Analysis and Use of Information and Communication Tools in the Economics of Climate Change

Aline Chiabai

September 2009

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- Measures to mitigate the amount of climate change experienced

- International Dimensions of Climate Policy

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Analysis and Use of Information and Communication Tools
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Aline Chiabai[1]

The use of Information and Communication Technologies (ICT) in the context of climate change is of great importance in the scientific community, but can also play an important role in the policy context. On the one hand, the results achievable for mitigation and adaptation are influencing the policy arena, and on the other hand these instruments represent an opportunity for decision-makers of applying innovative forms of public administration based on stakeholder's involvement, which can reduce the existing gap between policy-makers and citizens (Oates, 2003).

The paper provides an analysis of the main ICT tools and methods used in climate change economics by means of a questionnaire-based survey and focus groups discussion with specific experts in this context. The issues addressed are related with the use and relevance of ICT in the different research area of climate change, the perceived usefulness of these tools, and their importance in the scientific, economic and policy contexts. The main problems and limitations of ICT are investigated, together with the potentiality they can play in future research.

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[1] Basque Centre for Climate Change (BC3). Gran Via, 35 – 2, 48009 Bilbao, Spain. E-mail: aline.chiabai@bc3research.org.

1. Introduction

The methodological framework used to perform the analysis of Information and Communication Technologies tools (ICT) in economics of climate change is built on the combined use of focus groups techniques and questionnaire-based survey.

In a first phase, the research activities of specific institutions and universities are investigated and studied, in order to identify the key research areas and fields in climate change context, key tasks, priorities and main estimation problems. Based on the results of this analysis, and building on the focus groups activities performed with climate change experts, a questionnaire is designed about the use of ICT tools in this context. The focus groups are also used to analyze in depth some of the ICT instruments used in climate change research, their extent of application and the importance of relevant research fields for future research programs. The framework for the whole analysis is built on the findings of Labelle et al (2008) who provided a survey of ICT applications for e-Environment[2].

The survey is administered to a number of experts in some selected research institutions identified in the first phase. The objectives of the questionnaire are to analyze: (i) the concrete use of some ICT tools, (ii) the perceived usefulness of ICT in different areas of research, (iii) accessibility, target uses, limitations, problems, and opportunities for future use of ICT, (iv) the perceived relevance of ICT tools in terms of their scientific, economic and political exploitation. The structure of the questionnaire is presented in the next section.

In the following section the methodological approach is presented, with the questionnaire structure and survey administration, and the results obtained are discussed in light of the relevant research fields for future research programs.

2. Methodological approach: survey-based analysis

2.1. The questionnaire

The questionnaire has been pretested during focus group discussions and one-o-one interviews, and has been designed in order to facilitate the respondent. The questionnaire is structured into five sections. The first section (A) provides a brief description of the Information and Communication Technology tools (ICT), adapted from the definition used in the report "IXTs for e-Environment" (Labelle et al, 2008)[3]:

The use of ICT tools in climate change research is analyzed in the research areas of modelling and simulation, socio-economic analysis, policy analysis and planning, and finally capacity building.

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[2] Labelle et al (2008) specify that e-Environment includes "the use and promotion of ICTs as an instrument for environmental protection and the sustainable use of natural resources, the initiation of actions and implementation of projects and programs for sustainable production and consumption and the environmentally safe disposal and recycling of discarded hardware and components used in ICTs, and the establishment of monitoring systems, using ICTs, to forecast and monitor the impact of natural and man-made disasters particularly in developing countries, and small economies" (Geneva Plan of Action, 2003 – World Summit on the Information Society (WSIS) Action Line C7 - http://www.itu.int/wsis/docs/geneva/official/poa.html#c7-20).

[3] The definition has been slightly changed after pretesting the questionnaire and the most appropriate wording has been chosen based on respondents' suggestions: "Information and communication technology (ICT) refers to any communication device or system, including computer and networking hardware and software, radio, television, mobile phones, satellite systems, control systems and sensors, information systems and software (e.g. databases, model simulation, etc) statistics, Geographic Information Systems (GIS), and all other services and applications associated with them (e.g. internet services, data processing)".

