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"Exploration of mitigation and adaptation: their cost and their links with sustainable development"

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Abstract: The pace of climate change and the consequent warming of the Earth's surface is increasing vulnerability and decreasing adaptive capacity. Achieving a successful adaptation depends on the development of technology, institutional organization, financing availability and the exchange of information. Populations living in arid and semi-arid zones, low-lying coastal areas, land with water shortages or at risk of overflow or small islands are particularly vulnerable to climate change. Due to increasing population density in sensitive areas, some regions have become more vulnerable to events such as storms, floods and droughts, like the river basins and coastal plains. Human activities have fragmented and increased the vulnerability of ecosystems, which limit both, their natural adaptation and the effectiveness of the measures adopted. Adaptation means to carry out the necessary modifications for society to adapt to new climatic conditions in order to reduce their vulnerability to climate change. Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) and to moderate potential damages, to take advantage of opportunities or face the consequences. Adaptation reduces the adverse impacts of climate change and enhance beneficial impacts, but will not prevent substantial cost that are produced by all damages. The performances require adaptation actions. These are defined and implemented at national, regional or local levels since many of the impacts and vulnerabilities depend on the particular economic, geographic and social circumstances of each country or region. We will present some

adaptation strategies at national and local level and revise some cases of its implementation in several vulnerable areas.

However, adaptation to climate change must be closely related to mitigation policies because the degree of change planned in different climatic variables is a function of the concentration levels that are achieved by greenhouse gases in the atmosphere. Mitigation and adaptation are therefore complementary actions. In the long term, climate change without mitigation measures will likely exceed the adaptive capacity of natural, managed and human systems. Early adoption of mitigation measures would break the dependence on carbon-intensive infrastructures and reduce adaptation needs to climate change. It also can save on adaptation cost. Therefore mitigation is the key objective of the global warming problem but little is being done in this field. We will present some proposals of "preventive economically efficient" policies at a global and regional level which will constitute the complement to the adaptation aspect. This paper begins with an overview on the complexities of vulnerability in the context of poverty and climate change. It continues with an exploration of mitigation and adaptation strategies, their cost and their links with sustainable development.

Keywords: *Climate change, adaptation- mitigation responses.*

I. Introduction

Climate change is one of the main global problems we have to solve in the XXIst century due to its impacts over the global economy. These, like health and the social impacts, will be suffered with more intensity by the future generations. Therefore it is necessary to reduce gas emissions and, at the same time, to look for new ways to adapt to global warming.

In order to response to the consequences of climate change, we usually point out two types of policy:

a) Mitigation. This response tries to reduce climate impacts reducing the growth of emissions. This can be done either reducing greenhouse gas emissions or increasing the capacity to absorb them (in sinks like forests or through technological innovation).

b) Adaptation. This response tries to do the necessary changes to be adapted to the new climate conditions. Climate change is already occurring so it is necessary to adopt these type of measures, for example, changing the crops to species better adapted to the new climate circumstances, limiting the urban buildings in the coasts, building structures to protect the coasts to rises in the sea level and integrating the adaptation policies with other fields linked to climate change like health, agriculture or infrastructure.

To develop good and efficient adaptation policies we have to know the present and prevent future impacts, calibrate its intensity and the time the will take place. Adaptation strategies demand actions that can be developed at national, regional and local levels since many of the consequences and climate change effects depend on the particular economic, geographic and social circumstances of each country or region.

This paper tries to analize some important aspects of adopting mitigation and adaptation strategies. We will show some international experiences of cities or regions

that are implementing local instruments and we'll also point the complications and barriers which are sometimes associated to these.

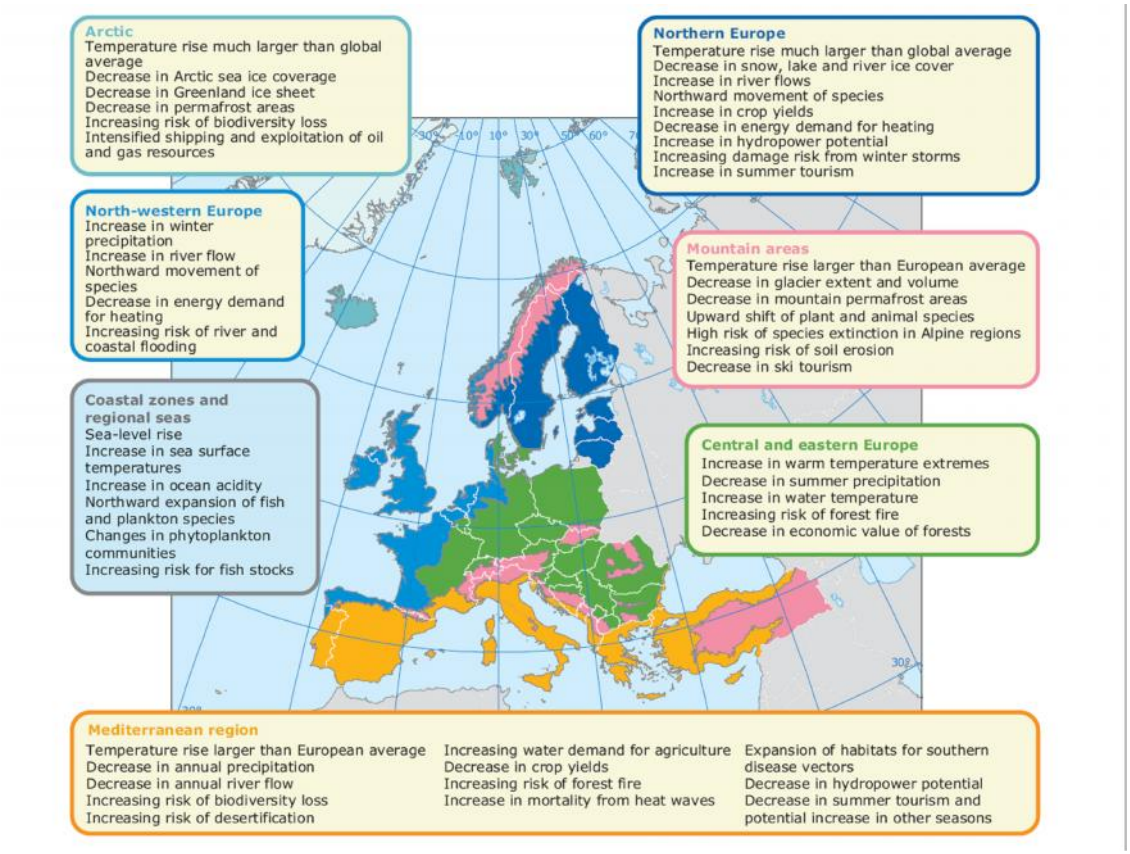
II. Vulnerability and Impacts.

