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Climate Change Impacts and Adaptation Strategies In Italy. An Economic Assessment

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Summary

In this paper, the economic value of the impacts of climate change is assessed for different Italian economic sectors and regions. Sectoral and regional impacts are then aggregated to provide a macroeconomic estimate of variations in GDP induced by climate change in the next decades. Autonomous adaptation induced by changes in relative prices and in stocks of natural and economic resources is fully taken into account. The model also considers international trade effects. Results show that in Italy aggregate GDP losses induced by climate change are likely to be small. However, some economic sectors (e.g. tourism) and the alpine regions will suffer significant economic damages.

Keywords: Impacts, Climate Change, Adaptation, GDP Losses, Tourism

JEL Classification: O13, Q43, Q5, R13

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1. Introduction

Climate change is no longer a potential future threat, rather we are already experiencing the impacts of a changing climate and an increased incidence and changed pattern of extreme weather events. The Fourth IPCC report (IPCC, 2007 a, b, c) concludes that there is high evidence that the observed changes in the global climate systems are influenced by human activities. In support of the conclusions of the IPCC Third assessment report (IPCC, 2001), the Fourth assessment stresses how human-induced climate change will not only affect global temperature, but will lead to changes in the entire climate system, including precipitation patterns and intensity, wind patterns, sea level rise, frequency and intensity of extreme weather events. It also points out that the impacts of these changes will be felt differently in different regions of the world.

The Mediterranean area is certainly one of the most vulnerable regions in the world, for its population density, for the concentration of economic activities in coastal zones, and for its climatic borderline equilibrium. According to recent simulation models, the Mediterranean will experience an increase in average temperature double the global temperature rise, a significant increase in heat waves, and a strong decrease in precipitations. The lags in the climate system highlighted by the Fourth IPCC reports – and in particular by the findings of Working Group III – imply that, even if the world's emissions of greenhouse gases were stabilised today, we would still observe a global average temperature increase, with all the associated impacts. Adaptation to unavoidable climate changes, therefore, becomes an important coping strategy, alongside with more traditional mitigation strategies which attempt to reduce emissions of greenhouse gases.

The UNFCCC is placing increasing emphasis on adaptation to climate change, through its five-year Nairobi Work Programme, which has the objective of helping countries, and in particular developing countries, in defining and implementing national adaptation strategies. At the European level, the recent publication of the *Green Paper on Climate Change and Adaptation* shows how the European Union is playing a leading role in promoting adaptation, a challenge taken up by many member states, including Italy. The recent National Climate Change Conference, promoted by the Italian Ministry of Environment and Protection of Land and Sea, focused indeed on adaptation and aimed at kick-starting the process of developing a national adaptation strategy in Italy.

The literature on adaptation and its costs is growing, but relatively little consensus is reached on either methodologies or estimates. Adaptation costs are sometimes estimated assuming adaptation as an undifferentiated strategy, i.e. using total costs as a reference (see, for example, Cline, 1992; Tol, 1995; Fankhauser, 1995). These estimates are clearly highly uncertain, partly because of the coarse geographical scale used (see, Stern *et al*., 2006). Integrated assessment modelling frameworks have been used by, for instance, Bosello (2006a, 2006b) and Hope (1995, 2006). On the other hand, another strand of the literature concentrates on adaptation strategies to specific climate change impacts, notably sea level rise (e.g. Yohe, 1990; Cline, 1992; Titus, 1992; Hope *et al*., 1993; Hoozemans *et al*., 1993; Tol, 1995, 2002; Fankhauser, 1995; Nicholls and Leatherman, 1995;Yohe *et al.*, 1995, 1996; Fankhauser *et al.*, 1998; Titus *et al.*, 1998; Deke *et al.*, 2001; Darwin and Tol, 2001; Nicholls and Klein, 2003, Bosello *et al.*, 2006a). Adaptation strategies in agriculture have also been extensively studied (e.g. Kurukulasulya and Rosenthal, 2003; Bindi and Howden, 2004; Bosello and Zhang, 2006, Soutwhorth *et al.*, 2002, Reilly *et al.*, 2003). There is a general consensus that while moderate warming will negatively affect agricultural systems in the developing world, it will benefit those of developed countries (see e.g. Rosenzweig and Parry, 1994, Kane *et al.*, 1992, Darwin *et al.*, 1995). Finally, studies on the impacts of climate change on human health and the effectiveness of adaptation strategies are being carried out, among others, by WHO (2005, 2006), Bosello *et al.* (2006b), Alberini and Chiabai (2007), Kovats (2003), Moore (1998), Kovats and Ebi (2006), Michelozzi *et al.* (2004).

This paper is a first attempt at quantifying and valuing in monetary terms the costs of climate change on the Italian economy, as well as providing a first assessment of some adaptation strategies that are currently being explored or experimented with. The focus is on four areas, which have been identified as key vulnerabilities for Italy: the Alps and glacier ecosystems; coastal zones; arid areas and areas threatened by desertification; and finally areas vulnerable to floods and landslides[1]. Using existing literature, we first identify the physical impacts of climate change on the four vulnerable areas, and we estimate their economic value. The first necessary step is indeed the identification and quantification of the impacts of climate change in physical terms. Secondly, these physical impacts should be translated into monetary value in terms of, for instance, forgone profits, or damages to infrastructures.

Clearly, the valuation exercise is fraught with difficulties: for one, we still lack accurate projections about the likely physical impacts of climate change, in particular at the national and regional level. Secondly, translating physical impacts into monetary values is not straightforward, in particular when the impacts of climate change affect environmental goods and services which are not traded in the market, such as, for instance, biodiversity or landscape beauty.

Even though scientists are attempting to fill in the first knowledge gap by constructing integrated climate models that allow the downscaling of global climate change scenarios, significant uncertainty remains. Furthermore, specific efforts for Italy have not yet been made. There are specific studies (see introduction) but we still lack reliable predictions of the change in the magnitude and value of these phenomena as a consequence of climate change.