The second section (B) asks the respondent to indicate the main research areas related to climate change on which he is currently working. Section C presents a list of ICT tools and asks the respondent to indicate which tools he is using and the perceived usefulness of the selected tools in his research activities. The respondent is then asked to report, for each identified tool in use, extent of application, main limitations and problems, and finally its potential for future uses.

Section D focuses on the relevance of ICT tools under different contexts: scientific, economic and political. This issue has been first addressed in focus groups discussion in order to understand how the three types of relevance are perceived by the respondents and which features they include. Once the main features for each context are identified, the respondent is asked to rank them in terms of the importance he think ICT tools could have in those contexts (from the lowest importance, equal to 1, to the highest importance, equal to 9). This question allows to analyze the type of relevance given to ICT tools (by the experts) and to identify which contexts are judged to be more important for ICT development in the future.

The last section (E) includes some socio-demographic questions: gender, age, country of residence, professional position, degree or training, and type of organization where the respondent works. These questions are usually included as they help in interpreting the responses given, and provide a context for the study.

2.2 Administration of the survey

The questionnaire has been administered by email to 40 experts working in climate change research in different institutions taken as a basis for the study. A total number of 18 questionnaires have been completed. The survey applies specifically to the economic field of research about climate change, as most the interviewed experts are environmental economists. The present study does not therefore represent a comprehensive analysis of all the research institutions operating in the diverse areas of climate change, and the sample used for the survey is not representative of the whole community of researchers in this context. The results of the survey are discussed in the following sections.

As regards the individual characteristics of the respondents, males account for less than half of the sample (8) and the age ranges from 26 to 56 years, with an average of 36. Respondents are from different European countries, including France, Italy, The Netherlands, Norway and Spain. As regards the professional background of the experts, economics and environmental science are the most common fields. Finally, most of the experts work in private or public research centers or universities, while other types of organizations (private consultancy companies, administration/government, non-governmental organizations) are less represented.

3. Results of the analysis

3.1. Key areas of climate change with ICT applications

There are five main research areas in the climate change context, which can be considered for ICT application: (i) observation and monitoring, (ii) modeling and simulation, (iii) socio-economic analysis, (iv) policy analysis and planning, and (v) capacity building.

In the observation and monitoring area[4], data collection and recording systems are used to monitor climate and meteorological impacts, to record and stock a huge amount of data and information about weather with high geographical and temporal coverage. ICT tools in this area include satellite observation, direct sensors, data archives, database management systems, geographic information systems (GIS) and telecommunication networks. Data stored are applied for example in meteorological observation and disaster early warning systems based on real-time information platforms.

In the modeling and simulation area, computational and processing tools are used to model climate, socio-economic impacts and other environmental impacts. In this area of research, data collected in the first area (observation and monitoring) are processed and analyzed in order to understand how ecological systems work, and to correlate observed data with other measures related to the environment, like health impacts, biodiversity, economic system. ICT tools in this context are for example algorithms for simulation, database management systems, GIS. ICT applications include bio-physical models, socio-economic models and integrated models. These models have to deal with specific methodological issues such as the estimation of direct and indirect impacts on different economic sectors, spatial aggregation of the impacts on different regions, temporal aggregation of costs and benefits, uncertainty in selecting the optimal pathway in economic scenarios (Tol and Fankhauser, 1998).

The socio-economic area includes tools for estimating damages associated with climate change, costs and benefits of mitigation and adaptation measures (and their cost-effectiveness) and to analyze related contingent effects, like distributional impacts and equity issues (IPCC, 2007). In this context specific statistical tools for monetary valuation are used, as well as computer-assisted interview tools for collecting data about climate-related damages (stated preference approach). The tools used in this area are based on micro-economic analysis, while those used for modeling the socio-economic impacts in the previous area are based on macro-economic simulation models.

In the policy analysis area, planning at different geographical level (international, national and regional) uses data and results from the first three areas in order to facilitate coordinate decision-making and management, to formulate policies and strategic plans, to perform risk assessment, and to put in place forecasting systems. Mitigation policies include GHG emission management, reduction and controls of emissions. Examples of adaptation policies are early warning systems (e.g. SMS broadcasts over mobile telephone), emergency response planning, land and water user management systems. Key ICT tools in this area include decision support systems, database management systems, GIS, models to assist decision making, mapping systems, internet and networks on the web to share best practices. Specific tools are also needed for planning, management, implementation, monitoring and evaluation activities related to mitigation and adaptation policies[5].

