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Trade Liberalization, Local Air Pollution, and Public Health in Tunisia: Assessing the Ancillary Health Benefits of Pollution Abatement Policy”

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Abstract

Since the middle of the past century, Tunisia is embarked in an ambitious trade reform program aiming to improve its integration in the world economy, boost growth through valorising comparative advantages, and reduce unemployment among its population. However, and despite the positive role that trade may plays in improving growth through better allocation of domestic resources and lower costs of imported equipments and raw materials, the risk is to amplify output in sectors intensive in energy in a country where energy still subsidized. Introducing pollution abatement tax has been suggested as a way to achieve ancillary benefits from reduced local air toxics. The highest level of local air pollution is found in heavily populated cities where labor is concentrated and where labor health is believed to have been significantly impacted.

The objective of this paper is to address this important issue. It identifies the optimal and “no regrets” pollution abatement tax on a net welfare function, which integrates both net health benefits and adjustment costs. The paper uses a Computable General Equilibrium (CGE) model for the assessment that allows the health benefits to feedback into the economy. A health effects sub-model takes the local air emissions output from the CGE model and assesses the implications for ambient air concentration levels and health effects.

The results suggest an “optimal” abatement rate in 2020 of around 25% of CO2 reduction compared with the baseline 2020 emissions. However, the most significant impact concerns the relatively small aggregate cost of pollution abatement in terms of forgone real average growth rate of GDP between 2010 and 2020 for the trade scenario with “optimal” climate policy. Finally, the major consequence of pollution abatement policies is the reduction of production generated by polluting activities against a higher production of less polluting activities

1. Introduction

There has been an explosion of interest in the potential benefits of pollution abatement to offset some of the costs of reducing gas emissions. While the list of such effects is long and the benefits from each are large, pollution will yield far better deal when these benefits are ignored. Until quite recently, literature on direct and ancillary benefits, came from developed countries, especially the US and Europe. Davis et al. (2000) identify four categories of effects of pollution abatement namely health, ecological, economic, and social. In addition to considering the full range of sources of benefits, it is also vital to consider costs. These may arise both from increases in externality-causing activities as well as changes in spatial distribution of emissions. The annual cost of environmental damages in some of the MENA countries varies from 4 to 9% of GDP. These costs are higher than those for Eastern Europe (5%) and substantially higher than those for OECD countries (2 to 3%). Moreover, it has been estimated that the environmental health burden is about 14% of the total health burden in the MENA region. Out of this total, about 3% is attributable to urban air pollution (Chemingui, 2002).

The wider literature on direct and ancillary benefits of pollution abatement makes clear that these effects are significant and countries adopting these policies will be winners in many ways. Most studies focus on health impacts of pollution abatement but others suggest the possibility of increase crop yields. The questions are whether the policies of pollution emissions abatement will be feasible and whether they will be costly or not. Will the benefits of these policies be higher than their costs? And what will be the role of trade policies on emissions? Most studies were done on developed countries, but the number applied in developing countries is still very limited[1].

However, the economic costs of climate protection measures, juxtaposed with the significant scientific uncertainties about the extent and impacts of climate change, have generally favored a "wait-and-see" attitude on the part of policy makers. In fact, and despite the recent rising of the awareness of governments to the pollution problems, the progress in global climate policy negotiations has been slow. Policy makers around the world find themselves under strong pressure to enhance domestic competitiveness rather than curtail it by adopting costly energy taxes. The situation is compounded in developing countries by a rightful preoccupation with meeting basic human needs.

To these challenges, the intensification of trade liberalization initiatives around the world either in the forms of regional integration agreements (FTAs, Custom Unions, Common market…) or under the WTO is believed to increases pressures on the environment due to the needs for higher competition on both domestic and foreign markets. Accordingly, reducing production costs and improving comparative advantages may not make the implementation of pollution abatement policies at least easy or possible. In fact, the impact of economic growth on pollution is believed to be intensified by trade liberalization measures. To the three effects of economic growth on the volume of pollution emissions[2], free trade is expected to raise income, which makes scale and technique effects tend to offset each other. The net impact on environment is then determined by the composition effect (Beghin et al., 1994 and 1999[a] and 1999[b]). Efficiency gains induced by outward-oriented strategy lead to positive scale effects on pollution. The technology effect is also influenced by trade policy as removal of trade restrictions changes relative input prices, input mix, and hence the pollution intensity of production. And finally, the composition effect reflects the realization of comparative advantages, which may be in either dirty or clean activities.

Generally, the impact of trade liberalization on the environment may be positive, provided it is accompanied by effective environmental policies (OECD, 1995). Trade liberalization improves the efficiency of resources allocation, promotes economic growth and increases general welfare. Therefore, it is viewed as a positive agent that can provide resources for the improvement of the environment (Aldaba, R.M and C. Cororaton, 2002). However, Vogel (2000) suggested that for relatively poor countries, increased economic growth and economic interdependence generally does result in a deterioration of domestic environmental quality: pollution levels increase and natural resources are depleted at an accelerating rate. However, environmental quality tends to improve as per capita income increases because nations are in a better position to devote resources to conservation and pollution control.

Most of the existing literature on ecological tax reforms in open economies tends to focus, in a public finance setting, on the interactions between this new fiscal instrument and public expenditures on environmental protection and pollution abatement. However, a second part of the literature focuses on showing the anciallry benefits of pollution abatement tax through a close look to the expected improvement in population health and agricultural yields.

Thus, and given that trade liberalization can affect the environment primarily through changes in emissions of harmful substances into the air, water and/or land, our primary goal is to address this apparent contrast in the missions of environmental and trade policies by providing measurement of the costs and benefits related to a pollution abatement policy which can be implemented by Tunisia. The costs may rise from lower economic growth linked to the implementation of pollution abatement policy while gains are mainly those in the forms of "ancillary benefits".

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[1]Bussolo et O'Connor (2001) estimate the health impact of environmental degradation in India, while Chemingui (2002) estimate the economic costs of pollution abatement policy in Tunisia in the context of its FTA with the EU.

[2] These effects are scale, technology, and composition effects. Scale effect is observed when greater economic activity raises demand of all inputs and increases emissions. Technological effect exists and tends to reduce emissions when higher effluent charges encourage firms to shift toward cleaner production process. Finally, composition effect is observed when income growth shifts preferences toward cleaner goods and the share of pollution-intensive goods in output fall

This type of analysis is important for a country like Tunisia that has just finalized the implementation of its economic partnership agreement with the European Union over the period 1996-2008 as well as the Greater Arab Free Trade Area (GAFTA). Moreover, Tunisia is currently implementing additional Free Trade Agreements (FTAs) with other partners such Turkey and the European Free Trade Association member countries (EFTA) and negotiating others with the Central African Economic and Monetary Community. Bilateral negotiations with the EU are also under way to extend the association agreement to services, agricultural products, and processed food given that the current agreement provides for free trade limited to industrial products.

Thus, the objective of this paper is to determine the optimal carbon tax rate that may be implemented by Tunisia to achieve higher welfare gains in the context of continued trade liberalization schemes. Higher welfare gains mean higher anciallary health benefits conjuged with the lower economic cost. To do so, this research is based on a prospective inquiry, which is more adequate than retrospective studies to inform policy-making. The Tunisian government is undertaking profound institutional changes and is facing shrinking trade-related sources of revenues and, within over-stressed budgets, is required to enforce environmental protection policies. However, policy makers will not be able to implement, or even win the approval for, environmental norms just because it may be too difficult to prove their benefits (which are diffused) while it is easier to identify their costs (and potential losers). Our results aim at helping policy-making in this area by providing new evidence on the synergies, the advantages and the potential trade-offs of an environmental policy in an open economy. At a minimum, this new evidence, on the one hand, will elucidate *how* an environmental policy may foster sustainable competitiveness and work to provide measurable benefits and, on the other hand, it will offer some *quantitative* estimate of its effects in terms of increased trade, enhanced welfare, and faster growth. By showing both the qualitative properties and quantitative consequences of alternative policy actions and by testing results against the variation of crucial exogenous parameters (sensitivity analysis), this study offers some guidelines for a sound environmental policy in Tunisia.

The analysis makes use of a CGE model of the Tunisian economy to simulate climate policy. This type of models has become a standard tool for integrated assessment of climate change. The principal advantage of this approach lies in the ability to capture feedbacks effects and market interdependencies that may either mute or accentuate first-order effects, say, of a carbon tax. The disadvantages include a lack of technological detail and possible sensitivity of results to variation of certain key parameter values. Of the six greenhouse gases regulated by the Kyoto Protocol, only CO2 is incorporated into the model. The model estimates the impact of limiting growth of CO2 emissions on local air quality, the health of the Tunisian population, and the economic performance of the country. The reduction of CO2 emissions is achieved through the implementation of a CO2 abatement tax at various rates.

The paper is organized as follows. Section 2 describes the economic and energy structure of Tunisia basic data on pollutant emissions as well as air quality in major cities. Section 3 presents the modeling approach taken and the data used in analyzing climate policy in Tunisia. Section 4 analyses the baseline scenario simulation and section 5 displays alternative policy scenarios along with the results of sensitivity analysis and a comparative assessment with the findings for other countries. Section 6 concludes with a discussion of policy implications.

2. Background on the Tunisian energy use and pollutant emissions

With a population near 10.5 millions citizens and 1.3% of demographic growth, Tunisia has one of Africa and the Middle East's highest per-capita GDPs (PPP) with 7996$. In 2008 it had a GDP of $41 billion (official exchange rates), or $82 billion (PPP).

Tunisia has undergone steady urban development over the past few decades. The urbanization rate has increased from 49% in 1975 to around 75% in 2009. The majority of the urban population lives in towns and cities clustered along the coast, where the biggest cities and the most dynamic centers of activity life are. Nine out of ten industrial units are also located along the coast.

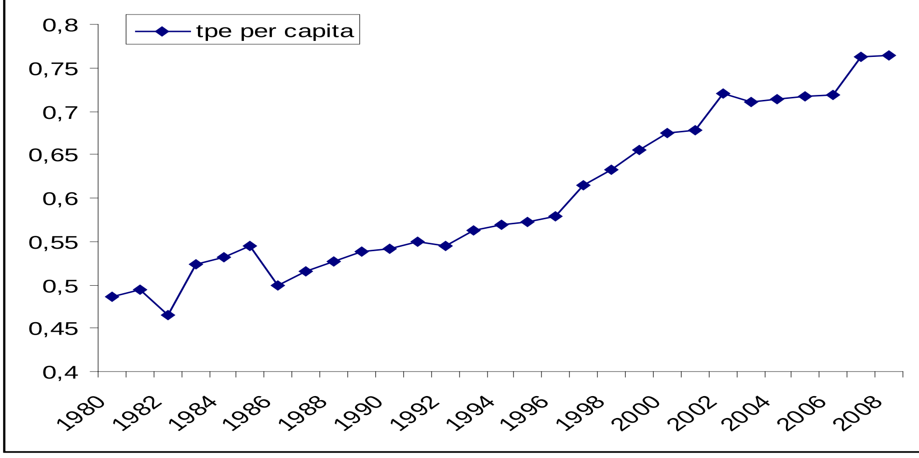
Of the 6 Tunisian cities with over 100 000 inhabitants (Tunis, Sfax, Sousse, Bizete, Kairouan and Gabes), only Kairouan is located in the interior.

During the last 20 years, Tunisia has had an average annual growth rate of 5%, which is expected to increase into the future with the expected improvement in business environment after the revolution of January 14th 2011. More importantly, from the standpoint of this study, such growth entails changes in the use of energy since that the structure of the Tunisian economy is changing. This shift is due mainly to the important economic reforms that have been instituted aimed at domestic liberalization and closer integration into the world economy. The expected lower corruption and higher investment should boost economic growth and consequently increase pressures on the uses of natural resources, such as energy.

The Tunisian economy is undergoing a process of structural transformation, with agricultural GDP share shrinking and those of industry and services growing. Agricultural share of GDP fell from 21% during the sixties to roughly 11% in 2008, with most of the increase occurring in the services sector. The Tunisian economy is quite diverse ranging from agriculture, mining, manufacturing, petroleum products and tourism. The industrial sector stands for 25.7% of the GDP and services 62.8%. The industrial sector is mainly made up of clothing and footwear manufacturing, production of car parts, and electric machinery.

