ICT Diffusion in an Aging Society: a Scenario Analysis

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Abstract. The relevance of Information and Communication Technologies (ICTs) is progressively increasing in every aspect of modern life. At the same time, the aging trend most European countries are experiencing, may significantly impact on their absorptive capacity of innovation, which is a key determinant of socioeconomic development, with deep policy implications for both the private and the public sector. The aim of this paper is thus to investigate the relationship between age and technological diffusion. The analysis is performed using the Internet as a case study, combining agent-based simulation with classical statistical analysis. Three different demographic scenarios are considered, representing different geographical areas as well as possible alternative futures. The results obtained show that the age factor and the demographic trends exert a significant influence on both the dynamics and length of the diffusion process.

Keywords: diffusion of innovation, aging, policy, agent-based simulation, ICT governance.

1   Introduction

The diffusion of Information and Communication Technologies (ICTs) in nearly every crevice of society has significantly increased and extended the importance of network externalities deriving from the use of compatible technologies by critical masses of users. Furthermore, ICT diffusion has contributed to render the competitiveness and equality of socioeconomic systems strictly dependent on their capacity to absorb innovation and fruitfully put it into practice.

At the same time, the aging trend present in European societies is bound to pose significant challenges to the process of innovation adoption and use. This trend is currently particularly severe. As an example, in Italy (one of the "eldest" European

countries) the percentage of people over 65 as of 2008 is equal to 20% and is expected to reach 35% by 2050 [1].

Technological paradigms are, in fact, highly intertwined with users' generations, whose ability to migrate across them is significantly influenced -among other factors- by age, and this is particularly true for innovations that are related to knowledge and cognition [2]. If the demographic distribution of a population were in steady state, technology diffusion processes, though dependent on age, would be independent from the distribution. However, when the demographic distribution does change, it is likely that this will affect technology diffusion processes. In such scenario, national and regional governments might have to deal with unprecedented challenges requiring a profound rethinking of the policy and strategic approaches so far implemented. The situation thus calls for a deep understanding of the problem dynamics and dimensions, necessary to identify timely policy responses and the minimization of errors.

This paper presents the results of the first phase of the I-PAS project financed by Regione Piemonte (IT) on 'Innovation Policies for an Aging Society'. The main objective of such project is to investigate the influence of the aging trend on the innovation absorption capacity of a socioeconomic system, and to identify the most suitable policy responses. A decision support tool will be developed allowing to test different policies, thus resulting in more informed political choices. The present article constitutes a preliminary contribution to the achievement of such objectives, starting to investigate the relationship between demographic trends and the corresponding evolution of diffusion phenomena.

The research question, object of the present paper, can be summarized in: "*what will be the impact of demographic changes on technology adoption?*". Answering this question represents a first step to assess policies to make timely and more informed choices on which course of action to take.

Different demographic scenarios are considered, in order to represent three main trends currently present worldwide (Figure 2):

- Setting 1, *aging* societies: populations experiencing a heavy aging trend, i.e. aged people is going to constitute the prevailing part of the population (e.g. Italy, Germany, Japan);
- Setting 2, *middle-aged* societies: populations in which the middle-aged demographic distribution will expand, becoming dominant (e.g. India);
- Setting 3, *young* societies: populations in which the aging phenomenon is going to be only slightly present (e.g. sub-Saharan countries), thus going to be mainly composed by young cohorts.

The change of technological adoption is simulated through agent-based modeling, in order to overcome the limits of "traditional" analytical models in the treatment of complex dynamic systems. The results of the simulation are subsequently explored via statistical analyses in order to obtain a flexible yet robust methodology.

The article is structured as follows: in the next Section a literature review on technology diffusion related to the aging issue is proposed; Section 3 presents demographic data and trends; an example of technology diffusion data related to age is given. In Section 4, three demographic settings are introduced: simulation

parameters and assumptions are described and results are then discussed. Finally, conclusions are drawn and some implications for further research and practice are discussed.

2   State of the art

The demographic change due to an increase of the elderly population represents a well-known phenomenon currently experienced in many countries [3, 4].

Over the last decade, the core of the literature dealing with the aging of societies has mainly focused on welfare state systems. To exemplify, Casey [5] discussed the possible impacts of aging on expenditure and fiscal pressures. Anderson [6] studied the effects of population aging on retirement policies, as well as on health spending and on workforce composition, seeking to identify policy actions useful to face the phenomenon.