A vulnerability can be defined as "a function of the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects)".

It is important to note that while the contribution of greenhouse emissions is global, the impacts of climate change stir vulnerabilities in a disproportionate way. Climate change deepens poverty and challenges poverty reduction strategies. The poor in developing countries are more at risk from the impacts because of their limited capacity to cope with existing climate variability and future change. Climate change will almost certainly make the process of eradicating poverty and to achieve the Millennium Development Goal 7 more difficult because of direct effects on poor people and the assets upon which they depend; and the increasing level of risk to which countries, cities and people already extremely vulnerable to shocks are likely to be exposed. Different social groups have different vulnerabilities. The urban poor in developing countries, and most of all women, elderly and children, are the most vulnerable (McMichael, *et al*, 2003).

The vulnerability of individuals and communities to climate change impacts is not simply determined by the location of their settlements, but also by how those settlements are serviced, how effective and capable their local governments are and to what extent communities are able to cope with climate change impacts. That is the adaptation capacity. It is widely accepted that the poorest communities are the most vulnerable, because they lack access even to the most basic urban services placing them at a comparative disadvantage and challenging their capabilities to take on additional stresses caused by climate change. Least developed countries in Africa, and Small Islands Developing States are the hot-spots where impacts of climate change, such as sea-level rise, inland flooding, drought periods and their subsequent consequences hit people most (Dasgupta, *et al*, 2007). Such complex vulnerabilities require comprehensive responses that link climate change adaptation and mitigation efforts to the sustainable development of these communities enhancing their adaptive capacity. Annex 1 shows the impacts on GDP caused by the sea level rise in most afected countries.

Chart 1. Key observed and projected climate change and impacts for the main regions in Europe



Source: EEA Report No 12/2012

Chart 1 shows the projected and also already present climate change impacts that will take place in some European regions. As we can observe all european regions are susceptible of suffering important impacts. The Mediterranean region will suffer the highest rise in temperature and also the strongest decrease in annual precipitation. This situation will lead, among other impacts, to increasing desertification, decrease in annual river flow, biodiversity loss and increase in mortality risk during heat waves.

It is important to note that climate change might have an impact on health systems by increasing the demand for health services beyond the capacities of those systems. It may also interfere with their ability to cope with demand by undermining infrastructure, technology and the availability of workforce. This is linked to emergency preparedness and response. As a result of climate change, health systems will need to prepare for gradual changes in health outcomes, sudden extreme events (e.g. heat-waves, infectious disease outbreaks), an extra burden of disease and potential new conditions. Climate change will affect human health, either directly - in relation to the physiological effects of extreme weather events, or indirectly through altered human behaviours (e.g. environmentally induced migration, more time spent outdoors), the increased transmission of food or vector-borne diseases, or other effects of climate change, such as flooding. An increase in some of these impacts has already been observed in Europe over recent decades (for example, the summer heat waves in 2003 alone are believed to have resulted in more than 70 000 excess deaths). Not all climate related changes are negative for human health as for example in temperate areas, milder winters will lead to less cold-related fatalities (SWD(2013) 136 final).

The primary concern in Europe is linked to heat-related morbidity and mortality , due to increases in annual temperature and extremes of heat, although these issues are also influenced by socio-economic changes due to population growth and the ageing of the

population. In Member States, it is estimated that mortality increases by 1– 4% for each one-degree rise in temperature, meaning that heat related mortality could rise by 30 000 deaths per year by the 2030s and by 50 000 to 110 000 deaths per year by the 2080 (SWD(2013) 136 final).

Therefore, and viewing the impacts showed above, we can conclude that it is not sufficient to concentrate on either mitigation or adaptation, but a combination of these results in the most sustainable outcomes. We must bear in mind that populations living in arid and semi-arid zones, low-lying coastal areas, land with water shortages or at risk of overflow or small islands are particularly vulnerable to climate change. Due to increasing population density in sensitive areas, some regions have become more vulnerable to events such as storms, floods and droughts, like the river basins and coastal plains. Human activities have fragmented and increased the vulnerability of ecosystems, which limit both, their natural adaptation and the effectiveness of the measures adopted.

Mitigation and adaptation efforts need to be combined appropriately and linked with the sustainable development of communities. Both approaches need to be managed by carefully planning for alternative solutions, prioritizing those that are cost-effective and minimize negative consequences, and enhancing local governments' leadership. But it is important to take into account that the extent to which individuals had an incentive to invest in adaptation would depend on the nature and clarity of the policies put in place for current and future mitigation. Greater policy uncertainty would change the incentives for investment in adaptation.

III. Adaptation Instruments

Adaptation means to carry out the necessary modifications for society to adapt to new climatic conditions in order to reduce their vulnerability to climate change. Following the IPCC, adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) and to moderate potential damages, to take advantage of opportunities or face the consequences.

There are already many countries which have National Adaptation Plans for climate change. In general, the National Adaptation Strategies (NAS) are focused on specific vulnerable sectors or regions, such as flood risk or heat wave plans. Some countries have also sectoral adaptation strategies and impact and vulnerability assesments. Some strategies also address inter connections between sectors. For example, the Spanish strategy notes that water resources, biodiversity and coastal zones have a major impact on other sectors, such as agriculture, forestry and tourism, whose development is to a large extent dependent on adaptation possibilities in the key sectors (PNACC, 2006)[1].

In Spain, the National Adaptation Plan for Climate Change, approved in 2006, is the general framework for the assessing impacts activities, vulnerability and adaptation to climate change. There are also two monitoring reports (2008 and 2011). In the same way, we count with the AdapteCCa Platform, created on the initiative of the Climate Change Office and the Biodiversity Foundation, along with the responsible units for adaptation to climate change in the Autonomous Communities. They jointly identify the need for having an instrument that provides communication and information exchange among experts, organizations and institutions at all levels. There are some other national institutions. The law 1/2005 , of March 9 , creates the Policy

[1] Plan Nacional de Adaptación al Cambio Climático (2006).