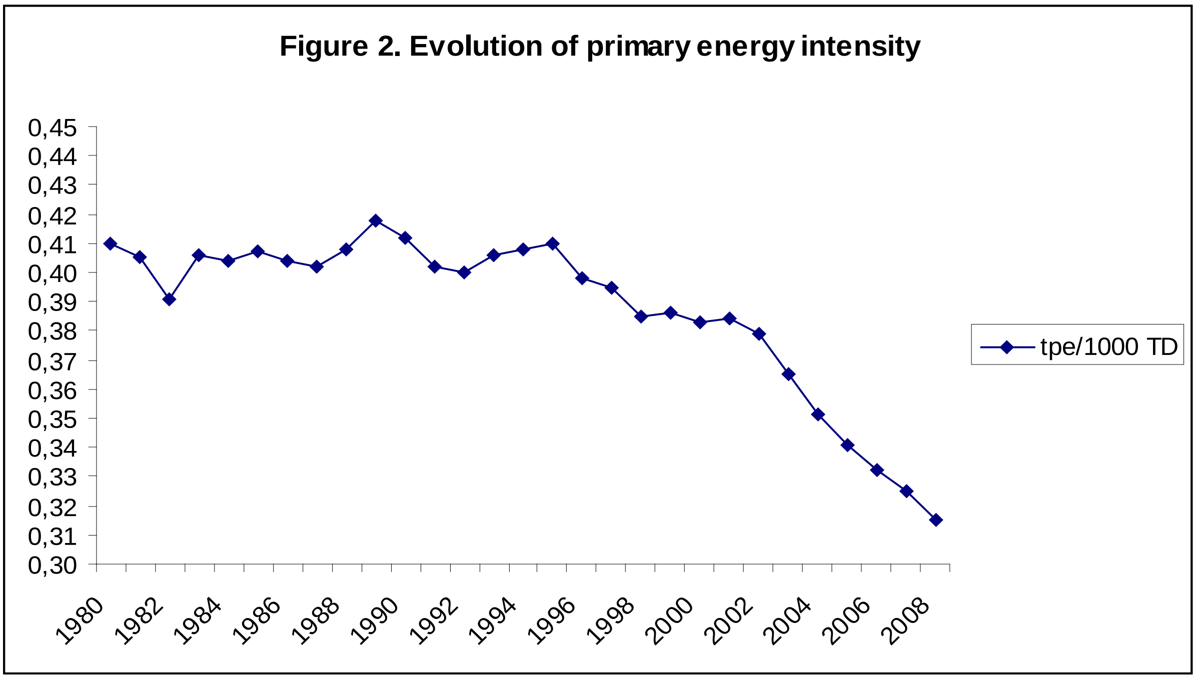
2.1. Energy uses. The primary energy consumption per capita is about 0.765 metric ton of equivalent oil (tpe) per capita in 2008, which is still weak, compared to developed countries. This unitary consumption was 0.486 tpe/capita in 1990, that is a rate of increase estimated to 1.6% per year. Figure 1 illustrates the evolution of primary energy consumption per capita during the period 1980-2008. It shows a relative stagnation over the period 2000-2007, a significant increase in 2008, and the beginning of stabilization in 2008. The active policy of control for energy uses undertaken by the Tunisian government since 2000 contributed to the control of the growth in energy uses. The aims of this policy were reducing energy imports and controlling subsidies on their domestic prices.

Fig 1. Evolution of primary energy consumption per capita



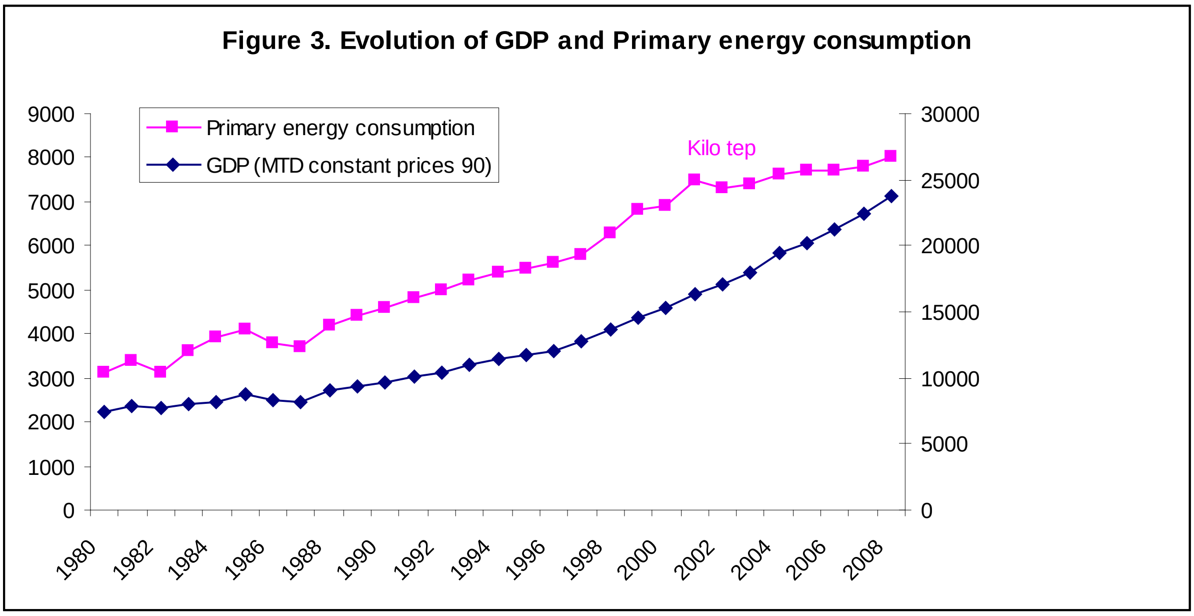
Source: ANME (2010).

As per capita incomes and manufacturing contribution to GDP continue to raise, it is expected that energy demand will increase in the coming years, even if the energy intensity of GDP declined (see Figure 2). The energy intensity expressed as the ratio between primary energy consumption and the GDP at constant prices of 1990. Figure 2 shows that energy intensity stopped increasing in the 1990s and has since then declined to the lowest level in the MENA region (World Bank, 2009). However, the intensity remains high compared to some other Mediterranean countries such as Greece and Portugal. Nevertheless, thanks to the energy control policy undertaken by the Tunisian government, energy intensity has recorded a strong decrease of 2.6% per year since 2000. Moreover, energy expenditures or energy consumption valued at international energy prices accounted for 12% of GDP in 2006 in Tunisia (World Bank, 2009), which is too high compared to industrialized countries such Japan (4%) or more advanced countries such Greece (7%).



Source: ANME (2010).
*Tpe/1000 TD: metric ton of equivalent oil per thousand of Tunisian Dinar 1990.

However, recent observations confirm that economic growth is more uncoupled from the consumption of primary energy in Tunisia. Figure 3 shows that over the period 1980-2008, the GDP increased on average by 4.4% per annum whereas the primary energy demand increased by only 3.4% per annum. Moreover, and between 2000 and 2008, the growth of the GDP was on average 4.9% against only 2.1% for energy consumption.



Source: ANME (2010).

Tunisian primary energy production is estimated to 6825 thousands of metric ton equivalent oil, from which 61.7% is crude petroleum and 38% natural gas. The rest is composed of primary wind electricity (INS, 2009). Considering only commercial energy, the recent consumption trend shows an increase by more than 6% between 2004 and 2008 with some fluctuations across the years. It has been observed that Tunisia is increasingly turning to natural gas to meet domestic energy demand. Indeed, natural gas consumption, which represented 47% in 2004, has increased to 53% in 2008. At the same period, a decrease of fuel consumption has been observed passing from 52% of total domestic energy demand in 2004 to around 47% in 2008 (see table 1). The state-owned natural gas and electricity company, Société Tunisienne de l'Electricité et du Gaz (STEG), has promoted the use of natural gas through an incentive system that began in 2005.

Table 1. Evolution of commercial energy consumption during the period 2004-2008 (in %)

	2004	2005	2006	2007	2008
Coal	0,3	0,1	0,0	0,0	0,0
Fuel	52,1	51,1	50,7	50,3	46,9
Natural gas	47,0	48,2	48,9	49,5	52,9
Wind primary electricity	0,6	0,6	0,4	0,3	0,2
Total	100	100	100	100	100

Source: INS (2009)

In Tunisia, the growth in commercial energy use has been accompanied by an even faster growth in electricity use, reflecting the switch from direct consumption of fossil fuels to the consumption of electricity in both the industrial and the household sectors. Indeed, the total consumption of electricity has risen from 9992 to 11874 millions KW between 2004 and 2008, which represents a yearly average growth rate of 4.4%. In terms of power generation, thermal is by far the largest source, representing around 58% of total electricity supply, with the bulk of that coming from natural gas (89%). Table 2 summarizes the recent evolution of electricity production by source.

Table 2. Electricity production evolution by source (10^6 KWh)

	2004	2005	2006	2007	2008
Thermal	37,1	41,1	38,6	42,4	57,9
Combined cycle	43,7	41,0	42,4	37,7	14,8
Natural gas	10,0	9,3	11,2	12,9	19,1
Hydro	1,2	1,1	0,7	0,4	0,3
Wind mill	0,4	0,3	0,3	0,3	0,4
Self production*	7,6	7,2	6,8	6,3	7,5
Total in percentage	100	100	100	100	100
Total in volume	12454	13006	13410	13968	11078

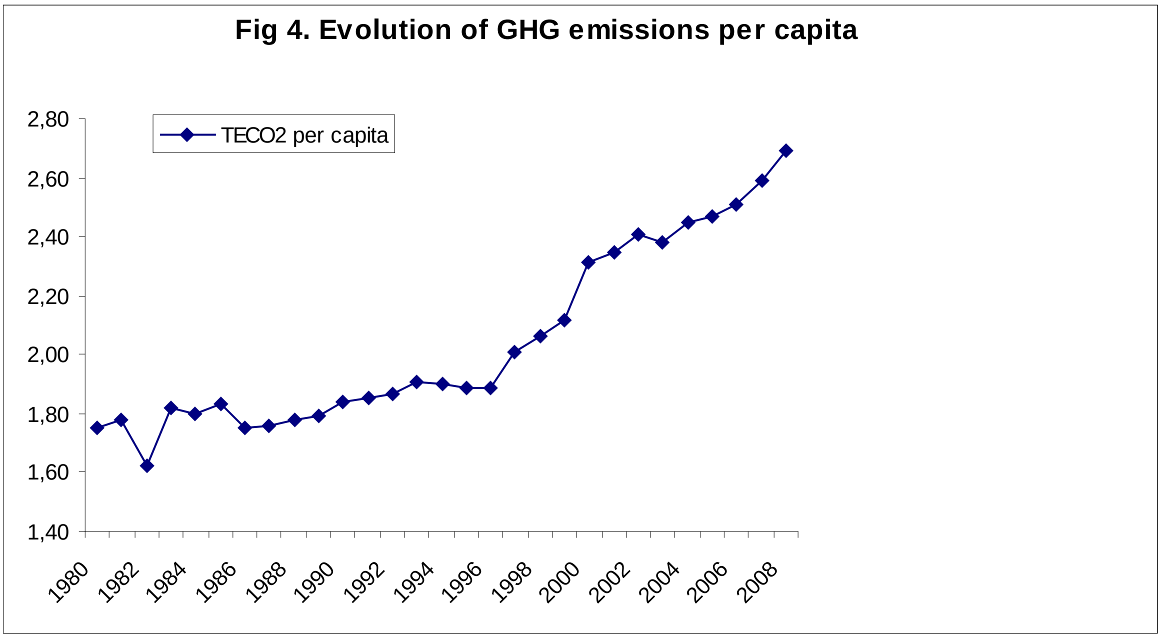
* Self production is generally generated by private plants and the rest is supplied by STEG.

2.2. Tunisia's Emissions profile. Tunisia is a Non-Annex I country and hence it cannot be forced by the Kyoto Protocol to take action to mitigate climate change. However, among other things, being a party to the Kyoto Protocol, commits Tunisia to participate in the negotiations and produce periodical emission inventories of its greenhouse gases (GHG).