On the other hand, economists are required to develop more accurate or new valuation techniques, which would allow the translation of climate change impacts to a monetary value, in particular for those impacts which do not affect traded goods and services. The main objective of valuation techniques is to

[1] For more details, see: Bigano and Pauli (2007) for hydrological risks; Bosello *et al.* (2007) for alpine areas; Breil *et al.* (2007) for coastal zones; and Gambarelli *et al.* (2007) for desertification risks. These papers are available only in Italian.

provide the tools needed for grouping (translating) alternative options to address current and future problems into a common unit. The options to consider would be composed of both climate change scenarios, but also of a different mix of mitigation and adaptation policies, and their relation to climate change. Translating all impacts, costs and benefits to a common denominator – notably money – can be useful as it allows a simpler identification of an "optimal" response to climate change, through extended cost and benefit analyses.

Generally speaking, valuation techniques can be divided into two broad categories: on the one hand, bottom-up approaches (also called partial equilibrium) focus on the impacts of climate change on specific sectors and environments. On the other hand, top-down (also called general equilibrium) approaches consider all sectors simultaneously, and how impacts in one sector propagate through different transmission media (e.g. changes in prices and quantity) to other sectors of the economy. The choice of the most appropriate valuation technique will depend upon the context of the analysis: it is important to point out, however, that top-down and bottom-up approaches should not be considered as mutually exclusive, rather, they are complementary, as a general equilibrium analysis necessarily relies upon bottom-up valuation techniques to identify and value sectoral impacts, which can then be aggregated in a general equilibrium model.

In this paper, we will follow this methodological approach. First, we will quantify, using bottom-up valuation techniques, the monetary costs of climate change impacts on key vulnerable sectors of the Italian economy. We then aggregate these impacts into a Computable General Equilibrium (CGE) model, which allows us to trace the overall effects of climate change on the Italian economy when we allow market forces to adjust. An approach based on CGE, therefore, allows us to quantify autonomous adaptation, which acts through market forces, as opposed to planned adaptation, which requires public intervention. On the other hand, it also allows us to yield a macroeconomic cost of climate change, which aggregates the consequences of different impacts of climate change on all sectors. We will use changes in GDP losses as an aggregate, macroeconomic indicator of the economic value of future impacts of climate change on the Italian economic system.

Before turning to the main results, it must be emphasised that the existing literature on the impacts of climate change and their economic costs at the regional or national scale is still incomplete, and Italy is no exception. We therefore extensively rely on benefit transfer techniques (see, for instance, Navrud, 1994; Bergland *et al.*, 1995), and adapt existing estimates for other countries, in particular in Europe, to the Italian situation.

The structure of the paper is as follows. Section 2 will review the main results on the physical impacts of climate change in Italy and will provide an economic assessment of these impacts. Section 3 will focus on adaptation measures and their estimated costs in some sectors and areas. Section 4 will aggregate the economic value of different climate change impacts through a CGE model of the world economy in which the Italian economic system and its interactions with other countries are explicitly modelled. A concluding section summarises our results and identifies the main knowledge gaps.

2. The impacts of climate change in Italy

Climate change is expected to impact Italy in several ways, both negative and positive. According to existing studies, four are the key sectors that are likely to be severely affected by observed and expected changes in the climate system. For each of them in turn, we identify the main physical impacts of climate change, and estimate the monetary costs.

2.1 Alpine areas

Alpine areas are very fragile ecosystems which are not only exposed to the impacts of climate change – we already observe a significant retreat of glaciers and snow lines – but are also subjected to strong anthropic pressures through, for instance, infrastructure development and tourism. Climate change is therefore expected to further exacerbate the observed conflicts (Diaz *et al.*, 2003).

The existing studies on the likely physical impacts of climate change on alpine areas are not specific to Italy, but the similarities of ecosystems allow us to identify four major impacts. Temperature increases will lead to less snow and snow reliability, thus impacting significantly the winter tourism industry. An increase in extreme weather events will also decrease the attractiveness of alpine resorts, and increase the costs of maintaining and protecting infrastructures. On the other hand, summer tourism may benefit from higher temperature. Whereas alpine agriculture may benefit from higher temperature and CO_2 fertilisation (Calanca *et al.*, 2006), plants and animals species composition will change, with a northward shift of the most sensitive species (Kullman 2002; Körner, 2003; Egli *et al.*, 2004; Sandvik *et al.*, 2004; Walther, 2004), and significant loss of biodiversity (Thuiller *et al.*, 2005). An increase in dry spells may lead to more forest fires, with all the consequences for both the ecosystems and human beings.

Our work attempted to provide an economic value to these physical impacts. Consider, for example, the tourism sector – and in particular winter tourism. The starting point is the expectation of an upward shift of the snow reliability by approximately 150 m for each degree centigrade of higher temperature (Föhn 1990; Haeberli and Beniston, 1998). This may lead to significant losses for Italian ski resorts, summarised in Table 1.

Using different climate change scenarios and related decreases in snow cover in winter resorts, Bigano and Bosello (2007) find that the expected average reduction in income from winter tourism is about 10.2% in 2030 and 10.8% in 2090 for Italy. Had the Italian Alps experienced the hypothesised 2030 snow-cover scenario in 2006, there would have been a 2.4 million Euros loss in the Veneto region, and 587 million Euros loss in Trentino Alto Adige (see Table 2).

Table 1: Economic loss (million Euros) to Italian ski resorts

	> 1650 (+1°C)	> 1800 (+2°C)	> 2100 (+4°C)
Valle d'Aosta	4,706	13,977	39,861
Piemonte	10,666	18,667	32,000
Lombardia	Na	Na	Na
Veneto	Na	Na	Na
Trentino	Na	Na	Na
Alto Adige	23,762	92,081	139,607
Friuli Venezia Giulia	13,625	13,625	13,625

Elaborated from EURAC data (2007) and the project HERMES (Zanetti *et al.*, 2005)

Table 2: Decrease in direct income from tourism in Alpine areas

	Decrease (%) with respect to 2030 (*)	Million Euros (**)
Piemonte	-10.2	-33.12
Valle d'Aosta	-4.0	-14.30
Lombardia	-7.1	-29.11
Trentino Alto Adige	-14.1	-587.05
Veneto	-0.3	-2.46
Friuli - Venezia Giulia	-15.7	-28.91