Finally, capacity building includes efforts to increase public awareness of climate change, to facilitate participation systems to decision-making processes, and to promote education and learning. In this context ICT instruments include e-learning tools, online learning applications for developing countries, access to relevant knowledge at local level, e-governance systems. The potentialities offered by the new communication technologies represent an opportunity for decision-makers to experiment and

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[4] This area of research is not addressed in the current study as the instruments used, the expertise required and the problems faced in that area are quite different from the other four areas. The specificities of that context would suggest a separate analysis. The other four areas are more interconnected in terms of activities, tools and objectives, and are often performed under the same institution by different experts and research groups.

[5] Effective implementation of adaptation and mitigation policies is not considered in this study as it lies outside the area of research, involving governments and administration levels (municipalities, central governments), as well as economic sectors such as transport, energy and private industrial enterprises.

apply innovative forms of public administration based on the so-called "bottom-up approach" (Margoli and Resnick, 2000). Involvement of stakeholders is of particular importance for anticipatory adaptation (Few, 2006), which implies preventive actions to be planned before the impact occurs in order to avoid the risk of the adverse avent.

The ICT tools analyzed in this report include information systems, computational analysis systems (modeling and simulation), decision support systems and integrated environmental information systems, according to Page and Rautenstrauch (2001), while observation systems, monitoring and control tools are excluded from this analysis.

3.2. Use of ICT tools in climate change research

Use and relevance of ICTs in the identified research areas of climate change are specifically addressed in the survey questionnaire. Respondents are asked first to indicate the research areas related to climate change in which they are currently working. Results show that the great majority of the respondents (13) work in "socio-economic analysis" (SEA), and a substantial number (11) work in "policy analysis" (PA). Half of them also work in "modeling and simulation" (MS) and in the "capacity building" research areas (CB). All these research areas are strictly connected. Most of the modelers, actually, also work in socio-economic and policy analysis areas, as these are mutually supporting. On the one hand, they use some of the methods and tools developed in SEA (such as CEA or CBA, and market based valuation, used specifically in the socio-economic and integrated models) to perform their analysis. On the other hand, the output of modeling is an important input for policy analysis (integrated assessment models, IAM, are used for scenario building and planning).

Most of the socio-economic analysts deal with policy analysis as well (the estimation of the climate change impacts or damages are used for scenario building), while most of the policy analysts (and specifically those working in scenario building) are involved in research and academic networking.

Respondents have been then asked to report which tools they are currently using in their research activities[6]. Secondly, they are asked to indicate the usefulness of each identified tool in their area of activity, using a likert scale ranging from 1 (=not useful) to 5 (=very useful), with a middle level of 3 (=somehow useful). The relevance of ICT in sub-categories is analyzed by the number of preferences attributed to high or medium usefulness of the tool.

Frequency of use is reported in Figure 1 below. Internet and web-based services (INT) are the most common ICT tools and are used by all the interviewed experts and in all the research areas surveyed. Statistical software for data analysis (STAT), information management systems (ACCESS) and modeling tools (MOD) are used by the great majority of the interviewed experts, while the use of GIS, web 2.0, mobile technologies (MOB), decision support systems (DSS), computer-assisted interviews tools (CAI) and e-learning tools (e-LEARN) are less common and can be found only in some specific research activities.

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[6] The ICT tools listed in the questionnaire are based on the information provided by ICT-ENSURE, and has been complemented by some further tools used in economics of climate change.