Tunisia's GHG emissions are still weak compared to the industrialized countries. Indeed, as illustrated by figure 4, GHG emissions per capita have evolved from 1.75 in 1980 to 2.69 metric tons of CO_2 (TECO_2), far below the Annex I countries average of 16.1 metric tons of CO_2 per capita which was recorded in 2004. Hence, over the period 1980-2008, the average rate of increase of Tunisia's CO_2 emissions is about 1.5% per annum. Expressed per unit of GDP, GHG emissions evolved from 1.48 in 1980 to 1.11 TECO_2/1000 TD in 2008, which represents an average reduction of carbon intensity by 1% per annum on the whole period (1980-2008). Furthermore, this decline has been accelerated since 2000 with a 2.1% average annual decrease thanks to the conjunction of several factors such as:

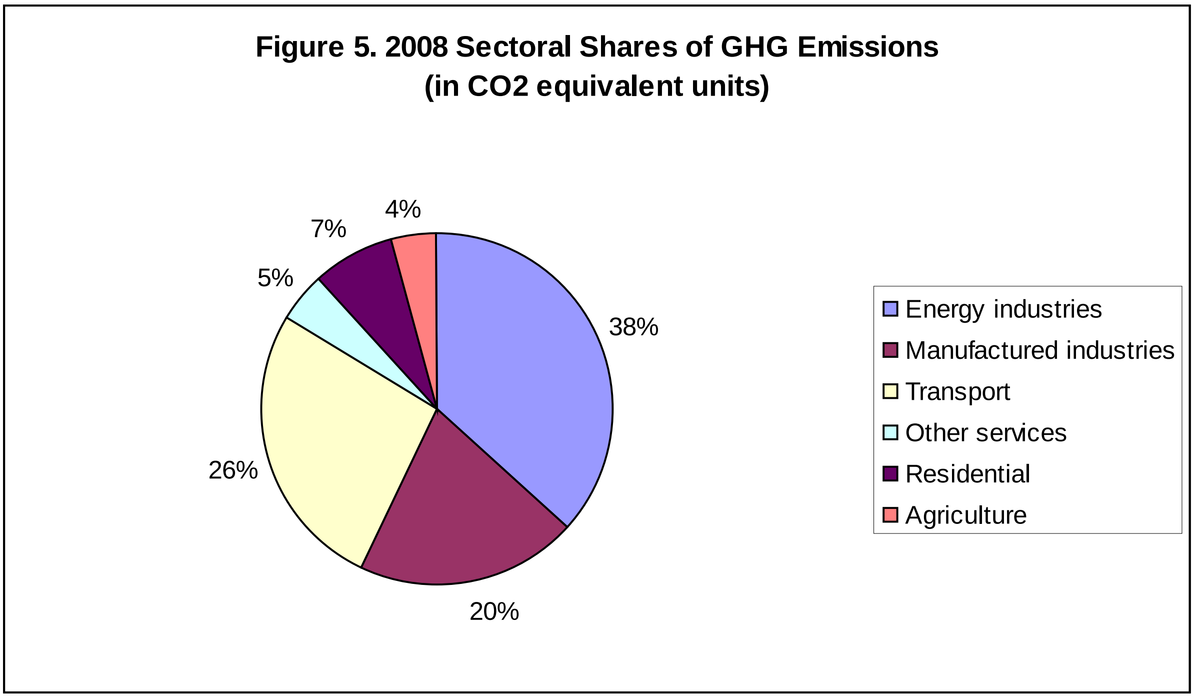
- The orientation of the Tunisian economy towards less energy intensive sectors
- The improvement of energy efficiency mainly in manufactured industries
- The development of natural gas use
- The shift in electricity production technology towards combined cycle

However, Tunisia has a relative high ratio of CO_2 emissions to total primary energy supply amounting to 3.48 TCO_2 per metric ton of equivalent oil reflecting the high share of petroleum in energy use (51.2%).



* Source: ANME (2010).
* $TECO_2$: metric ton of CO_2

Figure 5 provides sectoral shares of GHG emissions. It shows that energy industries predominate followed by transport and manufactured industries CO_2 emissions. Moreover, CO_2 emissions in 2008 are approximately 2.5 times those of 1980 and have grown from 10 to 25.5 millions metric ton of CO_2.



* Source: ANME (2010).

The structure of emission produced by the energy sector is dominated by CO_2, which represents around 91% of total sector emissions whereas CH_4 and N_2O emissions are relatively limited with 8 and 1% of the total energy sector emissions (see figure 6).

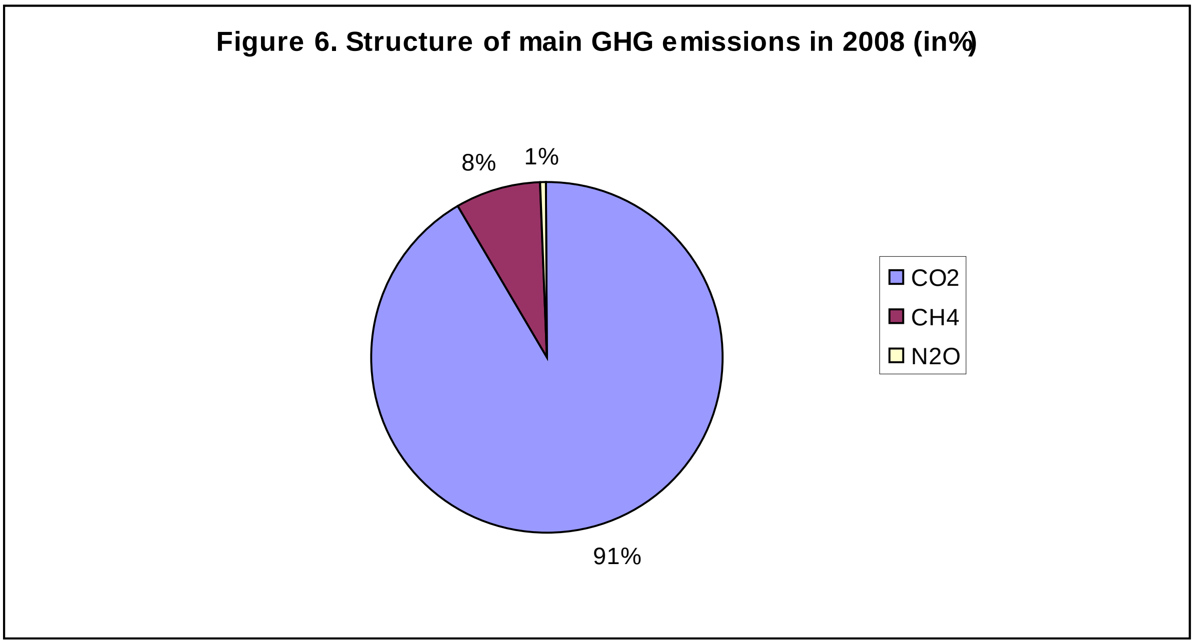


Table 3 illustrates the source and distribution of GHG emissions by type of gas. It shows that 95.1% of total CO_2 emissions originate from combustion. Fugitive emissions represent only 4.9%. Methane emissions come mainly from residential whereas nitrogen dioxide from residential and agriculture. Nitrogen Oxides and Volatile Organic Compound originate from the transport sector and finally residential and transport sectors are the main responsible of monoxide carbon emissions.

Table 3. Source and distribution of GHG emissions by type of gas in 2008 (in Kilo Tone equivalent of CO_2 ($KTCO_2$)

GHG	CO_2	CH_4	N_2O	Nox	VOC	CO
Energetic combustion	24 224	277	143	87	60	425
Energy industries	8 891	13	24	12	1	16
Manufactured industries	4 936	5	8	13	0	1
Transport	6 399	13	23	48	37	195
Other services	1 152	5	3	2	0	4
Residential	1 805	239	47	6	21	208
Agriculture	1 041	3	38	6	1	2
Fugitive emission	1 252	1 907	12	0	172	0
Total	25 476	2 184	155	87	232	425

Source: Authors' compilations using data from ANME (2010).

Finally, it has been observed that Carbon emissions per kWh of electricity declined significantly from 0.96 to 0.518 $kgCO_2/kWh$ between 1980 and 2008. Moreover, the evolution of emissions from the electricity sector shows two different periods. The first period from 1980 to 1994 has been marked by the prevalence of gas turbines and thermal. The corresponding emissions level was estimated at an average of 0.74 $kgCO_2/kWh$. The second period covering the years 1995 to 2008 was marked by the introduction of the combined cycle technology in 1996 and the extensive development of natural gas use. Consequently, emissions level decreased to 0.518 $kgCO_2/kWh$ in 2008.

2.3. Local Air Quality in Tunisia's Metropolises. Fossil fuels are the major source of many local and regional air pollutants in Tunisia. These include sulphure dioxid (SO_2), nitrogen oxides (NOx), suspended particulate matter (SPM), volatile organic compounds (VOC), carbon monoxide (CO), and Ozone (O_3). These pollutants in turn are associated with certain adverse effects on human health, crop yields and materials. In terms of health, the clearest and most consistent associations have been found between SPM and O_3 exposure, on the one hand, and both mortality (from acute exposure) and morbidity, on the other (Davis et al., 2000). Table 4 presents the major pollutants, their origins as well as their effects on health and environment.

Table 4. Major Air Pollutants, Their Sources and Their Environmental Impacts

Pollutant	Major Sources	Transformations in Atmosphere	Major End-Points	Nature of Effects
Particulates	Fossil fuel combustion (exc. Natural gas) construction, natural dust (small proportion inhalable)		(i) Health	a) Mortality b) Morbidity: respiratory and cardiovascular complications
	Coal and diesel fuel combustion		(ii) Materials	c) Soiling
Sulphur dioxide ($SO2$) and sulphate aerosols ($SO4$)	Fuel combustion	$SO2$ transported, transformed into and suspended/deposited as $SO4$	(i) Health (ii) Soils, forests, aquatic ecosystems	a) Mortality b)Morbidity: respiratory illness Acidification
Nitrogen oxides (NOX) and nitrates ($NO2$ and $HNO3$)		Precursor to acid rain; Constituent in formation of photochemical smog and of tropospheric $O3$	i) Health ii) Visibility	Respiratory problems Reduced enjoyment
Volatile organic compounds (VOCs)	Fuel combustion	Constituent in formation of photochemical smog	i) Visibility	Reduced amenity value Cancer
Ozone ($O3$)		Formed from oxidation of NOX in the presence of sunlight and reactive VOCs	ii) Health Health	Acute respiratory distress at high concentrations (asthma)
Lead (Pb)	Gasoline		Health	a)Adults: hypertension; stroke b) Children: Reduced IQ
Carbon monoxide (CO)	Fuel combustion, including biomass		Health	a) Asphyxiation b) Stillbirth

Source: Bussolo and O'Connor (2001)

The Tunisian Ministry of Environment and Sustainable Development has established standards regarding the main pollutants. Limiting values are those for which health risks are important and guidelines values for welfare (see table 5).

Table 5. Air Quality Standards in Tunisia

	Average type	Exceeding authorisation	Limiting value (related to health)	Guide value (related to welfare)
CO	8 hours	2 times/30 days	9 ppm- 10 mg/m^3	9 ppm- 10 mg/m^3
	1 hour	2 times/30 days	35 ppm- 40 mg/m^3	26 ppm- 30 mg/m^3
NO_2	Annual average	-	0.106 ppm- 200 mg/m^3	0.08 ppm- 150 mg/m^3
	1 hour	1 time/30 days	0.35 ppm- 660 mg/m^3	0.212 ppm- 400 mg/m^3
O_3	1 hour	2 times/30 days	0.12 ppm- 235 mg/m^3	0.077-0.102 ppm- 150 to 200 $\mu g/m^3$
Suspended particulate (PM 10)	Annual average	-	80 $\mu g/m^3$	40 to 60 $\mu g/m^3$
	24 hours	1 time/ 12 months	260 $\mu g/m^3$	120 $\mu g/m^3$
SO_2	Annual average	-	0.03 ppm- 80 $\mu g/m^3$	0.019 ppm- 50 $\mu g/m^3$
	24 hours	1 time/ 12 months	0.12 ppm- 365 $\mu g/m^3$	0.041 ppm- 125 $\mu g/m^3$
	3hours	1 time/ 12 months	0.5 ppm- 1300 $\mu g/m^3$	-
Pb	Annual average	-	2 $\mu g/m^3$	0.5 to 1 $\mu g/m^3$
H_2S	1 hour	1 time/ 12 months	200 $\mu g/m^3$	-

Source: ANPE (2008).