More recently, the issue of aging has been embraced by the European Commission as part of its eInclusion policy. This resulted in a number of studies and projects mainly focused on understanding how ICT could improve the life of elderly people [7, 8]. Nevertheless, little attention has so far been paid to the aggregate effect of aging on the innovation absorption performance of a socioeconomic system.

The role of innovation as a major driving force in economic growth and social development has been in fact repeatedly recognized over the last decades. Technological progress has been found to be responsible for up to one half of the growth of a country economy [9].

Looking at the literature on diffusion of innovation, the role of age in technological adoption is not clearly defined. As Rogers wrote [10], "about half of the diffusion studies on the relationship of age and innovativeness show no relationship, a few found that earlier adopters are younger, and some indicate they are older". However, no empirical evidence is provided in Rogers' book. In addition, this literature strand mainly refers to types of innovation that may be considered significantly different in terms of preconditions for adoption from Internet related technologies (e.g. cognitive skills, IT literacy, language barriers in accessing a significant portion of the content available for non-English speaking users, etc.). For this reason, it is probably the right time to reconsider investigating this relationship to shed some light on the potential impacts that the ageing of societies could exert on countries' ability to absorb innovation.

In this respect, the strand of literature focusing on digital divide has provided useful insights on the differences among generation in the adoption and usage of ICTs [11-14]. This in an attempt to foster a higher level of eInclusion that is considered to be instrumental to increase social cohesion, quality of life and the diffusion of complementary activities such as eGovernment, eParticipation and eCommerce. As a matter of fact, while eGovernment is establishing as the most important public sector reform strategy, age is a factor which may strongly affect its usage [15].

The contribution that this paper intends to bring to the existing body of knowledge on this topic is threefold. Firstly, an investigation of the relationship between Rogers'

categories of adopters for Internet related technologies. Secondly, a better understanding of the diffusion process within age classes in terms of innovation and imitation. Thirdly, a dynamic assessment (through agent based simulation) of the future impact of the aging societies on their ability to absorb innovation.

3   Data and Demographic Trends

As introduced in Section 1, the aging phenomenon is going to represent one of the main socioeconomic challenges in the next decades. As an example, Figure 1 shows the comparison of the old-age dependency ratio in some World countries in 2010 and 2050 [16]; this indicator represents the number of people aged 65 and over as percentage of labor force (aged 15-64); for instance, Japanese and Italian old-age dependency ratios will double.
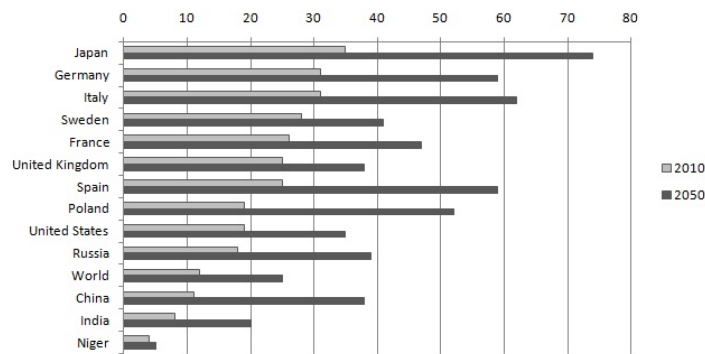

Fig. 1. Old-age dependency ratios in 2010 and 2050 in some World countries (source: United Nations, 2009).

The aging trend is noticeable also in the population pyramid shift that some countries are experiencing (Figure 2): on the one hand, the declining birth rate is going to reduce young generations consistency, and on the other hand the postponement of decease age will increase life expectancy. Even the migratory flows (accounted for in the demographic projections shown in Figure 2) seem not to exert any significant offsetting effect.

In order to analyze the relationship between the aging trend and technological adoption, the process of Internet diffusion has been used as a case study.