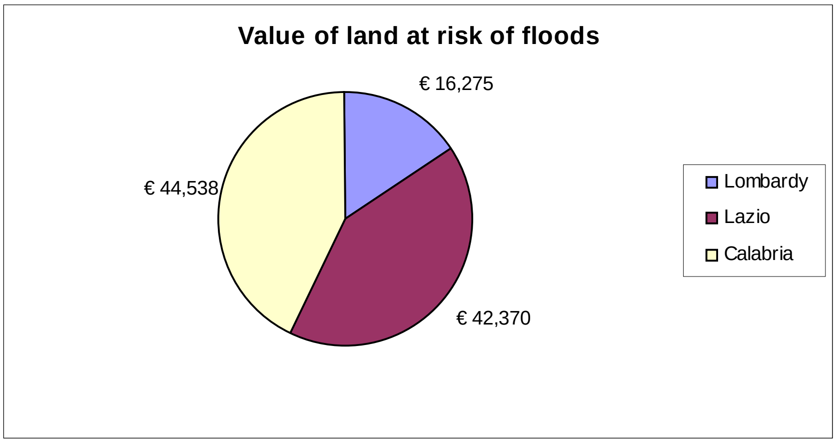
Bigano and Bosello (2007)

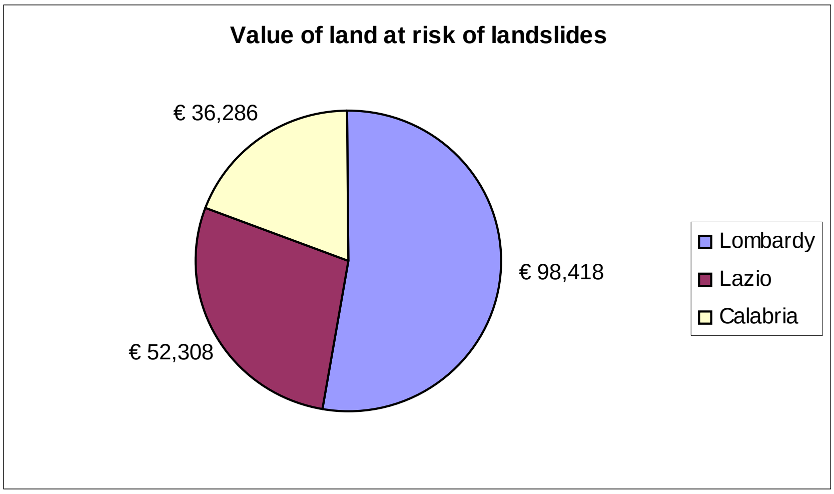
(*) Average value for the four climate IPCC change scenarios A1, A2, B1, B2, expressed as % change with respect to the baseline "no climate change" scenario
(**) The loss is estimated by transposing the % reduction to the 2006 income of the tourism industry, reported by Unioncamere (2006)

2.2 Floods and landslides: the Italian hydro-geological system

The impacts of climate change on the risks of floods and landslides vary widely across Europe. This is a consequence of very different hydro-geological situations, like long and dry summers in the South and periods of increased river runoff in the North due to the melting of glaciers. In Italy, the most vulnerable area is the River Po basin. Landslides have received relatively little attention in the climate change literature, perhaps because of their more localised impacts. The increased risks of floods and landslides as a consequence of changes in the climate systems is expected to lead to injuries and loss of lives, as well as to the spread of water-related diseases and pollution. Infrastructures may be lost or damaged, as well as crops and agricultural land. Tourism flows may be interrupted or diverted, at least until pristine conditions are restored in areas affected by floods or landslides. Perhaps more significantly, irreversible damages may occur to unique cultural heritage, art masterpieces and buildings. Natural ecosystems and biodiversity may be lost or displaced.

Figure 1: Value of agricultural land at risk of floods and landslides in Lombardy, Lazio and Calabria





Source: from CORINE, APAT, INEA and EU-FEDN data, based on average land value per hectare.

To date, there are no estimates of these impacts for Italy, with specific reference to the increased risk of floods and landslides. Past experience, however, shows that the 28 large floods that hit Italy between 1939 and 2004 caused 694 victims, 1.5 million homeless, affected 2.85 million people and caused 32.7 million US$ worth of damages. The 13 largest landslides that occurred between 1991 and 2003 caused 2,584 deaths. According to the EM-DAT database, the largest landslides cost the country 1.2 billion dollars. A first attempt at estimating the direct costs of increased risks of floods and landslides in three regions in Italy (Lombardy, Calabria and Lazio) indicates the value of land at risk of floods at approximately 103 million Euros, and at risk of landslides at 187 million Euros (see Figure 1).

2.3 Coastal zones and marine environment

Coastal areas are important assets for Italy, with many economic activities such as tourism, agriculture, industries here localised. Coastal zones are also subjected to significant anthropic pressures, which make them more vulnerable to the impacts of climate change, in particular, sea level rise (SLR) and an increased incidence of extreme weather events. Loss of valuable land due to SLR is one of the major impacts of climate change, even though tectonic movements do, to some extent, mitigate the impacts[2]. Together with land, infrastructures and ecosystems may be lost to SLR, or damaged because of increased coastal erosion or extreme weather events. Extremely hot temperatures are likely to displace summer tourism away from coastal areas, and this trend is likely to be exacerbated by increasing shortage of water resources. The sea temperature is expected to increase, leading to northward shift of biodiversity and commercially valuable species (EEA, 2005), or invasion by alien species.

As for the other sectors, currently there are no estimates of the damages that climate change is likely to cause in coastal areas. Some efforts in this direction have nonetheless begun, with studies aiming at quantifying the value of the stock at risk of flooding due to SLR. Recent research by FEEM and ENEA has focused on vulnerable areas such as the Fondi plains (Lazio) and the Sangro river basin (Abruzzi), where the direct costs[3] of climate change in terms of land loss have been estimated. In these studies, the costs of climate change in the Sangro River basin are estimated at about 14 million Euros (Breil *et al.*, 2007) for the reference scenario at 2100. When the increase in hydro-geological vulnerability is added to SLR, costs increase to about 73 million Euros.