Eleven stations are established in Tunisia to monitor various pollution indicators of which five are in great Tunis (the capital) and the rest are located in selected coastal cities where industrial activities are important: Bizerte, Sfax, Gabes, Sousse. Only one station is located in central Tunisia.

Tables 6 to 9 present measurements for the main pollutant concentrations in selected Tunisian cities. Table 6 shows the evolution of the annual average PM10 concentrations (respirable particles with diameter < 10µ), which constitutes the major health risk from particulates (fine particulates with diameter < 2.5µ are not measured in Tunisia). Two from six Tunisian cities registered yearly concentrations averages above limiting values in 2008 that is presenting health risks for citizens whereas 5 from 6 exceed welfare guidelines. Sfax city presents the highest particles concentration in 2008 with an annual average of 90 µg/m^3 and a 24h average of 335 µg/m^3 compared to limiting values of 80 and 260 µg/m^3 respectively. Several peaks were recorded all over stations and some of them exceed largely limiting values. For example, Sfax suburban station recorded peaks over 350 µg/m^3 of PM10 concentration.

Table 6. Solid Particulate concentration in selected Tunisian cities PM10 (2004-2008) in (µg/m^3)

PM10	2004		2005		2006		2007		2008	
	Av/year	24 h	Av/year	24 h	Av/year	24 h	Av/year	24 h	Av/year	24 h
Bab Saâdoun	85	526	82	195	88	316	91	328	77	190
Bizerte	83	466	91	249	98	711	80	248	67	216
Sfax city	-	-	-	197	87	318	87	240	90	335
Ben Arous	-	-	-	-	78	141	81	279	74	183
Sousse	-	-	-	105	54	181	57	172	55	143
Sfax south suburban	-	-	180	117	94	582	90	264	89	326

Source: ANPE (2008).

The main sources of respirable and fine particles in Tunisia's cities are thought to be steel metallurgy, cement manufacture, incineration wastes and car traffic. Thus, there can be no doubt that significantly reducing particulates concentrations (whether averages, peaks, or both) would save lives and improve the health status and productivity of population. Besides mortality risk reductions, improved air quality should also yield reductions in morbidity of various sorts, notably respiratory ailments.

While most of the health benefits from improved air quality are expected to come from reduced particulate emissions and concentrations, the other air pollutants can also pose health risks. Tables 7 and 8 present the evolution of sulphur dioxide and nitrogen dioxide concentrations in selected Tunisian cities. The comparison of the recorded observations to table 5 reveals the following. For nitrogen dioxide and sulphur dioxide, neither limiting nor guide average values excess have been recorded in all stations in 2008. However peaks have been recorded in the case of sulphur dioxide in Gabes and Sfax cities with concentrations above 150 µg/m^3 and 110 µg/m^3 respectively.

Table 7. Sulphur dioxide concentration in selected Tunisian cities (2005-2008) in (µg/m^3)

SO_2	2005			2006			2007			2008		
	Av/year	24h	3 h	Av/year	24h	3 h	Av/year	24h	3 h	Av/year	24h	3 h
Sousse	-	-	-	5	24	53	-	-	-	4	22	62
Sfax city	-	-	-	5	99	176	3	27	123	4	38	160
Sfax south suburban	-	227	729	72	1591	4302	35	363	1292	18	216	1076
Gabès	-	-	-	-	-	-	-	-	-	26	294	1462

Source: ANPE (2008).

Table 8. Nitrogen dioxide concentration in selected Tunisian cities (2005-2008) in (μg/m^3)

SO_2	2005			2006			2007			2008		
	Av/year	24h	1 h	Av/year	24h	1 h	Av/year	24h	1 h	Av/year	24h	1 h
Bab Saâdoun	18	95	307	25	48	104	15	25	56	36	-	150
Bizerte	11	42	110	17	39	79	10	23	87	-	61	-
Sousse	-	42	87	17	54	102	12	58	119	10	34	61
Sfax south suburban	-	52	102	19	46	116	17	189	274	25	70	70
Kairouan	-	-	-	-	-	-	-	-	-	20	40	86
Gabès	-	-	-	-	-	-	-	-	-	13	29	78

Source: ANPE (2008).

While the process of energy substitution undertaken by Tunisia towards more natural gas used for electricity production has the advantage of reducing CO_2 and particulate emissions, which is online with climate policy measures, it has the drawback of increasing NOx and VOC emissions relative to the baseline. This highlights the need to assess both positive and negative effects of a given policy in order to evaluate net costs or benefits.

3. Methodology

3.1 The CGE model. The model employed is a dynamic computable general equilibrium (CGE) with a structure similar to a number of others built at the OECD Development Centre and used in studies of optimal environmental policy in an open economy (Beghin et al, 1996). While this is not the first use of an economy-wide model for assessing ancillary benefits of climate policy (see Burtraw and Toman, 1997 for US; Dessus and O'Connor, 1999 for Chile; Bussolo and O'Connor, 2001, for India; Garbaccio et al. 2000 for China; and Aldaba and Cororaton, 2002, for Philippines), it is to our knowledge the first use of such a model for this purpose in a MENA country.

The Tunisian model has been calibrated using a detailed social accounting matrix (SAM) for the year 2006. All markets are modeled as perfectly competitive, with flexible price adjustment. The production technology exhibits constant returns to scale (CRS) and the production structure consists of a series of nested CES functions. The model is dynamic recursive and is solved for the period 2006-2020. The labor force and productivity growth rates are exogenous, with the model solving endogenously for the savings and investment rate. Capital is of the putty-clay variety, with higher substitution elasticities applicable to new investment than to existing (already installed) stock. In what follows, an overview of the most important features of the standard model is provided. However, and for assessing the impacts of climate policy on pollution, two components of the model are particularly important: the energy bundle and the pollution coefficient matrix, which are described in more details in the next sections.

Production. The Constant Elasticity of Substitution (CES) constant returns to scale production function is a nested structure taking into account the assumed substitution possibilities in the choice of production factors. Output results from two composite goods: non-energy intermediates and energy plus value added. The intermediate aggregate is obtained combining all products in fixed proportions (Leontief structure). The value added and energy components are decomposed in two parts: aggregate labor and capital, which includes energy. The capital-energy bundle is further disaggregated into its basic components. By distinguishing between "new" and "old" vintages, the capital existing at the beginning of each period, or already installed, can be separated from that resulting from contemporary investment (putty/semi-putty production function). Finally, the energy aggregate includes three energy substitutes: petroleum products, natural gas, and electricity. Substitution elasticities reflect adjustment possibilities in the demand for factors of production originating from variations in their relative prices.

Income Distribution and Absorption. Labor income is allocated totally to households. Likewise capital revenues are distributed among households, government and rest of the world. Households save the after-tax residual of that revenue. Private consumption demand is obtained through maximization of household specific utility function following the Extended Linear Expenditure System (ELES).[3] Household utility is a function of consumption of different goods and saving. Income elasticities are different for each household and commodity. Once their total value is determined, government and investment demands[4] are disaggregated in sectoral demands according to fixed coefficient functions.

International Trade. Imperfect substitution among goods originating in different geographical areas is a standard assumption included in this model.[5] Imports demand results from a CES aggregation function of domestic and imported goods. Export supply is symmetrically modeled as a Constant Elasticity of Transformation (CET) function. Producers decide to allocate their output to domestic or foreign markets responding to relative prices.
The balance of payments equilibrium is determined by the equality of foreign savings (which are exogenous) to the value for the current account. With fixed world prices (small country assumption) and capital inflows, all adjustments are accommodated by changes in the real exchange rate[6],

Model Closure and Dynamics. The equilibrium condition on the balance of payments is combined with other closure conditions so that the model can be solved for each period. First, the government's budget surplus (or deficit) is fixed and the household income tax schedule shifts in order to achieve the predetermined net government position. Secondly, investment must equal savings, which originate from households, government and rest of the world.

The dynamic structure of the model results from the equilibrium condition between savings and investment. A change in the savings volume influences capital accumulation in the following period. Exogenously determined growth rates are assumed for the other factors that affect the growth path of the economy, such as: population and labor supply, labor and capital productivity and energy efficiency factor. Agents are assumed to be myopic and base their decisions on static expectations about prices and quantities. The model dynamics are therefore recursive, generating a sequence of static equilibria.[7]

Policy instruments. The model includes a variety of instruments of economic policy, direct and indirect taxes on production, consumption and income, tariffs and other taxes and subsidies on international transactions. Each of these tax/subsidy items is differentiated by sector, production factor, consumption type, and income source. The shock introduced in the policy simulation is a tax levied on the carbon content of fuel. The tax level is endogenously calculated by targeting rates of CO2 emission abatement relative to a growth baseline. Carbon-tax revenues are redistributed lump sum to households.

3.2. The extended model. The standard model has been extended to incorporate additional features for the analysis of ancillary benefits of pollution abatement policy. The following sub-sections provide an overview of these additional features.

Modeling emissions. Modeling the effect of climate policy on emissions of local air pollutants requires, as a starting point, credible estimates of baseline emissions. The National Agency of Energy Control (NAEC) provides most of the available data on the volumes of emissions by pollutants while some others has been estimated. The NAEC's data provides the level of emission

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[3] A useful reference for the ELES approach is found ***in Lluch (1973).***

[4] Aggregate investment is set equal to aggregate savings, while aggregate government expenditures are exogenously fixed.

[5] ***Armington (1969).***

[6] Increased import demand, due to trade liberalization must be financed by increased exports, and these can expand owing to the improved resource allocation. Price decreases in importable drive resources towards export sectors and contribute to falling domestic resource costs (or real exchange rate depreciation).

[7] The model's long-run properties are discussed in the technical document.

by specific pollutant generated by the main economic activities and over a recent period of time. The data also reports the levels of emission by pollutant and type of used fuel (see section 2 on energy uses and emissions profile of Tunisia).

Emissions are determined by either intermediate or final consumption of polluting products. In addition, certain industries display an autonomous emission component linked directly to their output levels. This is introduced in order to include some polluting production processes that would not be account for by only considering the vectors of their intermediates consumption. It is assumed that labor and capital do not pollute. Emissions coefficients associated with each type of consumption and production are either directly based on published or unpublished source of emissions inventory data for Tunisia or estimated using some techniques that are explained later in more details. A change in sectoral output, or in consumption vector, both in levels or composition, therefore affects emission volumes. Formally, the total value for a given polluting emission takes the form:

$$E = \sum_i \sum_j \alpha_j C_{i,j} + \sum_i \beta_i X_i^{Output} + \sum_J \alpha_J X_i^{Ar\min gton}$$

Where i is the sector index, j the consumed product index, C intermediate consumption, X^{Output} is output, $X^{Ar\min gton}$ is final consumption (at the Armington composite good level), α_j represents the emission volume associated with one unit consumption of product j and β_i is the emission volume associated with one unit production of sector i. Thus, the first two elements of the right hand side expression represent production-generated emissions, the third one consumption-generated emissions.

The volume of emissions is measured in metric tons. Many types of polluting substances may be included in the model subject to data availability. Toxic emissions in air, water and soil depend primarily on the consumption of chemicals (especially fertilizers for water pollution); oil derived products and mineral products. Bio-accumulative emissions differ from the previous ones for their long term effects on bio organisms, due to their high lead (or other heavy metal) concentration. Again, these are distinguished according to the medium where they are released: into the air, water and soil. These emissions are a result of the use of mineral and metal products, generally found in construction-related sectors. There are 5 types of toxic substances released in the air: Sulphur dioxide (SO2), nitrogen dioxide (NO2), Carbon monoxide (CO), volatile organic compounds (VOC) and suspended particulates (PART). Their levels depend primarily on fuels consumption: oil and coal derived products. In the present model, only toxic substances released in the air are integrated.