Coordination Commission on Climate Change as a link for coordination and collaboration between the Central Government and the Autonomous Communities for implementing the international trading emission system. Attached to the Ministry of Agriculture, Food and Environment were created the Interministerial Commission on Climate Change and the National Climate Council, to monitor functions and propose various policies related to climate change.

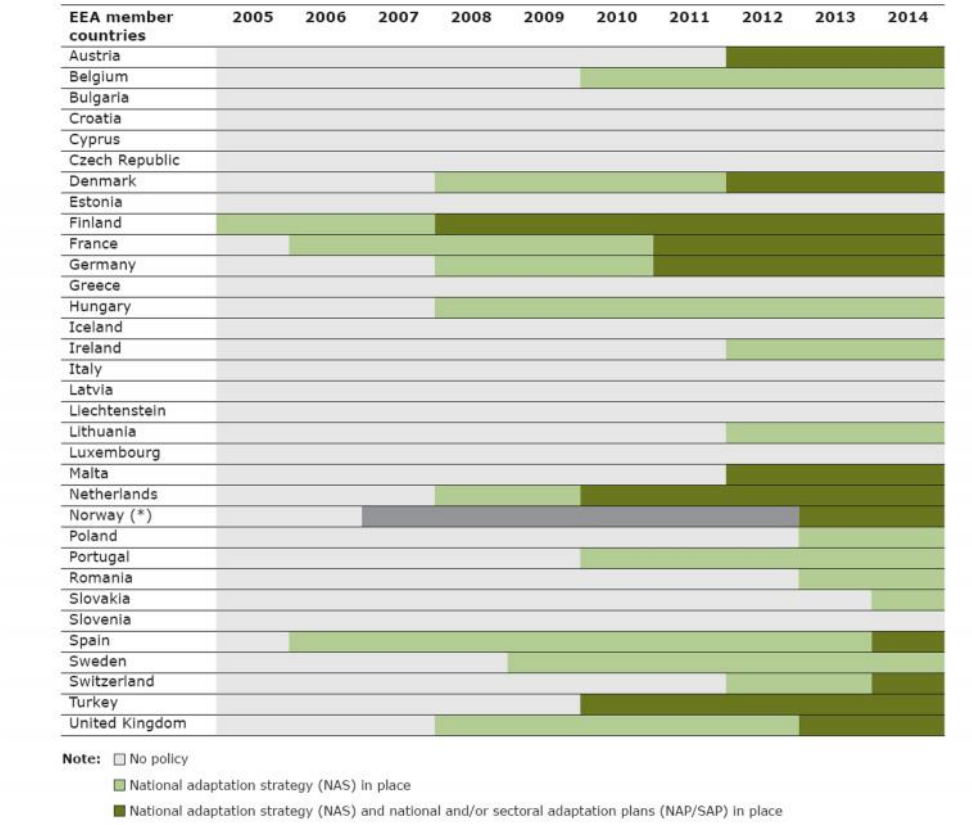
At a regional level, adaptation counts whith several organitations such as the Spanish Office for Climate Change, the Catalan Office for Climate Change, the Institute for Research on Climate Change in Zaragoza, the BC3 , Basque Centre for Climate Change, etc.

At the European level, we must mention the EU Strategy on Adaptation to Climate Change, adopted in April 2013, which sets the framework and mechanisms for decision-making in the EU for current and future climate impacts. The EU strategy focuses on three main objectives: To promote the activities of the Member States, the action "climate proof" in the EU, and better decision making. There is also the Directorate-General for Climate Action ("DG CLIMA") which was established in February 2010, climate change being previously included in the remit of DG Environment of the European Commission. It leads international negotiations on climate, helps the EU to deal with the consequences of climate change and to meet its targets for 2020, as well as develops and implements the EU Emissions Trading System. There is also another important instrument in Europe, Climate-ADAPT[2]. It aims to support Europe in adapting to climate change. It is an initiative of the European Comission that helps users to share information on vulnerability of regions and sectors, national and trasnational adaptation satrategies, adaptation case studdies and adaptation options.

Twenty-one EU member countries have adopted a NAS, to date. But 12 countries in total have set out more detailed national adaptation plans (NAPs). Table 1 provides this information. The sectors that have attracted the greatest attention throughout Europe in terms of risk and vulnerability assessment at national level are agriculture, water, forestry, human health and biodiversity.

Table 1. Status of national adaptation strategies and national adaptation plans in European countries

[2] Annex 1 shows the adaptation platforms across Europe.



Source: EEA Report No 4/2014

IV. Mitigation Instruments

The most efficient economic instruments are those that introduce different incentives to achieve lower levels of emissions , altering , in consequence, the price system . Therefore, they are also known as market economic incentives . They constitute the backbone of the preventive economic policies (mitigation) aimed to amiliorate global warming. These are designed to reduce GHG emissions. The option to take preventive action depends on the relationship between the costs of reducing GHG emissions and the damage these gases can produce if they are not subject to any control.

Sinks creation is also one of the priority actions. The loss of natural forests in the world contributes more to emissions than the annual global transport sector itself. Any reduction in the deforestation is a highly cost effective method of reducing emissions carbon . Today, prevention is an efficient alternative to adapt to climate change and improve energy efficiency. It carries less risk and promotes sustainable development.

Mitigation strategies to improve such efficiency are numerous and diverse. As an example we can name the carbon tax (alters the market price of energy), emissions permits , regulations and standards, removing subsidies on fossil fuels, reforestation programs, public information programs on energy efficiency, specific measures on the various economic sectors, especially industry and transport, renewables, efficient technologies, etc.

But are the economic incentives, like carbon taxes, the instruments that can gain in efficiency. Their goal is to alter the price system to reduce or modify economic activities

that could be harmful to the environment. However, administrative regulations are still measures very much used to protect environment. These are not specifically economic incentives and may not affect the price system . They are usually more expensive and less efficient than economic incentives.

On the other hand, note that the adoption of preventive measures is not only justified by the risk avoided, it is also necessary that they have an effective starting point. The adoption of incremental steps is important as we might otherwise incur unnecessary high costs (transition or adjustment). Thus, policies should be effective from the first step and, at the same time, adaptable to the present needs. For example, if we fix a carbon tax, it should not be based on an excessively high rate since we would not leave time for markets and technology to adapt to the new changes, - or prices would have to do it incurring an excessive cost-. But it is not advisable to maintain the same rate in the long term, since factors such as population growth and, consequently , greater energy demand may require higher tax rates in order to avoid more substantial emissions (García, 2014). It can also happen that the development and implementation of energy efficient technologies would facilitate tax reduction. The availability of new and clean technologies is a prerequisite, although not a guarantee, to reduce carbon emissions at a reasonable cost.