Figure 1. Use of ICT tools in economics of climate change.
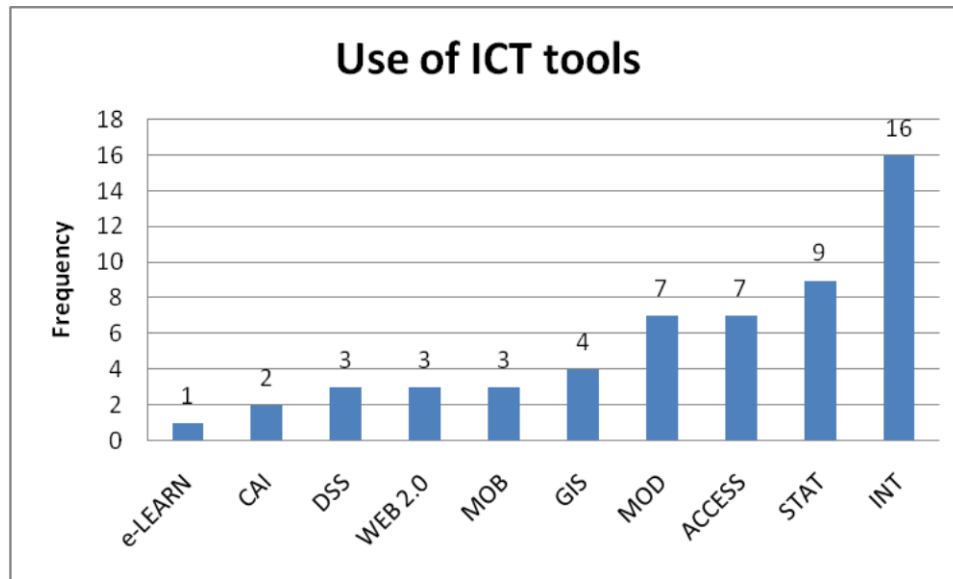
As regards usefulness, the results are reported in Table 1. Internet-based services are given the highest score in all research activities (4 and 5), but the highest relevance is attributed to the socio-economic analysis (SEA) and policy analysis (PA) areas. Computer-assisted interview services are used mostly in the socio-economic analysis (SEA) and policy analysis (PA), but they have been attributed a medium usefulness (score 3). Other tools are actually considered more important in these areas, such as statistical packages and web-based services. Modeling and simulation are used, as expected, in the modeling area (MS), for policy analysis (PA) and in participation processes (included in IAM), but the highest relevance is recorded in the first area. These tools are perceived as very useful in both modeling and capacity building areas, but in the latter their relevance is lower due to a lower use. Statistical tools and software are used in all research areas and they are always perceived as very useful, but the highest relevance is recorded in SEA and PA, as they represent the main instrument for analyzing data and computing estimates.

GIS is considered very useful in all areas, but has a higher relevance for modeling (MS). Information management is used in policy analysis (PA) and capacity building (CB), but it is perceived as very useful also in the other areas. Decision support systems are relevant specifically for policy analysis (PA) but are used also in modeling (MS). E-learning tools are relevant especially, as expected, in the capacity building area for distance learning programs and education (CB). Cooperative systems (web 2.0) are mainly used in capacity building area (CB) where they have the highest relevance, but can be useful also for socio-economic analysis. In this latter they show nevertheless a low relevance as they not very widespread. Mobile technologies are used in the context of participatory tools and for e-governance systems (even if still not very widespread), while they are not relevant in other contexts.

As regards the extent of application (and relative information flow) of the identified instruments, three main categories of tools can be distinguished: (i) "generalized tools" for the general public, such as internet and web-based services, characterized by high accessibility and usability; (ii) "specialized tools" requiring some basic training, such as statistical tools and computer-based interviews packages, characterized by a medium level of accessibility and usability; (iii) "highly specialized tools" for specific kind of users, such as modeling and simulation, characterized by very low accessibility and usability.

Access to some types of tools such as computer-assisted based interviews is quite expensive. These tools are often not directly used by research institutions as the survey administration is generally subcontracted to specialized institutions.

Table 1. Perceived usefulness and relevance of ICT tools in different research areas of climate change.

