	0,14	0,00	0,11	0,00	0,03	0,00
INDUSTRY	2,28	0,07	1,84	0,05	0,45	0,01
ENERGY AND WATER	0,40	0,01	0,32	0,01	0,08	0,00
CONSTRUCTION	0,72	0,02	0,58	0,02	0,13	0,00
SERVICES	5,15	0,15	4,12	0,12	1,03	0,03
TRANSPORT	0,61	0,02	0,49	0,01	0,12	0,00
GOVERNMENT	1,12	0,03	0,89	0,03	0,22	0,01

	POLICY 1		**POLICY 2**		**NET**	
JOBS CREATED	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**	**TOTAL**	**MEDIAN**
AGRICULTURE	1	0	1	0	0	0,01
MINING	0	0	0	0	0	0,00
INDUSTRY	13	0	11	0	3	0,07
ENERGY AND WATER	1	0	1	0	0	0,01
CONSTRUCTION	5	0	4	0	1	0,03
SERVICES	45	1	36	1	9	0,26
TRASPORT	4	0	3	0	1	0,02
GOVERNMENT	0	0	0	0	0	0,00

The data are grouped according to macro categories thus providing a summary of the effects of the two policies and the resources necessary for their implementation. The table shows that there is an impact on all sectors; however, it is greater on productive activities. The effects of the policy produced by the difference between added value generated in the case of the Policy scenario and added value generated in the contra-factual scenario, lending support to the hypothesis that investment in training can pay off in positive effects on the entire system: activation of upgrading interventions and direct and indirect movement of the economy. It moreover very clearly illustrates that the sectors in question (when only the productive and not institutional sectors are considered) can be divided into two groups where most of the effects of the interventions are concentrated: energy, construction and services.

This is understandable since these are the sectors most involved in carrying out upgrading procedures (ranging from construction firms to the various professionals involved in different ways in the operations). There are other effects – not analyzed here – relating to the structure of the SAM matrix multipliers, showing that the indirect effects can also be significant in sectors which are not, naturally, directly linked to the investments made (such as health care, for example, in the graph). When a policy of investment in training is implemented permitting the diffusion and application of Energy Efficiency measures, there is an impact over the entire socio-economic context since Social Well-being increases. The benefits of the Energy Efficiency policy appear only if other kinds of policies which validate and promote development policies are implemented.

Only an increase in employment, generated by increased demand for interventions, will have a cascading effect, as follows:

1. Dual effect – that is, physical and mental – on subjects' health;
2. income;
3. GDP growth;
4. increased consumption;
5. increase in savings;
6. environmental wellness;
7. decreased fuel poverty;
8. decrease in CO2;
9. increase in social security.

These nine impacts are only some of the possible benefits, since there are multiple effects on social well-being. The theoretical and methodological aspects permit us to state that the actions triggered even by a single social agent can modify the entire social system, above all if the action implemented brings with it determined logical behaviour aimed at well-being. The pursuit of well-being by a single individual involves all social behaviour, because the collective social consciousness of well-being moves with each subject.

4 Discussion

The research aimed to observe the role of Training in the use of and investment in Energy Efficiency measures. More specifically, it analyzed how training, promoted by the policies addressed to firms, is spread to other agents in the social system.

The effect of training spreads with social proximity, persuasion, support and individual attitudes. These categories were borrowed from the 1990 model of Nowak, Szamrej and Latané and the study's equation was specifically re-formulated according to the superstructure of the phenomenon under consideration. The Cubeddu model studies the role that firms play in relation to the subjects within their area, a power given from the relation between persuasion and support:

($\hat{\iota}_p = PNTB_i * N_0^{1/2} * (P_i/S_i)/N_0$)[21].

The analysis is applied to the Lazio Region and is based on the behaviour of three main subjects (Family, Trainers and Businesses), which put into practice and respond to the policies proposed by the fourth (Government). The study of the Lazio Region permitted the collection of primary data – albeit not statistically important – on which the social model and integration was then constructed.

Training entails social influence, shown by the persuasion which is reinforced by incentivizing subjects' well-being. With training courses, trainers provide support to the persuasion of the subjects because they believe, as is evident from the answers to the questionnaire, that training brings impacts of short, medium and long duration. They maintain that by modifying the technological approach, an improvement in individual and collective well-being occurs.

The model presented with ABM shows that training carried out by businesses has effects on the families: 100 business firms trained correspond to 1000 families which as a result of persuasion and influence are in their turn trained.

The agent-based model created with NetLogo shows that the probability of implementing Energy Efficiency activities grows in relation to the level of training the subjects have, to the level of external persuasion exercised by the

[21] Impact of Persuasion Power (P) in Cubeddu (2017), mentioned above where:
$\hat{\iota}_p$ = Persuasion Power Impact
$PNTB_i$ = Probability of New Training in the i-th policy
P_i = level of persuasion outside one's family nucleus
S_i = level of support outside the family nucleus
N_0 = number of people interested in change
$\overline{N_0}$ = average number of people interested in change
$\overline{\hat{\iota}_p}$ = average pressure resulting from simulation.

businesses and the residents themselves and to the level of support, thanks also to the number of subjects who changed attitude. The social model shows that training entails policy diffusion with the application if its mechanisms, but only if there is real investment in training. In this process social persuasion exercised on the families and support is activated.
Investment in training is one of the incentive tools for policy implementation and diffusion. Incentives are fundamental because they bring the economic sphere into social behaviour. Concretely, the adoption of Energy Efficiency policy is ascertained through the number of interventions carried out, as well as participation in the training courses.
In order to obtain the socio-economic impacts of such investments the social model data was inserted into the Social Accountability Matrix (SAM), which shows that with an increase in information and training there is an immediate increase in human capital employed, in addition to the economic capital in the subjects' possession. There are immediate impacts, for example in the building sector, real estate and professional activity (employment); cascading impacts follow, first of all on health and social services, then on electrical energy, gas and steam and ultimately on commerce. These impacts produce immediate benefits observable in the short, medium and long term. One of these is employment, which naturally occurs, as a result of training as well, because it becomes clear that there is the need to create new job positions.
In analyzing local dynamics, it becomes important to explain the phenomena according to an integrated model. In this analysis, it was possible to exploit this approach in order to be able to observe its impacts. The study of the local dimension makes it possible to integrate different systems and to formulate a new integrated paradigm. The figure of the social actor moving over the territory and acting to achieve his goals connects the social with the economic aspect. In fact, only with a paradigm of interconnection is it possible to interpret the social system in its entirety.

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