Market incentives have always been a tool used by environmental economists since they have a very direct application for most environmental problems. Climate change is an environmental externality that requires urgent action by all the countries. Today, in the context of economic crisis market incentives become a necessary claim since they clearly constitute public intervention mechanisms. This means that taxes can get very interesting advantages from the cost efficiency point of view (static and dynamic efficiency). We already know that the carbon tax encourages dynamic efficiency[3], ie, the development of more efficient technologies.

Moreover, in the present international context taxes are becoming more necessary to counteract the potential increase in fossil fuels demand, particularly the coal, for its moderate prices and large stockpiles, the oil, for its abundant reserves, and, the natural gas, being now an alternative energy source to the most polluting fossil fuels. Finally, if we can increase the prices of energy products through market instruments this will lead to improvements in energy efficiency, reducing external vulnerability and dependence (Labandeira, 2011).

The economic incentives have already been widely studied. Normaly we are talking about carbon taxes and emissions markets (cap and trade). As I have mentioned recently[4], the tax is a better option than the emissions permit system since the later provides a result that depends on the initial allocation of permits (which has implications for their distribution) and on price changes (permits set a price per unit or per ton of carbon). This is relevant because the carbon price fluctuation makes it difficult to estimate the total cost that the issuing permits would involve. In general, emission permits generate greater incentives for technological development than pure regulatory systems but, in many cases, they constitute a weaker incentive than the

[3] Generally, a tax on emissions provides stronger incentives to develop and implement new and cleaner technologies than any other policy based on the quantitative control of emissions. This means that the tax dynamic efficiency is higher.

[4] For a complete analysis of the carbon tax see García (2012), link: http://dx.doi.org/10.5209/rev_NOMA.2012.v34.n2.40734. Also, see ICADE. Revista cuatrimestral de las Facultades de Derecho y Ciencias Económicas y Empresariales, nº 93 septiembre-diciembre 2014, ISSN: 1889-7045

carbon tax. The explanation is simple. If several companies adopt new technologies, the total demand for permits, together with their price, will fall. Then the profitability of adopting the new technology will decrease and with it the incentive to develop new methods of production. Furthermore, emission permit markets are highly speculative as their operations revolve around the prices behavior. All this makes the tax a better option.

Besides, a well designed carbon tax can create significant environmental and economic benefits. A strategy to establish a domestic effective tax on carbon that captures the benefits described above must meet three general requirements (WRI, 1995):

1. Minimize economic losses that arise in the short term, through the efficient use of the tax revenues.
2. Maximize economic returns by reducing other taxes.
3. Compensate negatively affected groups.

This is what we know today as the Environmental Tax Reform. This reform uses taxation and other fiscal instruments to capture revenues while benefiting the environment. For developed countries, carbon taxes can replace other taxes, such as taxes on income and capital as well as improving economic conditions reducing unemployment. In developing countries, revenues from carbon taxes can be allocated on poverty measures such as infrastructure development or creating incentives for a more energy efficient industry. The environmental tax reform provides an opportunity to develop tax strategies that mitigate climate change while improving economic growth and development.

Nowadays, it is necessary a tax reform which uses the public revenue from carbon taxes to reduce other taxes that distort and discourage labor or capital. This reform is especially needed to boost economic activity and growth, even more when we move in a context of very inflated public deficits. It becomes more interesting when there is no loss of resources to the public sector. In times of economic difficulties, more than ever, we need to see implemented the so called multiple dividend taxation of GHG, that is, environmental improvement, promotion of clean technologies, reduction of energy dependence and increase of employment and economic activity.

V. Adaptation and Mitigation Implementation. Some International Strategies.

According to a survey[5] carried out in spring/summer 2012 among 196 European cities in the framework of the EU Cities Adapt project, the main hazards European cities have faced or are expected to face are:

- Periods of very hot weather or heat waves (often made even more severe by the Urban Heat Island Effect);
- Flooding from heavy rainfall;
- Storms;
- Water scarcity and droughts.

[5] EU Cities Adapt Survey Report 2012. Available from: http://eucities-adapt.eu/cms/assets/NewFolder/Appendix-3-Survey-v1-AEA.pdf.

To avoid, in some cases, and try to adapt to these impacts, several cities have alredy adopted or implemented local adaptation strategies. Here we resume a few suscesful examples of adaptation strategies applied in European and American cities or regions.

A Waterplaza for Rotterdam, The Netherlands:

Rotterdam, the second largest city of The Netherlands, is highly exposed to climate change impacts. Large sections of the city are located below the sea level, and the region is facing increased rainfall, more frequent floods, sea level rise and increasing temperatures. The adaptation strategy, Rotterdam Climate Proof[6], which began in 2008, sets out a path for the city to achieve resilience by 2025. The strategy is based on three pillars: knowledge, actions and exposure (dedicated respectively to raise awareness) and, implement measures (and then show-case them). These are mainly the following[7]:

i. Build and furnish adaptively equipping in the outer dyke areas, to seek clever combinations of protection (dykes), spatial planning (e.g. elevating some sections, floating buildings) and damage control (such as evacuation routes, water-resistant design of homes and external spaces, etc.). This is the so-called multi-layered approach.
ii. Harness the outdoor space and buildings for water storage and 'smart' water drainage, linked to the urban task at the specific locations; this creates more flexibility in the potential solutions and provides the opportunity to add quality to the environment. This could include, for example, an underground water storage facility linked to car parks or blue-green networks in the city.
iii. Actively encourage heat resistance as part of the design, renovation and maintenance of buildings, outdoor spaces and the road and public utility infrastructure. This could be achieved by, for example, incorporating trees and greenery and creating shade and adequate insulation in homes and offices.