ICT TOOLS	RESEARCH AREAS			
	MODELLING & SIMULATION (MS)	SOCIO-EC ANALYSIS (SEA)	POLICY ANALYSIS (PA)	CAPACITY BUILDING (CB)
INTERNET	5 (++)	5 (+++)	5 (+++)	5 (++)
COMPUTER-ASSISTED INTERVIEWS	1	3 (++)	3 (++)	1
MODELLING	5 (+++)	2	3 (++)	5 (++)
STATISTICAL SOFTWARE	5 (++)	5 (+++)	5 (+++)	5 (+)
GIS	5 (+++)	5 (++)	5 (+)	5 (+)
INFORMATION MANAGEMENT (ACCESS)	5 (+)	5 (++)	5 (++)	5 (+)
KNOWLEDGE MANAGEMENT (DSS)	5 (+)	1	4 (++)	1
e-LEARNING	1	1	1	5 (+++)
COOPERATIVE SYSTEMS (WEB 2.0)	1	3 (+)	2	5 (+++)
MOBILE TECHNOLOGIES	1	1	1	2

Note: usefulness measured using likert scale (1=not useful, 3=somehow useful, 5=very useful); relevance measured by the preferences reported for high and medium usefulness (+low relevance, ++medium relevance, +++high relevance).

3.3. Scientific, economic and political relevance of ICT tools

The relevance of ICT tools in climate change research has been analysed in terms of scientific, economic and political importance of each instrument. Three features have been identified during focus groups discussion for each context. The scientific relevance is analyzed in term of improvement of multidisciplinary research, increasing exchange in the scientific community and increasing accessibility to sophisticated analysis by user-friendly tools. The economic relevance embraces the reduction of the costs of research, the opportunity to transfer the tool into a business context, and to education for e-learning processes. Finally the political relevance embraces the interface with policy-makers, the participation of citizens in the decision-making process, and the increasing public awareness of climate change.

The perceived importance of ICT tools in each context is analysed by asking the respondents to rank the above mentioned features in terms of the role that ICT could play in those contexts (using a ranking scale where score 1 identifies the lowest level and score 9 the highest level). The analysis aims at identifying the areas where ICT is judged more relevant and the relative importance of each feature. For this purpose, the number of preferences reported by the respondents in one of the three highest levels in the ranking are analysed.

The highest importance is attributed to the scientific features, which have received the highest score (Figure 2). According to the respondents' answers, ICT is considered of particular importance to increase exchange in the scientific community (EXCHANGE) and accessibility to sophisticated analysis by user-friendly tools (ACCESSIBILITY). The possibility offered by ICT to improve multidisciplinary research (MULTIDISCIPLINARY) is also judged important but with a lower priority.

Figure 2. Scientific relevance of ICT.
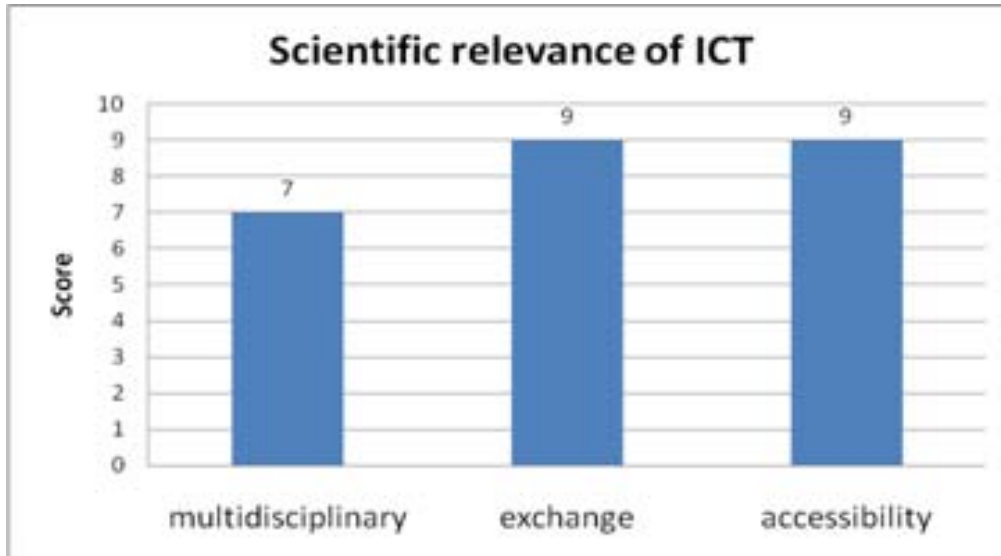
The economic features of ICT are judged to be less important, with an overall score much lower compared to the scientific features (Figure 3). The opportunity to transfer ICT tools into business contexts (BUSINESS) has received the lowest score. Of somewhat higher importance is judged the possibility of ICT to reduce the costs of research (COST) and the possibility to transfer the tools to education for e-learning processes (EDUCATION).