Modeling the links between emissions, ambient concentration and exposure. The translation of emissions reductions into changes in ambient concentrations requires a dispersion model for each pollutant linking location-specific emissions to location-specific concentrations. In the Tunisian case, there is no source-specific pollution inventory, but there is pollution monitoring data giving readings of ambient concentrations for various major cities in the country. Using this information, the averages concentrations in 2006 for the various pollutants have been estimated. Then, the estimated averages concentrations for the considered set of pollutants were linked to sectoral emissions by taking the national average of emissions, assuming that pollution intensity at national level is the weighted average of pollution intensity across the various cities of the country. For that purpose, a linear relationship between emissions and concentrations was assumed, which means that a y% reduction in a given sector emissions will also yield a y% reduction in ambient concentration, all else equal. However, to link changed emissions to changed human exposure, it is necessary to have more than a "simple average" measure of ambient concentration, since actual exposure of individuals may differ significantly from the average. For example, the average Tunisia-wide ambient concentration of SO2 is around 26 γg/m3, which is the result of averaging five main cities: Tunis (36), Sousse (10), Sfax south suburban (25), Kairouan (20) and Gabes (29). If however, 50%

of the population lives in or around Tunis; 20% in or around Sfax, 5% in or around Kairouan and 5% in or around Gabes, the simple average gives a very misleading picture of actual exposures (and potential health effects). Thus and for the needs of this study, the ambient concentration measures have been weighted by their respective proportions of the Tunisian population living "near" each station. This weighted average is assumed to better approximate actual exposure levels. However, this is still far from perfect measure of actual exposure. The equation below represents the simple dispersion model. Air concentration levels are determined using a matrix of dispersion coefficients, which vary according to the pollutant and stack height.

$$Concentr_p = \sum_{stck} dispers_{p,stck} E_{p,stck}$$

Where $Concentr_p$ refers to the country-wide average concentration of a given pollutant p. $dispers_{p,stck}$ represent the degree of differenciation among source types, according the presumed average stack height of emissions from different sectors – high, medium, and low and finally $E_{p,stck}$ is the city wide p emissions from each of the sectors differentiated by typical stack height[8].

This equation yields the following results: 1) for low and medium height sources, the concentration/exposure per unit of emissions is strictly inversely related to the city's radius, which means that the wider the area over which emissions are dispersed, the smaller their effect on average ambient concentration; 2) the emissions-exposure relationship for high-stack emissions follows an inverted-U shape in the city's radius, as high stacks contribute more widely to area emissions than low or medium-stack emissions, so the contribution to area-average exposure rises at first with city size, and 3) high-stack sources yield a concentration/exposure per unit of emissions very far below low-stack emissions for virtually any size of city and significantly below medium-stack emissions until city size approaches a radius of 30 Km. For Dessus and O'Connor (1999), this suggests that, in terms of reaping ancillary health benefits from energy use changes, it clearly matters where those change occur in terms of economic sectors.

Modeling health effects. Once concentration is calculated, disease intensity is estimated through the dose-response equation (1). Notice that the parameter dose maps concentration levels for various pollutants into intensities of a range of diseases[9]. Equation 2 calculates a damage value by multiplying a unit cost parameter, uc, times the disease intensity.

Disease and Damage Equations

(1) $$Disease_{r,d} = \sum_p (dose_{d,p} Concentr_{r,p}) Pop_r$$

(2) $$Damage_r = \sum_d uc_d Disease_{r,d}$$

Whenever valuation studies of air quality improvements include both mortality and morbidity benefits, the largest estimated monetary benefit is found to be that associated with reduced morbidity risk, which is the estimated value of a statistical life (VSL).

There is a large literature providing VSL estimates for developed countries but very few for developing countries (Chile and India for example). In general, the epidemiological evidence linking suspended particulates (especially, respirable particulates) to mortality and acute morbidity

[8] Garbaccio et al. (2000) and Cifuentes et al. (1999) provide detailed description of this approach.

[9] It may be useful to recall that the set d,p and stck group respectively disease types, pollutants and stack heights.

appears to be the strongest. In the case of Santiago for example, a statistically significant, positive relationship has been established between PM-10 and both health endpoint (Dessus and O'Connor, 1999). It has been established that from 1989 to 1991, a 10γg/m3 decrease in daily PM-10 levels was associated with a 1.1% decrease in mortality, a result consistent with findings of studies for several US cities (Schwartez, 1994). With respect to other pollutants, the epidemiological evidence is somewhat less extensive and conclusive than for particulates.

Health effects are usually measured in heterogeneous units, depending on health endpoint and pollutant. For instance, mortality effects are normally measured in increased incidence of premature death while morbidity effects may be measured in terms of either increased frequency of specific symptoms, increased frequency of hospital admissions, or increased number of days of restricted activity attributable to said condition. For economic analysis, there is a need of aggregation of these heterogeneous health impact measures in a common way. To do so, the welfare changes from reduced risk of death and illness measured in terms of individuals' "willingness to pay" (WTP) for these health improvements is used in the present study. The WTP measure is rooted in consumer demand theory, wherein income-constrained individuals choose among all the possible consumption bundles those that yield the highest level of satisfaction or utility. Then, assuming that individuals are maximizing utility before some welfare-improving change in environmental quality, the welfare measure allows knowing what is the most that individuals would be willing to pay to secure that environmental improvement. The logic is that they would only be willing to pay up to the point where, weighing the income foregone against the environmental quality improvement, they would be no worse off than in the status quo. Aggregation of WTP across all individuals gives a measure of how much this environmental improvement is worth to society as a whole.

More specifically, Tunisian dinar values must be attached to changes in mortality risk and changes in incidence of morbidity. There is a vast valuation literature for the United States (see Viscusi, 1993), but no comparable literature for Tunisia and precious little for other developing countries. The absence of Tunisia-specific valuation studies necessitates a transfer of benefits estimates from studies done elsewhere, with appropriate adjustments for differences in living standards and other relevant variables. Dessus and O'Connor (1999) suggest four approaches for making estimations for a developing country. The first approach is to select among the numerous studies the one(s) that pertain to a study site deemed to have relevant characteristics most like those of the country under analysis. The second is to average estimates across the various studies to obtain a mean value for a particular impact, without regard to site-specific characteristics. The third is to take a range of estimates from the various studies and to calculate a comparable range for the country under analysis. The fourth is to conduct a meta-analysis of existing studies, so as to take advantage of the information on determinants of risk valuation contained in those studies. In the present study, we opted for the third approach in estimating monetary values of unit changes in various health endpoints in Tunisia by the year 2020.

To perform such estimation, first we calculate the Tunisian PPP per capita income in 2020 based on the assumption made on the expected growth rates of GDP over the baseline scenario (see below). Second we estimate the share of Tunisian PPP GDP per capita in 2020 relative to 2010 Chile level. The results show that Tunisia's PPP per capita income in 2020 should be roughly 0.76 of the 2010 Chile level, so that the end-year VSL estimate for Tunisia needs to be adjusted upward accordingly. By just how much depends on the assumed income elasticity of VSL. Since the VSL estimate for Tunisia is a transferred value based on estimation carried out for Chile, where PPP per capita income is around twice than that in Tunisia, the choice of income elasticity of VSL makes a difference to the Tunisian VSL estimate. A number of morbidity risk studies find an income elasticity of WTP below unity (Alberini et al, 1997), while the results of mortality risk studies are less consistent given that they yield an elasticity estimate significantly greater than one (Bowland and Beghin, 1998 for the case of the city of Santiago). Since we have no a priory reason to prefer one hypothesis to the other, we initially assume an income elasticity of unity for the base case and perform sensitivity analysis around this value. Similarly, we assume a base-case income elasticity of WTP for morbidity reductions equal to unity, and then we perform sensitivity analysis. Table 9 contains estimated monetary benefits associated with a unit change in each of the health endpoints enumerated previously.

Table 9: Monetary Values Estimates of Unit Changes in various health endpoints

	Estimate for Chile, 2010	Equivalent estimate for Tunisia, 2020	Units
Value of statistical life (VSL)	2.1	1.6	$million/death avoided
Respiratory hospital admission (RHA)	5871	4488.2	$/event
Emergency room visit (ERV)	166	126.9	$/event
Restricted activity day (RAD)	47.8	36.5	$/day
Minor restricted activity day (MIRAD)	20.2	15.4	$/day
Clinic visit for LRI in children	160	122.3	$/visit
Chronic bronchitis in adults	197633	151085.5	$/case
Asthma attack	27.8	21.3	$/attack day
Respiratory symptom day	5.6	4.3	$/day
Child respiratory symptom day	4.5	3.4	$/day
Adult chest discomfort case	5.6	4.3	$/event
Eye irritation	5.6	4.3	$/event day
Headache episode (avg. Of mild and severe)	22.6	17.3	$/event day
IG decrement	2460	1880.6	$/point lose
Hypertension in adult males	579	442.6	$/case
Non-fatal heart attack	44117	33726.3	$/event

Notes: The conversion factor for the Tunisian estimates is the ratio (2020 per capita for Tunisia at 2005 PPPs/2010 per capita GDP for Chile at 2010 PPPs) = 0.76, which assumes an income elasticity of WTP for both mortality and morbidity benefits = 1. The 2020 Tunisian per capita GDP figure is based on an annual growth rate of 3.6 per cent, which is the rate achieved during the period 2000-2007 in Tunisia.

Modeling Pollution Abatement tax. Policy interventions, aimed at improving health and welfare, are of many sorts. This is why governments need to estimate the relative cost-effectiveness of different sorts of interventions. Existing literature on pollution abatement instruments distinguished two main instruments usually used by the government. The first one is when the government chooses the instruments of pollution abatement and in this case, the scope of all studies is to look at its effects or the costs of this policy, mainly on macroeconomic and sectoral levels. The second way is when the government fixes a pollution emission levels, and looks at the policy instruments to be used in order to achieve these targets. In the two cases, the choice of instrument is very important. We can distinguish at least two instruments: technological standard and pollution tax. In this study we opted for the pollution tax as instrument for pollution emissions abatement. Literature on CGE model based on technological standard use the notion of product differentiation. For this purpose, it distinguished more than one product for the same category, mostly two categories (green product and dirty product). The model integrates a specific production and consumption functions for each specific product. The same differentiation is also considered at the level of international trade functions, which integrates products differentiation at geographic level but also with respect to production technology (green or dirty production process) and the level of associated pollution emissions (see Schubert and Zagame (1998)).

In this paper, and given the modelling and the calibration process of a CGE model, the use of pollution tax seems to be more realistic and easier. Existing literature on ecological tax reforms in open economies tends to focus on the following two aspects: the effects of trade reforms onto the environment and the consequences of environmental policies on trade flows. More recent literature examines, in a public finance setting, the interactions between new fiscal instruments and pre-existing taxes. Trade instruments to protect the environment have been found to be a blunt and inefficient approach to environmental policy. In a first best world, policy instruments directly linked to the source of the externality (production and consumption activities, rather than trade) are proved to be much more efficient: Pigouvian taxes on effluents, abatement subsidies, marketable pollution permits should be used in this case. But even in a second best world, the optimal policy to abate emissions would be a targeted uniform tax per unit of pollution, as this would *directly* discourage the emissions of pollutants, in contrast with trade measures, which will affect pollution activities only *indirectly* through additional distortions and resource misallocations (Bussolo et al., 2003).

Environmental regulations, by modifying production costs, influence trade patterns through changes in comparative advantage. A standard prediction for countries with large absorptive capacity and loose ecological norms is a specialisation in dirty industries (pollution heavens). Empirical research tends to confirm that developing economies specialise in 'dirty' industries. This could suggest that developing economies have a real comparative advantage in dirty productions, and hence a trade-off between trade liberalisation and environmental preservation could occur. Another set of issues that received quite a bit of attention concerns the appealing idea of tax discrimination between "good" things, such as trade (or labour), and "bad things", such as pollution. In particular, the idea of tax swaps (substituting distortionary taxes revenues with environmental tax proceeds) suggested the possibility of generating a double dividend (less pollution and a more efficient economy). Numerous studies have analysed various kinds of tax swaps and one major conclusion is that the potential "free lunch" may be eroded by general equilibrium effects causing changes in the relative prices of inputs and outputs and that only certain special second best initial conditions will guarantee it.