Coastal adaptation in Almada, Portugal:

Due to increased demographic pressure, which led to the erection of illegal housing the region is prone to sea flooding and heavy impacts from storms. To save this important natural area and increase local resilience to climate change, the municipality developed specific adaptive measures[8] aimed at preserving its identity as a fishing community, but also taking into account trends, which put pressure on the area, such as tourism. These are mainly:

i. Improve natural cooling
ii. Use of solar energy in buildings
iii. Conservative average sea-level rise limits
iv. Development of urban green corridors
v. Construction of terrace defenses
vi. Rehabilitation of river banks with riparian vegetation
vii. Creation of retention basins or wet pounds system

[6] http://www.rotterdamclimateinitiative.nl/documents/RCP/English/RCP_adaptatie_eng.pdf

[7] http://www.deltacities.com/cities/rotterdam/climate-change-adaptation

[8] http://eucities-adapt.eu

viii. Dune restoration (natural buffers).

Los Angeles (CA), USA:

The GreenLA Climate Action Plan[9]identifies over 50 individual action items,some new, many on-going, that will lead Los Angeles to lower GHG emission levels. These actions form the core of the City's program and include measures over which the City has a great deal of control. They include changes to city operations, goals for changing city employee behavior, further encouraging sustainable practices for the private sector and residents, and greening city facilities of regional importance. Much of the plan focuses on energy, including greening the power from the largest municipal utility in the United States, helping people save energy, and making Los Angeles a world leader in green buildings. Here are some examples:

i. Reduce the urban heat island effect by adjusting building codes to favor "green" and "cool" roofs and cool pavements for new construction; Increasing tree canopy in neighborhoods with higher temperatures; Continuing to build new parks and increase open space.
ii. Provide incentives for solar rooftop installations to provide insulation and additional power supply (Installation of new solar lighting equipment, applied in 2012).
iii. Decrease demand for power on hot days by promoting customer rebates for energy efficiency. Making all municipal buildings energy efficient.
iv. Ensure water conservation by reducing outdoor water use by encouraging the use of climate appropriate landscaping; Continuing aggressive rebates for indoor water conservation tools such as low-flow toilets, showerheads, and faucets. Expand storm water capture programs.
v. Work with the private sector to offer effective incentives for the growth of local green businesses. Work with local educational institutions such as universities, community colleges, and adult education programs to provide City residents the skills needed to work for green businesses.
vi. Expanding bike infrastructure to promote alternative clean transport
vii. Rebates to incentivize electric car ownership, etc. Convert 100% of Metropolitan Transportation Authority buses to alternative fuels (85% entire fleet powered by alternative fuels, applied in 2012).
viii. Design and construct a district cooling plant and distribution system to supply chilled water to downtown Los Angeles buildings for space cooling application (applied in 2012), etc.

Comunidad de Madrid, Spain:

Emissions of greenhouse gases in the Community of Madrid represent 6.2% of total national emissions. Among these, transport accounts for some 53 % of total CO2 emissions, followed by residential, commercial and institutional sectors. It is for this reason that the Strategy of Air Quality[10] of the Community of Madrid sets a target of 15% for reducing CO2 emissions in the transport sector and, another 15 % in the residential, commercial and institutional sectors, with respect to the values inventoried in 2005 .

[9] Climate Action Plan, GreenLA, 2007.
[10] Estrategia de calidad del aire y cambio climático de la Comunidad de Madrid 2013-2020 (www.madrid.org).

The fifty-eight measures established are joined in four sectoral programs aimed at reducing pollutants emissions in the main sectors of Comunity of Madrid, and in four horizontal programs that collect performances with a transverse extent and affecting two or more of these sectors. For example, the transport sector, given its relevance in the Community, has been divided into six main lines of action :

i. Transportation:
   - Cleaner Technology and Fuel
   - Alternatives to private motorized traffic
   - Use of alternative modes of transport
   - Freight
   - Public transport
   - Airport
ii. Residential, commercial and institutional
iii. industry
iv. Agriculture and rural

Because transportation is the sector that emits the most, we show below some of the most important measures in place to reduce these emissions[11] :

i. Modernization of the autotaxi fleet with fuels and clean technologies.
ii. Promote the Public-private partnership to promote the use of gas vehicles .
iii. Implementation and consolidation of charging infrastructure and promoting the use of electric vehicles in the Community of Madrid.
iv. Renewal of institutional fleet under environmental criteria.
v. Tax incentives for the transformation of private transportation to cleaner technologies and fuels .
vi. Actions to promote the use of bicycles , motor-bike and walking.
vii. Promoting the use of shared vehicle (carpooling) and multiuser vehicle (carsharing) .
viii. Expanding the parking network
ix. Low emission zones and residential areas of priority.
x. Circulation of electric vehicles through BUS VAO lane.
xi. Reducing emissions from goods transport.
xii. Gasified Corridor Madrid- Castilla La Mancha -Valencia
xiii. Platforms reserved for public transport.
xiv. Improving public transport : metro, commuter and bus (urban and interurban) .
xv. Performances in underground bus-stations (intercambiadores) to improve the public transport offer.
xvi. Development workers mobility plans
xvii. Reducing emissions associated with airport traffic .

VI. Adaptation limits

The most important barriers to adaptation that countries usually report are:

i. the lack of financial/human resources
ii. uncertainties and unclear responsibilities
iii. lack of political commitment

[11] For a complete description of every measure see previous reference (10).

iv. adaptation needs are very context specific and need to be based on local vulnerabilities.
v. Interface national/regional/local authorities
vi. Cost

While several strategies cite the possible economic damage of unavoided climate change as a major motivating factor for action, no strategy actually presents an analysis of the costs of adaptation but some refer to general assessments such as, for example, the Stern review (Stern, 2006). Also, suggestions from aggregate model studies lead to the conclution that costs are likely to outweigh the benefits, and this fact seems to indicate the need to start adaptation policy development. There is as yet no systematic and reliable method to estimate the costs of adaptation for most adaptation options, partly because it is often difficult to separate climate concerns from other factors that influence adaptation actions (Biesbroek, 2010).

Although many countries, mostly European, have already designed National Strategies for Adaptation, it is important that adaptation is pursued in accordance with the regional level to create a clear interface enabling local and regional actors to communicate and cooperate effectively. This is due to the fact that it is at a city level that most of the impacts will take place due to the large concentration of built-up impermeable areas, and high population density in a relatively concentrated space. Therefore local-regional collaboration will enable better organisation and identification of capacities and responsibilities. Consequently, each level must cooperate and take a multi-level governance approach in order to develop coherent adaptation strategies (Committee of the Regions, 2013).