Figure 3. Economic relevance of ICT.
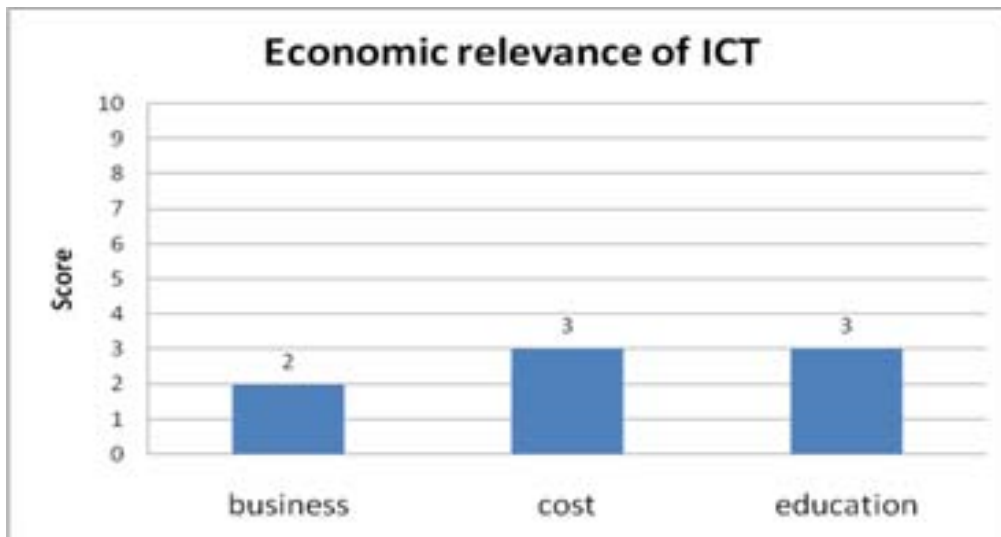
As regards the political features, these have been attributed a medium score, being judged as more important than the economic features but less important than the scientific ones (Figure 4). The use of ICT tools as interface with policy-makers (POLICY) and to raise public awareness of climate change (AWARENESS) have received the highest score, while the use of ICT as a mean of public participation in the decision-making process (PARTICIPATION) is considered less important.

These results suggest firstly that respondents are aware of the potential of ICT as communication tools with policy makers and to inform citizens. On the other hand, the use of ICT in participatory processes to promote "collective" decision-making and specific actions over the territory is still considered of lower relevance, even among experts using these tools.

Figure 4. Political relevance of ICT.
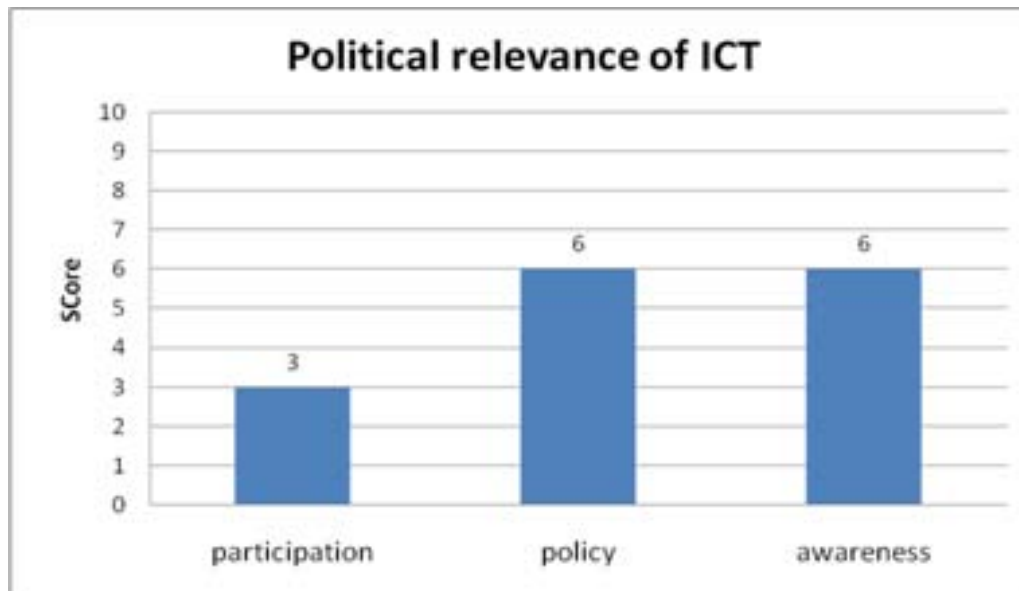
3.4. Future potential and limitation of ICT tools