The pollution taxes can be generated in the model in one of two ways. It can either be specified exogenously or it can be generated endogenously by specifying a constraint on the level of emission. In this study, the second option is adopted.

The tax is implemented as an excise tax per unit of emission. It is converted to a price wedge on the consumption of the commodity (as opposed to a tax on the emission), using the commodity specific emission coefficient. For example in Equation (3), the tax adds an additional price wedge between the unit cost of production exclusive of the pollution tax and the final cost of production. Let production be equal to 100 (million Dinars), and let the amount of pollution be equal to 1 tone of emission per 10 million Dinars of output. Then the total emission in this case is 10 tones. If the tax rate is equal to 25 Dinars per tone of emission, the total tax revenue for this sector will be 250 Dinars. In the formula below, β_i^p is equal to 0.1 (tones per million Dinars), XP is equal to 100 (millions Dinars), and τ^{Poll} is equal to 25 Dinars. The consumption based pollution tax is added to the Armington price, see Equation (4). However, the Armington decomposition occurs using basic prices, therefore, the taxes are removed from the Armington price in the decomposition formulae, see Equations (5) and (6).

Pollution abatement tax Equations

$$(3) \qquad PP_i XP_i = PX_i XP_i + \sum_p \beta_i^p XP_i \tau^{Poll}$$

$$(4) \qquad PA_i = \left[\beta_i^d PD_i^{1-\sigma_i^m} + \beta_i^m PM_i^{1-\sigma_i^m}\right]^{1/(1-\sigma_i^m)} + \sum_p \alpha_i^p \tau_{Poll}$$

$$(5) \qquad XD_i = \beta_i^d \left[(PA_i - \sum_p \alpha_i^p \tau^{Poll}) \big/ PD_i\right] XA_i$$

$$(6) \qquad XM_i = \beta_i^m \left[(PA_i - \sum_p \alpha_i^p \tau^{Poll}) \big/ PM_i\right] XA_i$$

β_i^p represents the pollution coefficient by sector (i) and type of pollutant (p), τ^{Poll} the pollution tax, XP is sectoral gross output, XD, is demand for domestic products, XM represents demand for imported goods, PP is the producer price, PX the aggregate unit cost, PA the Armington price, PM import price, and PD the price for domestic good.

Modeling welfare change with reduced health damages. The chosen yardstick for welfare is a measure of compensating variation (CV) proposed by Dessus and O'Connor (1999), which includes a term to reflect the exogenous component of welfare change from reduced health damages. Thus, if E is the monetary equivalent of the utility function, and y disposable income, then measurement is as follows for period t:

(10) $$(y^* - y) - (E(p^*, u) - E(p, u)) - (D^* - D)$$

Where u is utility, p the price system, and the star exponent the policy outcome. The first term, $y^* - y$, measures the gain (or loss) of disposable income caused by the policy shock. The second term measures the changes in expenditure needed after the policy shock to obtain the same level of utility as before. The third term represents the exogenous welfare component, with $(D - D^*)$ equaling the change in health damages based on measures other than "cost of illness" (COI).

3.3. Data. Three types of data are used to calibrate the model and estimate ancillary health benefits: the social accounting matrix (SAM), the pollution matrix, which consists of a matrix of pollution coefficients, and key parameters.

The SAM 2006. The model is calibrated on the data contained in the Tunisian SAM estimated for the year 2006 especially for the purpose of this study. It includes one aggregated household category, 1 labor type, 1 trade partner, 20 sectors, and 6 different air-polluting emissions. The sectoral disaggregation adopted in this study is justified by two main motivations. First, it includes the most energy-intensive sectors such as chemical industries and transport. Second, it integrates individually the three main sectors of energy: electricity, refined oil, and natural gas. Table 10 below displays the macroeconomic version of the SAM.

Table 10: MacroSam for Tunisia for 2006 (in millions TND)

	ACT	COM	LAB	CAP	HOU	GOV	ITS	DIM	ROW	SIN	TOT
Activities	0	76095.8	0	0	0	0	0	0	0	0	76095.8
Commodities	36728.7	0	0	0	26019.9	6176.7	0	0	21006.3	9847.6	99779.2
Labor	14972.5	0							73.1		15045.6
Capital	22027.4	0									22027.4
Households	0	0	15045.6	14513.1		2862.7			2133.8		34555.2
Government	0	0		5068.3	3024.7		2367.2	1755.7	121.7		12337.6
Indirect taxes net of subsidies	2367.2	0									2367.2
Duties on imports	0	1755.7									1755.7
Rest of the World	0	21927.7		2446	137.1	11.3					24522.1
Savings and Investments	0	0			5373.5	3286.9			1187.2	160.4	10008
TOT	76095.8	99779.2	15045.6	22027.4	34555.2	12337.6	2367.2	1755.7	24522.1	10008	

The pollution coefficients. The model includes a matrix of sectoral emission coefficients for the six air pollutant categories considered in this study. Given the lack of information on sectoral intensity of emission across periods of time and categories of energy uses, various steps were followed to estimate pollution coefficients for Tunisia. Despite the focus of this study on a limited number of pollutants, the estimation of pollution coefficients for the year 2006 was extended to various categories of pollutants for illustrative purpose. In addition to the five types of toxic substances released in the air described above, the carbon dioxide has been also incorporated in the pollutant matrix for the Tunisian economy, linked to sectoral consumption of the different fossil fuels, and applying standard CO_2 emission factors to each fuel type. This is very important given that CO_2 emissions represent about 90% of total GHG emissions in Tunisia in 2008. Moreover, the estimation of pollution coefficients covers an additional 7 types of polluting substances.

The estimation covers two sources of pollution: production and final consumption. In the first instance, pollution coefficients are derived from estimates for the United States of the World Bank's pioneering IPPS project (Hettige et al., 1995). The World Bank's pollution coefficients, which are output-based, have been transformed into input-based estimates by regressing them on intermediate inputs[10]. Second, the approach developed by Dessus et al. (1994) has been used to implement the pollution coefficients estimated for the United States to Tunisia. To do so, the concordance in the sectoral composition of the United States' study and the Tunisian SAM has been established. Given that the number of sectors in the United States' study was higher than the Tunisia's SAM, the estimation for the input emission coefficient for product j in Tunisia was estimated by assuming that it is equal to the sum of the coefficients for sub sectors of the product j in the US weighted by the United States shares of each sub sectors that constitute sector j. Once these coefficients are estimated, they have been expressed in Tunisia's local currency (TD) through their division first by the exchange rate and second by the inflation rate in the US during the period 1987-2006. Finally, the estimated output-based pollution coefficients were transformed into input-based pollution coefficients. This transformation is very important given that it allows the computation of emissions produced by intermediate as well as final uses.

Coefficients for the dummy variables were also transformed in the same way, in terms of sector disaggregation and currency. This dummy is directly associable to the level of production of the specified sector. Thus, the level of emission of the sector i in Tunisia is then calculated as the sum of emissions on intermediate consumption and those related to the level of production. In the final step, an adjustment of the estimated pollutants coefficients is made using available data on pollution in Tunisia. The adjustment covers both the volume of emissions per pollutants and the sources of these emissions. This method allows taking into consideration the technological gaps between Tunisia and the United States.

Tables 11 and 12 present the results of the estimation of the sectoral emission intensities for both production and final consumption specific to the year 2006. For an easier interpretation, the Tunisian economy has been aggregated into 6 macro sectors: agricultural (AgriF), chemical industries (ChemI), textiles (TextI), other manufactured industries (OthMI), non-manufactured industries (NmanI), and services (ServI). The last column displays economy-wide averages weighted by sectoral outputs; the middle 3 rows show respectively percent shares of sectoral production, export to output, and import to demand ratios. The bottom panel shows the same information but in the format of normalized emission coefficients. Accordingly, and for each type of pollutant, the sectoral coefficient is compared to the economy-wide average set equal to 100. From this summary table, it is possible to observe the distribution of emission intensities across sectors. This depends on the initial input-output structure of the Tunisian SAM (for the term aiCij) and on the vector of output (for the term Xioutput). For a given sector i, it would have a higher pollution intensity (E/Xioutput) when it consumes more polluting intermediates and have a higher value of its own coefficient (Bussolo and al, 2003). By considering the relative weight shown in the last three rows of the top panel of table 10; it is also possible to determine the most polluting industries in volume terms and what might be the environmental consequences of changes in competitiveness.

From the bottom panel of the table 11, the normalized coefficients show that the chemical sector records the higher emission intensities for TOXAIR, TOXWAT, TOXSOL, SO2, NO2, CO, VOC and PART effluents (8 on 13 total effluent categories). A tax proportional to emission intensities will therefore result in higher production costs for this sector, which in the base year accounts for only 4.1% of total output. The next two sectors that will be affected by this tax are other manufactured and non-manufactured industries. Other manufactured industries' and non–manufactured industries' output shares (respectively 24.3% and 16.9%) are larger than chemical sector, and may have more serious effects on aggregate GDP growth given the expected growth in their production costs. Therefore, the effects of a tax proportional to emission intensities on output

[10] Dessus, Roland-Holst and van der Mensbrugghe (1994) describes the used methodology.

growth of AgriF, TextI, and Services, will be less important than the previous sectors because they have lower coefficients of emission intensities.

The two last rows of the top panel of table 11 (export and import dependency ratios), shows the possible effect of increased trade and economic openness. For the more polluting sectors, trade liberalization and green taxes may leads to substitute imported by domestic goods. The degree of substitution depends on the value of the ratio Import/Demand. For example, given the high value of this ratio for the chemicals and textiles sectors, the substitution possibilities of domestic by imported goods will be less important than for the Agri, for which the import to demand ratio is very lower. The possibilities of substitution of domestic by imported goods, will be therefore higher if imported goods is more used as intermediates consumption. The final result will depend clearly on the initial level of protection and the sectoral resource distribution, which ultimately determine its comparative advantage and specialization due to trade liberalization. It will also depend on pollution intensities and the nature of green taxes to be applied for pollution abatement. For this reason, and in situations where a number of distortions and pollution determinants are present, the theory of international trade and environmental management is inadequate if used alone which justify again the use of computational tools in an attempt to assess the consequences of the policies described. CGE models are usually used for this purpose but until now this is the first study on estimating ancillary benefits of pollution abatement policies applied to MENA countries.

Table 11: Sectoral emission intensities for production – 2006 (metric tons per millions TD)

	Agri	Chemicals	Textiles	Other Manufacturing	Non Manufacturing Industries	Services	Total
TOXAIR	9,5	180,7	56,3	37,8	33,7	6	20,4
TOXWAT	18,8	464,1	11,7	73,9	45,6	12,4	37,3
TOXSOL	17,8	562,2	11,5	159,2	235,5	16,8	75
BIOAIR	28,2	515,1	12,9	395,8	670,5	28,9	160,1
BIOWAT	0,3	25,8	0,3	16,6	32,2	1,1	7,2
BIOSOL	294,1	10374,6	171	7198,7	13188,9	505,9	3025,6
SO2	17,9	493,2	11,4	64,7	39,8	11,5	35,8
NO2	11	298,1	77	37,3	18,9	6,8	23,6
CO	6,8	209,7	4,5	48,5	52,8	5,5	22,1
VOC	16	318,5	7,3	46,1	32,8	7,6	25
PART	3	82,4	1,9	12	5,8	1,9	6
BOD	7,9	17,4	0,2	13,8	21,8	0,8	5,9
TSS	9,5	966,4	10	621,5	1198,7	41,8	267,6
Output%	7,7	4,1	7,9	24,3	16,9	39,1	
Exp/Output	7,3	47,3	85,7	34,7	15,7	7,8	
Imp/Demand	30,7	191,9	159,1	104,1	156,3	131,9	
Normalized coefficients							
TOXAIR	46,6	885,8	276	185,3	46,6	885,8	100
TOXWAT	50,4	1244,2	31,4	198,1	50,4	1244,2	100
TOXSOL	23,7	749,6	15,3	212,3	23,7	749,6	100
BIOAIR	17,6	321,7	8,1	247,2	17,6	321,7	100
BIOWAT	4,2	358,3	4,2	230,6	4,2	358,3	100
BIOSOL	9,7	342,9	5,7	237,9	9,7	342,9	100
SO2	50	1377,7	31,8	180,7	50	1377,7	100
NO2	46,6	1263,1	326,3	158,1	46,6	1263,1	100
CO	30,8	948,9	20,4	219,5	30,8	948,9	100
VOC	64	1274	29,2	184,4	64	1274	100
PART	50	1373,3	31,7	200	50	1373,3	100
BOD	133,9	294,9	3,4	233,9	133,9	294,9	100
TSS	3,6	361,1	3,7	232,2	3,6	361,1	100

Source: Author’s calculations

Although production activities are the most important source for pollutants in any economy, final consumption of goods and services can equally cause pollution, especially for specific emission categories. Analogous results of emissions intensities for consumption are shown in Table 12. These estimated intensities expressed in volumes and coefficients refer to final consumption of goods and services (private and public consumption, investment goods included). From this table, we can observe that only consumption of chemicals (as the case of refined fuels and fertilizers) and other manufactured products generates emissions.