Other studies attempt to estimate the impacts of climate change on coastal tourism. The results of the WISE project (Galeotti *et al.*, 2004) highlight how extremely hot summers reduce tourism inflow to Italian regions on average by 1.22%, using data for the period 1986-1995. According to Gambarelli and Goria (2004) this has translated to a slight increase for coastal areas. These studies, however, do not consider the increased costs that coastal tourist destinations are likely to face as secondary impacts of climate change, such as water shortage and an increasingly significant rise in energy demand.

[2] In a recent study, ENEA (2007) estimates that the majority of the 33 coastal areas originally identified as at risk of floods because of their low altitude above sea level are in areas subject to upward tectonic movements. The Po river basin, the Versilia, the Fondi and Pontina plains are nonetheless quite vulnerable to SLR: in addition to their low latitude, there are strong subsidence phenomena in these areas.

[3] The estimated direct costs of climate change are a lower bound, since estimates do not consider non-use values, ecosystem services, loss of biodiversity, etc.

2.4 Areas at risks of desertification

About 5.5% of the Italian territory (16,500 km^2) is currently classified as at risk of desertification, mostly localised in the South of the country[4] (Apulia, Basilicata, Calabria, Sicily, and Sardinia). Climate change is expected to worsen the desertification trend already observed.

In addition to the direct economic impacts caused by loss of soil or soil degradation, desertification can lead to severe indirect socio-economic impacts, such as a decrease in agricultural production or in the productivity of other sectors (e.g. tourism), an increase of unemployment in rural areas, with consequent migration towards urban areas, conflicts over water uses, damages to properties and people as a consequence of increased frequency of fires, as well as biodiversity loss.

Even though there is still a substantial lack of estimated costs of desertification, as highlighted by the recent UNCCD conference held in Rome in December 2006, existing estimates can be used for a first attempt at quantifying the costs of desertification for Italy. Dregne and Nan-Ting (1992) estimated the global costs of desertification at about 7 US$/ha per year (1990 base year), at 38 US$/ha/year for non-irrigated land, and at 250 US$/ha/year for irrigated land. Using these estimates, the authors arrive at an estimated global cost of desertification of 42 billion US$. A more recent study which considers 11 countries in Latin America arrives at an estimated cost of 36 billion US$/year in these countries alone, an estimate which increases to approximately 54 billion US$/year when the value of biodiversity loss is considered. Using these figures and considering the 16,500 km^2 of land at risk in Italy, one can conclude that the costs of desertification in Italy are about 60-412 million US$/year, as a first approximation.

3. Adapting to climate change: strategies, costs and benefits

As stressed by many recent international and national initiatives, adaptation to climate change is an important component of countries' strategies to cope with the impacts of a changing climate, which should be considered alongside mitigation. The emphasis is thus gradually shifting from mitigation only to mitigation *and* adaptation, at least in Europe, as testified by the recent launch of the consultations for the European Green Paper on Climate Change and Adaptation (EC, 2007), and the first National Conference on Climate Change in Italy, which focused predominantly on adaptation strategies (Rome, 12-13 September 2007).

Adaptation strategies clearly have a cost, which must be assessed in relation to the ensuing benefits in terms of avoided damages from climate change and, whenever relevant, other ancillary benefits deriving from the adoption of adaptation measures. Yet, we currently have a very limited understanding of the costs and benefits of various adaptation strategies, and Italy is no exception. This section

[4] *Linee-Guida del Programma di Azione Nazionale di lotta alla siccità e desertificazion*e, Comitato Nazionale per la Lotta per la Desertificazione (CNLD), 22 luglio 1999, pubb. Ministero Ambiente e Territorio.

summarises the current state of the art in terms of adaptation strategies and their valuation for Italy, with reference to the key vulnerable areas previously identified.

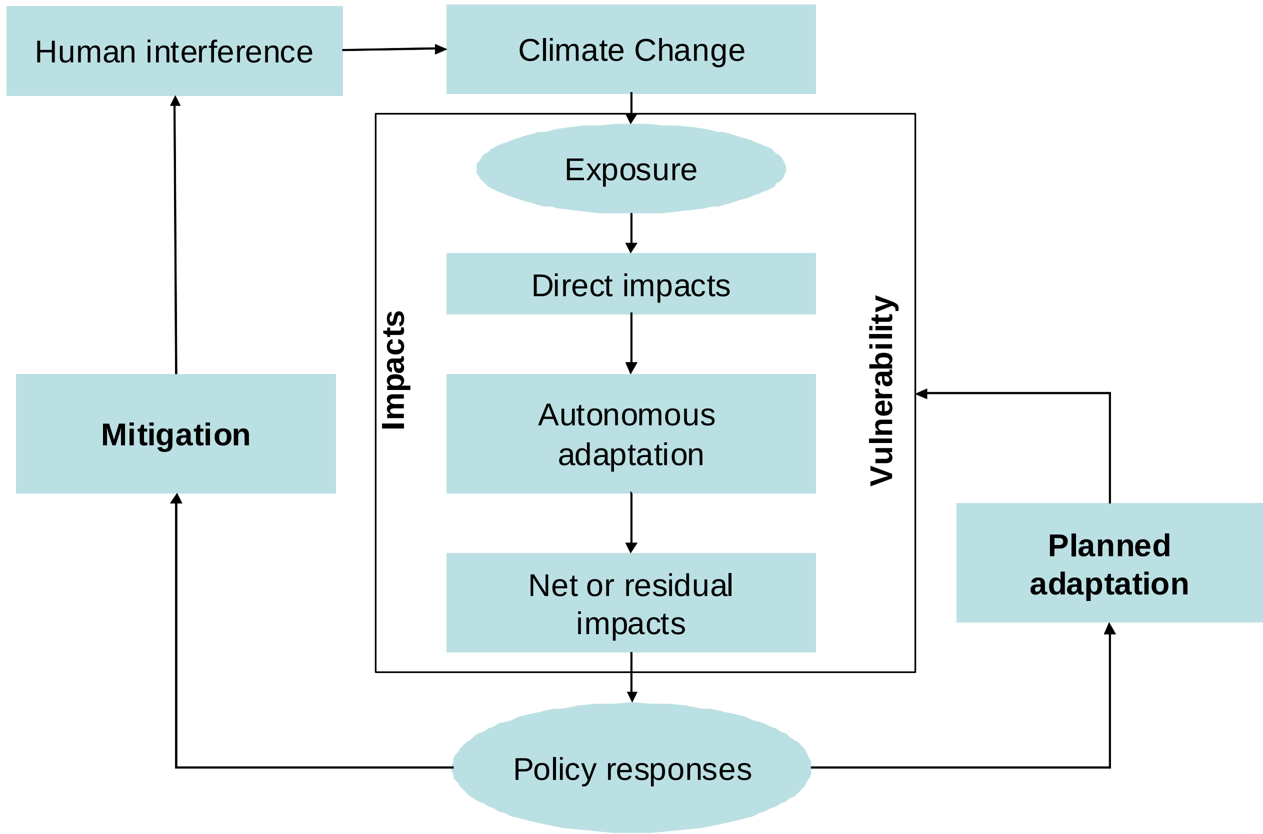
Several definitions of adaptation exist in the literature. Probably one of the most comprehensive (and quoted) definition of adaptation is that reported by the IPCC Third Assessment Report which defines adaptation as: "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli, and their effects or impacts. This term refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate" (IPCC, 2001). The UNFCCC provides also a "Glossary of Terms" in its Secretariat website. There, adaptation is explicitly defined as: "actions taken to help communities and ecosystems cope with changing climate conditions, such as the construction of flood walls to protect property from stronger storms and heavier precipitation, or the planting of agricultural crops and trees more suited to warmer temperatures and drier soil conditions" (Secretariat website, 2006, quoted by Levina and Tirpak, 2006).