The interviewed experts have identified concrete limitations and opportunities for future developments of the specific tools and models they are currently using. This analysis applies therefore to some particular tools instead of broad categories of instruments. For internet-based services, the main perceived limitations are information overload, data reliability, protection of personal data, open accessibility limited to some e-journals and databases, selection bias for online databases. Potential for future exploitation includes profiling and filters to access selected information, personalized information and content generation. Further indications have been reported regarding the possibility of developing scientific forums in specific areas of research, designing common databases for e-journals, increasing research networking (including developing countries) and availability of online computing services. For the analyzed modeling tools[7] the main perceived limitations regard open accessibility limited to old and reduced databases, data shortage, complexity of code equation limiting the development of new versions of the model, complexity for parameterization, unfriendly use, intellectual property right related issues

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[7] The models analyzed include ATEAM, IMAGE, GTAP, GEMPACK, IAM DICE, NGAUGE DSS, SISMDAIRY MODELLING FRAMEWORK.

and limited input data from real systems. Future potential uses are associated with development of the models for downscaling and treatment of uncertainty, possibility of using the database for different models depending on the research objectives, possibility of modifying the model to include different policies, use of wide databases covering different research areas, development of new versions allowing sectoral level analysis, and evaluation of mitigation and adaptation policies coming from current and future international agreements and national strategies on climate change.

For the identified statistical tools[8], the limitations include high costs of the software, unfriendly error transmission, scarce and unfriendly help tools, little flexibility in user menu and difficult programming language. Potential for the future include use of the statistical tools in new areas of research (such as e-participation process analyzing citizens preferences), improved usability to facilitate use in different areas of research, and the possibility of handing big datasets. Geo-referenced tool (GIS) limitations regard mainly the limited use for decision-making, the limitation in detailed map availability, unfriendly use, and the need of fine-tuning with final user for building interface and providing relevant information, which influence effectiveness of the tool. It main potential is the multi-functionality.

As regards finally the cooperative systems (such as e-governance), the main problems are associated with the need of establishing best practices, methods and tools for participation, and the fact that these instruments are not fully accepted in the decision-making process. Barriers include protection of personal data and information. As concerns the main potentials, these include the possibility of involving different stakeholders in policy discussion using multi-sectoral design approaches, and increasing awareness on climate change and autonomous adaptation which applies specifically to the citizens. Cooperative systems represent a high potential for public participation on relevant issues such as adaptation measures.

4. Conclusion

The main limitations and potentials identified by the respondents allow to analyze the research demand for ICT. The main points can be summarized as follows: (i) to increase accessibility and availability of datasets for computational analysis, modeling, communication, participatory processes, learning and education; (ii) to increase research networking, interactive services on the web and platform for data sharing; (iii) to use open standards and open architectures to reduce barriers to integration of different systems; (iv) to develop web-based participatory tools and related e-governance systems for public participation; (v) to increase integration of ICT in policy planning and formulation; (vi) to increase geo-referenced data availability and accessibility based on mapping software and GIS; and finally (vii) to reduce complexity of the models (more accessible codes and data).

As regards developing countries in particular, there is a need to encourage international collaboration and support to increase use and accessibility of ICT tools. Research networking and increased accessibility of online computing services would play a crucial role in this context.

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[8] The models analyzed include STATA, LIMDEP, GAUSS, SAS, SPSS.

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