The best way to reduce emissions from final consumption will result from technical efficiency in the production process. This technical efficiency, which results from the introduction of green tax proportional to emission intensities or specific to one or more particular emissions may accelerate the process of substitution between pollutants and clean intermediate consumption. Reduction in emissions from final consumption will be the result of the changes in emissions from production and not a direct change in consumption patterns. In some models where there is a possibility to substitution between goods in final consumption, the possibility to reduce emissions from final consumption depends on the value of elasticity of substitution between "clean" and "dirty" products from the same category (same use). This is the case of substitution among petrol fuels in the transport sector: premium, super, unleaded, regular…

Table 12: Sectoral emission intensities for consumption – 2006 (metric tons per millions TD)

	AgriFood	Chemicals	Textiles	Other Manufacturing	Non Manufacturing Industries	Services	Total
TOXAIR	0	301,2	0	23,9	0	0	11,7
TOXWAT	0	856,6	0	10	0	0	26,8
TOXSOL	0	752,8	0	42,5	0	0	27,3
BIOAIR	0	0	0	214,5	0	0	23,6
BIOWAT	0	0	0	4,9	0	0	0,5
BIOSOL	0	0	0	2929,6	0	0	322,3
SO2	0	925,4	0	4,7	0	0	28,3
NO2	0	567,8	0	2	0	0	17,3
CO	0	335,9	0	7,5	0	0	10,8
VOC	0	586,3	0	4,1	0	0	18
PART	0	155,9	0	0,7	0	0	4,8
BOD	0	0	0	3,3	0	0	0,4
TSS	0	0	0	180,7	0	0	19,9
Cons %	10	3	4	11	12	60	
Normalized coefficients							
TOXAIR	0	2574,4	0	204,3	0	0	100
TOXWAT	0	3196,3	0	37,3	0	0	100
TOXSOL	0	2757,5	0	155,7	0	0	100
BIOAIR	0	0	0	908,9	0	0	100
BIOWAT	0	0	0	980	0	0	100
BIOSOL	0	0	0	909	0	0	100
SO2	0	3270	0	16,6	0	0	100
NO2	0	3282,1	0	11,6	0	0	100
CO	0	3110,2	0	69,4	0	0	100
VOC	0	3257,2	0	22,8	0	0	100
PART	0	3247,9	0	14,6	0	0	100
BOD	0	0	0	825	0	0	100
TSS	0	0	0	908	0	0	100

Source: Author's calculations

Key parameters. The model calculates economy-wide costs of reducing the growth of CO2 emissions. There are a function describing substitutions among fuels, factors and intermediate inputs within a nested CES production structure. Within the energy bundle, substitution is possible among petroleum products, natural gas, and electricity. Similarly within the electricity sector itself, inter-fuel substitution is possible, though clearly easier with new capital investment than with existing capital stock.

The CES elasticity values in the model were taken from the GREEN model developed at the OECD (see Burniaux et al., 1992). The higher elasticity values for new investment than for existing capital stock reflect the "lock-in" effect of existing technology – e.g. the relatively high cost (per unit carbon reduction) of retrofitting an oil-fired power plant to burn natural gas versus building a new gas-fired plant. As the value of these parameters matters greatly to the overall welfare costs of carbon reduction, sensitivity analysis around the central values has been performed and results are discussed later in the report.

For the production function, the substitution elasticities reflect adjustment possibilities in the demand for production factors following variations in their relative prices. In particular, the central elasticity values in the model are: 0.00 between intermediates and value added with old capital plus energy; 0.50 between intermediate and the value added/capital energy aggregate incorporating new capital; 0.12 between aggregate labor and the old capital-energy bundle; 1.00 between aggregate labor and the new capital-energy bundle; 0.00 between old capital and energy; 0.80 between new capital and energy; 0.25 among different sources of energy associated with old capital; 2.00 among those associated with new capital.

Regarding income elasticities, they are different for each product, and vary from 0.50 for basic products to 1.30 for services. Finally, elasticities between domestic and foreign products are of comparable magnitude for import demand and export supply. Their values are 3.00 for agricultural goods, 2.00 for manufactured goods and 1.50 for services.

4. The baseline simulation

The baseline simulation is intended to present a most likely path of development of the Tunisian economy over the simulation period 2006-2020 in the absence of climate policy and additional trade liberalization measures. The construction of the baseline is intended to capture the influence not only of underlying demographic and economic factors but also of key policy measures and reforms on Tunisia's development path and on the evolution of the economy's energy and pollution intensities. The effects of climate policy and additional trade liberalization measures can then be compared to what would (probably) have happened in their absence.

Several assumptions have been made in order to define what seems to be the plausible development of the Tunisian economy up to 2020. This exercise in simulation must not however be seen as an exercise in forecasting, for which general equilibrium models are not the best tools. The definition of a benchmark using major exogenous hypotheses is intended merely to define a baseline scenario to which alternative policy scenarios can then be compared in order to isolate the specific impact of the latter. The fact that the value of the exogenous variables are set on *a priori* basis, within a realistic confidence interval, does not however have any major consequences. When the impact of alternative trade and environmental policies is assessed, it can be seen that these choices affect very little either amplitude or sign of the variations in the different aggregates relative to the baseline scenario (notably the measurement of ancillary health benefits).

4.1. Assumptions considered in the baseline scenario. In order to construct a baseline scenario, the values of a number of variables need to be set. Accordingly, the model has been calibrated for real GDP to grow according to the observed rate for 2007-2009 as reported in the WDI of the World Bank. From 2010 to 2014, the growth rates are from the IMF World Economic Outlook, 2009. It has been assumed that GDP for the period 2015-2020 basically grows at the same rhythm as in 2014. Over the same period, population is assumed to grow at an average annual rate of 1.2%. Between 2010 and 2020, labor market supply grows by 1.5% yearly.

The government spending is assumed to be constant as a % of GDP (around 15.8%). In this way, we are basically assuming that business stays as usual when it comes to government spending policy – and, in any case, government spending is by and large pro-cyclical in the case of Tunisia. Thus, in the baseline scenario, public savings are endogenous. In the alternative scenarios, they are exogenous (and remain at their baseline reference level), and are obtained by endogenous shifting of the VAT vector. In order to neutralize the impact of changing the latter as a reaction for example to a reduction in tariff revenue, we assume that the rate of VAT is gradually unified over the period 2010 to 2020. By 2020 there would be just one VAT rate applicable to all products and equal to the average revenue collected in 2006.

The rate of growth in total factor productivity (which relates solely to physical capital and labor) is also determined endogenously in the reference scenario. Notably, it is dependent on the rate of growth in the economy and the initial stock of physical capital, which in turn determines the rate at which the latter accumulates.

4.2. Macroeconomic trends. Table 13 present the macroeconomic results for the baseline simulation. It shows that absorption improved significantly after 2010. The improvement is drawn both from higher private and public final consumption as well as investments. Exports increased but at lower level than imports. The same table indicates that the composition of GDP remains fairly stable during the simulation period. For foreign and domestic government debt as % of GDP, they reflect the declining trend of the past years. They increase according to the pace at which borrowing increase. Borrowing increases according to information obtained from the Central Bank of Tunisia and the Ministry of Development and International Cooperation. Fixed government investment growth shows more fluctuation than government spending growth but the ratio of government investment and GDP is very stable. There is little appreciation of real exchange rate, which is consistent with imposed growth of non-tradable (especially of services that are provided by the government). Growth of both exports and imports does not seem to be affected notably by the RER.

Table 13. Real Macro Indicators (average percentage change over the period 2010-2020)

Absorption	6,2%
Consumption – private	6,8%
Consumption – government	3,8%
Fixed investment – private	6,2%
Fixed investment – government	5,5%
Exports	5,0%
Imports	5,5%
GDP at market prices	5,9%
Total factor employment (index)	2,8
Total factor productivity (index)	3,1
Real exchange rate (index)	-0,2

Source: Authors' calculations based on the model results

4.3. Trends in energy and emissions of CO2. In order to describe the trends in pollution emissions with respect to economic activity in Tunisia, the long-term pollution elasticities with respect to production and consumption of goods and services have been estimated. These elasticities are measured as the ratio of the yearly average growth rates of polluting emissions to those of production and consumption during the period 2006-2020 observed in the baseline scenario. These values of elasticities reflect the production technologies in Tunisia in the absence of environmental policy. The values of these elasticities are represented in the table 14.

With exception to TOXAIR and BOD, aggregate pollution grows at the same level as economic production given that most of these elasticities are close to the unity. However, for TOXAIR and BOD, the increase in production is expected to achieve a decrease in the pollution growth. The picture at the level of consumption is different. For all pollutants, any increase in consumption will be manifested by a decline in pollution growth. Thus, the expected changes in the Tunisian economy over the period 2006-2020 are not expected to induce an environmental degradation. In other words, the economic growth of Tunisian's economy in the absence of environmental policies will not accelerate the growth rates of pollutants emissions. Accordingly, the substitution possibilities between "clean" and "dirty" goods and services considered by the model are expected to achieve a stabilization of the pollution growth rates in Tunisia.

Table 14. Emission elasticities during the baseline scenario (2006-2020)

	Production	Consumption
TOXAIR	0.93	0.98
TOXWAT	1.02	0.97
TOXSOL	1.01	0.96
BIOAIR	1.01	0.99
BIOWAT	1.00	0.95
BIOSOL	1.01	0.96
SO2	1.00	0.97
NO2	1.01	0.95
CO	1.01	0.95
VOC	1.00	0.94
PART	1.01	0.94
BOD	0.95	0.94
TSS	1.00	0.95

Source: Author's calculations

According these features, volume of CO2 emissions over the period 2006-2020 is expected to increase only by 1.5% against an increase of energy consumption by around 2% for refined oil and natural gas and by 2.8% for electricity.

5. Trade and pollution abatement scenarios

Two scenarios are tested in the present report. The first is a pure trade policy scenario without pollution abatement policy (S1) while the second combines climate policy with trade liberalization measures (S2). Given that Tunisia is already embarked in a wide program of trade liberalization[11], the trade simulation assumes a completed removal of the remained tariff protection on both agricultural and non-agricultural imports. The tariff removal is implemented in a gradual way over the period 2012-2020. This means that from 2013, the applied tariffs on Tunisian imports for 2006 will be removed gradually until their complete phase-out in 2020. The selection of the year 2013 as a starting year is simply because WTO's members already committed to remove export subsidies on their agricultural exports by 2013 and most probably the Doha round will be concluded before that year. However, this scenario should not be considered as a policy scenario, because it is not probable to consider that Tunisia is ready to open its markets to products from some competing countries such as China, but given the current growth of Tunisian imports from China, it is a matter of reality much more than a simple regulatory framework. The second scenario adds to tariff removal a sequence of reductions of CO2 emissions by implementing an endogenously calculated CO2 tax. Emissions in the final year of our projections, i.e. 2020, are reduced from a minimum of 5 percent to a maximum of 30%. The abatement is delayed and implemented starting the year 2013[12] to match with the implementation of tariff removal.