Although age may by no means be considered as the only determinant of Internet access and usage (as a matter of fact, education and income have also been proven [13, 14] to exert a significant influence), the next section will attempt to investigate and isolate the influence that the age variable may exert on Internet adoption, setting the stage for the simulation of alternative scenarios aimed at testing the impacts of three different demographic trends on innovation absorptive capacity of a given socioeconomic system.
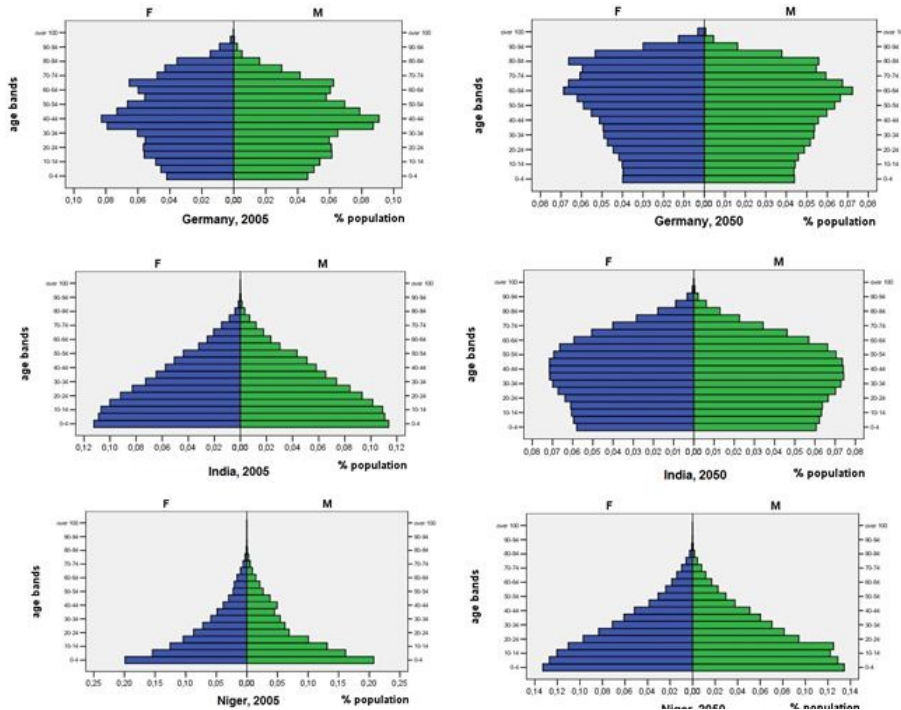
Fig. 2. Population pyramids of Germany, India and Niger: comparison between 2005 and 2050
(source: United Nations, 2009).

3.1   Internet Penetration Data by Age Groups: the Case of Germany

Figure 3 shows the data on the diffusion of Internet technology in Germany from 1997 to 2008, considering each age group separately [17]. It is interesting to map this pattern of diffusion within the different age groups against the well-known categorization of adopters by Rogers [10] in order to understand the distribution of Internet innovators and laggards as a function of age. To this aim, an estimate of earlier data (since 1990) by a logistic regression has been necessary to analyze the distribution of the first stage of diffusion (innovators).

The resulting composition of Rogers' categories for Internet diffusion divided by age groups is summarized in Figure 4. Some important considerations may be put forward:

— innovators are constituted almost exclusively by the active population (20-59 years old); it is likely that, in the first stages of diffusion, people began using the Internet because it was a necessity connected to work; furthermore, Internet connections were quite expensive, and only people with a substantial income were able to afford it;

- for subsequent categories (early adopters and early majority) the Internet diffused among younger people, becoming both an entertainment tool and a useful support for education;
- the number of elder people using Internet is increasing though penetration in the over-60 population is lower than 30%, and the threshold defining *laggards* (84% of total population) has not been reached yet.
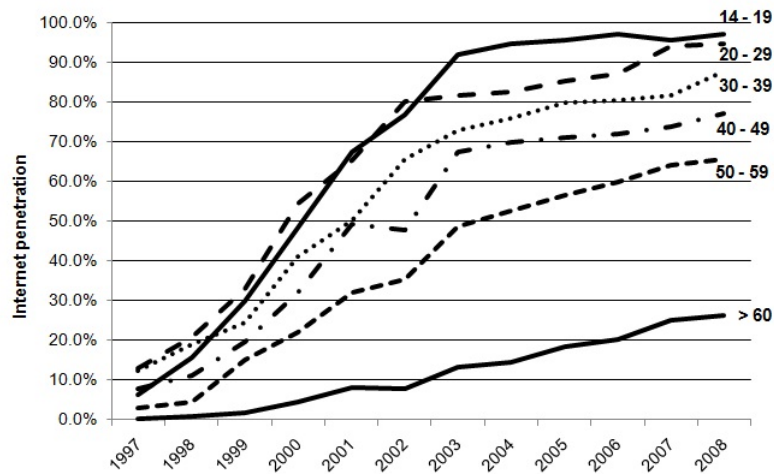