Cities must take action but their adaptation strategies need to be embedded in a coherent legislative and governance framework that enables different impacts to be dealt with by the appropriate level. This includes an adequate, multi-level knowledge base and distribution of authority and responsibility, stable governance structures over time, and, ideally, access to dedicated funding sources. To this end, local adaptation strategies should correspond to regional ones. In European countries it is important that support is provided in order to address existing barriers to urban adaptation such as lack of awareness, lack of local data and knowledge, and limited funding for adaptation measures.

Unfortunately not all countries can react to climate change at the same level. The adaptive capacity is directly related to the status of natural resources and the level of socio-economic development. Cities within developed countries are more likely to succeed in their efforts towards mitigation and adaptation than the developing world, which means that the degree of urban development might act as a precondition for a successful response to climate change. The latter leaves cities from developing countries with the overwhelming challenge of dealing with climate change and socio-economic development strategies at the same time. Without the financial resources and the institutional capacity to comprehensively manage climate change, developing countries will pay the price with more urban poverty, water and food scarcity, dissemination of diseases, urban migration or relocation of entire communities plus more environmental stresses. In this sense, the Human Development Aproach[12] focuses on improving people´s life and assumes that economic growth will lead, automatically, to greater wellbeing for all. Income growth is seen as a means to development, rather than an end in itself. It is also focused on the exposure to climatic hazards and the determinants of adaptive capacity from local communities. The latter translates into

[12] Human Development Reports (HDRs) have been released most years since 1990 and have explored different themes through the human development approach. They are produced by the Human Development Report Office for the United Nations Development Programme (UNDP).

the availability of financial, technological and human resources, as well as the access to information and to social and institutional structures.

Adaptation is very costly. Adaptation opportunities are limited compared to mitigation projects, due to the fact that many adaptation actions are costly and non-revenue generating. For example, in the the EU Adaptation Strategy LIFE[13] is an instrument to finance climate action, with a proposed budget for the Multiannual Financial Framework for LIFE of €3.2 billion, which includes a new sub-programme on climate action (around €800 million for the period 2014-2020)[14].

Mitigation can save on cost. Soft measures, such as land-use controls, information dissemination and economic incentives to reduce vulnerability, have a limited cost and can reduce the impact of hazards just by influencing human behaviour (e.g., by setting up an early warning system during heat-waves that advises vulnerable population groups to remain indoors during the hottest or most affected hours of the day).

Carbon taxes are revenew producers which, among other benefits, maximize economic returns by reducing other taxes or/and compensate negatively affected groups. The use of taxation and other fiscal instruments can capture revenues while benefiting the environment.

Nevertheless, involving different levels of government (e.g., the regional level and the national level) in adaptation planning can reduce costs and improve the efficacy of measures. It is critical to understand that while economic and human impacts affect cities disproportionately, adaptation measures often need planning beyond municipal borders to be effective (e.g., in the case of river management). For these reasons cities have been and will continue to be economically, socially and environmentally the most affected by climate change.

One of the difficulties of developing adaptation strategies following the Covenant of Mayors methodology[15] is to define a baseline, indicators and objectives. Contrary to emission reduction pledges, adaptation needs are very context specific and need to be based on local vulnerabilities. The indicators are difficult to develop because unlike pledges to reduce emissions, which are quantified in terms of tons of CO2, there is no specific single variable valid across all regions on adaptation with which to measure the type and level of adaptation[16].

Adaptation needs its own targets and also these need to be adjustable to different local situations. While mitigation targets' achievement can bequantitatively measured, a framework dedicated to adaptation would need to set its own set of benchmarks and

[13] LIFE is the European Programme for the Environment and Climate Action, for the period from 1 January 2014 until 31 December 2020. The legal basis for LIFE is Regulation (EU) No 1293/2013 of the European Parliament and of the Council of 11 December 2013

[14] The overall financial envelope for the implementation of the LIFE Programme is EUR 3.457 Billion, 75% of which is allocated to the sub-programme for environment (EUR 2,592,491,250) and 25% of which is allocated to the sub-programme Climate Action (EUR 864,163,750).

[15] The Covenant of Mayors is the mainstream European movement involving local and regional authorities, voluntarily committing to increasing energy efficiency and use of renewable energy sources on their territories. The key of the Covenant of Mayors methodology is the Sustainable Energy Action Plan (SEAP), in which signatories commit to a minimum CO2 emission reduction target of 20% by 2020 and define the actions they need to put in place to reach their commitment.

16 The impact assessment of the adaptation strategy calls for the Commission and the European Environment Agency (EEA) to create a list of indicators, as well as monitoring and assessment methodologies.

milestones, taking into account the specificity of adaptation and its process-based requirements.

Finally, adaptation is the result of a process involving many interrelated steps and various actors dependent on integrated planning between different municipal departments and allocation of funding for concrete measures. However, the picture with regard to adaptation in the developed world is still scattered, and in many cases, cities are implementing stand-alone measures not linked to a holistic adaptation process. In order to effectively respond to climate change, global actors at different levels require both a methodology and a tool to help them in the decision-making process. The methodology would be able to establish a mechanism to effectively coordinate efforts and set priorities within a human development approach towards climate change. On the other hand, the tool will allow global actors to identify if adaptation or mitigation, or adaptation and mitigation are needed to best cope with climatic variability (Laukkonena *et al,* 2009). This tool would enable them to visualize and compare all possible mechanisms in order to make choices and take decisions.

VII. Mitigation limits

When calculating and assessing the costs of economic policies to curb climate change (mitigation costs), we must consider several variables. Among the most important are the goals and timetables for internationally determined emissions, the tendency of the population and the economy (expectations are growing and with it a higher energy demand), the development of new technologies (the higher its availability and incorporation rate, the lower the need for economic incentives, thereby reducing costs), the replacement of capital rate[17] (abrupt changes in the stock of existing capital may entail high costs if it has not been repaid), the discount rate that is used to calculate the present value of the stream of future environmental benefits, possible actions taken by consumers and industries in response to the policies adopted, the consumption of fossil fuels, the growth rate of climate change, etc.

Estimates of the cost of reducing carbon dioxide emissions varies among studies. Some analysts believe that these costs would be negative because emissions could be eliminated by simply destroying distortions that energy markets produce. Others believe that if it were possible to reduce energy consumption at a negative cost it would have been done long time ago.