To calculate net welfare changes, it is required to calculate the effects on disposable income and ultimately consumption of having to commit a growing share of resources to CO2 abatement. The sum of the additional costs incurred by all productive sectors in adjusting to the carbon constraint, relative to the baseline scenario or the pure trade scenario, constitutes the aggregate abatement costs. In the model, abatement costs are calculated simply by setting all ancillary benefits equal to zero, then solving for the welfare changes associated with different rates of CO2

[11] Tunisia already implemented the FTA with the European Union and with Arab countries. Other FTAs are at the end of their implementation period such as with Turkey, European Free Trade Area member countries while other are under negotiations such as with COMESA.

[12] There are three options of implementing abatement: delayed to the end of the simulation period, immediate or gradually over the entire simulation period. Each option has its own advantages and inconvenient as the case when implementing trade reform. Arguments for delay usually centre around the scope of lowering abatement costs by waiting new technologies to become available. Arguments for early action usually cite costs averted from premature obsolescence of polluting capital equipment. In economic modeling, it is preferred to opt for a medium option which is in between no early and no delay, which means in the medium of the simulation period.

abatement. The net social gains (losses) from a given rate of CO_2 abatement are given by the sum of ancillary benefits (positive) and abatement costs (negative). As long as ancillary benefits exceed abatement costs, the level of abatement is a “no regrets” one. Testing the various abatement rates allows tracing a curve of welfare changes corresponding to these various abatement rates, which will determine “the optimal” rate of CO_2 abatement and the “no regrets” abatement rate”. Once these two abatements rates are determined, we move to the estimation of health benefits.

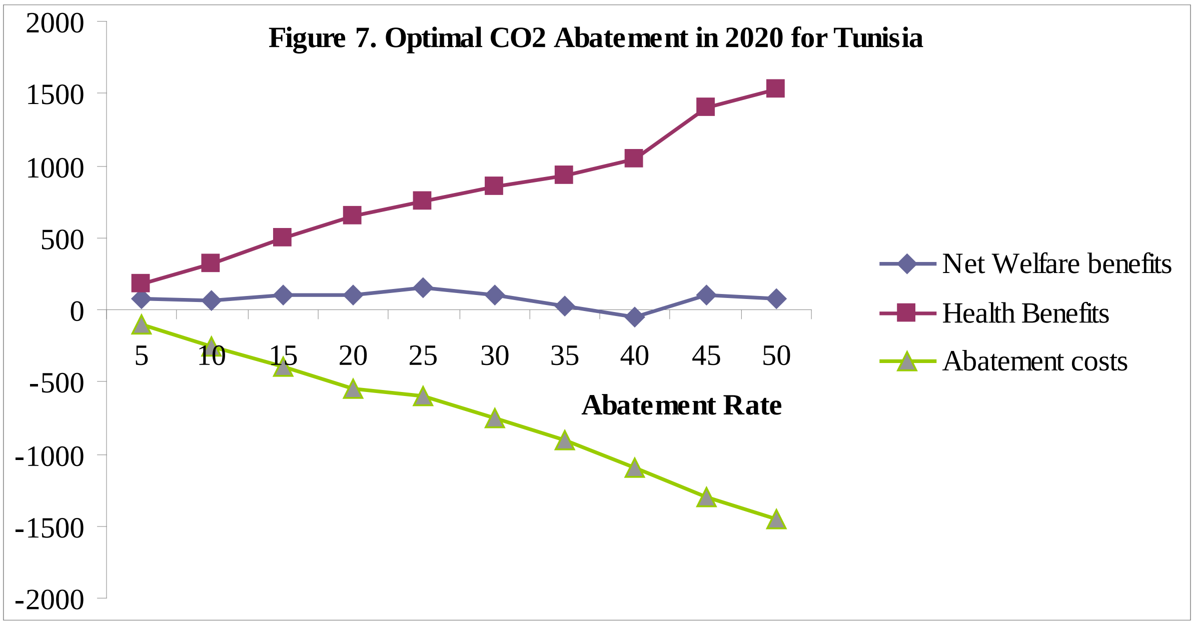
To run the alternative trade scenario with pollution abatement tax, the following rules are applied. First, the pollution tax revenues are re-distributed back to households in a revenue-neutral fashion through lump-sum transfers. Second, the value of the statistical life (VSL) is set equal to 1.6 million US$ in 2020.

5.1. Simulation results: “optimal” abatement. The solution of the model under the second scenario for different abatement rates allows the calculation of the net welfare gains (losses) from a given rate of CO_2 abatement. These gains or losses are given by the sum of ancillary benefits (positive) and abatement costs (negative) which is equal to the change in households’ disposable income in the “zero benefits” case. As long as ancillary benefits exceed welfare cost, the level of abatement is an “optimal” one.

To identify Tunisia-wide “optimum” and “no regrets” rates of CO_2 abatement from the baseline, the model is solved for successively higher CO_2 abatement rates (10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50%). At each abatement rate, welfare gains/losses relative to the baseline scenario are calculated in 2020. These abatement rates and the corresponding welfare changes trace out a curve on net welfare gains in 2020.

Figure 7 illustrates the effect of CO_2 abatement on welfare as measured by equivalent variation, on ancillary benefits, which is approximated by the value of changes in mortality and morbidity, and on net benefits, measured as the difference between the two. It suggests an “optimal” abatement rate in 2020 of around 25% of CO_2 reduction compared with the baseline 2020 emissions.

Figure 7. Optimal CO2 Abatement in 2020 for Tunisia



Of the total ancillary health benefits, mortality benefits constitute about 20%. Benefits from avoided IQ loss in children under seven contributes to 40%. The remainder benefits come from reduced incidence of disease (30%) and reduced pollution-related symptoms (10%).

Aggregate macroeconomics results of the two conducted simulations are presented in table 15.

Table 15. Macroeconomics results of alternative scenarios (in average percentage change over the period 2010-2020)

	Baseline	S1	S2
Absorption	6.2	6.6	7.1
Private consumption	6.8	7.3	7.2
Public consumption	3.8	4.3	4.1
Private investment	6.2	6.6	6.3
Public investment	5.5	5.9	5.9
Exports	5.0	6.5	6.3
Imports	5.5	7.0	6.9
GDP	5.9	6.2	6.1

Source: Author's calculations

The most significant impact concerns the relatively small aggregate cost (but negative) of pollution abatement in terms of forgone real average growth rate of GDP between 2010 and 2020 for the trade scenario with "optimal" climate policy. This small effect on economic growth can be explained by three major reasons. The first is related to the fact that these policies seem to affect productive resources (capital and labor) from more to less polluting activities. This first reason represents the composition effect, which plays an important role in this process. In fact, some sectors reduce their output and consequently their factor demands, other industries expand and take advantage of the non-polluting resources released by the contracting sectors. The second is related to the substitution possibilities among inputs, where we observe an increase in the use of less polluting inputs compared to more polluting ones. These changes in inputs combinations used in the production activities represent the process towards the implementation of cleaner technologies with more labor and capital and cleaner energy sources. The third reason is related to the distribution schema of the new taxes revenue generated by the green taxes. This additional revenue is distributed by the government to households, which in other terms reduce the adjustment costs related to the impact of pollution abatement policy on household welfare.

The major consequence of pollution abatement policies is the reduction of production generated by polluting activities (Extraction, Chemicals, Other Manufacturing) and the increase of production of less polluting activities (Agri-Food, Textiles, Non-Manufacturing, and Services). This is the immediate result of pulling resources from polluting to less or non-polluting sectors. Accordingly, the impact of the pollution abatement policy on the average annual growth rate of the economy-wide production over the period 2010-2020 is too small at an aggregate level. However, at detailed industrial level, the changes are more important, particularly in polluting sectors such as chemicals and extraction.

5.2. Sensitivity analysis of variations in net welfare. The influence of alternative values of trade and production elasticities on the nature of the results obtained in terms of variations in net welfare has been carried out. Differences in the net welfare are measured for 2020 comparative to their values in the respective original scenario (cf. Table 16).

In the first analysis (TRA), elasticities in international trade are halved for imports (substitution) and exports (transformation). This cut in substitutability between domestic and foreign products reduces the magnitude of the impact of a cut in tariffs which in turns reduce the positive effects of lowering production costs through cheaper imported equipments and raw materials. The second sensitivity analysis looks at factor mobility through doubling the substitution elasticity between capital and labor (PRO). This shows that the cost of pollution abatement is higher in terms of welfare, given that the adaptation process is hard which induces a higher adjustment cost for both trade and pollution abatement policies. The loses in welfare is higher in this second sensitivity analysis compared with the first one given that the amplitude of the abatement tax is higher than trade policy which is much lower in terms of percentage changes in relative prices. However, the conclusion given in the preceding section as to the optimal and “no regrets” pollution abatement tax remains fundamentally unchanged.

Table 16. Sensitivity analyses

	TRA	PRO
S1: Net welfare	- 0.1	- 1.1

6. Policy Implications

The climate change Kyoto protocol signed in the Third Conference of the Parties in December 1997 sets goals for emissions reduction for countries included in Annex I, which includes only developed countries. Non Annex I countries, mainly developing countries, do not need to abide to any emission reductions. However, the protocol sets up emissions trading framework that would allow countries (mainly Annex I) to invest in Green House Gas reduction projects in other countries (non Annex I), and share part of the emissions credits (Cifuentes et al., 2000). However, and in order to stabilize in a first step the global concentrations of Green House Gas and then starting their reduction, it will be necessary for all countries, including developing countries, to reduce their levels of emissions. Nevertheless, within the existing framework, it is not clear for a developing country if it is beneficial to enter voluntarily in an emission reduction scheme or not. In addition, for most developing countries, there is a range of higher development priorities such as reducing poverty and unemployment and enhancing economic growth through economic diversification. In these countries, governments may be hesitant to consider any emission abatement policies given their potential economic costs. Moreover, most of existing literature on benefits of GHG mitigation policies tends to understate the social welfare benefits by not including ancillary benefits. This in part had lead to insufficient GHG mitigation in most of developing countries that have highly polluted their main cities where their populations are concentrated.

This report captures the local health effects of reduced air toxics as an ancillary benefit of reducing pollution without allowing this benefit to feed back into the economy. The main reason is to provide an additional justification or motivation for policy makers to adopt policies aimed at pollution abatement. Using a dynamic CGE model, the study explored the issue when a carbon tax is used to reduce CO2 emissions.

The first policy conclusion from our analysis is that ancillary benefits in terms of health improvements from reduced air pollution in Tunisia’s major cities could justify CO2 abatement by 30%. However, it would be naïve to expect policy makers to be persuaded to act based on this analysis alone, especially if their primary mandate is to ensure sustained growth in GDP and lower poverty and unemployment.

Real GDP would be adversely affected by the carbon tax, with its 2020 level reduced by 3% from the baseline. While this is not negligible, it should be recalled that in the baseline Tunisia’s real GDP is projected to more than double (111%) by 2020. With a carbon tax designed to achieve 30% reduction in CO2 emissions, it would still increase by 108% by this date.

Some limits and potential extensions of the present study should be highlighted. These extensions may be operated at many levels. Firstly, it would be desirable to have an estimation of pollution coefficients specific to the economic activity in Tunisia at detailed sectoral level. This extension allows to re-estimate the “optimal” and “no-regrets” pollution abatement rate that allows analyzing the difference in terms of results with those based on the IPPS method. Second, technological effect is ignored in the estimations of emission coefficients, which remains constant over the simulation period. Generate alternate estimates of pollution coefficients across specific simulation periods could provide more realistic results on the “optimal” and “no-regrets” pollution abatement scenario. The third possible extension is related to the dynamic features of the used model. In fact, agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. The introduction of the emission taxes may affect agent’s decision on investment and consumption. The introduction of agent’s anticipations about taxes in the model is very important. Finally, the results of this study in terms of ancillary health benefits indicate the possibility to quantify the corresponding economic benefits/costs. The major economic benefits are labor productivity gains and medical treatment savings due to health status improvement from pollution abatement policy. Once the induced impacts on labor productivity and medical treatment savings are estimated, additional simulations can be performed to generate net effects of pollution abatement policy. It is important to note that medical treatment savings can be captured both by households and governments. For households, this will be translated by a change in the structure of final consumption by commodity while for government in terms of higher spending on other posts or reduced government deficit. Despite the importance of introducing these additional benefits endogenously in the model, these adjustments could be considered under a potential extension of this project.

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