The European Environment Agency published several reports on adaptation to climate change in the last couple of years (EEA, 2004, 2005 and 2007). It defines adaptation as "policies, practices, and projects with the effect of moderating damages and/or realising opportunities associated with climate change", including climate variability and extremes, and sea level rise (EEA, 2005).

Even though there is still a lack of a comprehensive and univocal definition of adaptation (see, for instance, EEA, 2007), several forms of adaptation can be distinguished: while on the one hand planned adaptation refers to activities undertaken under the guidance of public or private bodies, autonomous adaptation typically refers to the capacity of natural and human systems to naturally adapt to external shocks (see Figure 2). The former, therefore, includes activities explicitly aimed at reducing or cancelling the negative impacts of climate change and has its origin in the analysis of the likely impacts of climate change, and possible future scenarios. The latter is related to a system's resilience.

To define effective and efficient adaptation strategies and activities, one needs to be able to quantify the expected costs of adaptation, and their benefits both in terms of avoided climate change damage, and any other ancillary benefits that may arise from decreased vulnerability. For informed decisions, therefore, one would need to know the value of the damages of climate change impacts (discussed in Section 2) and how much of this damage can be avoided through adaptation activities. Let us summarise some preliminary results achieved in our study.

Figure 2: Linkages between adaptation and mitigation (adapted from *Stratégie nationale d'adaptation au changement climatique*, ONERC (Observatoire National sur les Effets Du Réchauffement Climatique, 2006).



3.1 Adaptation to climate change in Alpine areas

Several adaptation strategies exist and are already extensively used in the Italian Alps to mitigate the impacts of climate change, in particular in the tourism sector. The developments are triggered both by the severe threats to winter tourism, but also by the high profits of this sector. So, for instance, lack of snow can be counteracted using artificial snow, using ski slopes and infrastructures located at higher altitudes more intensively, or migrating existing infrastructures to higher altitudes.

The strategy most widely adopted in Italy is the use of artificial snow: 77% of our ski resorts have the needed equipment. Operation and maintenance costs are however high: producing 1 m^3 of snow requires 3-5 Euros (Bosello *et al.*, 2007), while installing artificial snow-making equipment costs around 25,000-100,000 Euro/ha (in Austria) or 650,000 Euro/km (in Switzerland). Operation and maintenance costs are as high as 8.5% of profits. Moreover, artificial snow requires significant water resources – it is estimated that 30cm of snow cover require 1,000-1,200 m^3 of water per hectare (Probstl, 2006). A rise in average temperature will lead to an increasing need to use artificial snow, therefore increasing both the costs and the likelihood of conflicts with other water users.

Diversifying the offers in order to capture a different segment of tourism industry (e.g. business travel, spas and wellness,…) can also be a winning strategy for the Italian Alps. In fact, about 30% of Italian and 33% of foreign tourists do not visit the Alps for specific winter sports (Unioncamere, 2006). Behavioural strategies are however unlikely to fully compensate for the significant reduction in winter tourism expected as a consequence of climate change, since winter tourism represents the largest source of income in the Alps (TCI, 2002).

3.2 Adaptation to increased risks of floods and landslides

Italy has a national plan aimed at reducing the risks of floods and landslides in the most vulnerable parts of its territory, as defined in law 267/98. According to APAT (2006), the most urgent measures funded up to 2006 cost the Public Administration 447.36 million Euros for the risk of floods, and 667.88 million Euros for the risk of landslides. The total costs of reducing the risks of floods and landslides in Italy is estimated at 42 billion Euros (of which, only 1.15 billion were budgeted for in 2006). But this estimate does not take into account the higher risks deriving from climate change scenarios, for which no assessment currently exists.

There are specific estimates for other European countries, in particular with respect to the risk of floods. For instance, Bosello *et al.* (2007) estimate the optimal investment in river dykes to protect the Netherlands against the increased risk of floods. One of the main results of this study is that adaptation strategies could reduce the damages of climate change by a significant amount and at a relatively low cost: optimal investment in protective infrastructures would reduce the damages of climate change to the Netherlands from 39.9 billion Euros to 1.1 billion Euros in the 21st century, at a cost of 1.5 billion Euros.

The European-funded project PESETA estimates the damages of climate change to the Upper Danube river basin. In particular, the project estimates the increase in floods with a return period of 100 years which can be attributed to climate change, and arrives at an estimated damage induced by climate change of 18.5 billion Euros for the IPCC SRES A2.