There are also different views on the evolution of other variables: how quickly will emissions increase in the absence of climate change policies, what energy efficiency improvements can occur independently of changes in prices, how easily less polluting fossil fuels and other energy sources be replaced and the availability and cost of new energy technologies that do not emit CO2. For example, carbon reductions through substitution of cleaner fossil fuels do not diminish the availability of energy but only reduce its carbon intensity, improving energy efficiency. According to Cline (1992), this setting should be able to halve the percentage necessary cut of the energy required to reduce carbon emissions. That is, a 70% cut, for example in carbon emissions should be achieved with a reduction of only 35% of the energy used. The amount of this decrease is indicated by the elasticity of output with respect to energy. If this elasticity was the suggested by Cline (0.06), then the 35% cut in energy would be accompanied by a reduction of approximately 2% of GNP.

[17] Refers to the period of the equipment natural life.

In short, the economic analysis performed by different authors using different models (some using the cost -benefit approach, others computing targets and dates of stabilizing emissions and observing what the welfare loss through loss of national product will be; others calculating the costs of implementing any financial instrument like the carbon tax, etc) suggests that small reductions in emissions and small improvements in sinks can be achieved at zero or very low cost. However, increasing cuts in emissions can lead to higher costs, unless more efficient technologies are implemented.

However, the total cost of reducing emissions may be lower if we implement a carbon tax policy, since, as each producer using fossil fuels pay the same tax, each of them will therefore have the same incentive to reduce emissions (see figure 1 in annex 2). However, the same cannot be applied to other policies. For example, by imposing a tax on oil (a single type of fossil fuel), vehicle owners have a greater incentive to reduce emissions than other pollutants, so that the cost of dealing with emissions reduction would be excessive. Then, with the carbon tax we could always redistribute to poorer groups the efficiency advantages of the tax, that is, the difference between the costs of achieving a certain level of emissions reduction with the carbon tax and the potential costs of an alternative policy.

Several recent studies show conclusive results on the effect that different tax rates may have on the fuel price, the resulting emission reductions and changes in welfare. Specifically, Dingell, Larson and Stara in Metcalf, GE et al (2008) show different tax rates that result in different emission paths. Clearly, more ambitious rates (Larson) get, eventually, greater emission reductions and also more welfare losses (GDP reductions)[18]. But, what it is interesting is that using gradual increasing tax rates, emissons can be suficiently controlled and welfare does not decrease. Revenues can also be distributted to low income population.

So far, given the degree of uncertainty regarding the impacts and given the relative expansion of better energy technologies (especially in developing countries) it seems that small reductions in emissions and growing sinks are widely justified. Now if we want those costs to diminish we must apply economically efficient instruments and a serious international coordination.

VIII. Final reflexions

While challenges persist to incorporate mitigation and adaptation in a coordinated manner, to achieve sincere sustainable development, both strategies are necessary.

The profile of climate change mitigation and adaptation strategies should be strengthened and incorporated alongside the agenda of sustainable development, because inherently climate change is and will continue to create extensive challenges. Effective implementation of mitigation and long-term adaptation strategies can also create opportunities, and while investments in adaptation will certainly have high upfront costs, large net benefits can occur over time, like reducing vulnerabilities and future risks (UNDP (2008) states that for every one USD invested in pre-disaster risk management (strategies for adaptation) in developing countries, losses of about seven USD can be prevented). Nevertheless, preventive policies, as economic incentives (carbon tax, etc) can save on adaptation cost. This means that preventive action must precede adaptation.

[18] More information is shown in Annex 2.

Mitigation and adaptation strategies require actions at many levels – the international, national, local, individual – and involve actors from the public and private sector, as well as educational institutions, NGOs and international organizations. Whether at national, local or an individual level: whatever is needed to cope with the impacts of climate change and to restrict further global warming, should be done. This principle is simple but its implementation is tricky. There is an obvious lack of an overall coordination, as well as a mechanism to monitor whether one measure (mitigation or adaptation) hinders the implementation of another (adaptation or mitigation). Without coordination it may prove that some efforts will be undertaken in vain.

Unfortunately not all countries can react to climate change at the same level. The adaptive capacity is directly related to the status of natural resources and the level of socio-economic development. Cities within developed countries are more likely to succeed in their efforts towards mitigation and adaptation than the developing world, which means that the degree of urban development might act as a precondition for a successful response to climate change. Therefore, an adequate approach towards climate change adaptation would be based on the determinants of development.

Finally, the complexity of climate change requires a clear methodology and adequate tools to follow. Up to now, applicable tools and methodologies have considered climate change adaptation as only one part of their focus next to other priorities. Additionally, most existing instruments give more emphasis towards the measurement of impacts and the model of scenarios rather than the assessment of adaptation (and mitigation) options. Therefore, there is a strong need of tools and procedures that could assist actors at different scales in the formulation, evaluation and implementation of best responses towards adaptation and mitigation.

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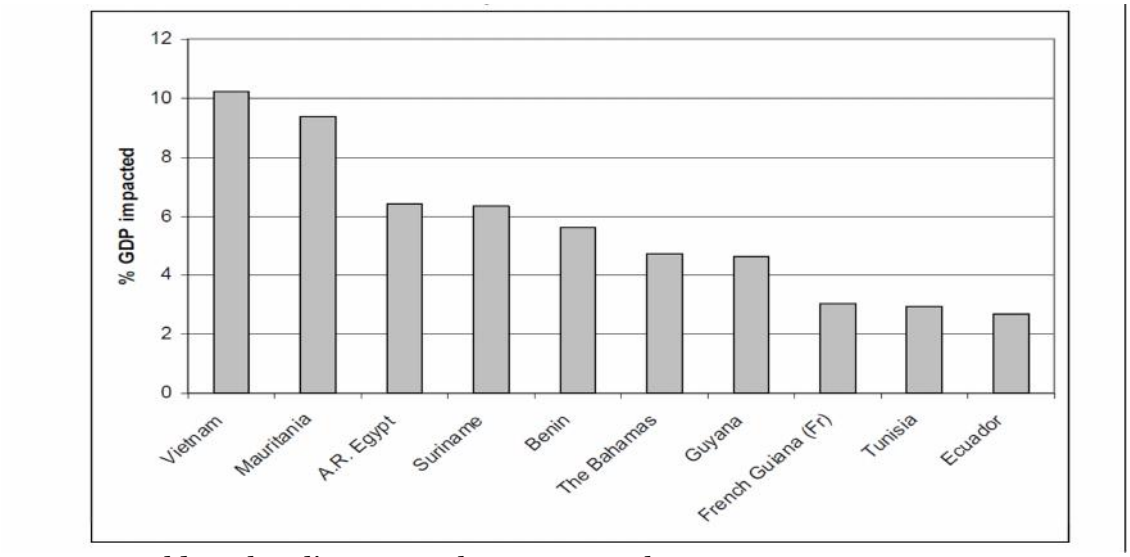
ANNEX 1

Most impacted countries by sea level rise: % loss of GDP



Source: World Bank Policy Research WP 4136, February 2007.