Fig. 3. Internet penetration by age in Germany, 1997 – 2008 (source: ARD/ZDF-Onlinestudie, 2008).
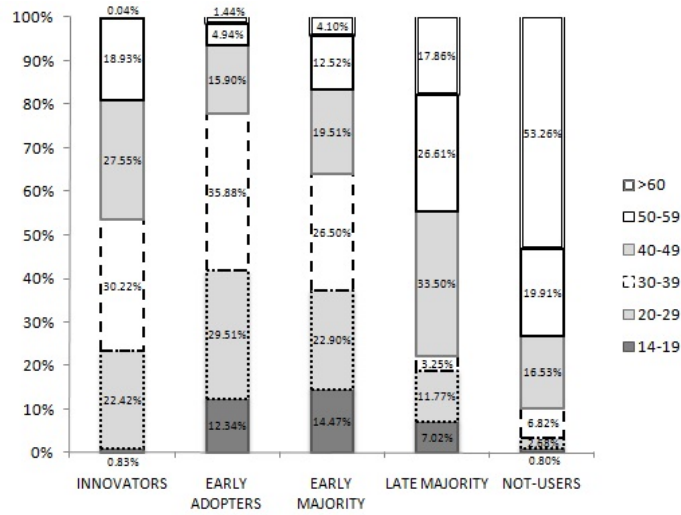

Fig. 4. Composition of Rogers' categories by age for Internet technology.

Other interesting results emerge by identifying the Bass model parameters [18] of the diffusion curves for each age group (Table 1); innovation (p) and imitation (q) parameters have been estimated using a non-linear regression model [19] and neglecting inter-group imitative effects.

Table 1. Estimates of Bass parameters for each age group.

	Innovation parameter (p)	Imitation parameter (q)
14 – 19	0.0360	0.7579
20 – 29	0.1111	0.2746
30 – 39	0.0970	0.1790
40 – 49	0.0828	0.1345
50 – 59	0.0522	0.1350
> 60	0.0098	0.1610

Not surprisingly, given the strong network externalities present in Internet technology, the diffusion process appears to have been strongly affected by an imitative effect and especially in the youngest population (14 – 19). Interestingly enough, both parameters substantially differ from one age group to another.

Once identified the main parameters involved in the diffusion of Internet technology as a function of age, it is possible to analyze how the technology adoption will evolve in different demographic scenarios.

4 Scenarios and simulations

Three settings (Figure 2) have been considered to represent the situation that different countries in the world could face in the future from a demographic perspective.

- The first scenario (*aging* societies) corresponds to the case of low birth rates and low death rates, peculiar of the population pyramids of developed countries. The parameters of this setting refer to Eurostat data about Germany in 2007 [1] and may be considered representative of other countries (such as Italy, Japan and Spain) affected by both current and future aging of the population.
- The second scenario (*middle-aged* societies) corresponds to the situation which countries characterized by high birth rates and low death rates could experience in the near future, such as India and Latin America. The parameters of this setting refer to India [16].
- The third scenario (*young* societies) corresponds to the case of high birth and death rates, peculiar of the population pyramids of most developing countries, such as African Sub-Saharan ones. The parameters of this setting refer to Niger [16].

Annual death rates and birth rates for each setting are summarized in Table 2 and 3, respectively.

Table 2. Annual death rates for each setting.

	Setting 1: *aging* societies	Setting 2: *middle-aged* societies	Setting 3: *young* societies
0 – 14	0.04 %	0.30 %	1.67 %
15 – 19	0.02 %	0.17 %	0.41 %
20 – 29	0.04 %	0.25 %	0.87 %
30 – 39	0.06 %	0.38 %	1.21 %
40 – 49	0.18 %	0.59 %	1.66 %
50 – 59	0.50 %	1.38 %	2.50 %
> 60	3.55 %	5.49 %	5.94 %

Table 3. Annual birth rates for each setting.