3.3 Adaptation in coastal areas and marine environment

As in the case of Alpine areas, several strategies are already being extensively used to protect coastal zones from sea level rise, increased erosion and other climate change impacts. These include technical measures (such as dykes) as well as behavioural strategies (e.g. changing location of recreational facilities), managerial interventions (e.g. changing agricultural practices in areas prone to floods), and political decisions (e.g. land use planning).

Recent results of the PESETA project, cited in the *Green Paper on Climate Change and Adaptation* (EC, 2007), quantify the costs of SLR for Europe, with and without adaptation. The results indicate that there are likely to be significant damages without adaptation (between 4-92 billion Euros/year), while adaptation can reduce the costs by 7-50%, and by up to 70% in the long run. However, specific economic evaluation of adaptation strategies along the Italian coasts are nearly inexistent, with the exception of very specific problems such as the dykes to protect the city of Venice (Chiabai and Nunes, 2006; Nunes and Chiabai, 2007). A notable exception is the research of Bosello *et al.* (2006b), who estimate the costs of inaction in terms of land lost to sea level rise and the optimal investment in coastal protection infrastructures in Italy. The results are summarised in Table 3.

Table 3: Impacts of sea level rise in Italy

Scenario	**A2**				**B2**			
SLR	Low	Low	High	High	Low	Low	High	High
Year	2020	2080	2020	2080	2020	2080	2020	2080
Land loss without coastal protection								
Km^2	5.4	25.3	16.8	1777.5	5.4	24.8	16.8	1.775,8
Value (million US$)	0.063	0.85	0.20	60.05	0.06	0.85	0.18	108.02
Cost of protection ("optimal" investment)								
% of GDP	0.0003	0.0006	0.0011	0.0061	0.0003	0.0006	0.0011	0.0062
Value (million US$)	450.1	1537.1	1773.4	15311.5	517.5	1503.7	1843.1	14396.0
Land loss with "optimal" coastal protection								
Km^2	4.6	20.4	12.2	55.5	4.6	20.4	12.2	55.5
Value (million US$)	0.054	0.685	0.145	18.759	0.051	0.74	0.131	3.376

These results indicate that the investment needed to protect Italian coasts against SLR is relatively low (between 0.0003% and 0.0011% of GDP in 2020, depending on the IPCC SRES scenario used), but high in relation to the value of land lost to flooding. This seems to be against the findings of some studies (see, for instance EC, 2007 for the whole of Europe), but in line with the results of other CGE models (e.g. Darwin and Tol, 2001; Deke *et al.*, 2001)

Significant efforts have been made to estimate the costs of sea level rise and temperature increases in the Adriatic Sea, in particular, in the city of Venice. Chiabai and Nunes (2007), for instance, estimate the impacts of climate change on coastal tourism, focusing on the historical centre of Venice; clams' aquaculture, focusing on the most important area of the Venice lagoon in terms of productivity; and sea level rise, quantifying the economic costs of floods for economic activities in the city of Venice. Their results are summarised in Table 4.

Table 4: The costs of climate change and selected adaptation strategies for the city of Venice

Costs of climate change in Venice in 2030*	**Million Euros**
Tourism sector (decrease in tourist flows)	34.9 – 42.9
Aquaculture (clams' aquaculture)	10.4 – 16.5
Damages to urban infrastructures (floors, walls and wall plasters, doors)	3.3 – 6.4
Damages caused by forced closing of economic activities (one week of high tide)	7.6 – 9.5
Social damages (city's usability)	49.2 – 86.2
Costs of adaptation measures in 2030*	
Private adaptation measures (water pumps, elevation of buildings, tanks,…).	0.6
Cost of adaptation measures for harbour activities (rental mooring and mooring)	0.9 – 1.5

* computed using a 3.5% discount rate.

3.4 Adaptation in areas at risk of desertification

The costs of desertification – and therefore the benefits of any strategy aiming at reducing them – can only be partly attributed to policies related to climate change. The process of desertification is in fact the result of several concomitant pressures on soil resources, human activities' pressures in *primis*. Measures to reduce soil degradation aim at adapting to a whole series of pressures, including but not limited to climate change.

With this in mind, it is easy to see why there are currently no estimates of the costs and benefits of adapting to the increased risk of desertification posed by climate change. As in the case of hydro-geological risks, however, Italy has developed in 1999 a National Action Plan for Combating Drought and Desertification (NAP). The NAP envisages a series of actions targeting agriculture, forestry, land planning, as well as awareness-raising strategies and education campaigns.

Most of the existing studies at the international level only consider the costs of desertification in relation to their impacts on agriculture. So, for instance, studies which focus on developed countries estimate agricultural losses attributable to climate change in the range of 40% (Rosenzweigth *et al.*, 1994) to 70% (Reilly *et al.*, 1994). Southworth *et al.* (2002) estimate the benefits of adaptation to the agricultural sector in the US, and conclude that a simple change in the timing of soy cropping could lead to an increase in yields by up to 120%. On the other hand, Stuczyinski *et al.* (2000) estimate that adaptation strategies in Poland could offset most of the losses in agricultural yields and, in some cases, could also lead to yields higher by 5%.

3.5 Adapting to heat waves in Italy

The heat waves that hit Europe in 2003 triggered a variety of studies to estimate the costs of such extreme events and the potential benefits of adaptation strategies, such as early warning systems and awareness campaigns. The phenomenon is important for Italy as well: the heat wave of 2003 hit the country in June-August, and caused an estimated 1,094 additional deaths in the city of Rome alone. Using existing estimates (e.g. Maddison and Bigano, 2003), Alberini *et al.* (2006) and Alberini and Chiabai (2007) estimate the benefits of avoiding an additional death caused by a heat wave at € 3,345,213. Thus, the benefit of an adaptation strategy in this context could be estimated by multiplying the value of an avoided death by the estimated number of lives saved thanks to the adaptation strategy.

Similarly, using the estimates of Kovats *et al.* (2003), Alberini and Chiabai (2007) estimate the costs of heat waves for Italy, in the absence of any adaptation strategy, at €281 millions for 2020 in Rome alone.