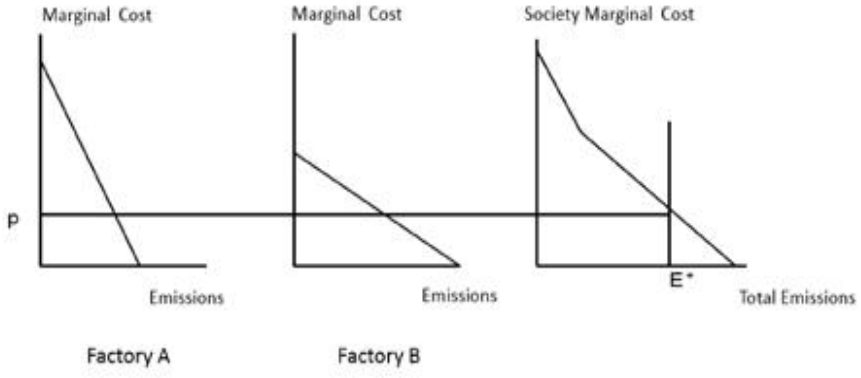
Adaptation platforms across Europe

Country	Title	Web-link
Austria	The Austrian Platform on Climate Change Adaptation	http://www.klimawandelanpassung.at
	Ministerium für ein Lebenswertes Österreich	http://www.klimaanpassung.lebensministerium.at
Denmark	Danish National Adaptation Platform	http://www.klimatilpasning.dk
Finland	Climate Guide (both mitigation and adaptation)	http://www.climateguide.fi
France	WIKLIMA	http://wiklimat.developpement-durable.gouv.fr/index.php/Wiklimat:Accueil
	The French Observatory	http://www.developpement-durable.gouv.fr/The-Observatory-ONERC.html
Germany	Germany: KomPass	http://www.umweltbundesamt.de/en/topics/climate-energy/climate-change-adaptation/kompass
Hungary	Climate Dialogue Forum	http://klimadialogus.mfgi.hu
Ireland	Climate Ireland	http://www.climateireland.ie
Norway	Norway Adaptation Platform	http://www.klimatilpasning.no
Poland	KLIMADA	http://klimada.mos.gov.pl
Spain	Spanish Adaptation Platform	http://www.adaptecca.es
Switzerland	Swiss Information Platform on Adaptation to Climate Change	http://www.bafu.admin.ch/klimaanpassung
Sweden	Swedish Portal for Climate Change Adaptation	http://www.klimatanpassning.se
Transnational	**Title**	**Web-link**
Pyrenees	OPCC Pyrenees	http://www.opcc-ctp.org
Alps	Alpine Convention	http://www.alpconv.org/en/climateportal/default.html
Europe	Climate-ADAPT	http://www.climate-adapt.eea.europa.eu

Source: EEA Report Nº 4/2014

ANNEX 2.

Figure 1. The costs of reducing carbon emissions

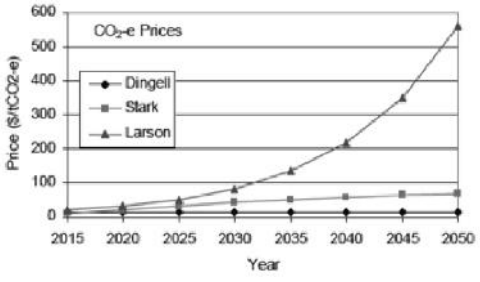


Source: Own

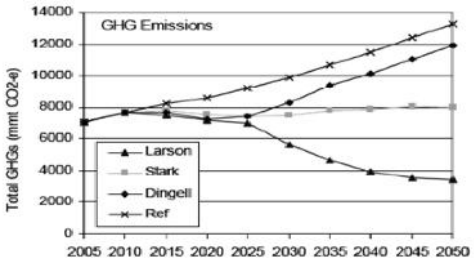
Figure 1 shows the costs of reducing carbon emissions in the two factories. The emissions are measured along the excises axis. The marginal cost curves show the cost of reducing emissions in one unit. The curves are decreasing indicating that large emission reductions increase the cost of reducing an additional ton of pollutant. We can impose a carbon tax rate of p monetary units (euros, dollars, etc..) per ton of carbon. Fixed an overall goal in E *, each factory will reduce emissions until the marginal cost equals the tax. Each unit will reduce pollutant emissions considering its MC (marginal cost) but will pay the same rate per ton of carbon. This would therefore be an effective policy.

Figure 2. Different carbon tax rates under study.

	CO_2-e Price ($/t$CO_2$-e)		
	Dingell	*Stark*	*Larson*
2015	14	10	20
2020	14	23	32
2025	14	34	52
2030	14	43	83
2035	14	51	134
2040	14	58	216
2045	14	64	348
2050	14	69	561



Emission trajectories and welfare changes.



	Welfare Changes (%)		
	Dingell	*Stark*	*Larson*
2015	0.01	0.01	0.01
2020	-0.09	-0.09	-0.16
2025	-0.25	-0.27	-0.24
2030	-0.21	-0.39	-0.74
2035	0.07	-0.32	-1.25
2040	0.21	-0.38	-1.71
2045	0.32	-0.38	-2.08
2050	0.49	-0.33	-2.23
2012-2015	0.10	-0.30	-1.21

Figure 2 shows how more ambitious rates (Larson) eventually lead to greater emission reductions. However, for the first 15 years, the application of different tax rates does not lead, in general, to important emission reductions or even great significant differences in these reductions. These estimates of the tax rate result in changes in welfare (Figure 2) which is measured for the loss of market consumption (that carries the tax) and offset by the gain in leisure time that also the tax produces (leisure associated to job losses).