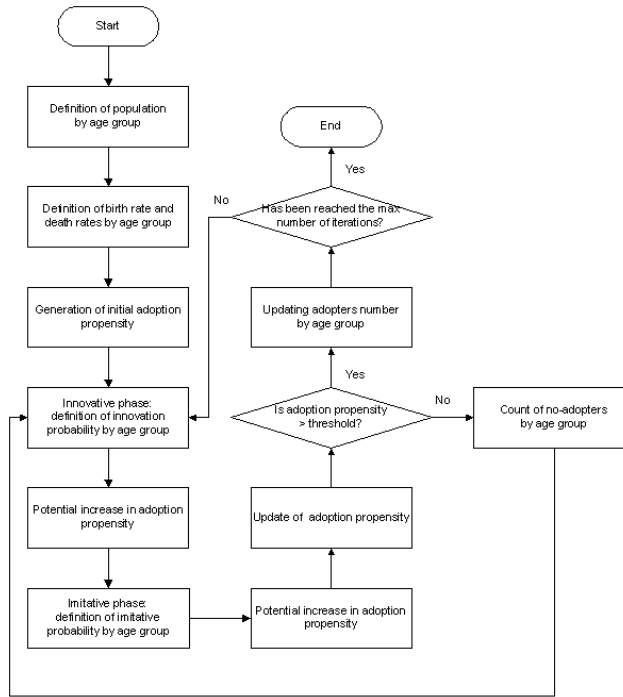|	Setting 1: *aging* societies	Setting 2: *middle-aged* societies	Setting 3: *young* societies
Birth rate	0.83 %	2.30 %	5.41 %

Fig. 5. Flowchart of the agent-based simulation.

For each scenario, 15 simulation runs have been performed, in order to have statistically significant outputs; the duration of a single simulation run corresponds to a period of 30 years (equivalent to 1600 time buckets).

The flowchart of the simulation is represented in Figure 5 and is based on the progressive growth of an "adoption propensity" by each individual – affected by exogenous and imitative effects – until an "adoption threshold" is reached. Age of each agent is deterministically updated as time goes by. The adoption threshold is kept fixed for the whole duration of the simulation; this hypothesis is valid if the difficulty of accessing the technology can be supposed to be constant during the entire time horizon. Future work will be performed in the case in which the adoption threshold varies in time. This would allow studying cases in which adoption becomes easier (e.g. if price tends to decrease) or more difficult (e.g. if it becomes more difficult to switch from an established to a new paradigm) as time goes by.

4.1   Simulations Results

Figure 6 represents the output of simulations referred to the first scenario (aging societies) and projecting into the future the diffusion processes presented in Figure 3.

This plot depicts the diffusion processes among the different age ranges and shows the persistence of an adoption gap between people aged over 60 and the rest of the population.
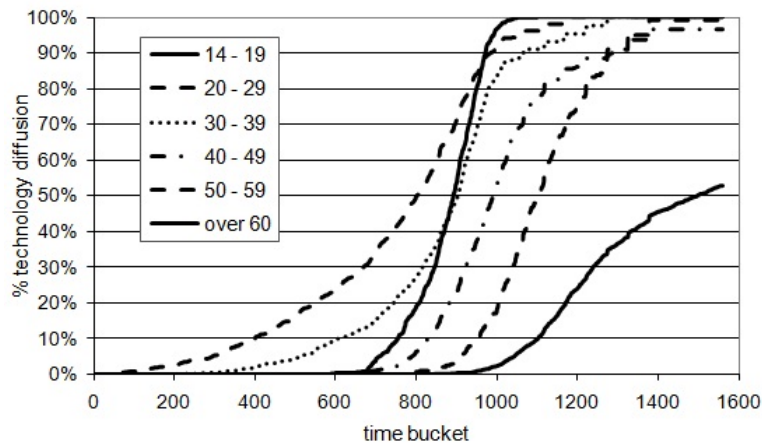

Fig. 6. Results of the simulation for Scenario 1: technology diffusion for each age group.

The digital gap of people aged over 60 is more noticeable in comparison with the correspondent demography (dashed line in Figure 7).

Due to lack of space available, we do not present detailed results for the other two settings. Figure 8 compares the diffusion curves of the three demographic scenarios over a thirty-year period for a possible future technology. *All the other variables being equal except for age* (therefore not accounting for, e.g., the socio-economic

context of each country), technology diffusion in aging societies (setting 1) is slower than in younger ones. In addition, using the concept of S-time-distance proposed by Sicherl [20], the time advantage between middle-aged/young societies and aging ones at the end of the simulation may be quantified in 9 years.
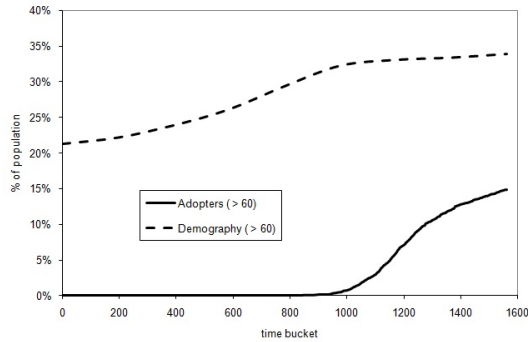

Fig. 7. Adoption of people aged over 60 in Scenario 1, compared with the demography.