Following the 2003 heat waves, several cities in Italy (e.g. Bologna, Rome, Milan, Turin), adopted an early warning systems (HHWSs) similar to the one implemented in the US, and described in Kovats and Ebi (2006). Using existing studies, it is possible to estimate the benefits of such adaptation strategy for different cities in Italy. Assume, for instance, that Rome were to experience a heat wave equal to the 2003 event. Using estimates of the effectiveness of HHWS in saving the lives of persons over 65 years of age, and reported in Ebi *et al*. (2004), the adaptation strategies would lead to 81 lives saved. Using existing estimates for the Value of a Statistical Life, Alberini and Chiabai (2007) estimate the benefits of adopting the HHWS system in the city of Rome at around €134.47 millions for one summer (2004 Euros). Even though the costs of implementing the HHWS are not available, the system is likely to cost less than 134 million Euros.

4. The macro-economic impacts of climate change in Italy

The assessment of impacts of climate change and their costs – summarised in Section 2 – as well as the costs and benefits of adaptation strategies – discussed in Section 3 – refer to specific areas, identified as particularly vulnerable to climate change for Italy as a whole and for specific sectors in particular (such as tourism or agriculture). These estimates do not take into account the interactions across sectors and the repercussions of climate change on the whole economy. It is therefore important to aggregate them with the aim of estimating the total costs of climate change for the Italian territory and its economic sectors, bearing in mind that Italy is strongly connected to the economies of other regions in the world.

This exercise can be carried out using a Computable General Equilibrium (CGE) model where several countries/regions of the world, including Italy, are modelled. By modelling how climate change shocks affect the main economic variables of the model (stocks and flows), we can estimate the future economic impacts of climate change for Italy (Roson, 2007).

Before presenting more in detail the model and its results, it is worth highlighting that the estimates refer to the costs of climate change or the benefits of adaptation net of the autonomous capacity to adapt that economic systems possess. In addition to adaptation strategies planned and implemented by public authorities or private individuals, economic systems can indeed adapt to climate change shocks through changes in prices, which will induce changes in production systems and variations in demand and supply of goods and services. Thus, the CGE model used for this study (an evolution of the GTAP model modified by FEEM) yields an estimate of the aggregate economic value of impacts of climate change for Italy *after* the economic system has adapted autonomously to climate change shocks.

The estimated damages are not the simple aggregation of individual impacts deriving from increasing temperature, sea level rise, changing precipitation patterns, so on and so forth. Rather, the estimated damages represent the residual costs of climate change, after the economic system is allowed to adjust through national and international reallocation of economic resources, driven by changes in prices, demand and supply (including international trade).

It is also worth highlighting that, in reading the results of the CGE model, one needs to bear in mind the meaning of macroeconomic variables in this context. So, for instance, an increase in investments for adaptation activities, forced by climate change, will appear in the model as an income flow for some sectors of the economy, and as such it will be reflected in the estimated GDP as a positive impact, rather than as a negative consequence of climate change. Similarly, the increase of the price of a good caused by the climate-induced scarcity of a resource could have a positive impact on GDP. This is one of the limitations of using GDP as an aggregate indicator of welfare, yet both the IPCC and existing studies use it for estimating the damages of climate change, and so we follow the common practice. The reader is advised, however, that the estimated damages of climate change may be relatively lower, as they are net of autonomous adaptation. And indeed the results of our model seem to indicate that the macro-economic costs of climate change in the presence of autonomous adaptation are essentially of a distributive nature, without affecting to a significant extent GDP, at least in the next few decades. Whereas some sectors (agriculture and tourism, for instance) are worse off, other sectors are not affected, or even benefit from climate change. The aggregated macroeconomic data can, by their very nature, gloss over impacts which are significant, but that affect the economy at a lower, disaggregated, scale.

In this initial exercise, it was not possible to consider all the impacts of climate change, either because of lack of data, or because of a significant uncertainty in relation to the physical effects of climate change. However, the results of our model are a first starting point in the assessment of the economic costs of climate change at the country level, net of autonomous adaptation, and considering climate change impacts (see Table 5) on: human health (and, therefore, labour and productivity); agriculture; tourism; energy supply and demand; coastal areas (in relation to sea level rise); and areas at risk of desertification. As highlighted in the previous sections, these are the most significant impacts for Italy.

Table 5. Climate change impacts considered in the macroeconomic analysis

Supply side impacts
Impacts on labour quantity (change in mortality – health effect of climate change)
Impacts on labour productivity (change in morbidity – health effect of climate change)
Impacts on land quantity (land loss due to sea level rise)
Impacts on land productivity (yield changes due to temperature and CO_2 concentration changes)
Impacts on capital quantity (infrastructure vulnerability to increase in frequency and intensity of extreme weather events)
Impacts on water quantity (climate change driven water scarcity)
Demand side effects
Impacts on energy demand (change in households' energy consumption patterns)
Impacts on recreational services demand (change in tourism flows)
Impacts on health care expenditure

We considered the impacts of climate change both on the national economy (which is made up of 17 economic sectors) and on other world's regions (see Table 6). We are thus able to consider the interdependencies among countries through international trade and, therefore, national economies.

The model has been used to assess the different consequences of the aforementioned climate change impacts at the regional and sectoral level. For example, the cost of a given impact – say sea level rise – has been assessed both in terms of some macro regional indicators, such as changes in GDP, international capital flows or terms of trade for each of the macro regions considered, and in terms of sectoral/industry indicators, i.e. changes in prices, production of and demand for each of the sectors modelled.

A benchmark is necessary to compute the costs of climate impacts. This implies that the model has been used to create a counterfactual picture of the economic system "in the absence of climate change" against which the impacts of climate change can be compared. Given that climate change will exert its major impacts in the future (even though some impacts are already detectable) the counterfactual has been computed for the year 2050. The economic assumptions and the sources that have been used for the "pseudo-calibration" of the model are described in Bosello *et al.* (2006a, 2006b).