This is probably due to the composition of non- or late adopters of the technology, which are concentrated in the elder population; since diffusion seems to propagate similarly in scenario 2 and 3, and since in such settings the proportion of people aged over 60 is quite similar, it is likely that the factor that influences the most the process of technology diffusion is the portion of people aged over 60 in the population, and not the composition of the remaining population. This information could be precious for policy makers, highlighting the concept that they should design and address specific policies to the elderly.
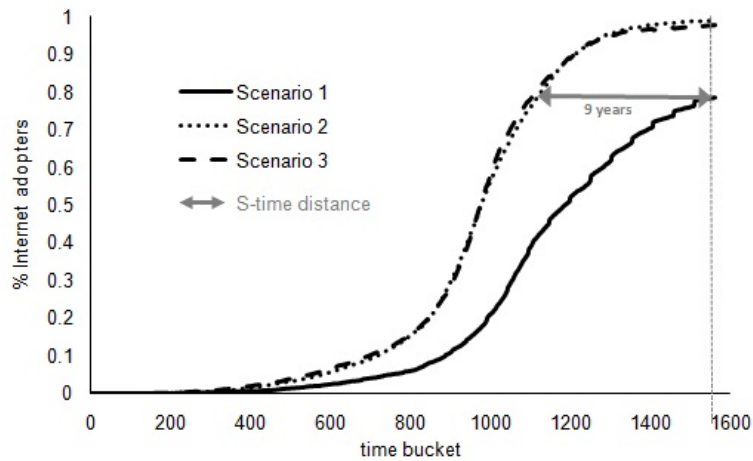

Fig. 8. Diffusion curves corresponding to the three scenarios.

5   Conclusions

This paper intended to present the results of the preliminary work conducted in the context of the I-PAS project. The analysis mainly focused on better understanding the relationship between age and technology adoption. This was done in an attempt to assess the relevance of the aging trends on the diffusion processes of future technologies and, more in general, on the innovation absorptive capacity of socioeconomic systems. To this aim three sets of analyses have been performed, using the Internet as a case of study.

Firstly, the diffusion process present inside each age group has been studied revealing that age impacts on both its innovative and imitative aspects. The word-of-mouth effect appears to be the most relevant across all age groups and to exert a strong influence on youngest people (14-19). A significant role of the imitative effect may also be found in the eldest portion of population (over 60). Furthermore, the distribution of age groups inside Rogers' categories has been analyzed, showing a higher concentration of over 60 among laggards (currently non-users). This represents an indication of the reduced propensity of this age group towards the adoption of innovation.

Secondly, the process of Internet diffusion for the "European" setting has been projected in the future through an agent-based simulation. The results obtained show that the eldest portion of the population (over 60) most likely will not become adopters for a long period, if at all.

Finally, the "European" *aging* scenario has been compared to other two demographic settings (*middle-aged* and *young* societies). This comparison allowed us to understand that the most influencing factor is the proportion of people aged over 60 in the population (as a matter of fact, the diffusion processes for other two scenarios do not show any significant difference). This translates into a potential digital gap between aging and younger societies, quantifiable –at the end of the time horizon- as a S-time distance of 9 years or a difference in penetration equal to about 20% (Figure 8).

When developing policies for the diffusion of a technology (such as the Internet), policy makers should therefore take into account the age factor, since it is one (obviously not the unique) relevant factor in the diffusion process. It is therefore of primary importance that policy makers become aware of which aging scenario they will have to face, and design and shape their actions accordingly.

Concluding, the results presented in this paper constitute a stepping stone for further investigation. Further research will be necessary in order to understand if and how these conclusions may be extended to other types of technologies. Future work will be directed towards the identification and simulation of alternative policies that may help reducing the impact of aging on the innovation absorptive capacity of a socioeconomic system. The comparative assessment of the effectiveness of alternative policy actions will in fact be instrumental to allow policy makers to timely respond to the challenges posed by the aging of society through more suitable and informed choices.

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