We assessed the economic impacts of climate change in two climate scenarios, on the basis of the most recent IPCC report (IPCC 2007a,b,c). One scenario assumes an increase in global average temperature of 0.93°C, and the other assumes an increase of 1.2°C. The main results are summarised in Table 7.[5]

Table 6: Regional and sectoral detail of ICES (static version)

Regional disaggregation	Sectoral disaggregation
USA: USA	**Rice:** Rice
CAN: Canada	**Wheat:** Wheat
WEU: Western Europe	**CerCrops:** Cereal Crops
JPK: Japan and Korea	**VegFruits:** Other Vegetables and Fruits
ANZ: Australia and New Zealand	**Animals:** Livestock
EEU: Eastern Europe	**Forestry:** Forestry
FSU: Former Soviet Union	**Fishing:** Fishing
MDE: Middle East	**Coal:** Coal
CAM: Central America	**Oil:** Oil
SAM: South America	**Gas:** Gas
SAS: South Asia	**Oil_Pcts:** Oil Products
SEA: South East Asia	**Electricity:** Electricity
CHI: China	**Water:** Water Distribution
NAF: North Africa	**En_Int_Ind:** Energy Intensive Industries
SSA: Sub Saharan Africa	**Oth_Ind:** Other Industries
SIS: Small Island States	**MServ:** Market Services
	NMServ: Non Market Services (Defence, Education , Health Care)

Table 7: The macroeconomic impacts of climate change in Italy

Increase in temperature in 2050	Economic sector most affected	GDP variation in 2050
+0.93°C	Services (from -0.71% to -0.87%) Energy (oil -1.88%, Gas: -3.72%, Electricity: + 1.8%) Cereals (-1.45%)	-0.12% to -0.16% equal to an equivalent variation loss of €20-30,000 millions
+ 1.2°C	n.a.	-0.16% to - 0.20%

[5] Given the limited space, it is not possible to show all results produced by the model. A more detailed presentation is contained in Roson (2007).

If the temperature were to increase to 0.93°C in 2050, Italy would experience a GDP loss between 0.12% and 0.16% – which would increase to 0.16-10.2% for a temperature increase of 1.2°C. In 2050, Italy would therefore suffer a loss equivalent to 20-30,000 million Euros in current prices.

It is interesting to look at what happens to different economic sectors in Italy. In the lower climate change scenario, services and some energy sectors would experience a significant productivity loss. In particular, oil and gas would be penalised because of lower global demand for these products, due mostly to lower needs for winter heating, while demand for electricity would increase because of cooling needs. In the climate change scenario which accounts for land lost to desertification, agricultural production is severely penalised, in particular cereal production (Roson, 2007).

Starting from these damage estimates, and using two different cost functions to relate temperature increase to economic damages, it is possible to arrive at an estimate for the damages to the Italian economy for the next century. The results are summarised in Table 8.

Table 8: Total cumulated damages of climate change for Italy, as percentage of cumulated GDP (2001-2100)

Scenario B1 (+0.93° C in 2050)	Damage – quadratic relation to temperature	Damage – exponential relation to temperature
Discount rate: 3%	0.12%	0.14%
Discount rate: 1%	0.18%	0.19%

Scenario A2 (+1.2°C in 2050)	Damage – quadratic relation to temperature	Damage – exponential relation to temperature
Discount rate: 3%	0.20%	0.22%
Discount rate: 1%	0.38%	0.36%

The estimates are in line with the IPCC Fourth Assessment Report (IPCC, 2007c), but significantly lower than the damage estimates of the Stern Review (Stern, 2007). One of the reasons is that our cost estimates account for autonomous adaptations of the economic system. Therefore, costs are computed after economic systems and markets have adapted to climate changes through changes in prices and quantities. Our estimates, however, are likely to be an underestimate of the real future cost of climate change not only because they account for autonomous adaptation, but also because they do not consider important non-market impacts, such as biodiversity loss, or the loss of cultural heritage. In addition, we limit our analysis to this century, whereas most relevant effects are likely to occur in the next century. Once again, it is worth stressing that the impacts of climate change in Italy are likely to affect different sectors differently, and have a predominantly redistributive nature: whereas some sectors and population segments will be severely affected, others will not, or will be more able to adapt autonomously.

5. Conclusions

In the last decade there has been substantial progress with respect to the theory and applications of methodologies to estimate the economic impacts of climate change, but rarely at the national level. As a consequence, the existing literature does not provide indications as to the economic valuation of the cost of inaction nor the (net) benefits of adaptation for Italy. The papers briefly summarised in this report thus represent the first attempt at identifying the key vulnerabilities of Italy, assessing the likely impacts of climate change, and providing their economic evaluation. The costs of climate change have been assessed for specific sectors and territorial areas, and then aggregated in a macro-economic model that traces the impacts of climate change on Italian total and sectoral GDP, bearing in mind the interactions of Italy's economy with the rest of the world.

Our results show that the total effect of climate change on the Italian economy is likely to be modest, at least in the first half of this century. More relevant impacts are expected in the second half of the century. However, our results provide an obvious underestimate of the total costs of climate change in Italy. First, only some impacts have been economically evaluated. For example, effects on biodiversity and cultural heritage could not be considered. Second, autonomous adaptation (e.g. sectoral re-structuring) has been included in the analysis. Therefore, our costs estimates are lowered by autonomous adaptation taking place through markets around the world. Thirdly, we computed equilibrium costs, thus neglecting some costs related to economic changes and transitions to a new, climate change-induced equilibrium. Finally, average costs hide some important sector specific or regional costs. For example, in this paper, we emphasised those for alpine regions and agriculture. Huge cost differences are also likely to emerge between Northern and Southern Italy.

From a policy perspective, our results suggest that investments in adaptation capacity are likely to be necessary also in the short term (for example in the energy sector). Therefore, an adaptation fund should be implemented at the national level (as well as the international level) to minimise the costs of adapting in different regions and sectors. Given the relevance of the financial resources required, Italy should start cumulating this fund as of now, while debating on its future financing and on its allocation criteria.

From a research perspective, much needs to be done to improve our knowledge of climate change impacts, of their repercussions on economic systems and of their economic value. In particular, valuation techniques need to be improved to better evaluate ecosystems and biodiversity services. Climate modellers need to downscale the results to specific geographical areas. Impact analyses should be focused on the future impacts of climate change, rather than on the assessment of past events. Finally, economic analysis must include in the models a variety of linkages between economic and financial activities and climate change. This paper is just a small step in this direction.

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